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All India Agricultural Students Association

AIASA is a professional organization of present and former students in the field of Agriculture, Veterinary, Dairy, and horticulture, fisheries, forestry, Home science, sericulture, ABM and other allied sciences, registered under Societies Registration Act 1860.

The Association was formally launched on 10th May, 2011 by the then Hon'ble Union Minister of State for Agriculture during the All India Convention on Agricultural Administrative Reforms and the website was launched by the Hon'ble Union Minister of Agriculture on the occasion of 87th ICAR Foundation Day on 25th-26th July, 2015 at Patna, Bihar. The Society was registered on 1st Dec 2011 under the Societies Registration Act 1860, with the approval of Ministry of Agriculture, ICAR and Ministry of Consumer Affairs. Down the course of time, the drift between the technical work force and bureaucracy has increased abysmally harming the cause of farming sector and farmers at the national and state level. Policy making in agriculture has been largely limited to subsidies and loan disbursement, with negligible component of science in it. AIASA envisions a common platform where Agriculturists/technocrats and Bureaucrats will work together for the Indian agriculture with a "right person at right place" mode, to promote more application of science which is often left back. AIASA is established with the prime motto to bridge the drift and strengthen the voice of the agriculturalists, veterinarians, fishery experts and personnel of all allied fields at states, national and international levels.

AIASA advocates for resolving the long pending issues of creation of the All India Cadre of "Indian Agriculture Service" for appointment of right person at the right place and grant of professional status to agriculture sector at par with other professions for better job opportunities and career advancement of the personnel serving the primary sector.

The Society is covered for exemption from Income Tax u/s 80G(5)(vi) vide Order no DELAE27111-19092016 dated 19.09.2016.

Aims and Objectives

- To promote National Integration, Patriotism, Communal Harmony with the development of leadership among members.
- To facilitate and foster the bond between the students & professionals (Teachers,

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Scientists, Technical officials and Farmers /entrepreneurs).

- Professional status to Agriculture sector and to establish Agriculture Council of India (ACI) with need based administrative reforms.
- Creation of Central/Indian Agriculture Services.
- Granting UPSC status to ASRB for recruitment under Indian Agriculture Services.
- To make efforts for improving the job opportunities by having specialized cadre for agriculture services in center & state.
- Introduction of Agriculture course in CBSE, ICSE and state boards at school levels.
- Granting Fellowship to Agricos on par with UGC, CSIR, DST etc. fellowships.
- To represent the students in the national and international policy making body.
- To eradicate bureaucratic interference and corruption at all the levels and strive for introducing transparent system.
- To find out immediate solution for all problems which may jeopardize the common interest of the members by meeting, discussion and other democratic ways to the concerned authorities and act as a communicator to authorities/govt.
- Attracting and retaining youth in agriculture.
- To make efforts for advancement of agricultural research, education, extension, agricultural trade and development activities and other policy issues for promoting sustainable production and productivity including conservation & judicious use of natural resources.
- To make effort and convince the higher authority for restructuring the entire agricultural administrative system/set up at par with other professions, which remain as it was since its inception in the pre-Independence era.

Mission

Empowering youth in agriculture for development of agriculture and the nation.

Vision

To foster the bond between agricultural students & professionals and to raise the voice for techno-administrative agriculture reforms including creation of Indian Agricultural Services and advancement in agriculture by involvement of agriculturists in policy formulation and implementation.

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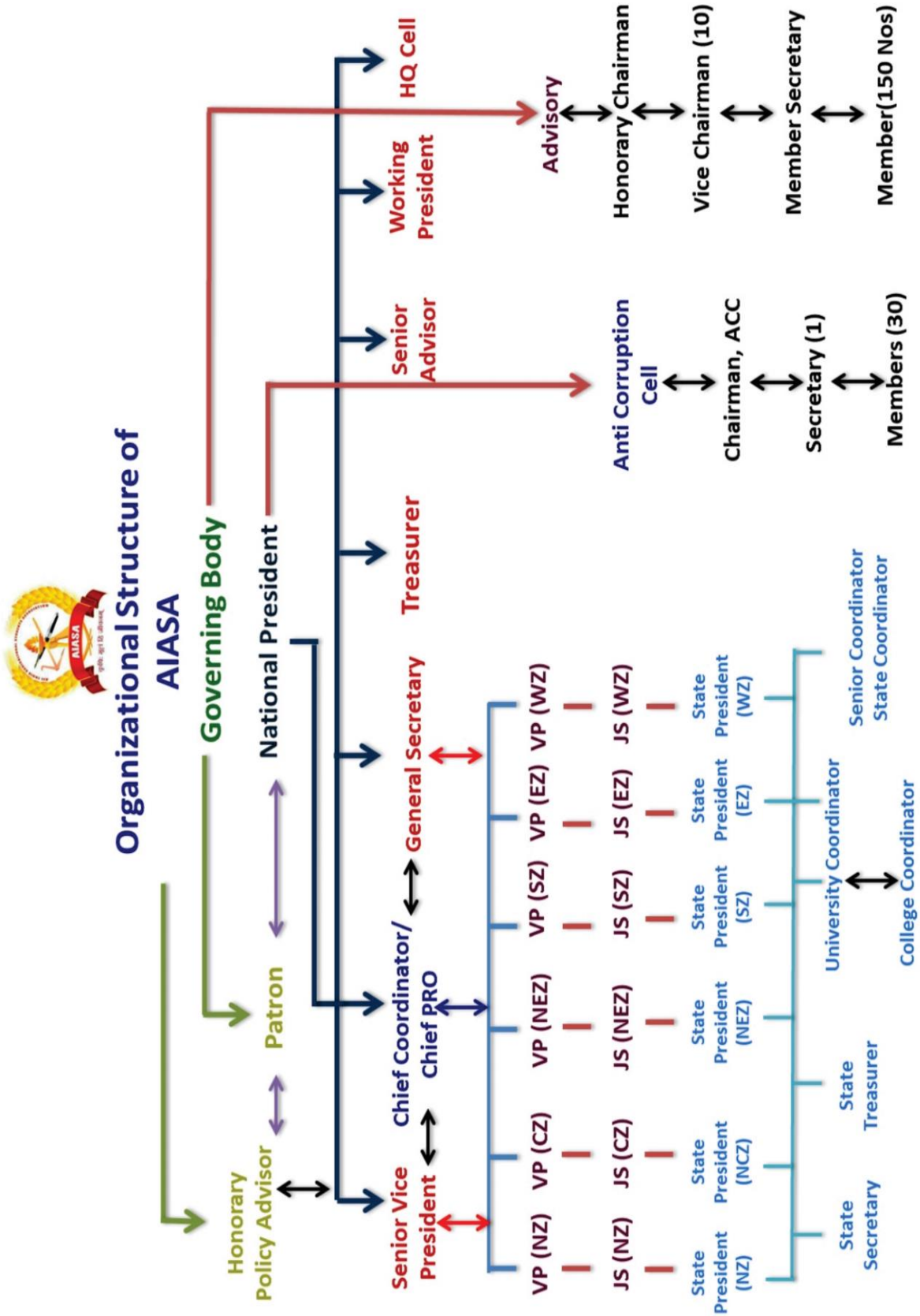

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SEAWEED - A PROMISING SOURCE OF CARBON SEQUESTRATION WITH INCOME GENERATION AND NUTRITIONAL SECURITY

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Abstract

Seaweed presents itself as a promising solution for addressing multiple challenges faced by our society today, including climate change, food security, and economic development. Seaweed cultivation offers a sustainable alternative to traditional agriculture and livestock farming, as it does not require freshwater or arable land, while also having the potential to sequester large amounts of carbon dioxide from the atmosphere. Additionally, seaweed is a rich source of valuable nutrients and can be used in a variety of food and non-food applications. Seaweed farming also provides opportunities for income generation in coastal communities, creating jobs and boosting local economies. However, it is important to ensure that seaweed farming is managed sustainably to avoid potential negative impacts on the environment. With careful planning and appropriate practices, seaweed farming has the potential to offer significant benefits both for the environment and local communities.

Keywords: *blue carbon, carbon sequestration, income generation, nutritional security*

Introduction

According to Levine (2016), seaweeds are mostly marine algae that can be found from the intertidal zone to a depth of 300 m. These sea plants have a wide range of habitats and can grow up to 60 m in length quickly (Pina-Pérez et al., 2017). Around 97% of aquatic plants are already cultivated, and half of the yield is consumed by humans (Costello et al., 2019). The FAO report (2021) states that whereas aquaculture produced 34.7 million tonnes, global capture production of aquatic plants, primarily seaweeds, was just 1.1 million tonnes in 2019. China, Indonesia, the Korea Republic, the Philippines, and the Democratic People's Republic of Korea have been named as the main producers. Based on the primary pigment present, seaweeds are primarily divided into three subclasses: brown (Phaeophyta), green (Chlorophyta), and red (Rhodophyta) (Pandey et al., 2020). The principal pigments in brown seaweeds are fucoxanthin and chlorophyll a, b, and c; in green seaweeds, chlorophyll a, b; and in red seaweeds, phycobilins and chlorophyll a, d. The production of brown, red, and green seaweeds in 2019 stood at 16.4 million tonnes, 18.3 million tonnes, and 0.16 million tonnes, respectively (FAO, 2021).

About carbon sequestration

The process of permanently storing carbon in soils, oceans, plants, and geological formations is known as carbon sequestration. The major contributors to biological carbon sequestration were

soil, forests, and oceans. The oceans take in about 25% of the carbon dioxide that humans emit each year. Through photosynthesis, plants store carbon in the soil where it can be utilised as soil organic carbon (SOC). Plant-rich landscapes like forests, grasslands, and rangelands absorb about 25% of the world's carbon emissions. Plants release their stored carbon into the atmosphere or transfer it to the soil when their leaves and branches fall off or when they die. The process of burying carbon dioxide in underground geologic formations, such as rocks, is known as geological carbon sequestration. Typically, carbon dioxide is extracted from an energy-related source, such as a power plant or a natural gas processing facility, or an industrial source, such as the production of steel or cement, and then injected into porous rocks for long-term storage.

Production of graphene, direct air capture (DAC), and other factors helped in technological carbon sequestration. the process of making the technology substance graphene using carbon dioxide as a basic material. Smart phone screens and other screens for technological equipment are made of graphene. A means by which to capture carbon directly from the air using advanced technology plants. However, this process is energy intensive and expensive.

About blue carbon related to seaweed

The term "blue carbon" simply refers to the carbon that the world's ocean and coastal ecosystems have stored. Along our coast, sea grasses, mangroves, and salt marshes "capture and hold" carbon, functioning as what is referred to as a carbon sink. The carbon that is stored in coastal and marine environments is referred to as "blue carbon." Mangroves, tidal and salt marshes, and seagrasses, collectively known as "blue carbon ecosystems," are extremely productive coastal ecosystems that are particularly significant for their capacity to store carbon in the form of plants and sediments below. Because they may store two to four times as much carbon as terrestrial forests, according to scientific evaluations, they are important for nature-based climate change solutions.

Seaweed farms emit carbon, which may be exported to the deep sea or buried in sediments, acting as a CO2 sink. By enhancing soil quality, replacing synthetic fertiliser, and lowering methane emissions from cattle when included in feed, seaweed aquaculture can also aid in reducing emissions from agriculture. By lowering wave energy, defending shorelines, raising pH levels, adding oxygen to the water, and reducing the local consequences of ocean acidification and deoxygenation, seaweed farming helps with climate change adaptation.

The emerging idea of "blue carbon," which refers to climate change mitigation strategies based on the capacity of marine plants to bind CO2, has not yet fully considered the potential of managing seaweed production to mitigate climate change by sequestering CO2. The reasoning behind this disregard is the idea that because most of the seaweed output is broken down in the water, it does not function as a net sink for CO2. Strongly autotrophic seaweed communities are in charge of a large portion of the CO2 absorption in marine vegetated habitats because

they produce considerably more organic matter through photosynthesis than is consumed by respiration in the ecosystem.

Nutrional composition of seaweed

In China, Japan, and Korea as well as several Latin American nations like Mexico, seaweed has been used traditionally as food for many centuries. There are a number of algae that are consumed by humans, but some of the most well-known ones are Undaria spp. (Wakame), Laminaria/Saccharina spp. (Kombu), and Porphyra/Pyropia spp. (Nori). Since there is a significant demand for algae for consumption in Japan, with an average intake of 14.3 g/day per adult, the production of algae is a growing industry in several nations like China and Japan. Large groups of algae (brown, red, and green) have very different protein contents.

Protein content in brown algae is typically low (5-24% of dry weight), but it is greater (10-47% of dry weight) in red and green algae. Algae proteins are typically high in glycine, arginine, alanine, and glutamic acid; they also include essential amino acids at amounts that are comparable to FAO/WHO recommendations. Lysine and cysteine serve as their limiting amino acids. The algae, which are recognised for their high mineral content between 8 and 40% of the dry weight of the seaweed, obtain a large abundance of mineral elements from the maritime environment in which they reside. The high concentrations of vital minerals including sodium, calcium, magnesium, potassium, chloride, sulphate, and phosphorus, as well as micronutrients like iodine, iron, zinc, copper, selenium, molybdenum, fluoride, manganese, boron, nickel, and cobalt, are noteworthy. In addition to being a significant source of minerals, algae are also a fantastic source of vitamins. Antioxidants come in many different forms in algae, including vitamins and shielding pigments. Both fat-soluble and water-soluble vitamins are present in seaweed. Algae are a great source of riboflavin, niacin, pantothenic acid, folic acid, vitamins A, B1, B12, C, D, and E. Additionally, algae are a good source of the lipophilic vitamins A (from -carotene) and E (tocopherols), as well as the B-group vitamins (especially B1 and B12).

Status of seaweed farming

Data from the Food and Agriculture Organisation (FAO) show that between 2000 and 2019 (FAO 2021), the world's output of seaweed (including farmed and wild) increased by over three times, from 118,000 tonnes to 358,200 tonnes. 97% of the world's aquaculture production in 2019 came from artificial farming. Asia accounts for 97.38% of the world's seaweed production, which is mostly produced on the five major continents. 99% of the seaweed in Asia is artificially cultivated. With 56.82% of the world's aquaculture production, China is specifically ranked as the top producer in the globe. Japanese kelp (Laminaria japonica), Gracilaria seaweeds (Gracilaria spp.), and nori Nei (Porphyra spp.) are the principal types of algae. The second is Indonesia, a significant seaweed-growing nation that produces 28.6% of the world's seaweed. The two main species are Eucheuma seaweeds nei (Eucheuma spp.) and Gracilaria seaweeds (Gracilaria spp.). Brown, red, and green seaweeds (apart from microalgae) are among the numerous seaweed species found in South Korea, which makes up 5.09 percent of the world's

total. The most sophisticated of them all is Japanese kelp (Laminaria japonica), followed by laver (Porphyra tenera) and wakame (Undaria pinnatifida). The Elkhorn Sea moss (Kappaphycus alvarezii), which covers more than 90% of the nation, is the primary crop planted in the Philippines' aquaculture, which represents 4.19% of the global market. 1.6% of the world's aquaculture is produced in North Korea, primarily in the form of Japanese kelp (Laminaria japonica). The majority of the seaweed grown in Japan is Japanese kelp (Laminaria japonica), wakame (Undaria pinnatifida), and laver (nori, Porphyra tenera). Malaysia contributes 0.53% of the world's aquaculture, primarily by cultivating Kappaphycus alvarezii, or Elkhorn Sea Moss. 95% of the seaweed consumed in North America, which makes up 1.36% of the global total, comes from natural sources. With 0.3% of the global production of seaweed, Chile is the world's largest producer. The country mostly cultivates Gracilaria and Spirulina maxima, although 99% of its seaweed comes from riverbeds in the wild.

In general, the world's seaweed culture production in 2019 was comprised of more than 95% of the following five varieties of seaweeds. 34.65% of all crops grown for human use are Laminaria and Saccharina, mostly for salads, condiments, and sauces. Carrageen from tropical algae Kappaphycus and Eucheuma made up 32.62% of the carrageen utilised to make carrageenan. 10.32%, 8.33%, and 7.16% of the total were accounted for by Gracilaria, Porphyra, and Undaria, respectively. Seaweeds (such as brown algae, leafy algae, and kelp) are frequently used as fsh feed in Asia and South African nations. For example, Laminaria and Sargassum are used as seaweed fertiliser in China, Kappaphycus is used as seaweed in India, and livestock feed is produced in the majority of European nations.

Pradhan mantri matsya sampada yojana (pmmsy) in seaweed sector

The Pradhan Mantri Matsya Sampada Yojana (PMMSY) has provisions to promote seaweed business in India. Total budget of Pradhan Mantri Matsya Sampada Yojna (PMMSY) is about Rs.20,500 cr. Rs 640.00 crore Investment by Government in seaweed sector. Objectives of PMMSY are to enhance production and productivity in the seaweed aquaculture in the country for harnessing the potential of the coastal waters and reduce reliance on wild harvest, To improve the seaweed value chain and industrial product diversification to meet domestic demand and thus reduce dependence on imports, To promote seaweed cultivation as a viable and sustainable livelihood amongst rural communities, especially for women, To establish an institutional mechanism in Research and Development in the seaweed farming and value chain and mechanism for effective Transfer of Technology.

In this scheme government provides 100% subsidy on Genetic Improvement Programme and Nucleus Breeding Centre and Innovative project on Seaweed Business under Central Sector Component. For establishment of Seaweed culture Rafts, including inputs, Seaweed culture with Monoline/Tubenet method, including inputs and sees bank for seaweeds government provides 40% Subsidy for General Category and 60% for SC/ST/Women.

FIGURE 1. SOME COMMON SEAWEED FOUND ALONG VERAVAL COAST, GUJARAT

Conclusion

In Conclusion, seaweed presents itself as a promising source of carbon sequestration, nutrition, and income generation. Seaweed cultivation offers a sustainable alternative to traditional agriculture and livestock farming, as it does not require freshwater or arable land. Moreover, seaweed has the potential to sequester large amounts of carbon dioxide from the atmosphere, helping to mitigate the impacts of climate change. Additionally, seaweed is a rich source of valuable nutrients, such as protein, minerals, and vitamins, and can be used in a variety of food and non-food applications.

Seaweed farming also provides opportunities for income generation in coastal communities, creating jobs and boosting local economies. However, like any form of agriculture, seaweed cultivation has its challenges, such as the need for appropriate technology and infrastructure,

and potential environmental impacts if not managed properly. Nonetheless, with careful planning and sustainable practices, seaweed farming has the potential to offer significant benefits both for the environment and local communities.

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SPACE FLIGHT MUTATION- A NOVEL APPROACH IN PLANT BREEDING

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Abstract

Space, also known as outer space, is the near-vacuum between celestial bodies. This is where all the planets, stars, galaxies and other objects are found. Extreme temperatures are seen from 2.6 Kelvin to 5.5 trillion Kelvin. A crop breeding technique that uses the variations of plants (seeds) induced in the space environment that can be reached by the recoverable spacecraft and high-altitude balloon to choose new germplasms and new materials on the ground, then to develop new crop varieties.

Keywords: *Space Flight Mutation, Space Breeding, Space Radiation and Abberations*

History of space flight mutations

Over the past decades, space technology has progressed by leaps and bounds in the world. Table 1 indicates the history of space flight mutation studies.

Shijian-8, the breeding satellite specially designed for the space breeding program, was launched on 9 September 2006. It carried over 2000 accessions of plant seeds belonging to 133 species (Liu *et al*. 2008).

Causes of Space Flight Mutation

1. Strong cosmic rays
2. Radiation
3. Microgravity
4. Weak geomagnetic field
5. Super vacuum
6. Strong vibration and blast force of spacecraft

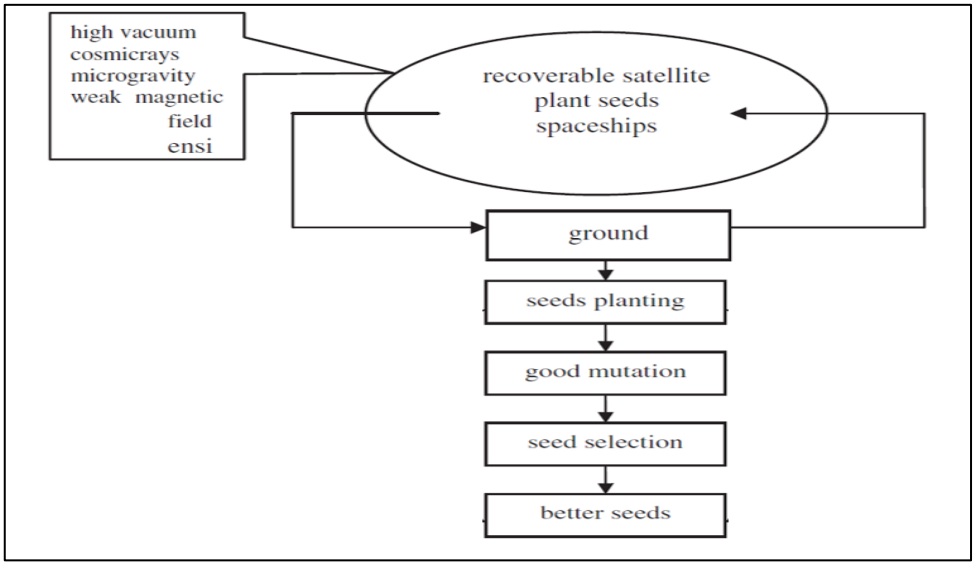
The procedure of space flight mutations:

Crop breeding in space, known in China as 'space breeding' and also called 'spaceflight mutation breeding', is a new technology in which crop seeds are carried by recoverable satellites into space and back to Earth after mutation-effect experiments in space. Early recoverable satellites, with a flight time running from five to eight days, conducted their flights at an orbit

of 170 to 420 km above Earth, their in-cabin temperature ranging from 5˚ to 30˚ centigrade (Xuemei and Xingshun, 2009).

While in space, the crop seeds undergo a process of mutation so that better seeds can be produced back on Earth. while space-breeding seeds and their subsequent generations would be planted, control seeds should also be planted as a reference and every detail should be recorded as evidence to prove their differences. The first generation of seeds for space experiments would usually not be selected for comparison. The second generation of mutated seed was a critical generation used to test mutation effects. The third and subsequent generations were used to test the stability of the seed mutation and the quality of the new strains (Figure 1). This technology is a typical tool used to improve agricultural production, so it is undeniably a new element of the space economy (Chengzhi, 2011).

Figure 1: Flow chart of space flight mutation



Mechanism of space flight mutations

- The reasons why the space environment could cause plant and chromosomal aberrations and then resulted in alterations of genetic characteristics are not very clear, space radiation is one possibility.
- The frequency of aberration was the highest when the root meristem or hypocotyl was hit.
- The longer seeds were kept in space, the higher the frequency of aberration was observed (Dutcher and Halsted 1994; Gu and Shen, 1989).
- The genomic polymorphism in 201 rice plants developed from space-flown seeds was investigated with RAPD analysis and found 30.2% of the polymorphism compared with plants from ground control seeds (Luo *et al*. 2006).
- Several early investigations in plant space biology led to changes to the content and characteristics of cell walls, an increase in the breakdown of xyloglucans, adjustments to polar auxin transport, or other morphological abnormalities are a few examples (Wolff *et al*., 2014 and Soga *et al*., 2002).

Key achievements in Chinese space breeding

China has now recorded breakthroughs in space breeding and in cultivating new and better types of seeds for cereals, vegetables and flowers (Table 2). Test planting in some areas has yielded a series of successes. At the end of the 20th century, some experts predicted that enough food could be provided for 30 million people in China if space breeding seeds were planted in 100 million mu (6.7 million hectares) and if there was a 10 percent increase in yield; total income would rise to RMB6 billion if vegetables were planted. The following table depicts the list of a few released varieties of various agriculture and horticultural crops in China (Chengzhi, 2011).

Table 1: History of Space Flight Mutations

Country	Year	Satellite	Organisms	Aim
USA	1966 to 1969	Biosat 1, Biosat 2 and Biosat 3	Plants, fungi, insects and monkey	Physiological changes and mutation changes
USSR	1966 to 1989	11 biosatellites	Plants, fungi, algae, insects, fish, poultry and mammals	Mutation effect, the effect of long-term weightlessness, wound recovery and reproduction in animals
China	1987	Fanhui shi weixing 9	Seeds, fungi and insect	Mutation studies

Table 2: List of released varieties of various agricultural and horticultural crops in China

Rice	*Teyouhang 1*, *II Youhang 1*, *Huahang 1*, *II Youhang 148*, *II Youhang 2*, *Liangyouhang 2*, *Peizataifeng*, *Peizahangqi*, *Shengbasimiao*, *Jinhangsimiao*, *Huahangsimiao*, *Yuehang 1*, *Zhe 101*, *Zhongzao 21*, *Zhongzheyou 1*, *Hangtian 36*
Wheat	*Taikong 1*, *Taikong 2*, *Taikong 5*, *Taikong 6*, *Longfumai 15*, *Longfumai 17*, *Hangmai 96*, *Hangmai 96* and *Shentai 1*
Green pepper seeds	*Yujiao 1* and *Yujiao 2*
Pepper	*Longjiao 9*
Tomato	*Yufan 1* and *Yufan 2*
Sesame	*Zhongzhi 11* and *Zhongzhi 13*
Cotton	*Zhongmiansuo 42* and *Zhongmiansuo 50*
Soybean	*Hangtian 2*

Problems of Space Flight Mutations

- Research on space mutation is a costly affair.
- There has not been any thorough research on mechanisms, cytological and molecular genetic reasons involved in space mutation.
- Destruction of seed material in space, sterility and low germination percentage of space seeds.
- Concerns about the safety of 'space food'
- Lack of popularization and industrialization.

Conclusion

Space agriculture is no longer a dream because it is a reality now in China. China has 72 space mutant varieties with an annual profit of 29.9 billion USD. Space agriculture spearheaded by space breeding is provided a brand-new perspective in trying to resolve the food problem. Space-induced mutations can be a novel and effective way to breed new varieties and to create distinctive genetic resources because of their wide mutation spectrum, high frequency of useful genetic variation as well as short breeding periods which are difficult using other breeding methods on the ground. To solve the problem of hunger due to the growing population, space flight mutation can be a significant contributor to the green revolution of the coming future.

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"Millets: The Climate-Resilient Superfood for a Sustainable Future"

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Abstract

Millets, a group of small-seeded grains, are emerging as a climate-resilient superfood with immense potential for promoting sustainable agriculture and mitigating the impacts of climate change. Millets require less water and fertilizer than traditional crops, and are adaptable to a wide range of climatic conditions, making them an ideal crop for regions facing water scarcity and unpredictable weather patterns. In addition to their environmental benefits, millets are highly nutritious, gluten-free, and have a low glycemic index, making them an excellent dietary choice for people with diverse nutritional needs. This article explores the role of millets in promoting sustainable agriculture and combating climate change, highlighting their unique properties that make them a pivotal component of a sustainable food system. Overall, the article makes a compelling case for the role of millets in building a more sustainable and resilient food system for the future.

Key Words- Millets, climate change, Climate Resilient superfood,

Introduction

Millets are a group of highly nutritious and drought-tolerant grains that have been cultivated for thousands of years in various parts of the world. Millets are known as 'Sri Anna' across the country. 'Sri Anna' means the best among all the food grains," In India, millets were traditionally consumed and cultivated but due to the push given to food security through Green Revolution in the 1960s, millets were rendered as 'orphan crops' – less consumed and almost forgotten. Before the Green Revolution, millets made up around 40% of all cultivated grains, which has dropped to around 20% over the years. Currently India produces about 80% of Asia & 20% of global production. They have been gaining renewed attention in recent years due to their ability to thrive in harsh environmental conditions and their potential to contribute to sustainable agriculture. Millets are often referred to as superfoods due to their exceptional nutritional value and health benefits. Millets are a rich source of vitamins, minerals, and dietary fiber, and they are also gluten-free, making them a great alternative for people with gluten intolerance. They have a low glycemic index, which means they are digested slowly, leading to a gradual release of glucose into the bloodstream and helping to regulate blood sugar levels. Furthermore, millets are high in antioxidants, which help to protect the body against cell damage and reduce the risk of chronic diseases such as cancer and heart disease (Arora & Singh, 2021). They also contain phytochemicals, which have anti-inflammatory and immune-boosting properties. They require minimal water and fertilizer inputs, making them ideal for cultivation in arid and marginal lands.

Moreover, their deep root system helps to improve soil fertility and water retention, which can contribute in mitigating the effects of climate change.

Figure 1 Different types of millets

Nutritional and Health benefits of Millets

In general, millets are known for their high nutritional value and health benefits, including:

- Rich source of protein, dietary fiber, essential vitamins and minerals
- Low glycemic index & anti-acidic property makes them a good choice for those with diabetes and thus reduces the risk of type 2 diabetes
- Ability to help regulate blood sugar levels and improve digestion
- Low content of gluten makes them a very suitable for those with celiac disease or gluten intolerance.
- It can reduce risk of gastrointestinal condition like gastric ulcers or colon cancer.

Millets contain phytochemicals, which have anti-inflammatory and immune-boosting properties which promote overall health and well-being

Climate-Resilient and Sustainable Superfood for the Future

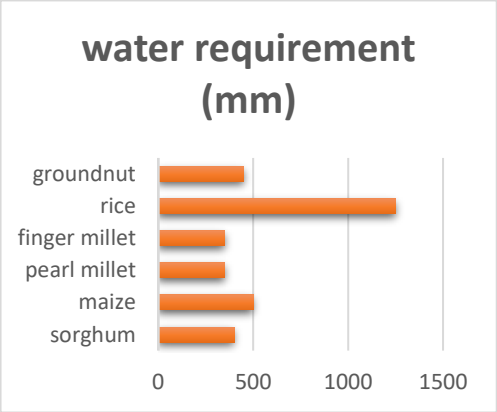

Figure 2. Water requirement of different crops

Climate change poses a significant threat to global food security. Rising temperatures, erratic rainfall, and extreme weather events are reducing crop yields and disrupting agricultural production systems worldwide. The Food and Agriculture Organization (FAO) estimates that climate change will reduce crop yields up to 25% by 2050, exacerbating food insecurity in vulnerable regions of the world (FAO, 2016).

In this context, millets have emerged as a promising crop for climate-resilient agriculture because in comparison to rice & wheat Millets are known for their exceptional adaptability to harsh environmental conditions, such as drought, heat, salinity, and their energy requirements and Global warming potential is minimal.

Table 1: Nutritional composition of Millets in comparison with Rice and Wheat

Millets	Carbohydrates(g)	Protein (g)	Fat (g)	Energy (Kcal)	Dietary Fibre (g)	Ca (mg)	P(mg)	Mg(mg)	Zn(mg)	Fe(mg)	Thiamine(mg)	Riboflavin(mg)	Niacin (mg)	Folic Acid (mg)
Sorghum	67.68	9. 97	1.73	334	10.2	27.6	274	133	1.9	3.9	0.35	0.14	2.1	39.4
Pearl millet	61.8	10 .96	5.43	347	11.49	27.4	289	124	2.76	6.42	0.25	0.2	0.86	36.11
Finger millet	66.82	7 .2	1.92	320.73	11.18	364	210	146	2.5	4.6	0.37	0.17	1.3	34.7
Kodo millet	66.19	8.92	2.55	331	6.39	15.27	101	122	1.65	2.34	0.29	0.2	1.49	39.99
Proso millet	70.4	12.5	1.1	341	-	14	206	153	1.4	0.8	0.41	0.28	4.5	-
Foxtail millet	60.1	1 2.3	4.3	331	-	31	188	31	2.4	2.8	0.59	0.11	3.2	15
Little millet	65.55	10 .13	3.89	346	7.72	16.1	130	91 .41	1.82	1.26	0.26	0.05	1.29	36.2
Barnyard millet	65.5	6 .2	2.2	307	-	20	280	32	3	5	0.33	0.1	4.2	
Wheat	64.7	1 0.6	1.47	321	11.23	39.36	315	1 25	2.85	3.97	0.46	0.15	2.68	30.1
Rice	78.24	7. 94	0.52	356	2.81	7.49	96	19 .3	1.21	0.65	0.05	0.05	1.69	9.32

Source: 1. Indian Food Composition Table 2017 – National Institute of Nutrition,
2. Nutritive value of Indian foods, 2004 - National Institute of Nutrition

They are also highly resistant to pests and diseases, reducing the need for chemical inputs. As a result, millets require fewer resources and have a lower carbon footprint than other crops such as rice and wheat (FAO, 2020). Despite their many advantages, millets have been largely neglected in modern agriculture systems. The Green Revolution of the 1960s and 1970s led to the widespread adoption of high-yield varieties of rice and wheat, which displaced traditional crops such as millets. In recent years, however, there has been a renewed interest in millets as a sustainable and climate-resilient crop.

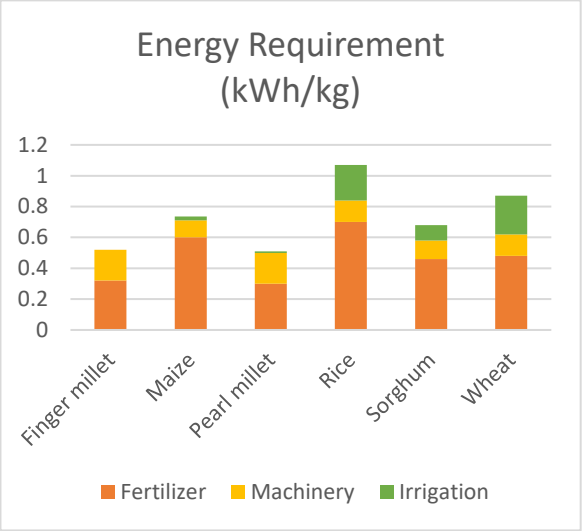

Figure 3. Energy consumption of different crops

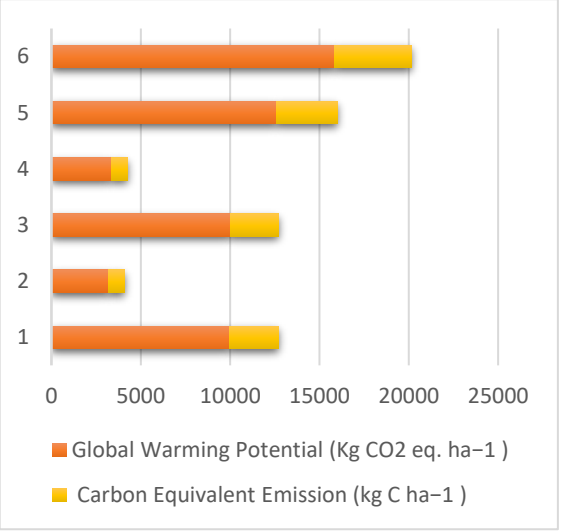

Figure 4. Global warming potential & carbon equivalent emission flux from soil

Conclusion:

Millets are a climate-resilient superfood that can contribute to sustainable agriculture and food security. As a climate-resilient superfood, millets offer a valuable alternative to traditional crops that are vulnerable to the effects of climate change. They are highly nutritious, drought-tolerant, and resilient to climate change. Millets also have several health benefits, including their antioxidant and anti-inflammatory properties. There is a growing recognition of the importance of promoting millets for a sustainable future, and several initiatives have been launched to promote their cultivation and consumption. Investing in millet production and consumption can not only improve food security and nutrition but also contribute to climate resilience, biodiversity conservation, and the livelihoods of farmers especially the marginal once. By promoting the cultivation and consumption of millets, we can build a more sustainable and resilient food system for the future.

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CLIMATE CHANGE AND FOOD SECURITY: AN OVERVIEW SPECIALLY IN INDIA

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Abstract

Climate change has added to the enormity of India's food-security challenges. While the relationship between the climate change and food security is complex, most studies focus on only one dimension of food security, i.e., food availability. But this paper will give an overview of the impact of climate change on India's food security, focusing on four dimensions – productivity, access, absorption, and edible insects. It finds that ensuring food security in the face of climate change will be a formidable challenge and recommends, among others, the adoption of sustainable agricultural practices, greater emphasis on urban food security and public health, provision of livelihood security, and long- term relief measures in the event of natural disasters.

Keywords: Climate change, food security, production, access, absorption and edible insects

Introduction

The impacts of human actions on our home planet are so large that many scientists are declaring a new phase of Earth's history. The old forces of nature that transformed Earth many millions of years ago, including meteorites and mega-volcanoes, are joined by another us. We have entered a new human dominated epoch of geological time called Anthropocene (1,2). For India, food security continues to be high on its list of development priorities because the country's relatively high rates of economic growth have not led to a reduction in hunger and undernutrition. India's gross domestic product at factor cost and per capita income grew at seven percent and five percent per annum, respectively, from 1990-91 to 2013-14 (3). For India, food security continues to be high on the lists of development priorities because the country's relatively high rate of economic growth have not led to a reduction in hunger and undernutrition. About 12 Indian states fall under the alarming category of the Global Hunger Index. Incidence of undernutrition has dropped only marginally from 210.1 million in 1990 to 194.6 million in 2014 (4). According to the National Family Health Survey 2015-16, the proportion of children under five years who are underweight is significantly high in states such as Bihar (43.9 percent), Madhya Pradesh (42.8 percent) and Andhra Pradesh (31.9 percent) (5). Per capita annual production of food grains increased from 183 kg during early-1970s to 207 kg bymid-1990s, even though country's population increased more than 50 per cent during this period (Economics Survey, 2007). After mid-1990s, per capita food grain production started

declining due to deceleration in the total factor productivity (TFP) growth (6). Moreover, it will be difficult to meet India's long term food requirements with domestic production alone (7). Kumar et al (2009) also find that with current production trends, meeting future demand for foodgrains through domestic production will be difficult (8).

This paper has an attempt to provide the future demand of foodgrains by estimating at the aggregated level, in terms of income, lifestyle and region, and the added-up estimates so obtained have been used to arrive at national level estimates.

How does climate change affect food security?

The World Food Summit in 1996 defined food security thus: "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food pReferences for an active and healthy life (9)." According to this definition, there are four main dimensions to food security: food availability, access to food, food absorption and edible insects. Thus, adequate food production alone is not a sufficient condition for a country's food security.

Food security is one of the leading concerns associated with climate change (10). Climate change affects food security in complex ways. It impacts crops, livestock, forestry, fisheries and aquaculture, and can cause grave social and economic consequences in the form of reduced incomes, eroded livelihoods, trade disruption and adverse health impacts. However, it is important to note that the net impact of climate change depends not only on the extent of the climatic shock but also on the underlying vulnerabilities. According to the Food and Agriculture Organization (2016), both biophysical and social vulnerabilities determine the net impact of climate change on food security (11).

Climate Impact

Sea Level Rise	Temperature Increase	Extreme Weather Events
• Flooding storms	Change in disease vectors	Higher intensity
• Sea surges	Coral bleaching	Delayed monsoon
• Erosion	Impact on fisheries	Long interval between rain spells
• Salination of land and water		Early withdrawal of monsoon

Source: Adapted from Climate Change: tackling the greatest human rights challenge of our time – Centre for International Environment Law and CARE International – February 2015

Affects of Water Cycle

- Higher rates of evapotranspiration from forests, rangeland and cropland
- Glacier melting and change in snowmelt regime

- Increased evaporation from reservoirs, water bodies and wetlands
- Increased variability of precipitations, more extreme events
- More pressure on groundwater to compensate for more variable surface water supply
- More frequent and longer periods of soil moisture deficit affecting crops
- Increased demand for irrigation water
- Longer periods of low flow affecting water users including industries, electricity generation and irrigation
- More frequent floods affecting human settlements and cropland
- Sea level rise and salt water intrusion
  Source: FAO 2013

Food production

Climate change presents an additional stress on India's long-term food security challenges as it affects food production in many ways. For one, it may cause significant increases in interannual and intra-seasonal variability of monsoon rainfall. According to World Bank estimates, based on the International Energy Agency's current policy scenario and other energy sector economic models, for a global mean warming of 4°C, there will be a 10-percentincrease in annual mean monsoon intensity and a 15-percent increase in year-to-year variability in monsoon precipitation (12). India's food production could drop 16% and the number of those risk for hunger could increase 23% by 2030 due to climate change, says a report by the International Food Policy Research Institute (IFPRI) on climate change and food systems. The World Bank (2013) also predicts that droughts will pose an increasing risk in the north-western part of India while southern India will experience an increase in wetness (13).

We are already experiencing acute food and water shortages... If we look at two degrees of global warming we know that areas that are currently growing staple crops will not be able to grow those at the same level of efficiency and effectiveness. Through changing weather patterns and increasing concentration of greenhouse gasses like methane in the atmosphere, agricultural productivity has already taken a hit. If global temperatures continue to rise unabated to more than 1.5 degrees C, then agricultural activity will be significantly affected and threaten to push millions into food scarcity. Changing weather patterns can result in longer and severe periods of drought and low precipitation. Extreme climate conditions like extreme rainfall, heat waves and more can also negatively affect crops and harvests (14).

Increasing humidity and heat also contribute to making the agricultural workforce less productive as wet-bulb temperatures, where humidity and heat are measured together, will continue to increase to dangerous levels and lead to the loss of productive days. "Differential human vulnerability to environmental hazards results from a range of social, economic, historical and political factors, all of which operate at multiples scales. Climate change is expected to have serious impacts for people living within these hotspot areas, as observed from loss of food crop yields to disasters such as floods, fluctuations in seasonal water availability or other systemic effects," the report said increased temperatures will cause yields to significantly reduce. Rice

and maize, two of the staple crops in India and the subcontinent will be particularly affected (14).

"In India, rice production can decrease by 10 percent to 30 percent, and maize production by 25 percent to 70 percent, assuming a range of temperature increase from 1 degree to 4 degree Celsius," the report said. Fruits and vegetables are similarly at risk due to various climatic factors. Potatoes and other starchy roots and tubers, while more resistant to temperature change, are highly sensitive to water scarcity. Additionally, increased heat and water scarcity can have critical impact during the tuber initiation stage. The perennial tree crops like grapevine, olive, almond, apple, coffee, and cocoa are also vulnerable to climate change (14).

Fisheries will also take a massive hit as warmer waters in general will reduced the amount of dissolved oxygen in water bodies, reducing the maximum supported population of fish. Livestock animals will be under stress from higher temperatures themselves. "Threats to food supplies and water availability, due to continued climate change, may increase the risk of social unrest and armed conflict, particularly in poorer countries, although other factors are also important," the report added (14).

While the world needs to come together to ensure the climate change doesn't see global temperature rise by 1.5 degrees C or more, at the same time adaptation measures need to be weighed in from this very moment. Adaptation and mitigation together can soften the blow of most of the climatic impact that global warming will have in the 21st century. "Adaptation is a very important part of managing climate change impacts. However, the effectiveness of most adaptation measures, including water related measures, falls sharply at higher levels of global warming above 1.5 degrees, showing that adaptation alone will not solve the crisis," said Aditi Mukherji, researcher at International Water Management Institute and contributing led author for the Chapter 4 The Intergovernmental Panel on Climate Change (IPCC) report, to Hindustan Times (14).

Food access

While there has been considerable progress in understanding the sensitivities of crop production to yield, there are relatively few models which assess the impact of climate change on access to food. According to the Fourth Assessment Report of the IPCC, depending on the climate change scenario, 200to 600 million more people globally could suffer from hunger by 2080 (Yohe et al., 2007) (15). Lloyd et al (2011) also make the projection that climate change will have significant effects on future undernutrition, even when the beneficial effects of economic growth are taken into account (16). According to their model predictions, there will be a 62-percent increase in severe stunting in South Asia and a 55-percent increase in east and south sub-Saharan Africa by 2050 (17).

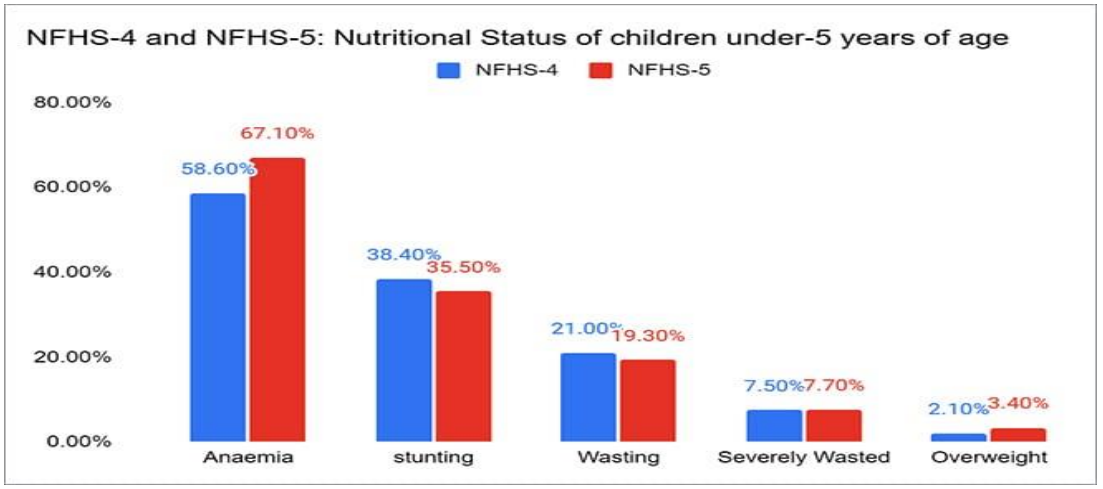
According to the US Centres of Disease Control, poor nutrition is one of the key factors in chronic illness like diabetes and heart diseases. Frequent consumption of fast foods is linked to cardiovascular disease, metabolic syndrome, certain cancers, and insulin resistance (18). Food

access and suboptimal medical care due to further institutionalised racism, contributing to a higher risk of diet-related illness and death for affected communities. Women experiencing food insecurity have worse maternal health and are more likely to undergo complications in childbirth and to have children with low birth weights. Insecure food access can affect children's growth and development, preventing them from reaching their potential in school and fully participating in social and community activities. Research suggests that children without consistent access to adequate food may be more likely to have anaemia, asthma, and oral health problems, to fall behind their peers academically and have lower mathematics and reading test scores, and to develop behavioural issues like aggression and anxiety (19).

According to Ramachandran (2014), food stocks begin to run out three or four months after harvest, farm jobs are unavailable and by the next monsoon/sowing season, food shortages peak to hunger (20). Climate change will also have an adverse impact on the livelihoods of fishers and forest-dependent people. Landless agricultural labourers wholly dependent on agricultural wages are at the highest risk of losing their access to food (21,22). Vedeld et al (2014) conducted a survey of nine villages in the drought-prone Jalna district of Maharashtra and found that local crop yields and annual incomes of farmers dropped by about 60 percent in the drought of31 2012-13 (23). Such a large fall in income is likely to have a huge impact on child nutrition because poor households typically spend the bulk of their earnings on food. In another study based on 14 flooded and 18 non-flooded villages of Jagatsinghpur district in Orissa, Rodriguez Llanes et al (2011) found that exposure to floods32 is associated with long-term malnutrition (24). According to their study, children exposed to floods during their first year of life presented higher levels of chronic malnutrition (25).

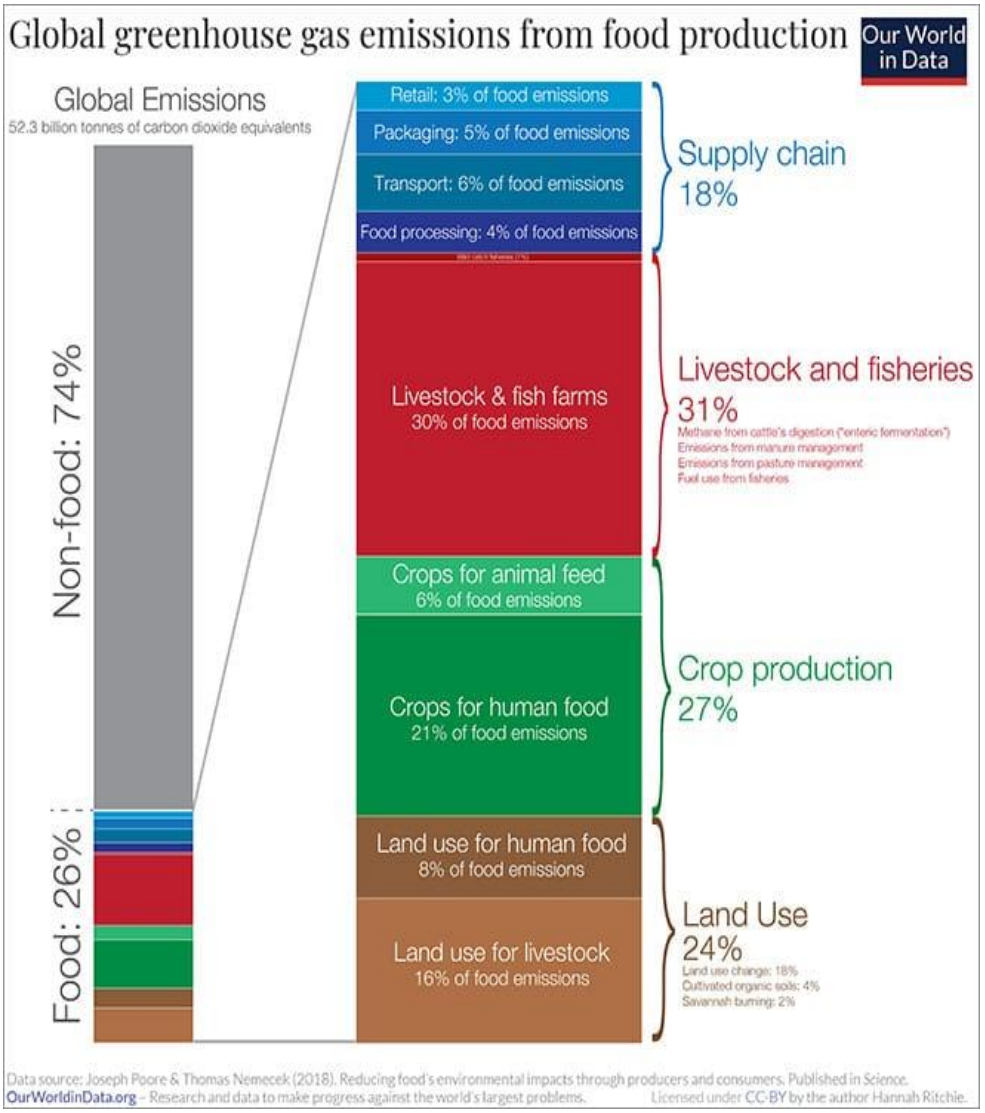
In 1966 the UN recognized food access as a human right in the International Covenant on Economic, Social and Cultural Rights. The Covenant stated that every person should have "physical and economic access at all times to adequate food," and the UN further noted that lack of food access impinges on other rights to health, right, water, housing, and education." Key to the UN's conceptualization of food as a human right was the intersection between food and health. This enabled the idea of food access as a human right to expand beyond simply meaning the food required for survival and instead to encompass the food needed for a sustainable, thriving life. A rights approach to food access also sets the stage for addressing food access at individual, household, and community levels (26). Recognition of food access as a human right is one step toward ensuring universal access to sufficient, nutritious food. However, ensuring the right to food also depends on deeper systemic changes to food production systems and solution to the social problems of income inequality and systemic racism. Achieving food sovereignty and ensuring universal food access requires the establishment of community-led, sustainable, plant-forward food systems. A human rights framework for food access must also promote strategies that will establish and safeguard access to healthy food sources for current and future generations (27).

Table 1: Child nutritional status in urban India (2021)



Source: National Family Health Survey 4 and 5

Table 2: Global greenhouse gas emissions from food production



Source: Our World in Data

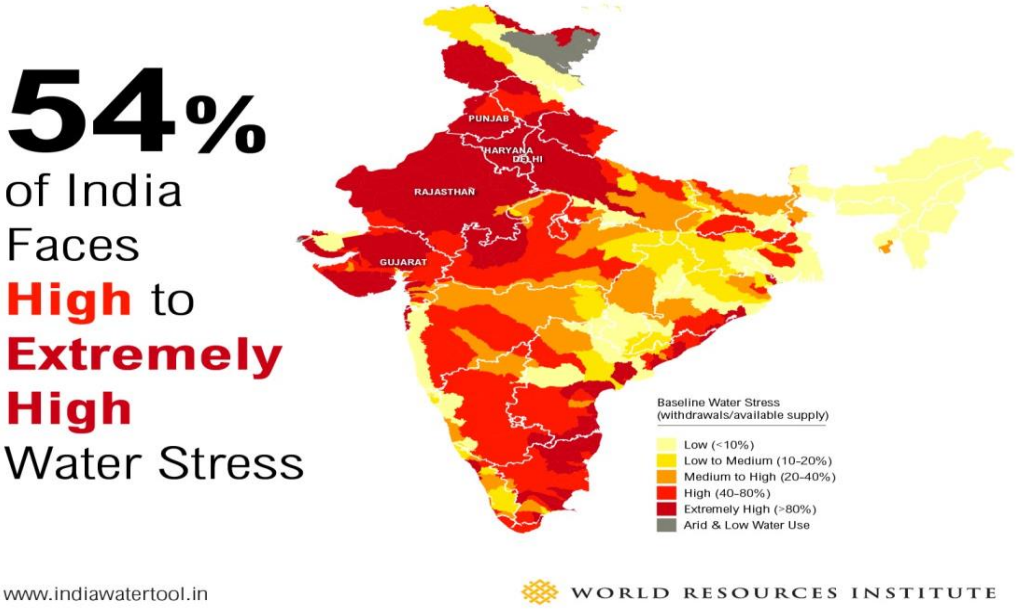


Figure 1: Water stress across India

Figure 2: Depth to water level (2019)

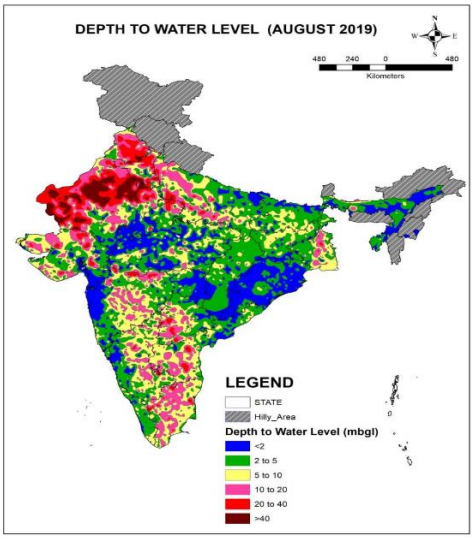
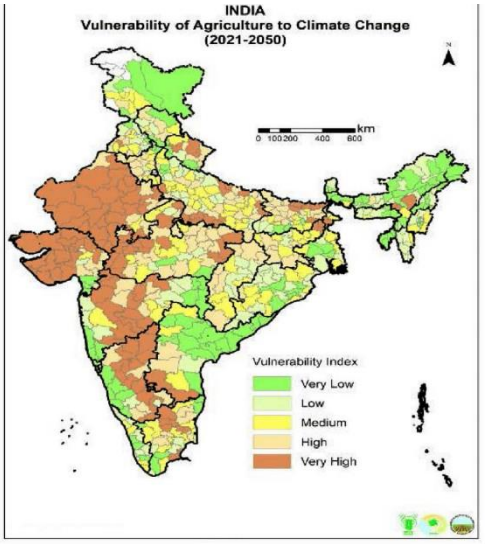


Figure 3: Vulnerability of Agriculture to Climate Change



Source: Central Ground Water Board (CGWB)

Climate change will exacerbate India's existing problems of urban food insecurity. The highest risks related to climate change are likely to be concentrated among the low-income groups residing in informal settlements which are often located in areas exposed to floods and landslides and where housing is especially vulnerable to extreme weather events such as wind and water hazards (28). Mumbai and Chennai are especially prone to bear the brunt of climate change (29). Dasgupta et al (2012) add Kolkata to the list of cities that are particularly vulnerable to climatic risks, (30) as climate change is likely to intensify the frequent flooding in the Hooghly river during monsoon (31). The poor inhabitants of Kolkata are most vulnerable as their homes

are located in low-lying areas or wetlands that are particularly prone to tidal and storm surges (32). Given that food is the single largest for poor urban households, displacement, loss of livelihood or damage to productive assets due to any such extreme weather event will have a direct impact on household food security (33). The urban poor has also been identified as the group most vulnerable to increases in food prices following production shocks and declines that are projected under future climate change (34).

Food absorption

There are many potential impacts of climate change on food absorption but there is a dearth of quantitative studies on the subject which focus on India. Overall, the global threat is that climate change could lead to a reduction of production and consumption of certain foods that play a critical role in the diets of poor rural and indigenous populations such as fish, fruits and vegetables, and wild foods (35). Change in climatic conditions could lead to a reduction in the nutritional quality of foods (reduced concentration in proteins and minerals like zinc and iron) due to elevated carbon dioxide levels (36). In India, where legumes (pulses) rather than meat are the main source of proteins, such changes in the quality of food crops will accelerate the largely neglected epidemic known as “hidden hunger” or micronutrient deficiency (37). Phalkey et al (2015) argue that micronutrient deficiencies increase the risk of acquiring an infectious disease which in turn worsens the problem of undernutrition, creating a vicious circle (38). Evidence from Botswana suggest that changes in climate that lead to an increase in temperature and a decrease in precipitation are associated with an increase in diarrhoeal disease in children (39). In India, children living in poor rural areas and urban slums are at higher risk of morbidity and mortality from diarrhoeal diseases. Projections made by Moors E. et al. (2013) say that climate change will lead to an average increase of about 13.1 percent in diarrhoea in the Ganga basin (40). Ramachandran (2014) also argues that climate change could lead to a reversal of India's achievements in reducing diarrhoea-related deaths (41).

The impact of climate change on vector borne diseases is fairly well documented. Climate change will lead to the emergence of new patterns of pests and diseases which will affect human health and lower the capacity to utilise food effectively, thereby posing new risks for food security. For instance, more people will be exposed to vector-borne diseases such as malaria, dengue and chikungunya.

According to Dhara, Schramm and Luber (2013), the entire population of India except those living in areas above 1700m above sea level are at risk of contracting malaria (42). The arboviral diseases chikungunya and dengue may also be influenced by climate as both are transmitted by the common vector Aedes aegypti (43). The urban poor living in informal settlements are particularly vulnerable, absent the basic facilities such as piped water, sanitation, clean drinking water, drainage systems, and heath facilities. High incidence of undernutrition due to poverty exposes the urban poor to diseases linked to climate impacts, which in turn aggravates undernutrition and ill-health and reduces the ability to adapt and build resilience to climate change (44). Adverse effects of malaria, diarrhoea and undernutrition have been found to be

concentrated among children due to physiological susceptibility. Children have been found to be at greater risk when food supplies are restricted (45).

Edible insects

Edible insects are very delicious. They are very (rich in protein, fat, vitamins and minerals). They are used in therapeutic purposes, easily available in the wild and easy to harvest. Some edible insects can be easily domesticated (silkworms and honeybees). They require small area of land for rearing and not necessarily a land-based activity. They can be fed on locally available plants, require less water of survival. They have high feed conversion efficiency and they emit less greenhouse gases (GHGs) than the most livestock (46). Proteins are very important essential nutrients for human growth and development and serve as a fuel source (47). There is a serious worldwide nutritional problem due to good quality protein deficiency affecting low income people (48). Protein and energy malnutrition has continued to plague the developing world despite the benefits reaped from Green Revolution (49). Protein energy malnutrition contributes more than 50% of the deaths of children under 5 years all over the developing countries (50). Insects are generally high in crude protein and fats however; their nutrient contents varies between species to species and also between their different development phases (51-54). Many edible insects are also rich in amino acids and micro minerals such as copper, iron, magnesium, manganese, selenium, calcium, sodium, potassium, phosphorous and zinc, as well as vitamins such as riboflavin, pantothenic acid and biotin and, in soe cases folic acid, all of which are valuable in terms of human nutrition (55-57).

Table 4: Nutritive value of different insects

Insect	Protein (gm)	Fat (gm)	Carbohydrate (gm)	Calcium (mg)	Iron (mg)
Giant water beetle	19.8	8.3	2.1	43.5	13.6
Red ant	13.9	3.5	2.9	47.8	5.7
Silk worm pupae	9.6	5.6	2.3	41.7	1.8
Meal worms	20.27	12.72	N/A	13.3	N/A
Wax worms	15.50	22.19	N/A	28.3	N/A
Super worms	17.41	17.89	N/A	12.4	N/A
Fly larvae	15.58	7.81	N/A	87.4	N/A
Dung beetle	17.2	4.3	2.0	30.9	7.7
Cricket	21.32	6.01	5.1	75.8	9.5
Small grasshopper	20.6	6.1	3.9	35.2	5.0
Large grasshopper	14.3	3.3	2.2	27.5	3.0
June beetle	13.4	1.4	2.9	22.6	6.0
Caterpillar	6.7	N/A	N/A	N/A	13.1
Termite	14.2	N/A	N/A	N/A	35.5
Weevil	6.7	N/A	N/A	N/A	13.1

Recommendations

Adoption Of Sustainable Agricultural Practices

Better management of water resources must be a key feature of sustainable agriculture. Water supply management options such as new storages and water harvesting are important, especially in the water-stressed regions of north-western India. Increase irrigation efficiency,

promote micro irrigation in water-deficient areas, better water resource infrastructure planning and restoration of water bodies in rural areas.

Table 5: List of some edible insects

Sl. No.	Order	Family	Scientific name	Common name
1	Coleoptera	Dytiscidae	*Dytiscus marginalis*	Great diving beetle
2	Coleoptera	Dytiscidae	*Hydrochera ricksecker*i	Water beetle
3	Coleoptera	Dytiscidae	*Cybis sp.*	Water beetle
4	Coleoptera	Dynastidae	*Eurytrachelus titan*	Beetle
5	Coleoptera	Dynastidae	*Eurytrachelus sp.*	Beetle
6	Coleoptera	Lucanidae	*Odontolabis cuvera*	Stag beetle
7	Coleoptera	Scarabaeidae	*Analeptes trifasciata*	Flat-faced longhorn beetle
8	Coleoptera	Scarabaeidae	*Lepidiota mansueta*	Scarab beetle
9	Coleoptera	Cerambycidae	*Batocera horsefieldi*	Long horn beetle
10	Coleoptera	Cerambycidae	*Batocera rufomaculata*	Long horn beetle
11	Coleoptera	Cerambycidae	*Dihammus cervinus*	Long horn beetle
12	Coleoptera	Curculionidae	*Rhynchophorus ferrugineus*	Palm weevil
13	Coleoptera	Curculionidae	*Rhynchophorus phoenicis*	Palm weevil
14	Hemiptera	Belostomatidae	*Lethocerus indicus*	Giant water bug
15	Hemiptera	Pentatomidae	*Ochrophora montana*	Pentatomid bug
16	Hemiptera	Nepidae	*Laccotrephes ruber*	Water scorpion
17	Hemiptera	Cicadidae	*Pomponia imperatoria*	Cicada
18	Hemiptera	Cicadidae	*Okanagana sp.*	Cicada
19	Hemiptera	Naucoridae	*Pelocoris femoratus*	Creeping water bug
20	Hymenoptera	Apidae	*Apis cerana*	Honey bee
21	Hymenoptera	Apidae	*Apis mellifera*	Honey bee
22	Hymenoptera	Apidae	*Apis florea*	Little bee
	Hymenoptera	Apidae	*Apis dorsata*	Giant Honey bee
23	Hymenoptera	Vespidae	*Vespa affinis*	Wasp
24	Hymenoptera	Vespidae	*Polistes stigmata*	Paper wasp
25	Hymenoptera	Vespidae	*Polistes olivaceus*	Paper wasp
26	Hymenoptera	Vespidae	*Parapolybia varia*	Lesser Paper wasp
27	Hymenoptera	Formicidae	*Oecophylla smaragdina*	Red Ant
28	Hymenoptera	Formicidae	*Dorylus orientalis*	Army ants
29	Hymenoptera	Formicidae	*Atta sp.*	Leaf cutter ants
30	Hymenoptera	Formicidae	*Myrmica rubra*	Common red ant
31	Hymenoptera	Formicidae	*Formica indica*	Wood ants
32	Orthoptera	Acrididae	*Chondacris rosea*	Short horn Grasshopper
33	Orthoptera	Acrididae	*Phlaeoba infumata*	Short horn Grasshopper
34	Orthoptera	Acrididae	*Melanoplus sp.*	Short horn Grasshopper
35	Orthoptera	Acrididae	*Oxya fuscovittata*	Short horn Grasshopper
36	Orthoptera	Acrididae	*Cyrtacanthacris aeruginosus*	Short horn Grasshopper
37	Orthoptera	Acrididae	*Hieroglyphus banian*	Short horn Grasshopper
38	Orthoptera	Acrididae	*Schistocerca gregaria*	Desert locust
39	Orthoptera	Acrididae	*Eupreponotus inflatus*	Short horn Grasshopper
40	Orthoptera	Acrididae	*Choroedocus robustus*	Short horn Grasshopper
41	Orthoptera	Pyrgomorphidae	*Zonocerus variegatus*	Grasshopper
42	Orthoptera	Gryllidae	*Schizodactylus monstrosa*	Cricket
43	Orthoptera	Gryllidae	*Gryllus campestris*	Field cricket
44	Orthoptera	Gryllidae	*Brachytrupes sp.*	Cricket
45	Orthoptera	Gryllidae	*Tarbinskiellus portentosus*	Cricket
46	Orthoptera	Gryllidae	*Acheta domestica*	House cricket
47	Orthoptera	Gryllidae	*Acheta sp.*	House cricket
48	Orthoptera	Gryllotalpidae	*Gryllotalpa africana*	Mole cricket
49	Orthoptera	Tettigoniidae	*Mecopoda elongata*	Bush cricket
50	Orthoptera	Tettigoniidae	*Ruspolia baileyi*	Bush cricket
51	Odonata	Libellulidae	*Crocothemis servilia*	Dragonfly
52	Odonata	Libellulidae	*Neurothemis fluctuans*	Dragonfly
53	Odonata	Aeshnidae	*Aeshna mixta*	Dragonfly
54	Lepidoptera	Bombycidae	*Bombyx mori*	Mulberry silkworm
55	Lepidoptera	Saturniidae	*Philosamia ricini*	Eri silkworm
56	Lepidoptera	Saturniidae	*Antheraea assamensis*	Muga silkworm
57	Lepidoptera	Saturniidae	*Cirinaforde sp.*	Wild silkworm
58	Lepidoptera	Notodontidae	*Anaphe infracta*	Moth
59	Lepidoptera	Notodontidae	*Anaphe reticulata*	Moth
60	Lepidoptera	Notodontidae	*Anaphe venata*	Moth
61	Dictyoptera	Mantidae	*Mantis religiosa*	Preying mantid
62	Dictyoptera	Mantidae	*Mantis inornate*	Preying mantid
63	Isoptera	Termitidae	*Odontotermes obesus*	Termite
64	Isoptera	Termitidae	*Macrotermes natalensis*	Termite
65	Isoptera	Termitidae	*Macrotermes bellicosus*	Termite
66	Isoptera	Termitidae	*Macrotermes sp.*	Termite
67	Isoptera	Rhinotermitidae	*Reticulitermes flavipes*	Termite

Stronger emphasis on public health

Despite the fact that the disease burden from vector borne and diarrhoea diseases is very high in urban slums and tribal areas of India, this area was overlooked when the original National Action Plan for Climate Change (NAPCC) was formulated. The Ministry of Health is currently formulating a National Mission for Health under the ambit of NAPCC but given the close relationship between climate change, infectious diseases and food absorption, public expenditure on health needs to be stepped up drastically.

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Soil Carbon: A Critical Link in Climate Change and Food Security

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Abstract

Climate change has major implications for agricultural productivity and food security, making it crucial to examine the role of soil carbon in mitigating these effects. This article provides an overview of the effects of climate change on soil carbon and explores strategies for promoting soil carbon sequestration through land management practices. It discusses the impacts of changing temperature and precipitation patterns on soil carbon, and highlights the importance of restoring degraded soils to increase soil carbon storage. We examined various land management practices, including cover cropping, conservation tillage, and organic amendments, and their potential to enhance soil carbon sequestration and suggests that site specific managemental practices should be chosen to conserve the habitat and promote carbon sequestration without compromising food security. It is important to improve soil health and carbon storage for increasing agricultural resilience and mitigating the effects of climate change on food security.

Keywords: *Climate change, Soil carbon, Carbon sequestration, Climate change mitigation and Food security*

Introduction

Climate change has become a major concern for global food security as it threatens to disrupt agricultural production through extreme weather events such as floods, droughts, and heatwaves. These events can cause crop failure, soil erosion, and reduced crop yields, which in turn can exacerbate food insecurity. Soil carbon sequestration, the process of storing carbon in the soil through natural or human-induced methods, has emerged as a promising strategy for mitigating the impacts of climate change on food security. The soil plays a critical role in regulating the Earth's climate, as it stores more carbon than the atmosphere and oceans combined. The carbon stored in soil helps to improve soil quality, increase water retention, and reduce nutrient loss, which are all crucial for sustainable agricultural production. Sustainable land management practices such as cover cropping, conservation tillage, and organic amendments can enhance soil carbon storage, and provide multiple benefits for both agricultural production and environmental sustainability. However, there are limitations and challenges associated with promoting soil carbon sequestration, including the cost of implementation, the need for technical expertise, and the lack of appropriate policies and

incentives. Soil carbon offset programs, which allow individuals and businesses to offset their carbon emissions by investing in soil carbon sequestration projects, can play a critical role in promoting sustainable land management practices and mitigating the effects of climate change on food security. In this article, we will examine the effects of climate change on soil carbon, explore the potential for sustainable land management practices to promote soil carbon sequestration, and discuss the role of soil carbon offset programs in mitigating the effects of climate change on food security.

EFFECTS OF CLIMATE CHANGE ON SOIL CARBON

Changes in temperature

Changes in temperature can greatly impact the amount of carbon stored in the soil. Shifts in patterns of precipitation and increases in temperature are two major components of ongoing climate change (IPCC, 2018). Warmer temperatures can increase the rate of decomposition of soil organic matter, which releases carbon into the atmosphere as carbon dioxide. This can lead to a reduction in soil carbon stocks over time, and thus contribute to increased levels of atmospheric carbon dioxide. Additionally, increased temperatures can lead to changes in soil microbial activity and nutrient cycling, which can further impact soil carbon levels. According to research, an increase in soil temperature from 21°C to 38°C accelerates the breakdown of organic materials (Broadbent, 2015). This effect is attributed to the stimulation of microbial activity (Fang et al., 2005) and the enhanced transport of soluble substrates within the soil (Fierer et al., 2005). Furthermore, as temperatures rise, it can lead to changes in plant growth and root exudation patterns. Plants typically release more carbon into the soil through their roots when temperatures are higher, which can stimulate microbial activity and enhance soil carbon storage. However, if plant growth is affected by other factors such as water availability, nutrient availability or disease, it can lead to a decrease in root exudation and soil carbon storage.

In general, changes in temperature resulting from climate change can have both direct and indirect impacts on soil carbon storage. Understanding these effects is crucial in developing strategies to mitigate the impacts of climate change on soil carbon, such as implementing sustainable land management practices and promoting soil health.

Changes in precipitation patterns

Changes in precipitation patterns due to climate change can have a significant impact on soil carbon. Alterations in the timing, frequency, and intensity of rainfall can affect the amount of carbon stored in the soil by influencing plant growth, soil microbial activity, and nutrient cycling. In regions where precipitation is decreasing due to climate change, soil carbon stocks can be depleted. This is because the amount of carbon that can be stored in the soil is often limited by the amount of water available. In areas where rainfall is already scarce, a reduction in precipitation can lead to lower plant productivity, less organic matter input, and lower microbial activity. Research has found that at wet areas, higher precipitation causes a decrease in dissolved organic carbon and microbial biomass carbon (Chen *et al.*, 2023). All of these factors can result in a decline in soil carbon storage.

On the other hand, in areas where precipitation is increasing due to climate change, there may be a temporary increase in soil carbon stocks. This is because increased rainfall can promote plant growth and stimulate microbial activity, resulting in greater carbon inputs into the soil. However, this effect can be short-lived and may lead to other issues such as soil erosion and nutrient leaching. Taking everything into account, changes in precipitation patterns can greatly impact soil carbon storage and can have long-lasting effects on soil health. Strategies for mitigating these effects may include implementing sustainable land management practices such as conservation tillage, cover cropping, and the use of organic amendments to promote soil health and carbon storage.

Changes in land use and management practices

Changes in land use and management practices refer to alterations made to the way land is used and managed for agricultural or other purposes. These changes can include modifications to crop rotations, tillage practices, fertilization methods, irrigation systems, and the use of cover crops, among others. Land use changes may involve the conversion of forest or grassland to cropland or pasture, while management practices may involve the application of organic amendments or other soil-improvement techniques. The goal of such changes is often to improve soil health and fertility, increase agricultural productivity, and reduce the negative impacts of farming on the environment, including soil erosion and greenhouse gas emissions. These changes can have significant impacts on soil carbon storage and play a key role in mitigating the effects of climate change on food security.

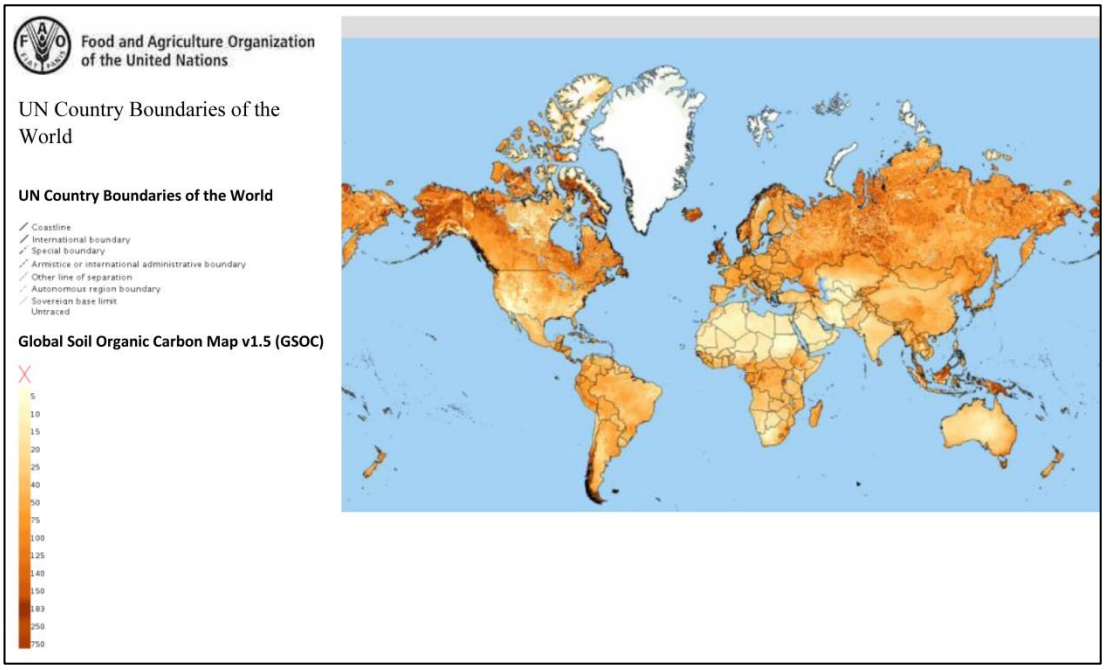

Figure 1. Global soil carbon content in the topsoil (0-30 cm depth)
(Source: FAO, 2023)

MITIGATING CLIMATE CHANGE THROUGH SOIL CARBON SEQUESTRATION

Soil carbon sequestration is the process of capturing and storing atmospheric carbon in the soil. Figure 1 gives the present scenario of Soil Organic Carbon (SOC) content in the topsoil (0-30 cm depth) for different countries. Increasing soil carbon levels can help mitigate the effects of climate change by reducing atmospheric carbon dioxide levels.

There are several sustainable land management practices that can promote soil carbon sequestration, including:

Carbon storage: Increased soil carbon storage can help mitigate climate change by reducing atmospheric carbon dioxide levels. Increased soil carbon levels can improve soil structure and fertility, enhance nutrient cycling and water holding capacity, and promote beneficial microbial activity. Improved soil health and fertility can increase crop yields, improve food quality, and promote food security.

Cover cropping: Planting cover crops between cash crops can help prevent soil erosion, increase organic matter input, and enhance soil microbial activity, leading to greater soil carbon storage. Cover cropping has been acknowledged as a successful strategy for promoting soil conservation, with further advantages for agriculture's sustainability and resilience (Duval *et al.*, 2016; Novara *et al*., 2021).

Conservation tillage: Reducing tillage intensity or frequency can promote soil health by reducing soil disturbance, enhancing water infiltration, and increasing soil organic matter content, thus promoting soil carbon storage. Studies conducted by Babu *et al.* (2023) showed that effective conservation tillage and diversified cropping improved soil carbon buildup.

Organic amendments and fertilizers: Applying organic amendments such as compost, manure, and biochar can enhance soil organic matter content, promoting soil carbon storage and soil health.

Crop rotation: Rotating crops can help enhance soil organic matter content and improve soil structure, leading to increased soil carbon storage. Yang *et al.* (2023) reported that crop rotations that are more intensive and produce more aboveground biomass have a higher likelihood of promoting lower carbon footprints and assist in the achievement of national emissions reduction goals, such as those aiming at net zero.

Fertilizers: Applying adequate amount of fertilizers in a scientific way can provide plants with essential nutrients, promoting plant growth and productivity, which in turn can increase organic matter inputs and promote soil carbon storage.

Reducing soil erosion: It can help maintain soil health and prevent carbon loss from the soil. Soil erosion can be reduced through the use of conservation tillage, cover crops, and vegetative barriers.

RESTORING SOIL CARBON IN DEGRADED SOILS

Soil degradation is a major issue worldwide, and degraded soils have significantly lower levels of soil organic carbon. This not only results in decreased soil fertility and productivity but

also contributes to climate change. Therefore, restoring soil carbon in degraded soils is an important goal for both improving soil health and mitigating climate change.

Importance of Restoring Degraded Soils

Improved soil health: Restoring degraded soils can help improve soil structure, fertility, and water holding capacity, leading to increased productivity and agricultural yields.

Climate change mitigation: Increasing soil carbon storage in degraded soils can help mitigate climate change by capturing atmospheric carbon and reducing greenhouse gas emissions.

Strategies for Soil Restoration

Land-use changes: Implementing land-use changes such as agroforestry, conservation agriculture, and intercropping can help improve soil structure and fertility, leading to increased soil carbon storage. Studies have shown that soil organic carbon and soil enzyme activities were significantly affected by land use types (Erdel *et al*., 2023).

Restoration of vegetation: Restoring vegetation cover through reforestation or afforestation can help promote soil health and carbon storage.

Soil conservation: Reducing soil erosion through the use of conservation tillage, cover cropping, and vegetative barriers can help maintain soil health and promote soil carbon storage.

Use of organic amendments: Incorporating organic amendments such as compost, manure, and biochar can enhance soil fertility and promote soil carbon storage.

Techniques for Enhancing Soil Carbon Storage

Soil carbon sequestration: Sequestering atmospheric carbon in the soil can be achieved through techniques such as conservation agriculture, no-till farming, and cover cropping.

Biochar: Incorporating biochar into the soil can help increase soil organic matter content and promote soil carbon storage. Biochar applications were found to be the most effective approach for increasing soil organic carbon content, resulting in an average increase of 39%. Cover crops and conservation tillage had less pronounced effects, with average increases of 6% and 5%, respectively, according to the findings of Bai *et al*. (2019).

Soil inoculants: Using soil inoculants such as mycorrhizal fungi and rhizobia can enhance soil microbial activity, leading to greater nutrient cycling and increased soil carbon storage.

In brief, restoring soil carbon in degraded soils is crucial for improving soil health, enhancing agricultural productivity, and mitigating climate change. The use of sustainable land management practices and the incorporation of organic amendments can promote soil carbon storage and help restore degraded soils. Techniques such as soil carbon sequestration, biochar, and soil inoculants can also be effective strategies for enhancing soil carbon storage.

Soil health for climate change adaptation and mitigation

Soil health plays a critical role in both mitigating and adapting to climate change. The health of soil ecosystems is closely linked to their ability to store and cycle carbon, making soil

health an important factor in reducing greenhouse gas emissions and increasing the resilience of agroecosystems to climate change impacts.

The Role of Soil Health in Mitigating Climate Change

Soil carbon sequestration: Soils have the potential to sequester significant amounts of carbon from the atmosphere, thereby reducing greenhouse gas emissions and mitigating climate change.

Nitrogen cycling: Soil microorganisms play an important role in nitrogen cycling, which is a critical process for reducing greenhouse gas emissions.

Water management: Healthy soils are better able to manage water, reducing the risk of floods and droughts, which are expected to become more frequent and intense with climate change.

The Potential of Soil Carbon Sequestration in Reducing Greenhouse Gas Emissions

Soil carbon storage: Soils have the potential to store large amounts of carbon, making them a significant tool for mitigating greenhouse effect and climate change.

Sustainable land management practices: Sustainable land management practices such as agroforestry, conservation agriculture, and cover cropping can enhance soil carbon storage and reduce greenhouse gas emissions. Practices chosen should be site specific, so that it ensures food security, carbon sequestration and habitat conservation at the same time.

Improving Soil Health for Climate Change Mitigation and Ensuring Food Security

Soil biodiversity: Soil biodiversity refers to the variety of living organisms found in soil, including bacteria, fungi, protozoa, nematodes, arthropods, and earthworms. Soil biodiversity plays a crucial role in maintaining healthy soils and supporting plant growth. These organisms are responsible for breaking down organic matter and releasing nutrients, which are essential for plant growth. Additionally, soil biodiversity helps to improve soil structure and porosity, which supports water infiltration and retention. One of the most important functions of soil biodiversity is carbon sequestration. Soil organisms play a key role in storing carbon in the soil, which helps to mitigate climate change by reducing the amount of carbon dioxide in the atmosphere. Soil organic matter, which is primarily composed of carbon, is a key indicator of soil health and is critical for maintaining healthy soils. Hence a soil with rich biodiversity is a potential productive soil, that can ensure food security if maintained well.

Soil structure: The physical structure of soil is important for water and air movement, nutrient cycling, carbon sequestration and plant growth. Improving soil structure through practices such as cover cropping and reduced tillage can enhance soil health and in turn crop yield.

Organic matter: Increasing soil organic matter content through the use of organic amendments such as compost, manure, and biochar can help promote soil health and enhance soil carbon storage. Soils rich in organic carbon provides an ideal medium by improving various soil properties and thus could make the soil best suitable for plant growth. Loss in soil fertility is a major concern that we are currently facing and it could be a serious threat for our future as well since we need food to feed our ever-increasing population. Hence, increasing organic matter by

returning it to the soil rather than the atmosphere could help solve two major threats, namely, food security and global warming.

Soil carbon sequestration has the potential to reduce greenhouse gas emissions, and soil health plays a crucial role in enhancing the resilience and sustainability of agricultural systems. Therefore, improving soil health is an important component of climate change mitigation and adaptation efforts, as well as ensuring food security for present and future generations.

Conclusion

In Conclusion, the importance of soil carbon in mitigating the effects of climate change on food security cannot be overstated. The potential for soil carbon sequestration through land management practices such as cover cropping, conservation tillage, and organic amendments is significant, and restoring degraded soils can increase soil carbon storage. It is imperative that we take action to promote soil health and carbon storage through sustainable land management practices which are site specific. By doing so, we can increase agricultural resilience and mitigate the impact of climate change on food security. It is essential that we increase awareness of the importance of soil carbon and take action to promote its storage and sequestration for the benefit of current and future generations.

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MUTATION: KEY FOR ENHANCING PRODUCTIVITY AGAINST CLIMATE CHANGE

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Abstract

Crop modification techniques must be increasingly accurate in creating smart crop varieties given the foreseeable risk that climate change poses to crop yield and the continuously rising needs of agricultural production. This paper analyses the history, present, and projected developments in mutant breeding for agricultural enhancement. It offers background information on plant mutation breeding tactics, basic and sophisticated methodologies, and a critical evaluation of this strategy in relation to other approaches for the genetic improvement of crops. A vital and extremely effective strategy in the global agricultural effort to feed a growing and nutrient-demanding human population is mutation breeding. The consequences and applications of the physical and chemical mutagens are examined. There has been an induction of mutations and these would result in the quick enhancement of crops with enhanced yield, biotic and abiotic stress, and decreased agronomic inputs. Thus, the development of designer crop varieties to address the dangers of global climate change and difficulties of global food insecurity will greatly benefit from mutation-assisted plant breeding.

Key words: developmental mutants, genetic diversity, molecular markers, and in vitro mutagenesis

Introduction

The fundamental prerequisite of plant breeding in creating plant varieties for sustainable food supply is the exploitation of natural and induced genetic variation. Because desired genotypes are few or do not exist, plant breeders are handicapped. The thirst for food to feed the world's expanding population continues to be a top priority, and plant breeders are under pressure to maintain food supply. Additionally, the unpredictable climate change has increased pressure to create sustainable solutions because of its direct impacts on agricultural production and food security. Although plant breeders are working tirelessly to maintain food production and nutrition and genetically improve plants using both traditional and contemporary methods, the solution doesn't seem to be very promising. However, they have successfully developed new cultivars with desirable features like high yield and resilience to biotic and abiotic stress by sexually hybridising the necessary genes from the existing

available gene pool and the related plant species. Induced mutations are created with the intention of increasing the mutation frequency rate in order to choose the best variants for plant breeding. The frequency of spontaneous mutations is quite low, making it challenging for plant breeders to take advantage of them. Both physical (like gamma radiation, x rays) and chemical (like EMS, MMS) mutagen treatments can cause mutations in crops grown from seeds and vegetatively propagated crops. The mutagen therapy damages the nuclear DNA, and new mutations are haphazardly and heritably introduced during the DNA repair procedure. To choose advantageous mutants with traits like flower colour, flower form, disease resistance, or early flowering types, plant breeders can pick changes in cytoplasmic organelles as well as genomic abnormalities (like Chromosome 1, 2, 3). When one or a few characteristics of an exceptional cultivar need to be changed, the ability to produce unselected genetic variation through mutation induction can improve vegetatively propagated plant. According to www-mvd.iaea.org, more than 3000 mutant varieties have already been formally approved in more than 60 countries. These varieties include those for rice, wheat, barley, sorghum, legumes, cotton, edible oil, ornamental plants, and fruits. To feed their continuously expanding populations, China and India are the two countries that create the most mutant types. Rice is the crop with the greatest number of mutant types that have been released. The maintenance of food and nutrition security is the top priority of plant breeders and geneticists, which is why choosing the key crops has become essential for achieving these goals under the conditions of limited arable land and climate change. A major concern and challenge to maintaining food supply globally are new issues like climate change and population expansion, among others. Terrestrial ecosystems and local temperatures will shift, frequently endangering human lives. Climate change will have a more negative impact on food and fibre production, environmental services, and rural livesin poorer nations. In addition, a significant portion of the population of poor countries—up to 80%— depends on agriculture for a living, making them more susceptible to climate change. The effects of other stressors, such as economic globalisation, urbanisation and its impact on the availability of rural labour and land, population growth and its impact on the availability of water and other resources, crop pests and diseases, land degradation and low soil fertility, poverty, etc., must also be taken into account when evaluating climate-related changes. Additionally, there is no longer any possibility of increasing arable land; rather, it is slowly being lost to other human growth activity. In order to sustain food production and feed the globe, plant breeders will turn for new, cutting-edge tools like mutation breeding.

Impact of climatic changes on agriculture

Resources, weather, and climate are absolutely necessary for agriculture. The existing water resources, arable land, environment, germplasm resources, and sustainable forestry practises areincreasingly being put under a tremendous deal of stress as a result of massive industrialization andthe continued rise of the human population. The

adverse effects on global food production and the increase in food prices are clearly evident. The effects of climatic changes such as gaseous pollution, loss of atmospheric ozone, increase in UV-B radiation, increase in atmospheric CO2, extreme variability of rainfall time and location, irregular lengths of growing seasons, intermittent dry spells, global warming, high temperatures, and degradation of water and soil resources could be one of the main causes of this issue.

Table: List of varieties released by mutation breeding.

Crop	Name of Variety	Country	Important Traits
Cotton	MCU 5, MCU 7	India	High Yielding (HY), Earliness
	Rasmia	India	
	Indore 2	India	
	Pusa Ageti	India	
Wheat	Lewis	USA	HY, lodging resistant, earliness Early maturity
	Stadler	USA	Better grain quality
	Sharbati Sanora	India	
Rice	KT 20-74	China	HY, Earliness
	SH 30-21	,,	,,
	Reimei	Japan	Low temp tolerant
	IIT 48 and 60	India	Early maturity

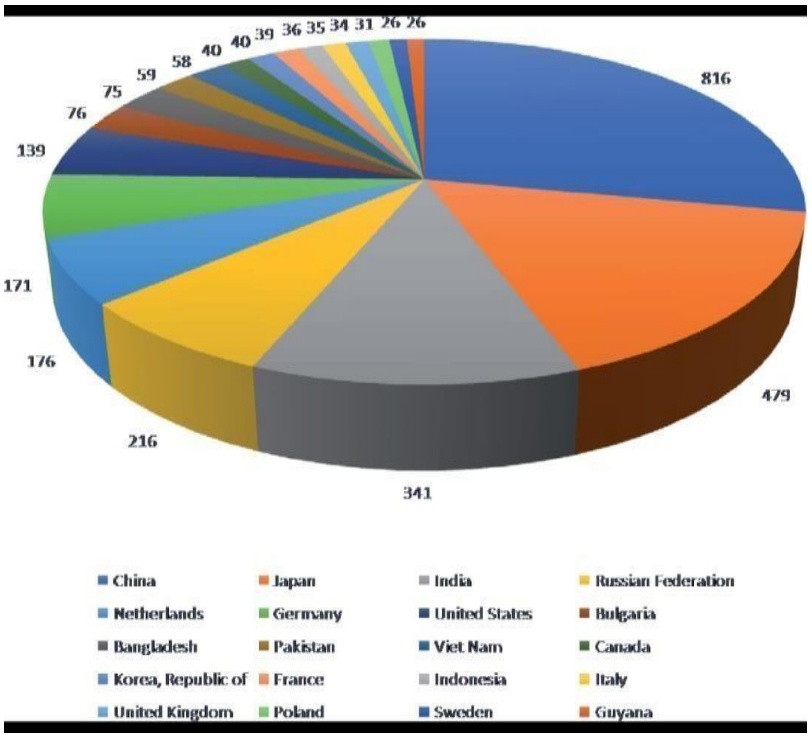


Figure: Number of mutant varieties released in 20 countries

Additionally, it is a difficult task for planners to overcome complex inherent uncertainties like our inability to make region-specific predictions of the rate, nature, and extent of climatic change, especially rainfall patterns, the threat of irreparable ecosystem damage, a very long planning horizon, long time lags between greenhouse gas emissions and climate effects, wide regional variation in causes and effects, the global scope of the problem, and the nascent nature of the issue. Due to the emergence of new pests, illnesses, and insects as well as the potential extinction of certain already present ones, global warming could have severe effects on agricultural production. The yield of a number of significant crops is also decreased by the ambient ozone concentration, either alone or in conjunction with other contaminants.

Techniques for minimising the effects of climatic changes

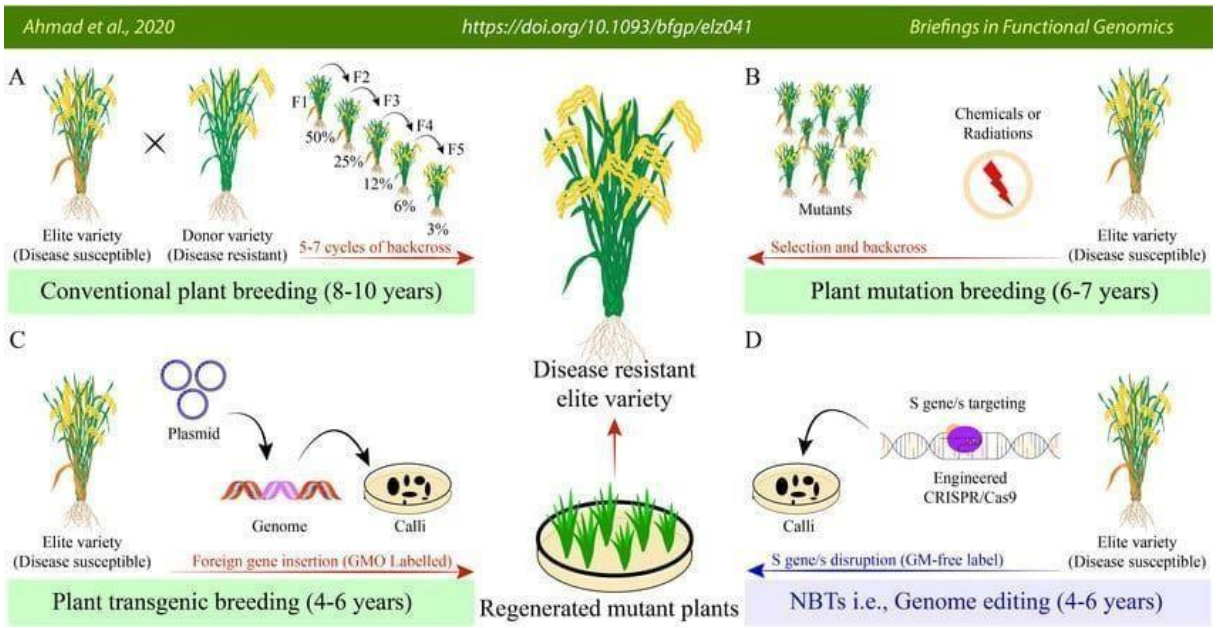
Plant breeders are under pressure to maintain food production in the face of climatic changes. Worldwide food prices have already increased, and both developed and developing nations are currently experiencing economic hardship as a result of rising food and fuel costs. However, the poor world is currently experiencing the most economic hardship. The global food crisis cannot be solved in the short term with a magic formula. Find the most suitable and economical strategies to maintain food production. Targeted breeding varieties may not be very helpful, and conventional breeding in combination with other methods such as mutagenesis, biotechnology, genetic engineering, or molecular breeding utilises local genetic resources to develop new cultivars that could handle frequent climatic changes.

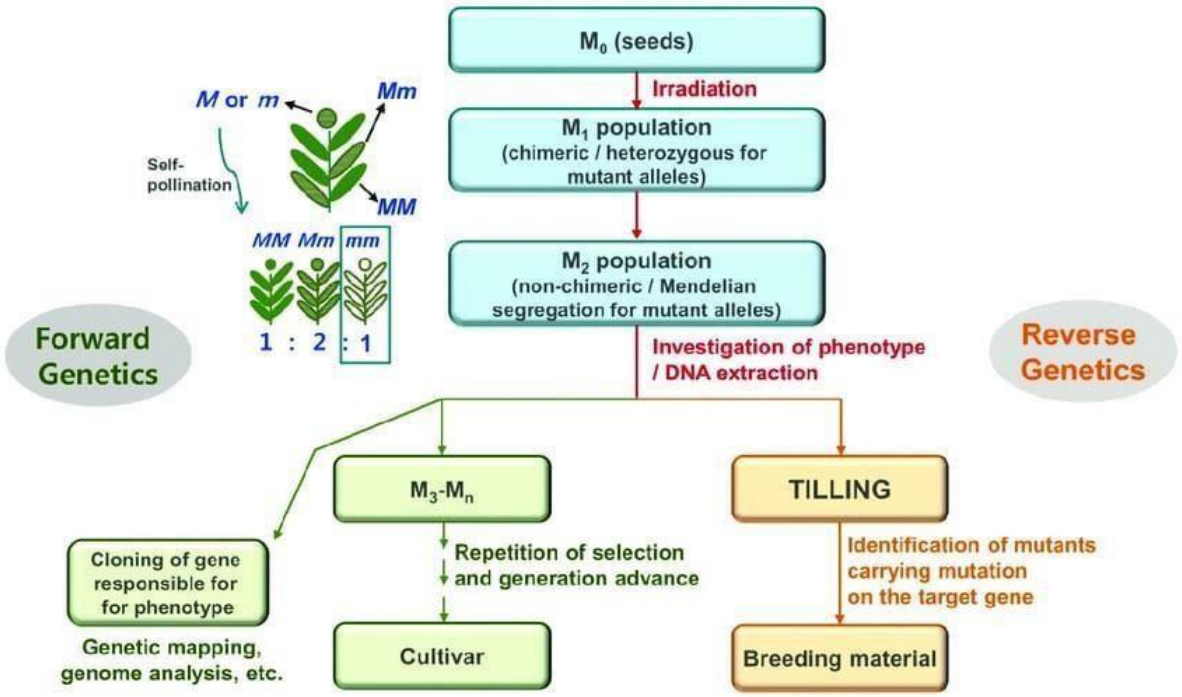
Mutation induction for quality and nutrition improvement

Hugo de Vries (1901) first introduced the term "mutation" to describe a sudden heritable alteration in an organism's DNA that was induced artificially by radiation, chemicals, viruses, transposons, or chromosomal abnormalities that happen during the reproductive process. These alterations, which include gene mutations, chromosomal mutations, and genomic mutations, can be passed down to the progeny. The most popular method for creating new, enhanced germplasm in crop plants is now induced mutation. Applying mutagens to plant cells in order to breed new crops is known as mutation breeding. The cornerstone of both breeding and evolution is genetic variation. Mutagenesis was embraced by plant breeders in 1940 as a method that produces mutations in plants more quickly. Techniques for induced mutation breeding are now the most effective, swiftly adopted, and commonly used strategies for crop improvement globally.

One of the key benefits of mutation breeding is the ability to identify mutants with various features. Under rapidly changing environmental conditions, mutant variants

have substantially higher odds of surviving. Before any new cost-effective procedures are discovered that are publicly availablewithout too many constraints, in my opinion, using nuclear technology to develop new varieties under changing climatic conditions would be the best course of action. Quality and nutritional components of food are equally vital to human diets as agricultural productivity increases. Enhancing essential minerals and amino acids for humans and animals, changing protein and fatty acid profiles for nutritional and health reasons, altering the physicochemical properties of starch for various end uses, increasing phytonutrients in fruits, and lowering anti-nutrients in staple foods are all necessary. Inducing mutations that improve the nutritional value of crop plants may be a significant function of induced mutations. 776 mutants have been induced for nutritional quality out of the 3000 mutant varieties internationally (www-mvd.iaea.org).In order to significantly lower the ongoing expenses associated with fortification and supplementing, methods should be focused on producing plants that can hold high quantities of minerals and vitamins in their edible sections (Shetty 2009). Success of this technique will depend on farmer acceptance of these varieties, customer acceptance of the edible sections of these varieties, and the body's ability to absorb the inserted micronutrients (Bouis, 2002). Before a plant breeding strategy can be implemented to tackle micronutrient deficiency, some issues must be resolved in order for it to work and be widely adopted, especially in developing nations (Bouis 2002).





Mutation induction methods

Globally, genetic enhancement of seed and vegetatively propagated crops has profited considerably from nuclear technology. Mutations can be induced using both chemical and physical mutagens. Gamma rays and ethyl-methane sulphonate (EMS) are two of them that are frequently utilised for inducing mutations. The ideal dose for inducing mutations is based on the initial determination of the LD50 dose.

1. **PHYSICAL MUTAGEN:** -The most popular technique for creating direct mutant varieties has been radiation-induced mutation induction, which accounts for 90% of variations produced (64% with gamma rays and 22% with X-rays). UV radiation and ionising radiation (X-rays, gamma rays, alpha and beta particles, protons, and neutrons) are the two forms of radiation that can be used to induce mutagenesis. Compared to ionising radiation, ultraviolet light (250–290 nm) has a moderate ability to permeate tissues. Ionising radiation can cause a wide range of distinct chemical alterations since it can reach deeper into the tissue. Physical mutagens have several advantages over chemical ones, including accurate dosimetry, sufficient repeatability, and, in the case of gamma rays, a high and homogeneous penetration in plant tissues. A recent report revealed the reemergence of a putative banana mutant, designated DPM25, with better output and fruit size as well as some resistance to Fusarium wilt, a potentially fatal disease that can spread throughout the world. The isolation of black Sigatoka disease putative resistant mutants by gamma irradiation from the susceptible banana variety "Grande Naine."

2. **CHEMICAL MUTAGENS: -**Chemical agents are useful because they offer high rates of mutation and mostly point mutations. The alkylating agents, such as ethyl methanesulphonate (EMS), diethyl sulphate (dES), ethyleneimine (EI), ethyl nitroso urethane (ENU), ethyl nitroso urea (ENH), and methyl nitroso urea (MNH), as well as azides, are the chemical mutagens that are most frequently used to induce mutations. By adjusting the treatment's concentration and duration, solvent (such dimethyl sulfoxide (DMSO)), or solution pH, the dose assessment for substances can be calculated. Banana shoot tips were also treated with chemical mutagens (EMS, DES, and sodium azide) to create variations for tolerance to Fusarium wilt. Chrysanthemum has been successfully subjected to EMS, with a frequency of 5.2% mutants.
3. **ION BEAM TECHNOLOGY :-** Gamma rays, X-rays, and neutrons, which have primarily been used for mutation induction in plants , are replaced by heavy ion beams (HIB), which are responsible for linear energy transfer (LET). As LET increases, higher biological effects, such as lethality, chromosomal aberration, etc., are induced as compared to most commonly used physical mutagens.A variety of mutants have been induced in maize and rice, wheat, anda number of different ornamental plants .

Achievements

Genetic enhancement of rice

The improvement of rice varieties through mutation breeding serves as the greatest illustration of the impact of induced rice mutants in applied research. The first rice varieties, KT 20- 74 and SH 30-21, which were created through induced mutation, and the first variety, Yenhsing-1, which was created through a cross-breeding scheme with a mutant, were both introduced in China in 1957. Soon after, the lodging-resistant semi-dwarf mutant Reimei was released in Japan, which has greatly enhanced changed the production of rice in the USA and Pakistan, respectively. A new variety of Basmati known as "Kashmir Basmati" was developed in Pakistan from the induced mutation of Basmati 370. Kashmir Basmati develops early, is cold tolerant, and keeps the aroma and cooking quality of the parent.'PNR- 381' and 'PNR- 102' are two early-ripening, aromatic mutation-derivedrice varieties that are widely cultivated in Haryana and Uttar Pradesh. Over the course of ten years, more than 10.6 million acres of land in China were used to grow the rice mutant "Zhefu 802." The 'RD6' fragrant indica rice variety was introduced to Thailand in 1977 with the help of gamma ray irradiations. Designing the strategies for the generation of hybrid rice types has greatly benefited from the induction of the thermosensitive genetic male-sterile (TGMS) mutant in the Japonica rice mutant PL-12, which is regulated by a single recessive gene. These mutations are crucial to the breeding of two line heterosis.

Enhancing the barley crop's resilience to lodging

The development of 'Diamant' and 'Golden Promise,' a gamma-ray induced semi-dwarf mutant, changed the brewing business in Europe. Mutation breeding has been utilised very successfully in the breeding of barley. In Europe, 'Diamant'-based crosses resulted in the development of a significant number of different barley cultivars. The 2006 release of Centenario, a high yielding crop with high protein content, early maturity, and resistance to yellow rust, has made a substantial contribution to the nation's food security. The gamma ray-induced mutants "Luther" and "Pennrad," respectively, had a 20% increase in yield, improved tillering and lodging resistance, and winter hardiness, better lodging resistance, and early ripening.

Developing drought and salinity tolerance in wheat crops

The mutant variety "Sharbati Sonora," which is semi-dwarf and doesn't lodge, has significantly increased wheat productivity in India. By gamma irradiating the red-grained Mexican cultivar "Sonara 60," "Sharbati Sonora" was created at the Indian Agriculture Research Institute in New Delhi, India. Ahigh producing mutant Stadler that was created in Missouri, USA, has greater lodging resistance, early maturity, and resistance to leaf rot and loose smut. Due to the cold-tolerant mutant types, the area under cultivation of durum wheat in Italy was greatly increased.

Developing early-maturing peanut varieties

A number of gamma-radiation-induced peanut mutants, including Yueyou No. 5, Yueyou No. 22, Yueyou No. 33, Yueyou 551, and Yueyou 187, were released in China as high yielding varieties under the name "Yueyou." Some of these (Changua No. 4, Lainog, Yueyou 551-38 and Yueyou 551) were early maturers with higher yields. TG

26 is a mutant type of peanut that was created at the Bhabha Atomic Research Centre in Bombay. It has a semi-dwarf plant habit, matures quickly, sets its pods compactly, bears more pods, has a higher harvest index, and is field-tolerant to serious diseases.

Chickpea mutants with increased production and resistance to wilt disease

Pusa - 408 (Ajay), Pusa - 413 (Atul), Pusa - 417 (Girnar), and Pusa - 547 are a set of High Yielding and Wilt Disease Resistant Chickpea Mutants that were created at I.A.R.I., New Delhi, and are based on the direct usage of induced micro-mutants in a legume crop worldwide. Mutant variety Pusa-547, released in 2006, performs well under late-sown circumstances in India's North-Western area, withthin testa, appealing bold seeds, better cooking quality, and high yields.

Case study

1. Developing nations are hardest hurt in satisfying food demands of their people due to the dual constraints of high population growth and catastrophic weather occurrences, with millions of people unable to get appropriate and nutritionally balanced food. To meet the increasing food needs of a population that is projected to reach 9.6 billion people by 2050, crop production must be raised by 70%. The best food crops for boosting agricultural production and achieving sustainable development objectives are legumes. Warm-season grain legume known as cowpea is frequently regarded as an underutilised crop with significant potential for genetic advancement. Increased seed yield and genetic diversity in the agro-economic attributes of two cowpea varieties treated with various dosages of gamma rays and sodium azide (SA) were the goals of a multi-year field experiment using induced mutagenesis. The study also sought to maximise the various SA and ray doses used singly and in combination.

   From M2 to M3 generation, the largest increase in seed yield was found using quantitative trait analysis. Among the 10 quantitative variables examined, seeds per pod and seed weight had a significant direct effect on yield and were positively associated. New high-yielding and nutrient-dense mutant lines were isolated after an extended phenotypic selection cycle from M2-M4 generations. These genetically diverse, high-yielding biofortified mutant lines could act as a source of elite genes and be an important genetic resource for upgrading low-yielding warm-season grain legumes.
2. Faba beans are one of the most significant grain legumes in the world due to their numerous applications and adaptability to a variety of climatic conditions. This study's goal was to compare the effects of single and combined doses of gamma radiation and ethyl methane sulphonate (EMS) on two different faba bean cultivars. There are few studies on gamma rays and EMS-induced mutagenesis in faba beans. Vikrant and PRT-12 seeds were genetically pure, uniform, dry, and dormant before being exposed to four different gamma

radiation doses (100, 200, 300, and 400 Gy) and EMS doses (0.01, 0.02, 0.03, and 0.04%).It is vital to evaluate the effectiveness and efficacy of mutagens since the utility of a mutagenic agent is determined by its capacity to cause a high frequency of beneficial mutations as opposed to undesired ones. The results showed the following trend: EMS > gamma rays+EMS > gamma rays, demonstrating that EMS is more successful at generating mutations than gamma rays. However, gamma rays were more effective than EMS in terms of mutagenesis efficiency as determined by seedling harm, with the trend being gamma rays > gamma rays+EMS > EMS.

Conclusion

Induced mutagenesis is one of the most crucial methods for increasing the genetic diversity and variation in crops to get beyond the bottleneck conditions that have been created by traditional breeding methods for a long time. Despite being a nearly seven decades old approach, induced mutagenesis has shown to be able to help unlock the genetic potential of plants and provide plant breeders with the raw materials they need to create the envisioned smart crop kinds. Crop varieties created through the use of mutation breeding are crucially improving livelihoods and ensuring global food and nutritional security. Additionally, mutagenesis has the benefit of isolating mutants with a variety of features that, ideally, would make them the best plants to grow in a changing climate. Use of mutagenesis in conjunction with plant tissue culture and the length of the culture period, particularly in cereals, may boost genetic variety for plant breeders to take advantage of.

Before genetic engineering becomes a common and dependable method in plant breeding, it could be used more regularly. The developing nations with rapid population increase cannot wait for high yields from genetic engineering. As a result, plant breeders can use genetic variability produced by mutation breeding.

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Impact of Climate Change on Food Security

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Abstract

Climate change has a direct and significant impact on food insecurity. As global temperatures rise, food production becomes more difficult and uncertain due to changes in weather patterns, extreme weather events, and other environmental disruptions. These challenges have wide-reaching implications for food supplies around the world, as food production is impacted by rising temperatures, increased drought frequency, decreases in soil fertility, and crop destruction from floods or storms. The effects of climate change on food security are particularly apparent in developing countries and can be seen in both the health of their citizens as well as the livelihoods of small farmers. When food availability is degraded due to changing climate conditions such as drought or flooding, there is a risk of malnutrition among vulnerable populations who struggle to access nutritious foods.

Keywords: Change, Climate, Farmers, Food, Malnutrition, Security

Introduction

The World Food Summit in 1996 defined food security as: "Food security exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food pReferences for an active and healthy life." Food security is one of the leading concerns associated with climate change. Climate change affects food security in complex ways and can cause grave social and economic consequences in the form of reduced incomes, eroded livelihoods, trade disruption and adverse health impacts. It will become more difficult to ensure food security under the changing climate for India where more than one third of the population is estimated to be absolutely poor and one half of all children are malnourished (Dev and Sharma, 2010).

- Since 2022, the number of people affected by global food insecurity rose from 135 million in 53 countries in 2019 to 345 million in 82 countries in 2022.
- Rising temperatures are negatively impacting food supplies through extreme weather events, natural disasters, economic and social disruption.
- Food supply systems need to consider climate change at an individual and community level.

Fig. 1. Impact of climate change on four dimensions of food security

10 ways to prevent food insecurity

1. Invest in food storage systems that can withstand extreme weather events.

2. Diversify food sources and agricultural production techniques to reduce risk.

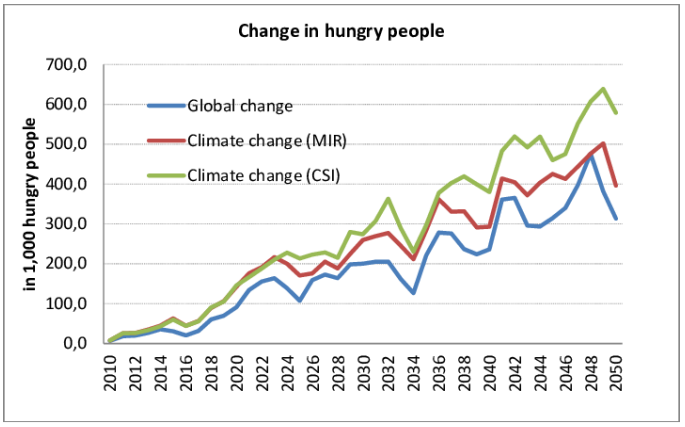
3. Adopt water management systems that reduce crop damage from floods or droughts.

4. Implement sustainable farming practices such as no-till agriculture, agroforestry, and cover crops.

5. Support smallholder farmers with access to credit and other services to ground economic empowerment.

6. Increase public awareness of food security challenges caused by climate change.

7. Increase organic carbon in soil to increase water retention in soil, increasing resilience to drought.



8. Promote education on food preservation techniques such as refrigeration, dehydration, etc.

9. Develop early warning systems for extreme weather events to enable food production adaptation by leveraging technologies that embrace data analytics and insights, predictive AI.

10. Invest in research and development for climate-resilient food crops.

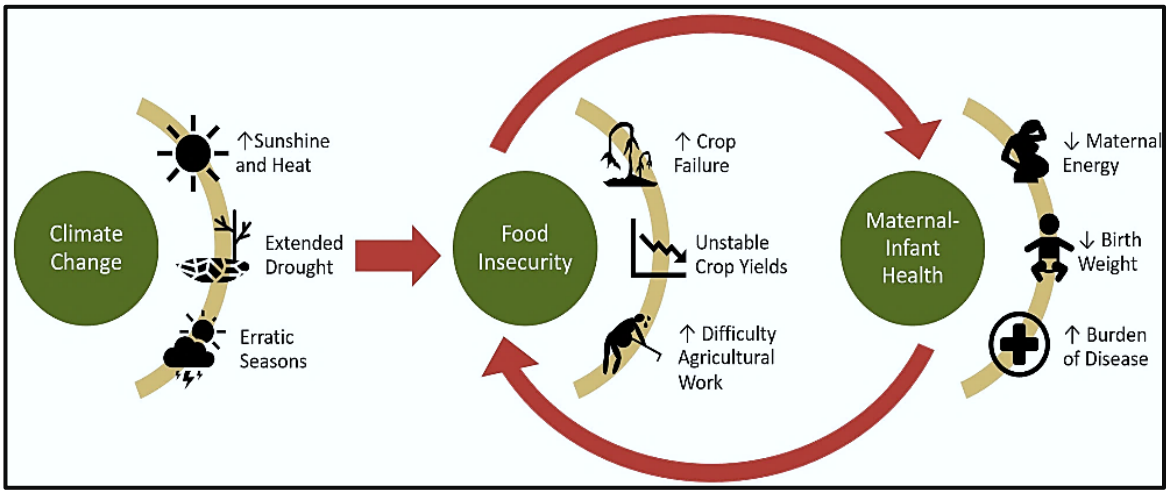


Fig. 2. Influence of climate change on hungry index of global population

Ways to achieve food security:

✓Climate resilient crops

✓ Agroforestry measures

✓Increasing area under irrigation

✓ Integrated farming system

✓ Adoption of sustainable agricultural practices

✓ Need for more impact assessment studies

✓ Contingency crop planning

✓ Long-term relief measures in the event of natural disasters

Climate resilient crops

Resilience: the capacity to recover quickly from difficulties

Climate resilient crop varieties, with enhanced tolerance to heat, drought, flooding, chilling and salinity stresses are essential in order to sustain and improve crop yields to cope with the challenges of climate change. Millets are considered as nutri cereals. These crops are grown in a variety of agro-ecological situations like plains, coast and hills as well as in diverse soils and varied rainfall. Rich diversity of small millets crops has made them well suited for contingency crop planning and also address the issues of climate change. These small millets contribute to the balanced diet, and can ensure nutritional security through regular consumption.

Agroforestry- the right tree in the right place for right purpose

In the present scenario of climate change, Agroforestry products can make a major contribution to the economic development of the millions of poor farmers by enhancing food security and alleviating poverty through tree-crop diversification than alone cultivation of sole agricultural crops. It plays a crucial role in climate change mitigation especially due to its tree component. Trees accumulate CO_2 (which is the most predominant GHG) in their biomass through a process called carbon sequestration and microclimatic condition which favors wide flora and fauna. Agroforestry system enhances the overall farm productivity, soil enrichment through litter fall, phytoremediation, watershed protection and biodiversity conservation. (Newaj *et al*, 2015)

No-Till Farming Reverse Climate Change?

"If all the land farmed around the world was in no-till, we could probably reverse climate change," Management of soil carbon can increase the amount of carbon in soil organic matter, which reduces carbon dioxide (CO_2) in the atmosphere and improves soil health. Reducing CO_2 emissions is important for mitigating the extent and impacts of climate change. Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop to reduce soil erosion and runoff, as well as other benefits such as carbon sequestration. (Mangalassery *et al*, 2014)

Integrated farming can fight climate change to ensure the food security

Making climate smart through integrated approach is also an ideal solution to ensure the food security of the ever- increasing global population at a time when there are twin problems of land degradation and carbon emissions. Within the broad concept of sustainable agriculture "Integrated Farming Systems" hold special position as in this system nothing is wasted, the byproduct of one system becomes the input for other. It refers to agricultural systems that

integrate livestock and crop production. Moreover, the system helps poor small farmers, who have very small land

Future action plan for achieving food security:

- Promote the cultivation of less water requirement crops (millets) and cultivars.
- Completion of incomplete irrigation projects and reclamation of water-logged areas.
- By 2030, there is a plan to put 69 million ha under micro-irrigation.
- Technologies such as conservative agriculture should be popularized.
- Diversification in cropping system (Agro- forestry and Agri-horticulture) for saving water and for efficient water management
- Promotion of alternative planting methods such as a system of rice intensification and direct seeded rice can lead to water saving and productivity increases
- Promote the cultivation of drought-tolerant crops and cultivars.
- Developing Weather Insurance products specific to regions and crops.
- Community Seed Banks should be created for drought- prone rainy seasons.

Conclusion

In developing countries like India, climate change has been the most burning issue for agriculture practices. The changing temperature and rainfall patterns and increasing carbon dioxide level will definitely have significant effects on agriculture and thus on food security of India Unbalanced use of nutrients, low water use efficiency, changes in pest/disease patterns, soil erosion, degradation and poor health, etc. would further worsen the situation. Climate smart agriculture, using drought resistant varieties, micro irrigation system, agroforestry, integrated farming system etc; will helps in food security.

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Impact of Climate Change on Major Food Crops and Millets

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Abstract

Since the agriculture is weather dependent enterprises, the global food systems mainly depend upon the climatic factors. The Climate change is the serious problem of last two centuries which silent thread to global food production leads to food insecurity. Due to anthropogenic activities, the greenhouse gases (GHGs) concentration is being increased after industrialization and the enhanced GHGs effect causes the global warming, which leads to changes in world general air circulation and precipitation patterns, increase in temperature. On the other hand Global dimming is also happening. Both have serious impact on crop production and productivity, which is highly unpredictable due to present climatic variability and climate change. The crop stimulation models projected that the yield of major stable food crops are more sensitive to the climate change, which leads to decrease in the yield globally and would leads to starvation and poverty in future. The major food crops namely Rice, Wheat, Maize, Pearl Millet, Sorghum and their projected yields in various studies related to climate changes are discussed in this paper. Many studies also reveal that Millets have the resilience towards the negative impact to climate change along with their nutritional benefits.

Keywords: *Climate change, Millets, Food security.*

Introduction

India is a second largest agriculture intensive economy and has relatively lower adaptation capacity to mitigate the negative consequences of climate change in crop farming (Singh & Narayanan, 2018). The climate is defined as average weather over a period of time. The climate change refers to a statistically significant variation in either the mean stage of climate or in its variability, persisting for an extended period of time. The Inter-Governmental Panel on Climatic Change (IPCC) of the United Nations in its recent report has again confirmed the global warming trend and projected that the globally averaged temperature of the air above the earth's surface would rise by 1.4-5.8°C over the next 100 years (IPCC, 2001). Climate change and agriculture are interrelated processes, both of which take place on global scale. Global warming is projected to have significant impact on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interactions of these elements. The overall effect of climate change on agriculture depends on the balance of these effects. Major impacts of climate change on agriculture are consequences of temperature increase, changes in rainfall patterns and increase in the levels of CO_2 within the atmosphere. The major stable food of the world, wheat and rice are more sensitive to climate change, which is the silent thread to food

security. The production of rabi crops such as wheat particularly in central India and southern India may be more seriously affected (Aggarwal, 2003). Studies have shown that almost all grain crops are sensitive climate changes. The impact of climate change of rice, wheat, maize, sorghum, pearl millet are discussed in this paper. The inclusion of more coarse grains or millets in cropping system may help making food supply withstand vagaries of climate change (Anurag, 2021). Millets having important characteristics of thermophillic which can thrive at relatively higher temperature and xerophillic which can reproduce in limited water input, which helps to resilient to climate change. Not only important to Climate change but also Millets are rich source of nutrients, antioxidants and proteins. Millets can sequester carbon thereby reducing the release of atmospheric CO_2. By that very helpful in mitigating climate change.

Impact of climate change on food Crops:

Rice:

Rice (*Oryza sativa*) is the major stable food crop in the world followed by wheat which is sensible to climate change a silent thread to food security. As a cereal grain, domesticated rice is the most widely consumed staple food for over half of the world's human population. Saseendran *et al* 2000 studied the effect of climate change on rice productivity in kerala using CERES-Rice v3. crop simulation model which resulted as when temperature elevations only was taken into consideration, the crop simulations show a decrease of 8% in crop maturity period and 6% in yield. The temperature sensitivity experiments had shown that for a positive change in temperature up to 5°C, there was a continuous decline in the yield. For every 1°C increment the decline in yield is about 6%. It was observed that the physiological effect of ambient CO_2 at 425 ppm concentration compensated for the yield losses due to increase in temperature up to 2°C. Decrease in rainfall results in yield loss at a constant rate of about 8% per 2 mm/day, up to about 16 mm/day. A simulation analysis was carried out using the InfoCrop-rice model to quantify impacts and adaptation gains, as well as to identify vulnerable regions for irrigated and rain fed rice cultivation in future climates in India by Soora *et al*., 2013 showed that the mean of all climate change would be reduce irrigated rice yields by ~4 % in 2020 (2010–2039), ~7 % in 2050 (2040–2069), and by ~10 % in 2080 (2070–2099) climate scenarios. Rainfed rice yields in India in the 2050 and 2080 scenarios projected to be decrease only marginally (< 2.5 %). (Soora *et al*., 2013). Empirical results based on SPFA and CDPFA models showed that any increment in rainfall may had been negative impact on rice production. Increasing in minimum temperature had a positive impact on rice production. (Kumar *et al*., 2020). With that rice files accounts for more greenhouse gas emissions (GHG) in total than that of any other plant food, it was estimated in 2021 to be responsible for 30% of agricultural methane emissions and 11% of agricultural nitrous oxide emissions (Gupta *et al*., 2021).

Wheat:

Wheat (*Triticum aestivum L.*) is the second most important cereal crop of India and plays a vital role in food and nutritional security of the country. Nearly 55 per cent of the world population depends on wheat for about 20 per cent of calories intake. It is one of the major food grains of

the country and a staple food of the people of North India, where people have preference for chapatti. The production of wheat, a crop sensitive to weather, may be influenced by climate change. The climate change would be reduced the wheat yield in India in the range of 6 to 23% by 2050 and 15 to 25% by 2080 (Kumar *et al*., 2014). Wheat production was being adversely affected due to increase in maximum temperature. Increasing in minimum temperature had negatively impact on wheat production. Results estimated through RRA model indicated that wheat production was also negatively affected due to increase in rainfall (Kumar *et al*., 2020). The studies revealed that the increase in temperature beyond 3 °C cancelled the beneficial impact of enhanced CO_2 (Attri *et al*., 2003).

Maize:

Maize (*Zea mays L*) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 mt) in the global grain production. Boomiraj *et al* 2013 stated that the spatio-temporal variation in existing climatic conditions and projected changes in temperature and rainfall would bring about differential impacts on monsoon maize crop in India. Decrease in the productivity of monsoon maize crop in 2050 and 2080 scenarios Upper Indo Gangetic plains due to regional climate change. The loss from current yield was projected, 13% and 17% in 2050 and 2080 respectively (Boomiraj *et al*.,2013) Xiang Li *et al*., 2011 concluded research that significant changes in climate conditions that alter the maize crop's growing environment and affect crop yields, a decrease in maize supply due to a decrease in maize yields.

Sorghum:

Sorghum [*Sorghum bicolor* (L.) Moench] ranked fourth among the world's most important crops. More than 70% of the world's total production of sorghum comes from the developing countries in Asia and Africa, where crop is grown with limited input of water and nutrients. In India, sorghum is cultivated during both kharif and rabi seasons mainly as a rainfed crop (92% of the area) with about 85% of the production concentrated in Maharashtra, Karnataka and Andhra Pradesh, all falling under warm semi-arid region. It had shown no significant increase in the yield of sorghum with the increase of CO2 (Sultan, 2013). It had been noted that under changing climate sorghum grain yields will constantly increase for both cultivars over the three future time periods with almost 85.3% increase as we approach the end of the century 2070-2099 (Emily Bosire *et al*.,2018). Sorghum future climate change scenario analysis showed that rainfed sorghum yields would be reduced at Akola, Anantpur, Coimbatore and Bijapur. One irrigation (50mm) at 40-45 days after sowing would be better adaptation strategies for rainfed kharif sorghum with existing varieties in the selected location of the SAT regions (Boomiraj et al., 2012). Adaptation strategies like changing variety and sowing dates reduced the climate change impacts to some extent, but complete amelioration of yield loss beyond 2^0C rise may not be obtained even after doubling of rainfall in most of the sorghum growing regions.

Pearl millet:

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the sixth most important cereal crop after rice, wheat, maize, barley and sorghum. It is widely grown on 30 million ha in the arid and semi-arid tropical regions of Asia and Africa, accounting for almost half of the global millet production (Satyavathi *et al*., 2021). In other countries, it is grown under intensive cultivation as a forage crop. Being a C_4 plant, pearl millet can account for 30% of global terrestrial carbon fixation along with other C_4 plants such as maize and sorghum (Choudhary *et al*., 2020). It also possesses several advantages such as early maturity, drought tolerance, the requirement of minimal inputs, and usually free from biotic and abiotic stresses. Its inherent ability to endure high temperatures up to 42°C during the reproductive phase makes it suitable for growth in extremely hot summers under irrigations making it a climate-resilient crop (Satyavathi *et al*., 2021).

Millets resilient to Climate change:

Millets are drought resistant crop, requires less water for its growth and development due to an efficient root system. It possesses higher nutritional value compared to other cereal crops such as rice, wheat and it have capable to emerge as a crop having enormous potential to feed the growing population. Millets can be grown in adverse conditions and thus will be able to save farmers and the agri-food industry from losses. As it grown in dry soil, tillage practices can be avoided reducing the duration of cultivation can promote carbon sequestration. Millets popularly known as "famine reserves" as it be stored for a considerable amount of time under appropriate storage conditions. **Sorghum (*Sorghum bicolor L.*)** can tolerate drought condition because of it's deep root system, waxy leaves, the presence of mortar cells in stem. It can withstand higher temperature at any stage of it's growth makes more suitable for grow it in dryland condition. **Pearl millet (*Pennisetum glaucum L*** grow on poor sandy soils. It is well suited for dry climates due to its ability to use moisture efficiently compared to sorghum or maize. It follows Drought escaping mechanism *i.e*, When drought condition suitation seems to be happen it can shorten it's life cycle and comes to flowering earlier. It usually grown in areas having marginal soil with low annual rainfall in the range of 200–500 mm. **Finger millet (*Eleusine corocana L.*)** has the best ability to tolerate salinity among cereals. **Foxtail millet (*Setaria italica L.*)** has a fast-ripening mechanism and a high photosynthetic efficiency; hence, it is perfectly suited to be used as a catch crop (Anurag, 2021). According to Zhang *et al*. this crop was more water efficient compared to maize and sorghum. **Proso millet (*Panicum miliaceum L.*)** is a relatively low-demanding crop with no known diseases and well suited for many soil types and climate conditions. **Barnyard millet (*Echinochloa frumentacea L*** is a drought-tolerant crop, grown widely in India, China, Japan, Pakistan, Africa, and Nepal possesses high nutritional qualities. **Kodo millet (*Paspalum scorbiculatum L.*)**, the coarsest cereal of the world said to possess the highest drought resistance among all minor millets and can thrive well in both shallow and deep soil. **Little millet (*Panicum sumatrense L.*)** the grains are like that of rice **withstands** both drought and water logging. It is Packed with the goodness of B-vitamins, minerals like calcium, iron, zinc, and potassium.

Conclusion:

Climate is the first and foremost determinant of agricultural productivity with direct impact on food production across the globe, since the climate of a region determines the nature and characteristics vegetation and crops. The climate change has showed the negative impact of major stable food crops of the world, which would be a highest threat to food security and increase the hunger and poverty. Hence, the scientist from all over the World, identify better adaptation and mitigation strategies to reduce the climate change impacts and ensures the food security. The Studies has shown millets potential resilience towards the climate change along with having many health benefits and environmental sustainability. The U.N. General assembly recently adopted a resolution, sponsored by India and supported by more than 70 countries, declaring 2023 as the International Year of Millets. The resolution is intended to increase public awareness on the health benefits of millets. The cultivation of millets is suitable to climate change.

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Promising Litchi Genotypes for Food Security under Changing Climatic Condition

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Abstract

Litchi is one of the emerging, highly nutritious and profitable fruit crop. As it is introduced crop, only few cultivars are grown in India which reflects its narrow genetic base. The most popular cultivars viz., Shahi, Rose Scented, Dehrarose, Deshi and Trikolia are highly susceptible to sun burn (SB) and fruit cracking (FC). Other cultivars viz., China, Mandaraji, Purbi and Bombai-1 are tolerant to SB and FC in normal condition but these cultivars are also prone to these problems under high temperature and low humidity condition. These SB and FC is big challenges before litchi growers. Affords have been made by ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar and new cultivars/genotypes explored/developed which are tolerant to SB and FC even under higher temperature. Three cultivars viz., Gandaki Lalima, Gandaki Sampada and Gandaki Yogita have been developed and six genotypes viz., NRCL-59, 83, 86, 87, 88 and 89 have been identified which are tolerant to SB and FC, having high yield and pulp recovery potential. These genotypes are capable to cope with extreme weather condition. These can be grown under changing climatic condition as they have capability to fight against higher temperature and provide nutritional security as they are highly nutritious for human health.

Key words: Litchi, Sun burn, Fruit cracking, Genotypes, Cuticle thickness

Introduction

Litchi (*Litchi chinensis* Sonn.) is a subtropical evergreen fruit tree and its cultivation is restricted to a few states in India. The total production of litchi in India is 720,000 metric tonnes from 96,000 ha (Anonymous, 2021). The area and production of litchi in the country have increased in the last 75 years. The area of litchi has been increased from 9,400 ha in 1949-50 to 1,04,000 ha in 2021-22. The share of litchi to the total area under fruit has increased from 0.75 to 1.70 percent. The increase in area between 1991-92 and 2021-22 (30 years) has been more than 80 percent, while production increased during the same period is to the tune of above 150 percent (Nath et al., 2022). Earlier, it was being grown mainly in northern parts of the country, but presently, it is being grown in southern parts also (Kerala, Karnataka, Tamil Nadu) where it is available in off-season during December-January (Nath *et al.* 2015). In India, litchi is grown mainly in Bihar, Assam, Tripura, West Bengal, Orissa, Punjab, Uttar Pradesh, Uttarakhand, Chhattisgarh, Jharkhand and Himachal Pradesh. Recently, litchi is reported to be doing well in southern parts of India and producing off-season fruit during December to January. Litchi is

very nutritious to the human health. A wide variation in litchi fruit quality parameters *viz*., TSS (17.04-19.98 °B), ascorbic acid (14.62-47.50 mg/100g), acidity (0.23-0.55 %), total sugar (10.05-13.54 %), reducing sugar (7.69-10.78 %), TSS/acidity ratio (33.98-84.19), phenol in pericarp (7.5-62.2 mg GAE/g) and seed (23.01-59.93 mg GAE/g), and flavonoids in pericarp (0.73-59.93 mg CE/g) and seed (2.41-27.50 mg CE/g) have been reported (Lal et al., 2018a and b). Litchi fruit yield and quality are affected by several physiological disorders such as fruit drop, sunburn, delayed fruit development, irregular fruiting and black spot, but fruit cracking has a bad effect and causes economic losses to litchi. Sun burn and fruit cracking are being major thread to litchi industry as litchi is highly susceptible to climate and global warming promoting higher temperature due to increases in carbon dioxide concentration. Sometimes fruit cracking causes losses up to 100%, especially in young litchi plants. Fruit cracking causes losses up to 5-70% (Singh et al., 2012). There is need to improve the productivity and also widening the genetic base. Concerted research efforts are required to develop suitable cultivars for various climatic conditions. It is also essential to develop promising lines/clones/ hybrids, which have larger fruit size, small/chicken-tongued seeds, higher pulp content, tolerance to sun burn and fruit cracking and having varied maturity groups to avoid the market gluts. Litchi has a very narrow genetic base and it has to be widened through selection of genotypes from the existing population. To keep the above points, ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar has started extensive works on improvement in litchi and identified promising genetic stock/genotypes.

Varietal situation in India

Litchi is introduced from China and in India, more than 30 selected cultivars are growing but commercially Shahi, China, Bedana, Late Bedana, Calcuttia and Longia are growing. In West Bengal, Bombai, Rose Scented and Shahi yield up to 40 kg/tree compared to 15-25 kg/tree in many other cultivars. These cultivars are large-fruited and have excellent eating quality. In Bihar, the important cultivars are Shahi, China, Bedana, Late Bedana, Dehrarose, Deshi, Trikolia, Rose Scented, Late Large Red, Green, Seedless No. 2, Purbi, Mandaraji, CHESS-II, Surguja Selection 1, Bombai-I and Bombai-II. In Uttarakhand, Punjab and Haryana, the varieties are Calcutta, Early Large Red, Early Seedless, Gulabi, Khatti, Late Seedless and Rose Scented, whereas the varieties recommended for growing in Punjab and Haryana are Calcutta, Dehradun, Muzaffarpur, Rose Scented, Saharanpur and Seedless Late. Early cultivars (Shahi, Deshi, Late Large Red, Dehrarose, Dehradun, Rose Scented, Trikolia) are susceptible to SB and FC and late cultivars (China, Bombai-1, Bombai-II, Mandaraji, Purbi, Calcuttia, Late Bedana, Calcuttia Late) are tolerant but these tolerant cultivars are prone to SB and FC under higher temperature (Figure 1 and Table 1).

Response of litchi under higher temperature condition

Litchi is highly influenced by climatic factors. Low temperature is required during winter before flowering for floral induction. Higher temperature before flowering results in mixed panicle of vegetative panicles thus no flowering and fruiting. Similarly, higher temperature during fruit growth and development during April and May results sun burn and fruit cracking. Sun burn is a type of direct heat injury where tissues exposed to direct light gets sun burnt while fruits

located in shade suffers less injury. Sunburn disorder is more severe in early cultivars of litchi. It was observed that sunburn predisposed to cracking. The portion of sunburn turned to cracking at a later stage. But in late cultivars, sun burn is not a big problem and fruit cracking starts directly without sun burn (Table 1). Litchi cracking took place mainly at the initial stage of rapid aril growth, which occurred after several weeks of pericarp growth. The main reason for cracking was thinness of the pericarp during the rapid aril growth, and this stage also coincided with a rise in temperature. The expansion of aril flesh exerted turgor pressure against the already grown skin pericarp. Cracking decreases the visual quality by promoting browning in exposed aril (Huang et al., 2004), and it enhances desiccation. Fruit cracking in litchi depends on both genetic and environmental factors (Li et al., 2001). Thus, different cultivars may show considerable variation in susceptibility to fruit cracking (Islam et al., 2003). Tolerant cultivars/genotypes possess higher thickness of cuticle and spongy layer.

Tolerant cultivars/genotypes to SB and FC

At ICAR-NRC on Litchi, Muzaffarpur, affords have been made to develop/identify tolerant genotypes to SB and FC, and three new improved varieties viz., Gandaki Sampada, Gandaki Lalima and Gandaki Yogita have been developed which are tolerant to SB and FC. The development of improved cultivars coupled with efficient cultural practices is vital for improving crop production in a region. Improved varieties of litchi have been identified and evaluated for their potential. Gandaki Sampada is a late-maturing strain that ripens during mid- June. Fruits are large in size, conical in shape and vermilion to carmine in colour at maturity with dark blackish-brown tubercles. Pulp is creamy white, soft and juicy, with a large fruit size (35-42 g), cracking resistance, pleasant aroma and good yield potential (120-140 kg -1 tree). This variety has potential for export purposes. Gandaki Yogita is a dwarf type variety, comparatively compact, and tolerant of heat waves and fluctuations in soil moisture. The fruits are free from fruit borers and are of very late maturity (10-15 June). Fruits are round in shape, tyrant rose in colour with dark tubercles and flexible seeds at maturity. Pulp recovery is 70-75%, possessing a melting texture with a pleasant aroma and a good blend of sugar and acid. This variety can be recommended for high-density planting as a specialist variety. Several genetic stocks have been identified from the genetic pools. NRCL-59 is a chance seedling selection which leave are similar to Shahi but fruits resemble China variety. Similarly, NRCL-83, 86, 88 and 89 are suitable for high pulp recovery, NRCL- 87 is a large-fruited (>28g) selection that ripens very late, during mid-June.

Gandaki Sampada

- Fruits are large in size (36.85 g), conical in shape, vermilion to carmine colour with 80 to 85 % pulp recovery.
- It has very high percentage of shrivelled and small seeded fruits.
- Suitable for industry due to high pulp content.

- Good yield potential (120-140 kg/tree).
- Tolerant to sun burn and fruit cracking.
- A late maturing strain ripens during mid-June.

Gandaki Lalima

- A highly nutrient efficient strain possessing dark green leaves and the capability to withstand climatic aberrations.
- Fruits are conical, bright marigold-orange red in colour with fruit weight 28-32 g.
- Tolerant to sun burn and fruit cracking.
- Late maturing cultivar ripens in the second week of June.

Gandaki Yogita

- It is slow growing and dwarf plant, tolerant to hot waves and fluctuations in soil moisture and tolerant to sun burn and fruit cracking.
- It can be recommended for high density planting as specialty variety.
- Very late maturity (5th – 15th June).

Genetic stocks identified at ICAR-NRC on Litchi

NRCL-59:

- Flowering and fruiting started during 5th year onward.
- Leaves are similar to Shahi but fruits are similar to China.
- It is deep pink colour.
- It is attractive to the consumers.
- It is tolerant to sun burn (6.23) and fruit cracking.
- It is late maturing genotype having fruit weight 22.56 g,
- TSS: 21.59 Brix, and high anthocyanin content in peel (96.56mg/100g).

NRCL-83

- It is slow growing and dwarf, suitable for HDP.
- Pulp content is 72.48 % and seed is small with an account of 8.73%.

- It is tolerant to sun burn and fruit cracking (3.54%).

NRCL-86

- It is regular and heavy bearer (heavy bunch).
- Fruit weight (24.25 g).
- High content of pulp (72 %).
- Suitable for processing industry.
- Chicken tongue seed (6.9%).
- Tolerant to sun burn and fruit cracking.

NRCL-87

- It is regular and heavy bearer.
- High fruit weight (29.69 g).
- Panicle girth is high.
- High pulp content (>70 %).
- Tolerant to sun burning and cracking.

NRCL-88

- It is slow growing and plant is dwarf having spreading branches.
- It can be grown under HDP.
- Leaves are small which curved upward from the mid rib.
- Average fruit weight is 16.22 g and yield is 16.48 kg/plants.
- Pulp content is 76.38 % and seed is small with an account of 7.63%.
- No sun burn is found and fruit cracking is 6.45%.

NRCL-89

- It is regular bearer.
- Leaves were small like Bedana which curved upward from the mid rib and a fruit like Shahi but shoulder is similar to Kasba. Fruit shape is oblong and colour is pinkish red at maturity.
- The average fruit weight is 25.63 g, peel weight-3.73 and seed weight is 3.75g.
- The pulp content is more than 70%.
- It is late ripening genotype which matures in mid-June.
- No sun burn and fruit cracking is observed.

Table 1. Response of litchi genotypes to sun burn and fruit cracking in different years

Cultivars	Sun burn (%)			Fruit cracking (%)		
	2017	2018	2019	2017	2018	2019
Late Large Red	10.65	37.58	48.67	9.45	39.48	49.56
Mandaraji	0.00	0.00	8.57	3.24	0.00	6.57
Purbi	0.00	0.00	9.68	4.58	0.00	6.28
Calcuttia	0.00	0.00	7.48	4.56	0.00	5.56
Shahi	4.26	25.86	38.54	5.28	26.45	38.97
Ajhauli	3.52	20.45	40.56	3.98	22.56	42.56
Green	4.68	26.45	42.85	5.68	28.62	43.58
China	0.00	0.00	6.57	2.35	0.00	8.67
Deshi	5.28	22.35	34.56	6.48	24.56	35.86
Trikolia	3.25	24.56	45.28	4.56	25.65	48.56
Dehrarose	6.58	32.48	49.38	10.45	33.45	51.45
Dehardun	7.65	33.65	50.58	8.65	35.65	52.36
Early Bedana	0.00	0.00	0.00	8.65	0.00	0.00
Bombai-1	0.00	0.00	4.12	0.10	0.00	2.35
Gandaki Lalima	0.00	0.00	0.00	0.00	0.00	0.00
Gandaki Sampada	0.00	0.00	0.00	0.00	0.00	0.00
Gandaki Yogita	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-59	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-83	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-86	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-87	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-88	0.00	0.00	0.00	0.00	0.00	0.00
NRCL-89	0.00	0.00	0.00	0.00	0.00	0.00

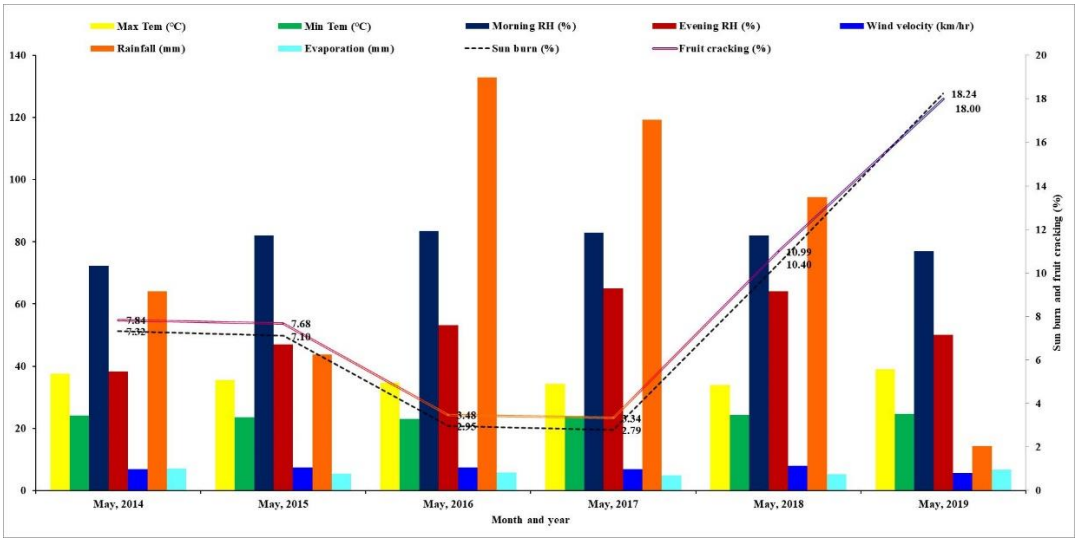

Figure 1: Relationship between sun burn, fruit cracking and climatic factors during fruit development periods of litchi. Average sun burn and fruit cracking percentage in different years.

Conclusion

The limited numbers of cultivars are available in India which are mainly seedling origin and show narrow genetic base. The available cultivars are severely affected from sun burn and fruit cracking. There is need to widen genetic diversity and to select superior genotypes over existing. The breeding efforts have been made by the group of scientist and three promising cultivars and six genetic stocks are identified which are tolerant to sun burn and fruit cracking, early and very late maturing, high pulp content and attractive to the consumers. These genotypes are free from sun burn and fruit cracking which would help to enhance productivity of litchi.

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Quorum Sensing System: A Serious Threat to Aquaculture

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Abstract

Infectious diseases pose serious risks to aquaculture in several countries. The virulence factors released by microbes that infect aquaculture systems and the development of biofilms, both of which are controlled by quorum sensing (QS), are directly connected to how adverse they are. As a result, QS disruption is a viable method for disease prevention in aquaculture systems. In addition to preventing the expression of genes linked to virulence, QS inhibitors (QSIs) also lessen the virulence of diseases that affect aquaculture. We investigate QS systems in significant aquaculture pathogens in this study, with a particular emphasis on the connection between QS mechanisms and bacterial pathogenicity in aquaculture. Further, clarify QS disruption tactics for diseases in the host that affect aquaculture.

Keywords: *Quorum Sensing, Autoinducers, Cell-Cell Communication, Bacterial Diseases.*

Introduction

One of the significant rising sectors during the last few decades is aquaculture. The world's population is expanding at an unmanageable rate, and technologies must be developed considering food security. To supplement the supply effect of the fisheries industry, aquaculture has developed. To meet the nutritional demands of customers everywhere, aquaculture is one of the most significant segments of the food supply chain. It is also one of the businesses that are growing the fastest. A significant amount of the human body's requirements for animal protein are met by fish protein, which is produced by aquaculture, the food sector with the greatest rate of development in the world. This business produces around 82.1 million tonnes of food yearly(Jayaprakashvel and Subramani, 2019). To fulfill the worldwide need for human nutrition, aquaculture output is thus growing daily. Aquaculture is thought to be intensifying, which might lead to issues with animal and ecological health. Disease outbreaks are a serious issue that negatively affects the production of aquaculture. Bacterial infections are the most prevalent cause of illness in fish and crustaceans, and they infect aquaculture species, causing a great deal of mortality. One of the major risks to commercial aquaculture is bacterial infections, which result in enormous economic losses. The losses resulting from bacterial illnesses are considerable, nevertheless, in both terms of capital and quality. Both aquaculture operations and hatchery farms may have disease-related shrimp issues. Among these, shrimp infections at hatcheries are the most dangerous, result in significant economic losses, and in the worst cases, they might completely shut down the business. In hatcheries and farms for aquaculture, antibiotics are frequently used to treat bacterial infections. However, frequent and

intense use of antibiotics in aquaculture hatcheries and farms develops selective pressure on the aquaculture animals. Additionally, it hurts the environment by breeding diseases and other bacteria in aquatic environments with genes that may be transferred to other bacteria and create reservoirs of bacteria that are resistant to drugs. Through horizontal gene transfer, resistant genes may spread from these reservoirs and influence human infections or drug-resistant bacteria from aquatic environments, which would ultimately be biomagnified and have an impact on public health. Therefore, given the current situation for managing aquatic infections, alternate tactics that won't breed pathogen resistance are preferred. Alternative tactics that can focus on the pathogenicity alone rather than the whole bacterium are now required.

The finding that bacteria are capable of quorum sensing (QS), or cell-to-cell communication, has changed our understanding of their pathogenicity. Small signal molecules termed autoinducers, which build up in the extracellular environment when high cell densities are attained, are produced, secreted, and detected by bacteria. Pseudomonas, Aeromonas, and Vibrio *spp*, which have been revealed to have various QS systems, are among the most prevalent bacterial diseases that harm aquaculture. As an illustration, Pseudomonas has four different QS system types, including LasI/R, RhlI/R, Pqs-PqsR, and Iqs, whereas Aeromonas possesses the AhyRI system. Due to their importance in influencing host survival, QS signals might be seen as an additional virulence factor.

Quorum Sensing

The ubiquitous phenomena of quorum sensing (QS) in bacteria have been recognized. Bacteria use a process known as "quorum sensing" that involves making, releasing, and detecting tiny signal molecules to coordinate the expression of certain genes in response to their population density. In bacteria, cell-to-cell communication is based on the generation and recognition of signal molecules that control gene expression in a cell-density-dependent way. The signal molecules that modify the response are known as autoinducers (AI), and this type of communication is referred to as quorum sensing (QS). QS autoinducers are generated and released during vegetative cell development, and they build up gradually in the microenvironment. The expression of genes involved in a variety of biological processes and responses, including bioluminescence, symbiosis, motility, sporulation, plasmid transference, competence, virulence, biofilm formation, toxins, and antibiotic production, is modulated when the bacterial population reaches a threshold density and a critical concentration of the inducer is reached(Medina-Martínez and Santana, 2012). There are several types of AI-QS systems that have been described, depending on the chemical makeup of the signal molecules and their receptors. All of the highly homologous QS systems and luxR/luxI together comprise the type 1 QS system. The molecules that make up the autoinducers are members of a broad group known as N-acyl homoserine lactones (AHL), which all have a conserved homoserine lactone ring connected to a changeable side chain of fatty acids with varying lengths and chemical substitutions. As shown in Figure 1, there are several sources for AHLs in the marine ecosystem.

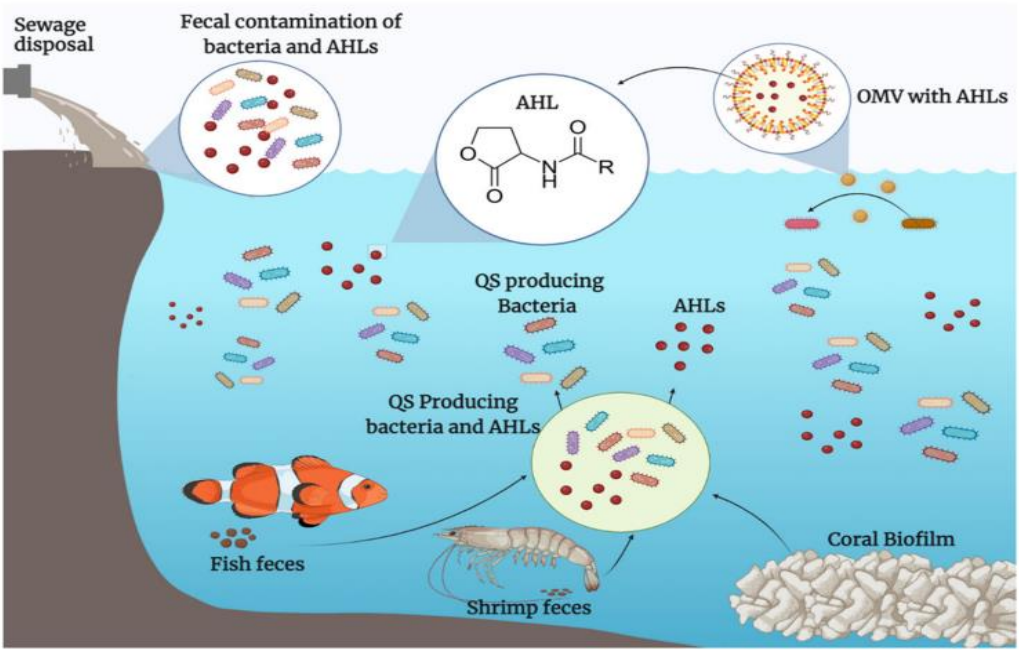

Fig 1. The sources of AHLs (QS Signal Molecules) in the marine ecosystem (Priya *et al.*, 2022)

A single enzyme, the product of the luxI gene or one of its homologs, is responsible for catalyzing the production of AHL from cellular metabolites. An intracellular cytosolic receptor (LuxR and homologues), which activates the transcription of the genes controlled by QS, recognizes AHL. A signal produced by the luxS gene product and associated homologues is the mechanism by which the type 2 QS system functions. In a multistep conversion from ribose homocysteine to a heterocyclic furanosyl molecule, which is frequently connected with a boron atom, AI type 2 is produced as a byproduct of SAM metabolism. The receptor has a receptor-kinase signal transcription complex and is a two-component membrane system. Acylated homoserine lactones (AHLs), also known as autoinducer-1 [AI-1], are the most extensively researched autoinducers and are used by Gram-negative bacteria, whereas peptide-type signals are employed by Gram-positive bacteria. Both Gram-negative and Gram-positive bacteria are capable of recognizing Autoinducer-2 (AI-2). According to reports, these signaling systems have an effect on the expression of genes that code for the creation of virulence factors, bioluminescence, enzyme production, and biofilm development as explained in table 1. By postponing the creation of virulence factors until the population density is high enough to overwhelm the host's immune system, these quorum-sensing pathogens most likely boost their odds of successfully infecting their host.

Table1. The quorum sensing systems of different aquatic pathogens and the link between quorum sensing and virulence factor expression (Defoirdt *et al.*, 2004)

Species	Signal	QS Regulated Virulence Factors
Aeromonas hydrophila	BHL[a], HHL[b]	Biofilm formation, exoprotease production
Aeromonas salmonicida	BHL[a], HHL[b]	Serine protease production
Vibrio anguillarum	ODHL[c]	Unknown
Vibrio harveyi	OHBHL[d], AI-2	siderophore production, production of type III secretion system components, extracellular toxin production
Vibrio vulnificus	AI-2	protease and hemolysin production, lethality in mice

[a] BHL: N-butanoyl-l-homoserine lactone; [b] HHL: N-hexanoyl-l-homoserine lactone; [c]ODHL: N-(3-oxodecanoyl)-l-homoserine lactone; [d] OHBHL: N-(3-hydroxybutanoyl)-l-homoserine lactone.

Impact of QS on Host

Drugs that target bacterial infections destroy those organisms, but the virulence factors that were previously produced by those pathogens persist for a long period. In research, *Vibrio tasmaniensis* and *V. crassostreae* were used to examine the effects of the QS signals on blue mussel larvae. They demonstrated that HAI-1 regulates *V. tasmaniensis* motility, CAI-1 controls *V. crassostreae* biofilm growth, and AI-2-mediated QS system controls *V. tasmaniensis* biofilm formation. Macrobrachium larvae have been demonstrated to be negatively impacted by AHL molecules, perhaps as a result of the bacteria that live around the larvae being stimulated to produce a variety of virulence factors. The survival and growth of the prawn larvae were significantly decreased by the daily injection of the AHL combination (1 mg/L).8 Another research with similar results found that the survival and Larval Stage Index (LSI) of prawn larvae were significantly decreased when fed daily with an AHL combination at a dose of 1 mg/L. As is the case with mammalian cells, the QS signal alone would have triggered several cellular pathways in the larvae, accelerating cell death. The capacity of immune cells to survive and proliferate is heavily influenced by QS signals like AHLs, which also have modulatory effects on other cells, including epithelial cells, as shown in Figure 2. According to another study, *Vibrio parahaemolyticus* and *V. harveyi* exhibit significant levels of expression of QS-related genes and toxin-excoding genes when infected with *Penaeus vannamei*. They have discovered a direct relationship between mortality rate and gene expression levels associated with virulence. This suggests that the host expresses pathogen QS-related genes. Mammalian cells immune systems are compromised by QS signals because they take control of several regulatory pathways (Priya *et al.*, 2022).

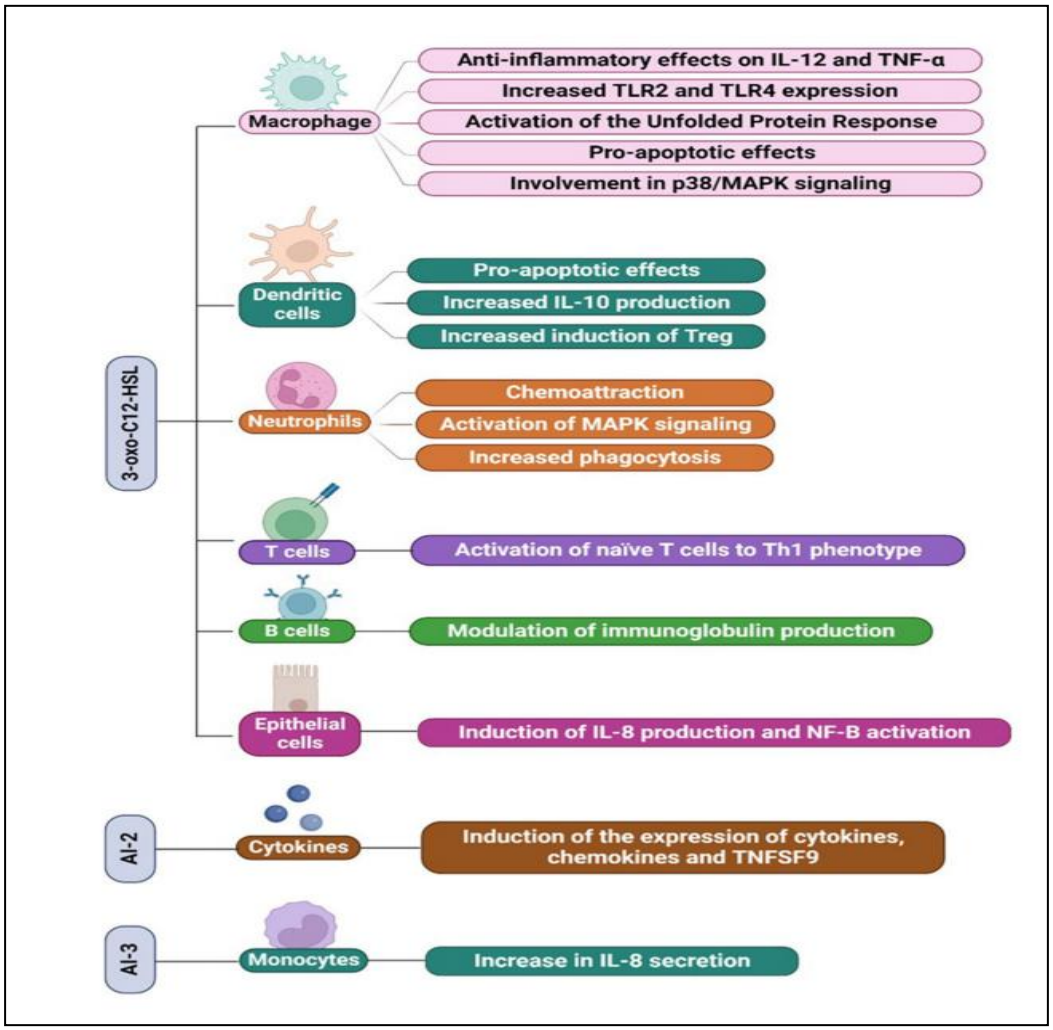

Fig 2. The activity of quorum sensing (QS) signaling molecules in the immune system(Priya *et al.*, 2022).

Impact of QS on Aquaculture Diseases

When exposed to AHLs, several aquaculture species exhibit high mortalities. Giant freshwater prawn and turbot larvae were much less able to thrive and survive when exposed to mixtures of several AHL molecules at a concentration of 1 mg/L. Moreover, when rainbow trout are infected with *V. anguillarum*, elevated AHL levels are seen in many organs. Because the effect is not seen when bacterial growth is inhibited by adding antibiotics along with the AHLs, it is likely that the detrimental effects of AHLs result from the activation of bacterial virulence factors that are regulated by QS. It has been shown that there is a connection between QS and virulence and that the three-channel QS system controls the expression of the empA metalloprotease *in V. anguillarum*, which is in charge of bacterial virulence in Atlantic salmon. It has also been demonstrated that quorum sensing regulates toxin T1, another virulence component that contributes to the pathogenicity of *V. harveyi* in *Penaeus monodon*. Competition for the LuxPQ receptor is sufficient to stop *V. harveyi* from becoming as virulent against brine shrimp by interfering with the AI-2 signal transduction pathway. In fact, a particular virulence component may be controlled by QS in one species but not in another, or a virulence trait may

be positively regulated by QS in one species but negatively regulated in another. For example, QS in *V. cholerae* inhibits biofilm development while inducing it in *V. anguillarum*. Metalloprotease is positively and negatively regulated in *V. harveyi*, while chitinase A. It is crucial to produce virulence at the right time, and the creation and identification of signal molecules may make this possible(Natrah *et al.*, 2011).

Conclusion

Our knowledge of bacteria's pathogenicity has evolved as a result of the discovery that they are capable of quorum sensing (QS) or cell-to-cell communication. Targeting QS signals instead of pathogen development or the QS receptor might eradicate infections because QS signals alone are harmful to the host. Now, an approach that can concentrate just on the pathogenicity of the bacteria rather than the entire organism is necessary. Therefore, research on the pathogen-free virulence factors in aquatic environments and their effects on hosts is important.

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Photosynthetic traits of rice landraces (Oryza sativa L.) under drought condition

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Abstract

Drought stress is mainly a serious limiting factor for rice production, which creates huge economic losses by becoming more serious issue with respect to global climate change. In the view of the current situations and forecasted global food demand, it is necessary to enhance the crop productivity on the drought prone rain fed lands with utmost priority.Rice is a main staple cereal crop in the world.Climate change mainly alters the plant phyllosphere and its resource allocations. The main aim of this experiment was to evaluate the "Photosynthetic attributes on drought tolerance of rice landraces" (*Oryzasativa* L.). A laboratory screening, hydroponic studies and pot culture experiments were conducted in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, during 2020-2021 to investigate the Photosynthetic attributes. Rice land races, namely Anna(R) 4, 337- IC116006, 224 - IC463809 were studied. The present findings showed that drought stress reduced the photosynthetic parameters and enhanced the chlorophyll index and soil temperature in all the land races. Among the land races, Anna(R) 4 performed better under drought stress conditions when compared to other.

Keywords: Photosynthesis, chlorophyll, tolerance, landrace, leaf temperature.

Introduction

Rice is a widely consumed stable food crop in the world after wheat crop for larger part of world's human population, particularly in Asia to meet out the daily calories of a growing population (Samal et al., 2018). The consumption and cultivation of rice in worldwide is about 509.87 million metric tonnes in the year 2021 (Shahbandeh *et al*., 2021). It is estimated around 515.35 million tonnes represent an increase of 4.18 million tons i.e., 0.82 % in rice production is required around the globe for the year 2022.

Rice is positioned best among the foremost inundated crops within the world since it requires more water to grow (Kumar *et al*., 2019). At the physiological, metabolic and molecular levels, drought influences the growth and development of rice by causing numerous changes (Liu *et al*., 2017a). Rice is suited to a wide extend of settings, in spite of the fact that is semi-aquatic nature makes paddy production more efficient at high soil moisture content. However, it is necessary to adopt the rice production in the rainfed ecosystem to meet out the need of the growing world population (Gleason *et al*., 2017).

Among the abiotic stress, drought is one of the most obvious factors that limits rice yield of existing rice cultivars which do not fare well in drought-stricken circumstances. India is a home to the diverse range of rice cultivars and landraces which are lesser-known by the farmers (Biswajit *et al*., 2017) have greater potential to tolerate the water scarcity by sustaining the optimum yield. Exploring the potential of rice landraces towards the drought tolerance could be the viable alternative for increasing food production in the coming years under rainfed ecosystem (Manikavelu *et al*., 2006).

Drought can occur at any stages of the growth and development of rice. At early growth stages such as seedling stage, drought occurs results in poor crop establishment and reduced yield (Pandey *et al*., 2021). Drought stress decreases reduced growth and development of rice by negatively affecting seedling vigour, germination, leaf membrane stability, photosynthetic rate and osmolyte content (Pandey *et al*., 2015; Mishra *et al*., 2018).

Though all the stages of rice crop are sensitive to water stress conditions, the degree of sensitivity of growth stage on drought stress decides the proper growth and development and reproductive efficiency of rice crop (Binodh *et al*., 2019; Vikram *et al*., 2016). Particularly rice at reproductive stage is a critical causing yield loss up to 40 % to 60 % under drought stress (Venkatesan *et al*., 2005). Hence, it is imperative to screen the germplasm to find out the drought tolerant traits at various stages in growth like seed germination, seedling and maturity of rice (Sarkar *et al*., 2011).

Materials and Methods

A laboratory screening, hydroponic studies and pot culture experiments were conducted in the Department of Crop Physiology during 2021 - 2022. It is located in the North Eastern Agro-climatic zone of Tamil Nadu at a latitude of 11.01 0N, Longitude of 76.39 0E and at an altitude of 426.7 m above Mean Sea Level.

For all the two treatments, separate set of plants with five replications were maintained in the pots. According to their duration, all the treatments *viz*., the control and treatment (drought stress) groups, were watered regularly up to 45th and 52nd DAS. The irrigation was withheld to create drought imposed at reproductive stage of plants i.e., 68th and 75th day after sowing respectively. During drought stress, soil moisture content was monitored using moisture meter or theta probe (Delta - T Soil moisture kit - model: SM150, Delta - T Devices, Cambridge) periodically and re-watering was done when the soil moisture reached below 20%. Under drought stress condition, leaves were completely rolled and started drying at tips and margins. After 75th day of drought stress, plants were watered regularly.

Preparation of pot mixture and sowing

Plastic pots of size 37cm diameter and 35cm height were filled with 24 Kg of clay pot mixture arranged by using clay loam, sand and FYM in the ratio of 3:2:1. For this experiment, 50g of seed per rice landraces was obtained and seed were grown by soaking in water for 24 hours. The sprouted seed were sown uniformly in well prepared pots maintain a thin film of water. Twenty-one days old seedlings were thinned at rate of three seedlings per pot. Thinning

was done on 25th day after sowing to maintain the uniform seedling number and optimum population.

Five replications per treatment per landraces was maintained and watered up to the respective stage of drought imposition at reproductive stage from booting to flowering. The crop was applied with recommended doses of fertilizers. Fertilizer dosage for pot culture was calculated by using per hectare recommendations of rice and other cultivation operations including plant protection measures were carried as per recommended package of practices of Crop production guide 2020, Tamil Nadu.

Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})

Photosynthetic rate was measured using a photosynthesis system (LI-6400 XT; LI-COR inc. Lincoln, Nebraska, USA). Photosynthetic rate was measured at a light intensity of 1500µmol m^{-2} s^{-1} PAR, a leaf temperature of 32˚C and a constant CO_2 concentration of 390 µmol CO_2 mol^{-1} in a chamber provided with buffer volume. The measurements at specified growth stages were recorded on the top most fully expanded leaf from the plants between 9.30 am to 11.00 am to avoid effects of photo inhibition. The average values were computed and expressed as µmol CO_2 m^{-2} s^{-1}.

Stomatal Conductance (mol H_2O m^{-2} s^{-1})

Stomatal conductance rate was measured using a Portable photosynthesis system (LI-6400 XT; LI-COR inc.Lincoln, Nebraska, USA) and expressed as mol H_2O m^{-2} s^{-1}.

Transpiration Rate (mmol H_2O m^{-2} s^{-1})

Transpiration rate was measured using a Portable photosynthesis system (LI-6400 XT; LI-COR inc. Lincoln, Nebraska, USA) and expressed as mmol H_2O m^{-2} s^{-1}.

Chlorophyll fluorescence (*Fv/Fm* ratio)

Chlorophyll fluorescence was measured using fluorescence meter (Opti-sciences OS1p). The key fluorescence parameters *Fo* (Initial fluorescence), *Fm* (Maximum Fluorescence), *Fv* (variable fluorescence) and the ratio of *Fv/Fm* were automatically calculated. *Fv/Fm* ratio has been proportional to quantum yield and show a high degree of relationship with photosynthesis.

Chlorophyll Index (SPAD value)

Chlorophyll index of rice leaves was measured using portable chlorophyll content meter (Minotla SPAD 502).

Leaf temperature (˚C)

The leaf temperature was expanded in fully expanded leaf using hand held infrared thermometer with laser marker (Model Waco). The leaf temperature was expressed in ˚C.

Results

Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})

Photosynthetic rate of the rice genotypes was observed at reproductive stage under drought conditions. Effect of drought stress on rice genotypes showed a significant differences (P<0.05) in photosynthetic rate. The rice genotype Anna (R) 4 recorded a higher photosynthetic rate (30.65 µmol CO_2 m^{-2} s^{-1}) and (28.35 µmol CO_2 m^{-2} s^{-1}) under control and stress conditions than the other landraces. Also, 337-IC116006 recorded higher photosynthetic rate (26.64 µmol CO_2 m^{-2} s^{-1}) and (25.25 µmol CO_2 m^{-2} s^{-1}) under both the conditions. The 224 - IC463809 recorded the minimum photosynthetic rate (23.36 µmol CO_2 m^{-2} s^{-1}) and (21.54 µmol CO_2 m^{-2} s^{-1}) under control and stress conditions. **(Table 1).**

Table 1. Effect of drought on photosynthetic rate (µmol CO_2 m^{-2} s^{-1})and stomatal conductance (mol H_2O m^{-2} s^{-1}) of rice landraces

Rice landraces	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})		
	Control	Drought	Mean
Anna(R) 4	30.65	28.35	29.50
337-IC116006	26.64	25.25	25.95
224-IC463809	23.36	21.54	22.45
Mean	26.88	25.05	25.97
	G	**T**	**G x T**
SEd	**0.004**	**0.003**	**0.006**
CD (0.05)	**0.008****	**0.006****	**0.012****

*Significant at 5 % level ** Significant at 1 % level

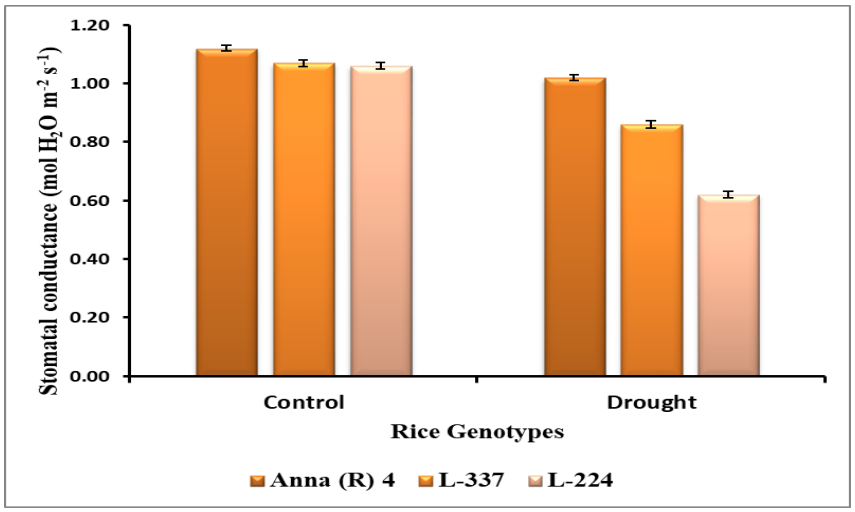


Fig 1. Effect of drought stress on stomatal conductance (mol H_2O m^{-2} s^{-1}) of rice landraces

Stomatal conductance (mol H_2O m^{-2} s^{-1})

An increase in stomatal conductance was observed from booting to flowering. There was a significant difference (P<0.05) among the rice genotypes in stomatal conductance under both the condition. Drought was observed to be the maximum for the reduction in stomatal conductance under reproductive stage of growth with irrespective of genotypes. Under control, Anna (R) 4 maintained the highest stomatal conductance (1.12 mol H_2O m^{-2} s^{-1}) followed by 337-IC116006 (1.07 mol H_2O m^{-2} s^{-1}). Among the genotypes, Anna (R) 4 (1.02 mol H_2O m^{-2} s^{-1}) followed by 337-IC116006 (0.86 mol H_2O m^{-2} s^{-1}) were recorded higher stomatal conductance under drought stress at reproductive stage. The 224 - IC463809 observed to be the lowest with stomatal conductance which recorded (1.06 mol H_2O m^{-2} s^{-1}) and (0.62 mol H_2O m^{-2} s^{-1}) under control and drought conditions **(Figure 1)**.

Transpiration rate (mmol H_2O m^{-2} s^{-1})

Significant differences (P<0.05) in transpiration rate were observed among the genotypes and treatments **(Table 2)**. Drought stress was found to impact the rate of transpiration. Among the genotypes, Anna (R) 4 recorded the highest transpiration rate (14.27 mmol H_2O m^{-2} s^{-1}) and (12.66 mmol H_2O m^{-2} s^{-1}) when compared with other landraces under control and stress conditions. 337-IC116006 was recorded higher transpiration rate (13.02 mmol H_2O m^{-2} s^{-1}) and (9.68 mmol H_2O m^{-2} s^{-1}) when compared with 224 - IC463809 under both the conditions. The lowest was recorded in 224 - IC463809 (10.33 µmol CO_2 m^{-2} s^{-1}) under control conditions. Under stress at reproductive stage, exhibited significant lower transpiration rate (6.52 µmol CO_2 m^{-2} s^{-1}).

Table 2. Effect of drought on transpiration rate (mmol H_2O m^{-2} s^{-1}) of rice landraces

Rice landraces	Transpiration rate (mmol H_2O m^{-2} s^{-1})		
	Control	Drought	Mean
Anna(R) 4	14.27	12.66	13.47
337- IC116006	13.02	9.68	11.35
224- IC463809	10.33	6.52	8.43
Mean	**12.54**	**9.62**	**11.08**
	G	**T**	**G x T**
SEd	**0.011**	**0.008**	**0.015**
CD (0.05)	**0.022****	**0.018****	**0.031****

*Significant at 5 % level ** Significant at 1 % level

Chlorophyll fluorescence (*Fv/Fm* ratio)

The ratio of *Fv/Fm* was found to increase as the growth advanced towards flowering. A non-significance was observed in chlorophyll fluorescence among the genotypes and their interaction effects. However higher values were recorded in Anna (R) 4 (0.76) and (0.66) under control and stress condition followed by 337- IC116006 recorded maximum *Fv/Fm* value (0.56)

and (0.47) under both the conditions **(Figure 2)**. A non-significant lower value (*Fv/Fm*) was recorded in 224 - IC463809 (0.47) and (0.36) under both the conditions.

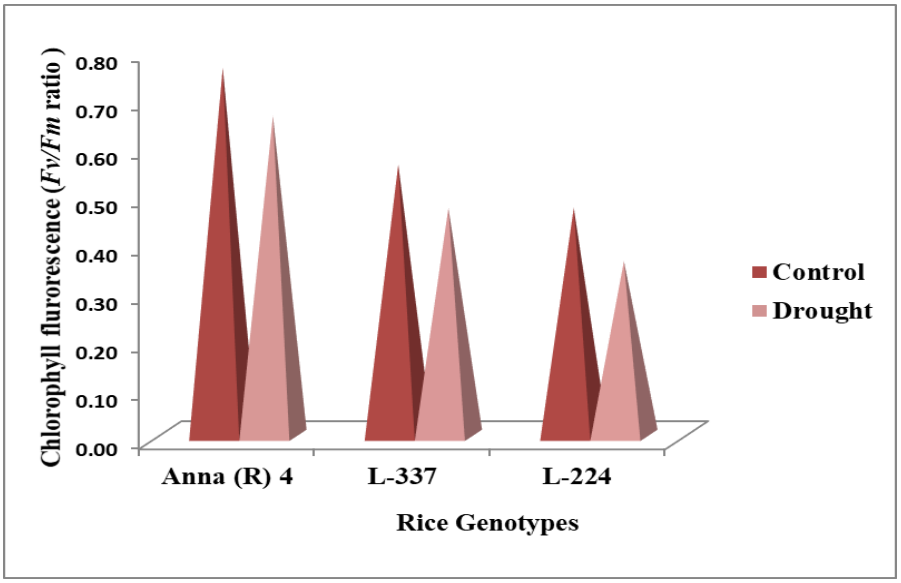


Fig 2. Effect of drought stress on chlorophyll fluorescence (*Fv/Fm* ratio) of rice landraces

Chlorophyll index (SPAD)

There was a significant difference between genotypes and treatments **(Table 3)**. Under control and drought conditions, Anna (R) 4 had higher chlorophyll index (34.66 to 32.26) followed by the landrace 337-IC116006 had chlorophyll index (33.39 to 30.79) under control and stress at reproductive stage. The landrace 224- IC463809 was recorded to maintain lower chlorophyll index (28.79) under stress at reproductive stage and 224 - IC463809 (26.70) under control conditions.

Table 3. Effect of drought on chlorophyll index (SPAD) of rice landraces

Rice landraces	Chlorophyll index (SPAD)		
	Control	Drought	Mean
Anna(R) 4	34.66	32.26	33.46
337- IC116006	33.39	30.79	32.09
224- IC463809	28.79	26.70	27.75
Mean	**32.28**	**29.92**	**31.10**
	G	**T**	**G x T**
SEd	**0.371**	**0.302**	**0.523**
CD (0.05)	**0.764****	**0.624****	**1.081****

*Significant at 5 % level ** Significant at 1 % level

Chlorophyll content (mg g^{-1})

Total chlorophyll content was significantly increased under control and stressed plants with irrespective of the genotypes from booting to flowering stage (**Figure 3**). Among the genotypes, a higher chlorophyll content was recorded in Anna (R) 4 (2.75 mg g^{-1}) followed by 337-IC116006 (2.44 mg g^{-1}) under control, whereas lower chlorophyll content were recorded during drought condition in Anna (R) 4 (1.96 mg g^{-1}) followed by 337- IC116006 (1.63 mg g^{-1}). The lowest chlorophyll content was recorded in 224 - IC463809 (1.96 mg g^{-1}) under control and (1.33 mg g^{-1}) drought condition.

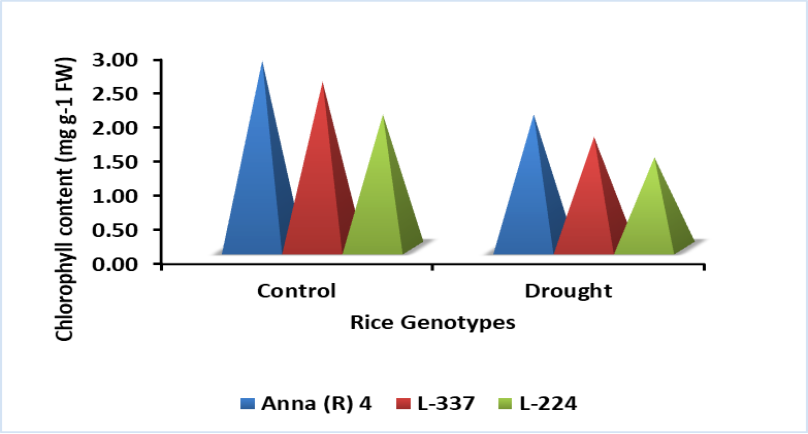


Fig. 3. Effect of drought stress on chlorophyll content (mg g^{-1} FW) of rice landraces

Leaf temperature (°C)

A non-significant was observed in leaf temperature between the treatments and among the genotypes and their interaction effects. The rice genotype Anna (R) 4 performed higher leaf temperature (28.05°C) and (29.32 °C) under control conditions and stress condition **(Table 4)**. Similar trend in 337-IC116006 noticed higher leaf temperature (28.15°C) and (30.63°C) under both the conditions. The 224 - IC463809 recorded the lowest leaf temperature (29.36°C) and (31.85°C) under control and stress condition.

Table 4. Effect of drought on Leaf temperature (°C) of rice landraces

Rice landraces	Leaf temperature (°C)		
	Control	Drought	Mean
Anna(R) 4	28.05	29.32	28.68
337- IC116006	28.15	30.63	29.39
224- IC463809	29.36	31.85	30.61
Mean	**28.52**	**28.75**	**28.64**
	G	**T**	**G x T**
SEd	**0.084**	**0.069**	**0.119**
CD (0.05)	**0.174****	**0.142****	**0.247***

*Significant at 5 % level ** Significant at 1 % level

Relative water content (%)

The Relative water content (RWC) showed a decrease trend from booting to flowering stage. Under control and stress at reproductive stage, the check variety Anna (R) 4 maintained a higher RWC value (85.71 %) and (78.13 %) followed by 337-IC116006 (75.42 %) and (66.67 %) than the landrace 224 - IC463809 (66.62 %) and (65.16 %) **(Figure 4).**

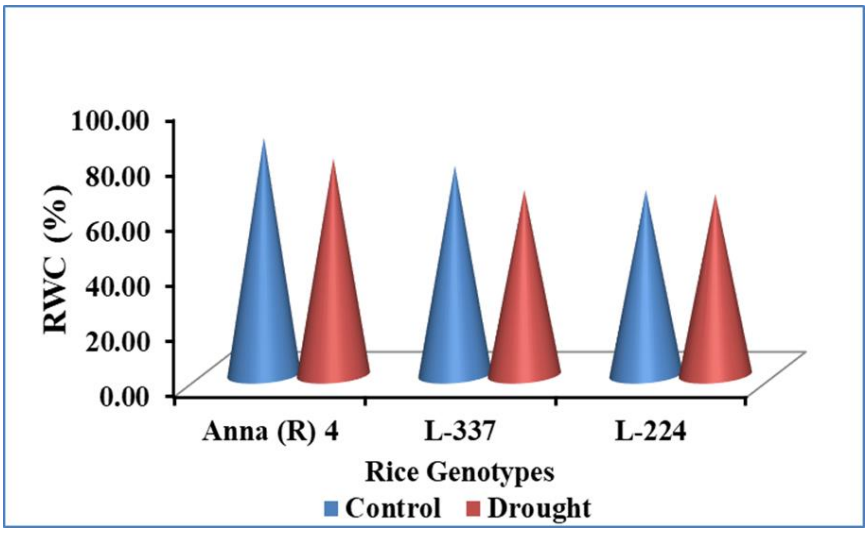


Fig 4. Effect of drought stress on RWC (%) of rice landraces

Discussion

Photosynthesis is the vital process has greater limitations under drought through various metabolic impairment which directly control the leaf water content, stomatal conductance and their water vapour level (Reddy *et al*., 2004). Particularly drought on reproductive stage limited the photosynthetic rate through the stomatal closure by reducing the influx of CO2 release spending of high energy for the regulation of Reactive oxygen species (Yang *et al*., 2010).

Several factors are involved in the declining photosynthesis such as stomatal closure, decline of turgor pressure, reduction in leaf gas exchange and decrease in CO2 assimilation ultimately damage the photosynthetic apparatus (Kakar *et al*., 2019). Wang *et al*. (2019) reported that the water stress damaged the normal functions of PSI and PSII, PSII function is very much important in reduction reaction and generation of ATP.

This was endorsed that drought stress changed the standard pace of photosynthesis as well as gas exchange traits in plants (Zhu *et al*., 2022). In the present study, the rice genotypes expressed that photosynthetic rate was highly reduced under drought stress might be the reason by disrupting the photosynthesis through the thylakoid membrane electron transport, the carbon reduction cycle and the stomatal control of the CO2 supply, together with an increased peroxidative demolition of lipids and unsettling influence of water balance (Vinod *et al*., 2019).

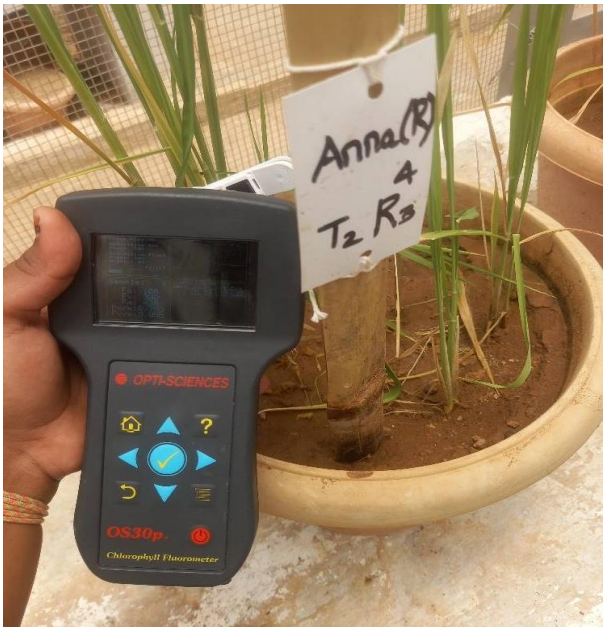
The present study also showed that the stomatal conductance (Fig.8.) and the transpiration rate were decreased under drought stress in all the rice genotypes. Drought stress seriously hampers the plant net photosynthesis in rice genotypes (Centritto *et al*., 2009; Yang *et*

al., 2014) stomatal conductance (Ji *et al*., 2012; Singh *et al*., 2013), transpiration rate (Cabuslay *et al*., 2002), intercellular CO2 and this could be the reasons for the reduction in the efficiency of photosynthetic machinery. Drought induced root to leaf signaling resulted in stomatal closure through transpiration rate (Leal-Alvarado *et al*., 2016).

Manojkumar *et al*. (2021) revealed that the reduced stomatal conductance resulted in decreased lower net chloroplast carbondioxide tension and reduced the photosynthetic efficiency. Comparative impact of drought stress in rice physiology have been contemplated Ding *et al*. (2014).

Measuring physiological traits during reproductive stage

Portable Photosynthetic System



Chlorophyll fluorescence

The observation on chlorophyll intensity through SPAD values and chlorophyll fluorescence values are directly correlated with water stressed genotypes. It described that the water stress induced the stressed plants failed to take and transport sufficient water and minerals for the biosynthesis of chlorophyll pigments (Wu *et al*., 2011). It was suggested that chlorophylls are the vital predecessors of photosynthesis by obtaining light and generation of reducing powers (Ha *et al*., 2019). Drought stress caused reduction in the potential of mesophyll cell to utilize the available carbon source lead the decreased in the quantity of chlorophyll (Puteh *et al*., 2013). Consequently, in the chlorophyll decline directly reduced the quantum generation of PSII i.e., *Fv/Fm* reported in water stressed rice plants (Li *et al*., 2020).

The plant and water relationships can be depicted through different representation such as water potential of the relative water content (Hameed *et al*., 2021). Water use efficiency can be considered to determine yield potential of plants under drought stress condition which represents the variation in water potential and turgor potential of the plants (Mishra *et al*., 2019).

The relative water content (RWC) (Fig.12.) and leaf temperature (Fig.13.) are negatively correlated under water stress condition reflected the drought tolerant capacity of crop plants and the higher leaf temperature and osmotic potential (Fig.14.) are positively correlated under drought stress (Bakht *et al*., 2020). It was justified that the increase in leaf temperature caused tissue dehydration which in turn reduced the internal tissue water content with reduced osmotic potential (Wang *et al*.,2019).

In the present study, lower RWC and lower osmotic potential were observed under higher leaf temperature in the susceptible landrace than the tolerant landrace (Bhat *et al*., 2022). Maisura *et al*. (2014) supported that the reduction in tissue water content and buffering temperature of plants under drought stress mainly depends on the maintenance of leaf water potential and turgor pressure of leaf decided the tolerance mechanism of crops.

Conclusion

The selected genotypes were categorized into tolerant, moderately tolerant and susceptible. Accordingly, the genotypes were observed for the morphological, physiological, biochemical characters and yield components. The summary of present findings are presented here under. The Conclusions arrived from the present study are summarized below.

- The most significant findings from this research is the identification of tolerant rice landrace *viz*., 337- IC116006 performed better under drought stress as compared to susceptible rice landrace 224- IC 463809.
- The physiological traits *viz*., photosynthetic rate, stomatal conductance, transpiration rate, chlorophyll fluorescence, chlorophyll index, relative water content, leaf temperature and osmotic potential were considered as indicators of drought tolerance were observed higher in the tolerant landrace 337-IC116006 as compared to susceptible landrace 224-IC463809.
- The gas exchange parameters revealed that thephotosynthetic rate, stomatal conductance and transpiration rate were higher in the landrace 337-IC116006.
- Higher chlorophyll index (SPAD), chlorophyll fluorescence (*Fv/Fm* ratio) and Relative water content (RWC) with low leaf temperature with low osmotic potential were observed in the landrace 337- IC116006 than the landrace 224- IC463809.

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PHYCOREMEDIATION OF EMERGING CONTAMINANTS: A FOCUS ON POTENTIAL MICROALGAL SPECIES

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Abstract

Anthropic actions have led to an increase in the number of effluents discharged into natural aquatic systems, resulting in the presence of Emerging contaminants that are highly persistent and detrimental to aquatic organisms. The development of sustainable treatment processes that effectively remove or degrade these compounds is essential. One promising solution is the use of microalgae for bioremediation, as it offers high efficiency, low cost, and potential for producing valuable products. Microalgal-based wastewater treatment systems have demonstrated efficient remediation of nutrients and natural disinfection compared to traditional methods. Additionally, microalgae-based bioremediation offers the advantage of recovering valuable resources through the biorefinery of microalgal biomass for a range of products. While the potential of microalgae for detoxifying pollutants has been known for 30 years, the use of microalgae for bioremediating Emerging contaminants has recently gained attention. The selection of a suitable microalgal species for bioremediation depends on the type and concentration of the contaminant, the quality of the wastewater, and the desired level of treatment. Some promising microalgal species for EC bioremediation includes *Chlorella vulgaris*, *Scenedesmus obliquus*, and *Nannochloropsis sp*. These species have shown promising results in removing various ECs, such as pharmaceuticals, pesticides, and personal care products. However, further research is needed to optimize the conditions for the growth of these microalgae and to determine the most effective treatment strategy. Inspite of several practical applicability, microalgae-based bioremediation is a promising approach for treating wastewater contaminated with ECs, and it offers the potential for producing valuable products while simultaneously protecting the environment.

Keywords: Emerging contaminants, wastewater treatment, bioremediation, Microalgae.

Introduction

In recent years, the number of effluents generated from anthropic actions has significantly increased, leading to changes in both the quantitative and qualitative aspects of the effluent composition discharged into the natural aquatic system (Kumar *et al.*, 2021). New substances with toxicological effects have been detected in such effluents at concentrations that pose a high risk to the environment and public health and can be termed as emerging contaminants or chemicals of emerging concern (CECs). Technically, United States Geological Survey (USGS) defines CECs as any synthetic or naturally occurring chemical or microorganism which is not

usually present in environment, but has the potential to enter the environment and cause known or suspected adverse effects on ecological and/or human health. It can be natural or synthetic and may include pharmaceuticals, personal care products, flame retardants, pesticides, industrial chemicals, and microplastics (Sabaliunas *et al*. 2003). All these contaminants are mostly concerned about aquatic system since wastewater discharge containing these chemicals are the major source of chemical pollutants in to the natural water body. Further emerging contaminants pose a severe challenge for wastewater treatment, as conventional treatment technologies are not designed to remove or degrade these compounds. Due to this emerging contaminant are highly persistent in the aquatic environment and can have detrimental effects on aquatic organism's reproductive systems (endocrine disruptors) and can accumulate throughout the food chain (Paul *et al*. 2019).

In the recent era, advancements in detection and treatment methods have contributed to a better understanding and control of the effects related to contaminated wastewater. Due to their hydrophobic characteristics and high bio-accumulative properties, these new pollutants are said to cause more toxic effect on the aquatic organism and also affects humans through various mechanisms (Pullaguri *et al*. 2020; Sharma *et al*. 2021). Hence, it is essential to trace out a new treatment technology which is novel and sustainable for the effective removal or degradation of these compounds. Some of the common techniques for the remediation of emerging contaminants typically involve membrane separation processes such as ultrafiltration, nanofiltration, and reverse osmosis; advanced oxidation processes such as photocatalysis, UV/H_2O_2, electro-Fenton, and ozonation; adsorption using activated carbon, carbon nanotubes, and graphene; and bioremediation techniques involving wetlands and microalgae (Wang *et al*. 2021). The selection of a suitable technology for treating wastewater contaminated with emerging contaminants depends on several factors, such as the type and concentration of the contaminant, the quality of the wastewater, and the desired level of treatment. However, the use of microalgae for bioremediation is gaining increasing attention due to its high efficiency, low cost, and potential for producing valuable products (Qiu *et al*., 2017).

Global and national status of emerging contaminants

Natural water resources act as the ultimate endpoint for the release of contaminants and this become a growing concern while dealing with sustainability and ecological protection. Results obtained from the last two decades of research on the ECs prove that the utilization of products laced with emerging contaminants had increased and there were no regulatory standards on various classes of ECs (Ramaswamy *et al*. 2011). Among the emerging contaminants, the most deleterious effect is caused by the group of chemicals called emerging pollutants including pesticides, pharmaceuticals, surfactants, personal care products, and phthalates (Biswas and Vellanki 2021). Globally pesticide occupies the major share as emerging pollutants. The worldwide use of pesticides has been steadily increasing over the past several decades. The Food and Agriculture Organization (FAO) of the United Nations estimates that worldwide pesticide use had grown by about 11% every year since 2000 and approximately 4.1 million tons of pesticides are used globally each year, with Asia and Latin America being the largest consumers. The persistence of pesticides in the environment and their complicated transport

through aquatic systems underscore more attention. Similarly, a report by the World Health Organization (WHO), traces pharmaceuticals in natural aquatic systems in over 100 countries. The most commonly detected pharmaceuticals include antibiotics, analgesics, and hormones. Another group of EPs includes additives used in Personal care products for their specific function (e.g. triclosan as biocides). The United States Geological Survey (USGS) found these compounds (triclosan and phthalates) were detected in over 70% of the streams tested in the United States. In India, uncontrolled and unregulated use of these chemicals in different consumer products resulted in increased detection in effluents from human and industrial origin. The contribution of emerging contaminants in aquatic environment comprises of 57% pesticides, 17%pharmaceuticals, 15% surfactants, 7% personal care products and 5% phthalates (Nag *et al.* 2018). The study conducted by the Central Pollution Control Board (CPCB) found that 31 out of 38 rivers in India were contaminated with pesticides, with some rivers showing levels of contamination above the permissible limits and over 90% of the surface water samples tested in India were contaminated with pharmaceuticals. Additionally, a study conducted by the Central Ground Water Board (CGWB) found that 19 out of 32 districts in the state of Punjab and many other parts of India, especially Delhi, Mumbai, Kolkata, and Hyderabad, had groundwater contaminated with pesticides and pharmaceuticals respectively (Manickavasagam *et al.* 2020). These statistics highlight the occurrence of emerging pollutants is showing increasing trend and opens up the immediate need for the remediation of contaminant release into the natural aquatic system.

Microalgae as a potential bioremediator for emerging contaminants

According to the United Nations, over 2 billion people lack access to safe drinking water, and by 2050, over half of the world's population could be facing water scarcity. With the increasing scarcity of water resources, ensuring the quality of water has become a pressing concern in the modern world. Maintaining the quality of water is crucial not only for human health but also for the health of ecosystems. The 2030 Agenda and the Sustainable Development Goals prioritize the improvement of water quality, acknowledging the significance of high-quality water for sustainable development and the urgent need to address this issue globally. In addition to the 2030 Agenda and the Sustainable Development Goals, several other international agreements and initiatives recognize the importance of water quality for sustainable development. For example, the United Nations General Assembly declared the period from 2018 to 2028 as the International Decade for Action on Water for Sustainable Development, which aims to promote the sustainable management of water resources and improve access to water and sanitation. The World Health Organization also emphasizes the importance of safe water for public health and has set guidelines for drinking water quality. Since conventional wastewater treatment plants (WWTP) are not yet equipped and suitable to remove these new contaminants, it is urgent to develop adequate wastewater treatment processes, which should be easily applicable, effective and eco-friendly, in order to prevent water quality degradation and to protect water resources. A possible solution can be the combination of physicochemical and biological treatment technologies aiming at the development of sustainable treatment processes includes

phycoremediation. In recent decades, microalgae have proven to be effective in bioremediating nutrients such as nitrogen, phosphorus, and carbon from various wastewater streams. Microalgal-based wastewater treatment systems have demonstrated lower capital and operational costs, more efficient nutrient pollution remediation, and natural disinfection compared to traditional wastewater treatment methods (Ortiz-Hernadez *et al.*, 2013). Microalgae also offer the potential for cost-effective remediation of emerging contaminants (ECs) when used in conjunction with wastewater treatment. Additionally, microalgae-based bioremediation offers the advantage of recovering valuable resources through the biorefinery of microalgal/bacterial biomass for a range of high-value and low-value products, including fertilizers, algal plastics and fibers, or protein-rich feed (Ata *et al.*, 2012). Although the potential of microalgae for detoxifying organic and inorganic pollutants has been known for 30 years, the use of microalgae for bioremediating ECs has only recently gained attention (Table 1).

Mechanism of phycoremediation

The mechanisms of ECs removal by microalgae include bioadsorption, bioaccumulation, and intracellular and extracellular biodegradation (Figure 1).

Bioadsorption

Microalgae cell walls contain various types of polymers, similar to cellulose, pectins, hemicelluloses, arabinogalactan proteins, extensin, and lignin (Qiu *et al.*, 2017). Due to the dominant functional groups such as carboxyl, phosphoryl, and amine, the cell wall of microalgae is negatively charged (Ata *et al.*, 2012). The sorption process of pollutants varies significantly based on the hydrophobicity, structure, and functional groups of different microalgal species and pollutants (Bilal *et al.*, 2018). Cationic pollutants are actively attracted to the microalgal surface through electrostatic interaction, resulting in effective biosorption (Bilal *et al.*, 2018). The bioadsorption of emerging contaminants (ECs) by microalgae cells has been extensively studied. The amount of ECs adsorbed by microalgae, including diclofenac, ibuprofen, paracetamol, metoprolol, trimethoprim, carbamazepine, estrone, β-estradiol, and ethinyl estradiol, has varied from 0 to 16.7% (Bilal *et al.*, 2018). Moreover, dead cell biomass of Scenedesmus obliquus and Chlorella pyrenoidosa was found to adsorb around 10% of the available progesterone and norgestrel. Bioadsorption is considered a passive process (Ardal *et al.*, 2014), and microalgae have shown the ability to adsorb pesticides and other organic pollutants such as aromatic compounds. In recent studies, various pesticides including atrazine, simazine, molinate, isoproturn, carbofuran, propanil, dimethoate, metoalcholar, pendimethalin, and pyriproxin were removed from the aqueous phase by cultivated algae via bioadsorption, with removal rates ranging from 87-96%. The efficiency of ECs adsorption depends mainly on the active surface groups and properties of microalgae (Ata *et al.*, 2012). For example, hydroxyl, carboxyl, and amine groups were identified as the predominant active surface groups in the adsorption of 2,4-Dichlorophenoxyacetic (2,4-D) by various microalgae species (Ata *et al.*, 2012). Microalgae cell walls, composed of carbohydrates, a fibril matrix, intercellular spaces, and sulphated polysaccharides, facilitate the adsorption of organic contaminants from water (Hammed *et al.*, 2016; Qiu *et al.*, 2017). However, microalgae exhibit different removal

efficiencies for different pollutants. A review suggests that the removal of ECs is influenced by two aspects: optimal biome conditions for the survival and activity of microalgae and the chemical structure of the pesticide. Factors related to microalgae include appropriate organism numbers, biological and substrate contact, pH, temperature, salinity, nutrients, light quality and intensity, available water, oxygen tension and redox potential, surface bonding.

Bioaccumulation

Bioaccumulation is a metabolic process in which microalgae actively uptake organic pollutants along with growth nutrients, as demonstrated in several studies (Jin *et al*., 2012; Kabra *et al*., 2014). The accumulation of pollutants can induce the production of reactive oxygen species (ROS) in microalgal cells, which can cause oxidative damage to cellular components such as lipids, proteins, and DNA, ultimately leading to programmed cell death (Kurade *et al*., 2016). However, microalgae possess various antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX), which are responsible for ROS removal and reducing algal cell damage (Zhang *et al*., 2011). The accumulation of pollutants by microalgae can also stimulate the expression of inducible genes to produce antioxidant enzymes, indicating the possibility of bioaccumulation in microalgae (Perezgarcia *et al*., 2013).
The integration of these two processes could effectively remove ECs by microalgae. Bioaccumulation can be expressed using the bio-concentration factor (BCF), which is the concentration quotient of a pollutant in an organism with respect to its surrounding environment (Bi *et al*., 2012). However, BCF values are influenced by several factors such as the bioconcentration mechanism, bioavailability of chemicals, physical barrier, methods of BCF determination, dissolved organic matter, metabolism, interspecies variation, ionization of ionizable compounds, and environmental conditions (Wang *et al*., 2014).

Intracellular Biodegradation

Biodegradation is a crucial process in the microalgal removal of contaminants in water (Matamoros *et al*., 2016). Microalgae have been found to effectively degrade organic matter in water into small molecules, which subsequently serve as nutrient sources for microalgae growth (Perez-Legaspi *et al*., 2016). The biodegradation of ECs in the environment is dependent on the metabolism of various enzymes. Esterase, transferase, and cytochrome P450 are considered the predominant enzymes in the processes of pesticide biotransformation and detoxification (Devonshire & Field, 2011). In addition, hydrolase, phosphatase, phosphotriesterase, oxygenase, and oxidoreductases are involved in the degradation process of ECs (Ortiz-Hernadez *et al*., 2013). The degradation of ECs is a multi-step process involving enzyme metabolism, including the activation of pollutants in the absence of functional groups by cytochrome P450 via oxidation, reduction, and hydroxylation reactions to obtain more hydrophilic, soluble, degradable, and less toxic compounds; forming conjugation with glutathione, glucose, and

malonate and transportation of such conjugates into vacuoles by glutathione transporters (Kumar & Singh, 2017; Asad *et al.*, 2017).

Extracellular Biodegradation

Microalgae can release extracellular polymeric substances (EPS) that include various compounds like polysaccharides, proteins, enzymes, and lipids. These EPS form a hydrated biofilm matrix that serves as an external digestive system by keeping extracellular enzymes near the cells, allowing them to metabolize organic compounds present in dissolved, colloidal, or solid form (Devonshire & Field, 2011). The charged polysaccharides and proteins present in the EPS can accumulate nutrients from the environment and sorb xenobiotics, aiding in environmental detoxification. EPS also act as surfactants and emulsifiers, increasing the bioavailability of persistent pollutants. These EPS interactions and those between EPS and microalgal cells can lead to extracellular degradation of organic compounds, including persistent pollutants, and can influence intracellular degradation through the byproducts formed.

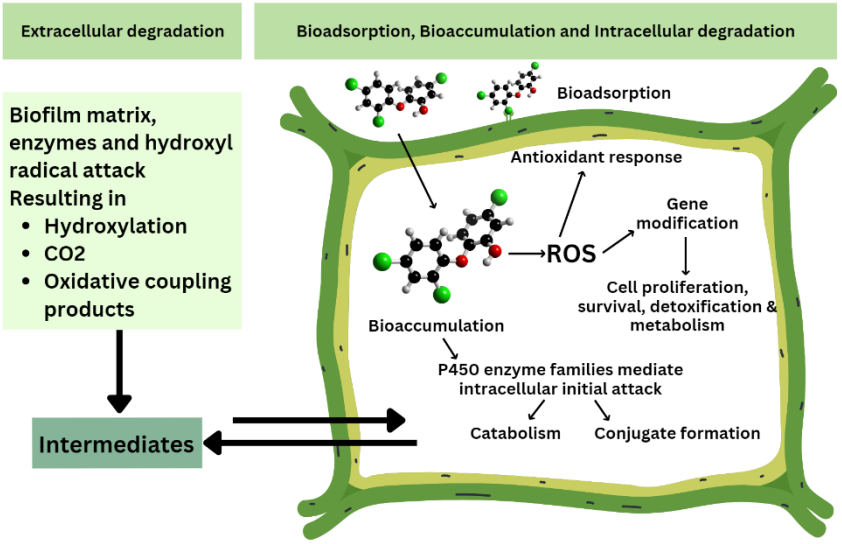

Figure 1. Mechanism of phycoremediation

Culture technologies

Microalgae have been recognized as a relevant method for secondary and/or tertiary treatment in wastewater treatment plants due to their ability to remove emerging contaminants. Microalgae can be cultivated in open and closed systems, such as stabilization ponds, high-rate algal ponds (HRAPs), and photobioreactors (PBRs). Photobioreactors (Figure 2) are closed systems that utilize light to cultivate microalgae for various purposes, such as wastewater treatment, CO_2 fixation, and biofuel production (Wang *et al.*, 2014). These systems offer several advantages over traditional open pond systems, including better control over environmental parameters, increased biomass productivity, and reduced contamination risks (Norvill *et al.*, 2016). PBRs can be designed in various configurations, including tubular, flat panel, and bubble

column, each with its own advantages and disadvantages (Dordio *et al*., 2010). High rate algal ponds (HRAPs) are another type of algal cultivation system that uses open ponds to grow algae. Unlike PBRs, HRAPs do not use a closed system, but instead rely on natural sunlight and the inherent mixing of the pond to facilitate algal growth. HRAPs can have higher productivity than traditional open ponds, as they are designed to maximize light penetration and optimize the algal growth rate. However, they also have some limitations such as susceptibility to contamination and limited control over algal growth conditions. (Singh *et al*., 2015). Open systems have advantages in construction and operation simplicity with low operating costs, but are vulnerable to contamination by other microorganisms, loss of CO_2 to the atmosphere, and require large land areas. In addition, the dependency on environmental variables such as temperature and light hinder the cultivation process. On the other hand, closed systems like PBRs have reduced microbial contamination and allow for the control of different variables, such as pH, temperature, light, and CO_2 concentration (Shriwastav *et al*.,2017). Several studies have investigated the effectiveness of microalgae cultivation in open systems for removing ECs. Stabilization ponds have been found to be the most appropriate design for removing certain ECs, such as caffeine, ibuprofen, paracetamol, methyl dihydrojasmonate, oxybenzone, and furosemide, across different seasons.contaminants, such as histamine blockers, diuretics, and macrolides, were also removed more efficiently in HRAPs and PBRs have shown to be effective in removing various ECs, such as ibuprofen, trimethoprim, carbamazepine, sulfamethoxazole, and caffeine (Paecheco Torgal *et al*., 2016).

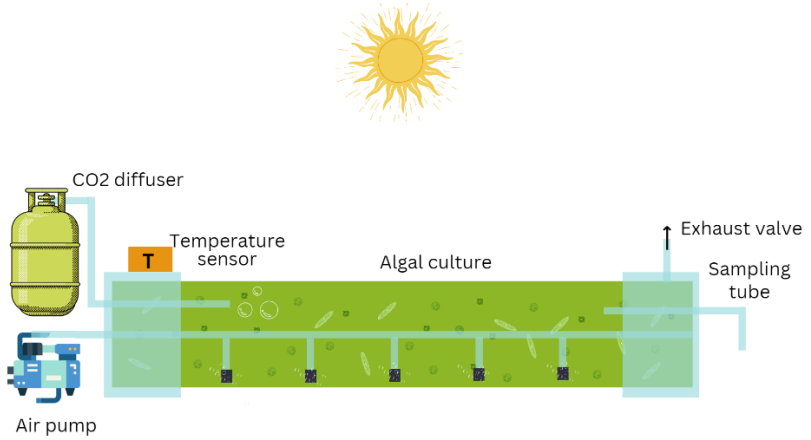

Figure 2. Photobioreactors

Reutilization of microalgae used for bioremediation

Biodiesel production

Biodiesel derived from microalgae is gaining popularity as a promising substitute for traditional fossil fuels, given its renewability, biodegradability, eco-friendliness, and lower emissions of greenhouse gases (Aghbashlo & Demirbas, 2016; Ahmad *et al*., 2011). In contrast to the first two generations of feedstocks, which are predominantly derived from plants and require large-scale production, microalgae as third-generation fuel can be grown on non-agricultural land, thus mitigating environmental problems such as pesticide contamination, excessive use of

fertilizers, depletion of vegetation, and alterations in land-use patterns (Aghbashlo & Demirbas, 2016). Furthermore, the use of wastewater as a growth medium for microalgae production can lower the economic burden of restoring farmland in subsequent stages (Smith *et al*., 2010). biodiesel from microalgae involves several key steps, including optimizing culture conditions, improving and acquiring microalgae lipid content, and carrying out the oil production process through transesterification (Chen *et al*., 2011; Suganya *et al*., 2016; Zhu *et al*., 2017). By limiting the supply of essential nutrients such as nitrogen, phosphorus, or oxygen, microalgae are encouraged to accumulate lipids, leading to higher rates of oil production (Zhu *et al*., 2014). Additionally, cultivating microalgae heterotrophically tends to result in higher lipid content, as reported by Chen *et al*. (2011). The method of harvesting microalgae depends on the culturing technique used and can involve centrifugation, ultrafiltration, sedimentation, air flotation, or flocculation, (Schenk *et al*., 2008; Zhu *et al*., 2017).

Biochar production

Biochar has gained attention in recent years for its potential in environmental restoration. It is produced by the pyrolysis of biomass under oxygen-deficient conditions, resulting in a material with a large specific surface area, developed micropore structure, and abundant surface functional groups (Zheng *et al*., 2017). Biochar derived from microalgal strains with higher polarity and more functional groups can be effective in removing contaminants from wastewater. This is likely due to the increased surface area and pore size, which allow for more binding sites for the pollutants. Additionally, the functional groups on the biochar surface can interact with the contaminants through various mechanisms such as hydrogen bonding, electrostatic interactions, and van der Waals forces, leading to enhanced adsorption. According to Zheng *et al*. (2017) biochars derived from microalgal strains (Chlorella sp., Chlamydomonas sp., and Coelastrum sp.) are effective of in adsorbing pollutants was compared to raw microalgal biomass and powdered activated carbon. These Adsorbents with higher polarity and more functional groups were more effective in removing contaminants than other common adsorbents and have potential for use in wastewater treatment.

Limitation

The use of microalgae for removing emerging contaminants (ECs) is facing significant challenges in commercial operations due to high production costs, even with the efforts of some researchers to pursue industrial-scale operations. While most experiments are conducted at the medium or photobioreactor level to generate high-value products, operational costs remain relatively expensive (Van Ginkel *et al*., 2015). Moreover, outdoor factors such as climate, temperature, light intensity, and the presence of exogenous organisms can restrict microalgae reproduction in open operating conditions, which poses a challenge for removing ECs. Additionally, microalgae are often threatened by various microbes such as amoeba, ciliates, rotifers, and bacteria, further impeding their use in EC removal outside of the laboratory environment. (Huo *et al*., 2018). Microalgae are small, single-celled organisms that float in water

and have a negatively charged hydrophilic surface, which makes it challenging for them to settle via gravity (Gultom *et al.*, 2014; Kim *et al.*, 2013). Harvesting microalgae during biodiesel production is still a difficult process due to its high energy intensity, leading to low operational efficiency and increased costs (Kang *et al.*, 2015). Different harvesting methods have their advantages and disadvantages, depending on the microalgae culture methods and product types. Therefore, a single harvesting method may not be sufficient to meet user demands and requires the simultaneous use of multiple methods (Kim *et al.*, 2013). Microalgae can utilize both pollutants and nutrients present in wastewater to promote their own growth, and specific nutrients can even be added to enhance commercial production. However, it's important to note that not all pollutants absorbed by microalgae can be degraded, which means some toxic substances could still remain in their biomass. This can potentially have negative effects on downstream processes and applications if not properly addressed (Usher *et al.*, 2014).

Table. 1. Bioremediation potential of microalgal species and its mechanism of contaminant removal

Emerging contaminants	**Potential Microalgae**	**Removal efficiency (%)**	**Mechanism**	**References**
17 β-Estadiol	*Chlamydomonas reinhardtii*	100	Bioadsorption, bio-uptake and biodegradation	Hom-Diaz *et al.*, 2015
	Desmodesmus subspicatus	95		
	Nannochloris sp.	60		Bai and Acharya 2019
	Selenastrum capricornutum	88		Hom-Diaz *et al.*, 2015
Acetaminophen	*Mixed consortia*	99	Biodegradation	Matamoro *et al.*, 2016
Bisphenol A	*Chlamydomonas mexicana*	24	Bio-uptake and biodegradation	Ji *et al.*, 2014
	Chlorella vulgaris	24		
7-amino cephalosporanie acid	*Chlorella sp.*	100	Photodegradation and bioadsorption	Gojkovic *et al.*, 2019
	Chlamydomonas sp.	100		
	Mychonastes sp.	100		
Bupropion	*Chlorella sorokiniana*	60	Bioadsorption	Gojkovic *et al.*, 2019
	Chlorella vulgaris	82		
	Chlorella saccharophila	88		
	Coelastrella sp.	89		

	Coelastrum astroideum	94		
	Desmodesmus sp.	86-90		
	Scenedesmus sp.	70		
	Scenedesmus obliquus	95		
Caffeine	*Mixed consortia*		Biodegradation	Gojkovic *et al.*, 2019
Carbamazepine	*Chlamydomonas mexicana*	35	Bioadsorption and Biodegradation	Xiong *et al.*, 2017
	Chlorella sorokiniana	10-30		De wilt *et al.*, 2016
	Desmodesmus sp.	71		Gojkovic *et al.*, 2019
	Mixed consortia	4-15		Zhou et al., 2014
	Nannochloris sp.	20		Bai and Acharya, 2016
	Scenedesmus obliquus	35		Xiong *et al.*, 2017
Ciprofloxacin	*Chlamydomonas mexicana*	13-56	Photodegradation, biodegradation	Xiong *et al.*, 2017
	Dictyosphaerium sp.	11		Gentili and Fick, 2017
	Nannochloris sp.	20		Gentili and Fick, 2017
	Mixed consortia	20-30		
Clomipramine	*Chlorella sorokiniana*	96	Bioadsorption	Gojkovic *et al.*, 2019
	Chlorella vulgaris,	100		Gojkovic *et al.*, 2019
	Chlorella saccharophila	100		
	Coelastrella sp.	34		
	Desmodesmus sp.	29-42		
	Scenedesmus sp.	73		
	Scenedesmus obliquus	78		
Diclofenac	*Chlorella sorokiniana*	30	Photodegradation, biodegradation	Escapa *et al.*, 2015
	Chlorella vulgaris	21		
	Mixed consortia	55		

Diphenhydramine	*Chlorella sorokiniana*	73	Biodegradation	Gojkovic *et al.*, 2019
	Scenedesmus sp.	86		Gojkovic *et al.*, 2019
	Scenedesmus obliquus	85		
	Chlorella vulgaris	98		
	Chlorella saccharophila	93		
	Coelastrella sp.	87		
	Coelastrum astroideum	87		
	Desmodesmus sp.	88-92		
Ibuprofen	*Chlorella sorokiniana*	100	Bio-uptake and biodegradation	De wilt *et al.*, 2016
	Nannochloris sp.	40		Bai and Acharya, 2016
	Navicula sp.	60		Ding *et al.*, 2017
	Mixed consortia	98		Hom-Diaz *et al* 2017
Orphenadrine	*Chlorella sorokiniana*	82	Bioadsorption	Gojkovic *et al.*, 2019
	Chlorella vulgaris	100		
	Chlorella saccharophila	98		
	Coelastrum astroideum	66		
	Coelastrella sp.	78		
	Desmodesmus sp.	75-82		
	Scenedesmus sp.	79		
	Scenedesmus obliquus	95		
Tramadol	*Dictyosphaerium sp.*	57	Bio-uptake and biodegradation	Gentili and Fick, 2017
	Chlorella vulgaris	51		Gojkovic *et al.*, 2019; Ali *et al.*, 2018
	Desmodesmus sp.	14-45		Gojkovic *et al.*, 2019
	Scenedesmus obliquus	91		Ali *et al.*, 2018

Triclosan	*Chlorella pyrenoidosa*	77	Biodegradation and photodegradation	Wang *et al*., 2013
	Microcystis aeruginosa	46		Huang *et al*., 2016
	Mixed consortia	31-58		Zhou *et al*., 2014
	Nannochloris sp.	72		Bai and Acharya, 2016
Paracetamol	*Chlorella sorokiniana*	41-69	Biodegradation and photodegradation	Escapa *et al*., 2015
	Mixed consortia	88-94		Zhou *et al*., 2014
Memantine	*Chlorella sorokiniana*	87	Bioadsorption and biodegradation	Gojkovic *et al*., 2019
	Chlorella vulgaris	100		
	Chlorella saccharophila	100		
	Coelastrella sp.	78		
	Coelastrum astroideum	73		
	Desmodesmus sp.	44-86		
	Scenedesmus sp.	92		
	Scenedesmus obliquus	86		

Conclusion

In Conclusion, bioremediation of emerging contaminant pollution in wastewater using microalgae presents a promising solution for environmental remediation and wastewater treatment. Microalgae have the ability to remove ECs from contaminated wastewater in an environmentally friendly and sustainable way. The potential of microalgae can be further explored through the development and application of new microalgal strains and the use of diversified resources. The recycled microalgal biomass can be further processed for the production of high-value products such as biodiesel and biochar. However, the use of microalgae for the removal of ECs is still at the laboratory level, and further research and development is needed to apply microalgal technology on an industrial scale. The application of engineering tools may render the process more cost-effective and environmentally sustainable in the future. Therefore, continued research and development in this area are important for achieving sustainable and efficient wastewater treatment and environmental remediation.

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Unleashing the Power of Microbes: The Promising Potential of the Aquaculture Microbiome

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Abstract

Aquaculture, the fastest-growing sector of agriculture, relies on the microbiome, which influences fish health and productivity. Microbes in the gut system of finfish exhibit symbiotic relationships, impacting hereditary traits, disease defence, and immunity. Research has focused on microbiome diversity and taxonomic identification in finfish and shellfish, with implications for physiological functions. Beneficial microbes can serve as alternatives to antibiotics, reducing superbug emergence and enhancing production rates. Microbiomes offer preventive measures against infectious diseases and accelerate drug development in various industries. Understanding host-microbiome interactions can modulate the aquaculture microbiome to promote aquatic organism health and industry growth. Targeted modulation of the shrimp and aquaculture microbiome is key for effective treatment strategies. By harnessing the microbiome's potential, aquaculture can achieve sustainable fish production, reduce antibiotic use, and prevent antibiotic-resistant superbugs.

Keywords: *Aquaculture, Microbiome, Superbug, Infectious disease, Antibiotic, Gut microbes*

Introduction

Aquaculture, responsible for half of the world's seafood production, reached a record of 214 million metric tons in 2020 (FAO, 2020). However, the industry faces challenges from infectious diseases caused by microorganisms, leading to economic losses. Traditional measures like antibiotics and vaccines have protected cultured species but have also led to the emergence of antimicrobial-resistant strains, raising concerns about environmental and human health. Safer and environmentally-friendly treatment strategies are now needed to address these challenges. Microbiome manipulation can enhance water quality and reduce infections, decreasing antimicrobial reliance in aquaculture. Modulating the microbiome of aquatic species as probiotics can overcome sector challenges. The gut microbiome positively influences aquatic health and growth, serving as a defense against infection-causing microbes and maintaining gut balance (Yukgehnaish *et al*., 2020). Since aquatic species are in direct contact with water, exploring the aquaculture microbiome is vital for their health and growth.

Microbiome

The microbiome is defined as a distinct microbial community with specific physiochemical properties (Berg *et al*., 2020). A healthy microbiome is characterized by a resistant, resilient, and functional core capable of maintaining stability despite internal or external factors (Lloyd-Price *et al*., 2016). Microbiomes in different habitats, such as the skin, gills, and gastrointestinal tract of finfish and shellfish, can limit pathogens through competition for resources and the production of antimicrobial compounds. Gut microbiomes are complex communities influenced by microbe-host interactions, diet, and environment, and are often considered an "extra organ" due to their crucial roles in intestinal development, overall health, and metabolism. Understanding the composition and functions of the microbiome is challenging due to its variability among individuals, growth stages, and geographic areas (Sandrini *et al*., 2015). Despite this complexity, a healthy microbiome is characterized by a stable and balanced ecology capable of resisting perturbations and maintaining the host's health.

Microbiome associated with the skin

The skin microbiome of fish can interfere with pathogen colonization through antagonistic activity and competition for adhesion sites/nutrients. Aerobic heterotrophic bacteria on fish skin are similar in abundance to the surrounding water, but the composition of the healthy fish skin microbiome differs from rearing water, with potential higher abundances of *Bacillus*, *Micrococcus*, and *Enterobacteriaceae* in warm water species (Gram and Ringø, 2005).

Microbiome associated with the gills

The gills of fish have been suggested to represent a challenging habitat for microbial colonization, with restricted areas of protected spaces such as clefts between pharyngeal arches and lamellae. Fish gill microbiota diversity is reported to be lower than that of fish skin, and culture-based studies have shown similarities between gill microbiota and surrounding water in various fish species such as Atlantic salmon, rainbow trout, turbot, striped bass, and Nile tilapia (Al-Harbi and Uddin, 2005). Stress factors such as poor water quality, temperature changes, overcrowding, trauma, and parasitism have been suggested to affect the microbiota of gills and skin in fish, with evidence supporting the influence of seasonality and poor water quality on gill microbiota (Cahill, 1990).

Microbiome associated with the gut

Izvekova *et al*. (2007) describe the gut microbial flora of marine and freshwater fish. Due to the differences in environmental circumstances, the gut microbial composition of freshwater fish differs. The gut of freshwater fish is dominated by *Aeromonas*, *Acinetobacter*, *Lactococcus*, *Pseudomonas*, *Flavobacterium*, obligate anaerobes (*Clostridium*, *Bacteroides* and *Fusobacterium*), and members of the Enterobacteriaceae family. Fish and other aquatic creatures have a unique connection with their surroundings and the microorganisms that live there. *Alcaligenes*, *Aeromonas*, *Alteromonas*, *Carnobacterium*, *Moraxella*, *Flavobacterium*, *Micrococcus*, *Pseudomonas*, and *Vibrio* are the predominant bacteria in the gut of marine fish.

Factor affecting the microbiome

1. Host physiological conditions and starvation: According to Dai *et al*. (2018), *L. vannamei* under starvation stress exhibits digestive and immunological functions that are correlated with the gut microbiota as shown in Figure 1. Starving shrimp lost critical gatekeeper microbial species including *Rhodobacteraceae sp*. and *Mesorhizobium sp*., making other crucial microbial species unstable and less effective and more vulnerable to pathogen attack. *Alphaproteobacteria* and *Actinobacteria*, which have the potential to produce antimicrobial and growth-promoting compounds, were abundant in the healthy *L. vannamei* microbiome, whereas *Vibrio* and *Pseudoalteromonas*, which are frequently found in aquaculture environments, were also present in significant quantities in the diseased shrimp. Hence, they proposed that the diseased condition decreases the host's ability to filter the invading strains.

2. Temperature: In aquaculture, temperatures above the optimal growth temperature are documented to induce stress, to reduce growth (Austin and Austin, 2016) and to disrupt microbial communities in the fish gut. Several studies claimed that variations in water temperature alter the load, pathogenicity and diversity of gut microorganisms in salmonids. In tilapia, cold exposure produced substantial changes in gut microbiome composition, by boosting Proteobacteria (*Vibrionales* and *Alteromonadales*) and lowering all other phyla.

3. Salinity: The gut and skin microbiomes of anadromous fish, such as Atlantic salmon, showed compositional shifts between freshwater and marine environments. In aquaculture, the transition from freshwater to saltwater induced changes in skin mucus and gut microbiomes, including increases in Proteobacteria and Firmicutes, and decreases in Bacteroidetes, Actinobacteria, Cyanobacteria, and Verrucomicrobia (Lokesh and Kiron, 2016; Rudi *et al*., 2018).

4. Diet: According to Vatsos (2016), feeding habits have a significant impact on the structure and composition of the gut microbiota. In general, omnivores and herbivores have more diverse gut flora than carnivores, which gradually declines in comparison. Trophic level is likely one of the most influential factors affecting the gut microbiota composition. Gut microbes also synthesize vitamins and amino acids in the gut of aquatic vertebrates. For example, the amount of vitamin B12 positively correlated with the abundance of anaerobic bacteria belonging to the genera Bacteroides and Clostridium, in Nile tilapia.

Role of microbiome

1. Digestion: Diet has long been related to the gut microbiome, providing information on the commensal relationship between certain microorganisms and the host. According to research by Ray *et al*. (2012), the teleost gut microbiota generates a variety of enzymes that aid in digestion, including carbohydrases, cellulases, phosphatases, esterases, lipases, and proteases. In zebrafish, gut colonisation by microorganisms promotes epithelial absorption of fatty acids and fish with intact microbiota have increased lipid accumulation in the intestinal epithelium compared to germ-free fish who lack microbiota.

2. Immunity: Since fish are constantly in touch with water, a source of pathogenic and opportunistic commensal bacteria, gut microbial populations have significant linkages to

immunity. The immune system and gut microbiome interact in a bilateral manner. For instance, secretory immunoglobulins in fish detect and coat intestinal bacteria to prevent them from penetrating the gut epithelium.

3. Stress response: The microbiome affects the HPA axis, stress response, and behavior, such as anxiety and locomotor behaviors, which may in turn impact feeding behavior and energy homeostasis. For example, enhancing the microbiota in zebrafish reduces anxiety-like behavior and stress response by lowering CRH expression and cortisol levels as shown in figure 2 (Forsatkar *et al*., 2017). Conversely, stress can alter intestinal mucosa structure, leading to changes in gut immune system and increased risk of infections. Acute stress in fish can result in sloughing off of mucus and removal of beneficial bacteria, potentially decreasing feeding rates.

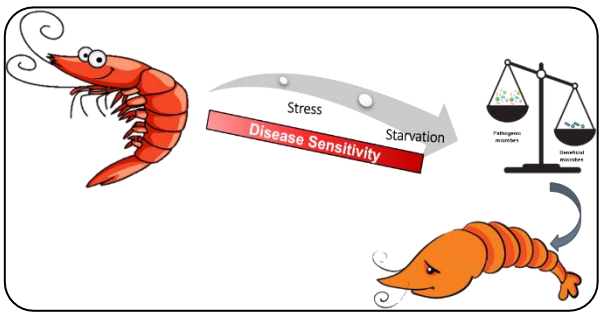

Figure 1. Factors influencing microbiota of shrimp

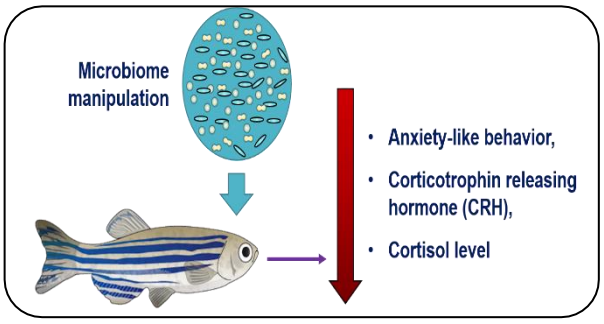

Figure 2. Stress response in zebrafish after microbiome manipulation

Table 1: Microbiome-based products

Target environment	Product	Purpose	Composition
Water and pond	PRO 4000X, AquaPro B	Degrade organic matter, reduce ammonia, Vibrio reduction	*Bacillus subtilis*, *Bacillus licheniformis*
	Waste and Sludge Reducer	Improve water and bottom quality, pathogen control	*Bacillus cereus* RRRL B-30535
	Pond Plus	Pathogen control, decomposition of organic substances	Spore forming bacteria
	Pond Protect	Ammonia and nitrite reduction	*Nitrosomonas eutropha*, *Nitrobacter winogradskyi*
Gut microbiome (feed, feed additive)	AquaPro F	Organic matter degradation, improved digestion of feed	Five strains of bacillus
	EcoBiol	Improve gut health	*Bacillus amyloliquefaciens*

Conclusion

The gut microbiome of commercially important fish is linked to digestion, metabolism, infectious diseases, and overall health, and has potential as a biomarker for fish health. Fish-derived bacteria have shown to inhibit biofilm formation by gram-negative pathogens. However, more research is needed to understand the relationship between fish disease and specific microbial species, and to optimize gut microbiome composition for disease mitigation. Further investigation into microbiome composition, diversity, and identification of microbes up to species level is crucial for disease management and improving aquaculture practices. The bio-pharma and aquaculture industries are interested in supporting such research for sustainable aquafarming.

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Genetic and Molecular Mechanism of Heat Tolerance in Crop Plants

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Abstract

Among the ever-changing components of the environment, the constantly rising ambient temperature is considered one of the most detrimental stresses. The global air temperature is predicted to rise by 0.2 °C per decade, which will lead to temperatures 1.8–4.0 °C higher than the current level by 2100. This prediction is creating apprehension among scientists, as heat stress has known effects on the life processes of organisms, acting directly or through the modification of surrounding environmental components. Plants, in particular, as sessile organisms, cannot move to more favorable environments; consequently, plant growth and developmental processes are substantially affected, often lethally, by high temperature (HT) stress.

Key words: *Heat stress, tolerance, Heat shock proteins (HSP), High temperature (HT) and Reactive oxygen species (ROS).*

Introduction

Heat stress causes multifarious, and often adverse, alterations in plant growth, development, physiological processes, and yield. One of the major consequences of HT stress is the excess generation of reactive oxygen species (ROS), which leads to oxidative stress. Plants continuously struggle for survival under various environmental stress conditions including HT. A plant is able, to some extent, to tolerate heat stress by physical changes within the plant body and frequently by creating signals for changing metabolism. Plants alter their metabolism in various ways in response to HT, particularly by producing compatible solutes that are able to organize proteins and cellular structures, maintain cell turgor by osmotic adjustment, and modify the antioxidant system to re-establish the cellular redox balance and homeostasis. At the molecular level, heat stress causes alterations in expression of genes involved in direct protection from HT stress. These include genes responsible for the expression of osmo-protectants, detoxifying enzymes, transporters, and regulatory proteins. In conditions such as HT, modification of physiological and biochemical processes by gene expression changes gradually leads to the development of heat tolerance in the form of acclimation, or in the ideal case, to adaptation. In recent times, exogenous applications of protectants in the form of osmo-protectants and nutrients have been found effective in mitigating HT stress-induced damage in plants.

Plant Response to Heat Stress

Plant responses to HT vary with the degree of temperature, duration and plant type. At extreme HT, cellular damage or cell death may occur within minutes, which may lead to a

catastrophic collapse of cellular organization. Heat stress affects all aspects of plant processes like germination, growth, development, reproduction and yield (Fig 1). Heat stress differentially affects the stability of various proteins, membranes, RNA species and cytoskeleton structures, and alters the efficiency of enzymatic reactions in the cell for which the major physiological processes obstacle and creates metabolic imbalance.

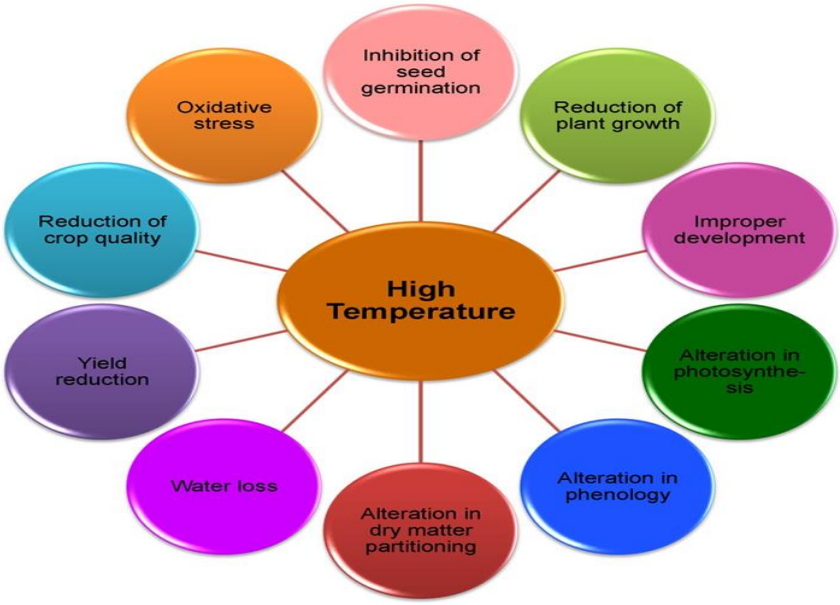

Figure 1. Effect of high temperature on plants.

Growth

Among the growth stages of plant the germination is affected first of all. Reduced germination percentage, plant emergence, abnormal seedlings, poor seedling vigor, reduced radicle and plumule growth of geminated seedlings are major impacts caused by heat stress documented in various cultivated plant species.

Photosynthesis

Photosynthesis is one of the most heat sensitive physiological processes in plant. In chloroplast, carbon metabolism of the stroma and photochemical reactions in thylakoid lamellae are considered as the primary sites of injury at HTs. Thylakoid membrane is highly susceptible to HT. Major alterations occur in chloroplasts like altered structural organization of thylakoids, loss of grana stacking and swelling of grana under heat stress.

Reproductive development

A few degrees elevation in temperature during flowering time can result in the loss of entire grain crop cycles. During reproduction, a short period of heat stress can cause significant decrease in floral buds and flowers abortion.

Yield

Even a small (1.5 °C) increase in temperature has significant negative effects on crop yields. Higher temperatures affect the grain yield mostly through affecting phenological development processes. Loss of productivity in heat stress is chiefly related to decrease

assimilatory capacity which is due to reduced photosynthesis by altered membrane stability and enhanced maintenance respiration costs, reduction in radiation use efficiency.

Oxidative stress

The reaction centers of PSI and PSII in chloroplasts are the major sites of ROS generation though ROS are also generated in other organelles viz. peroxisomes and mitochondria. Accumulation of ROS can lead to programmed cell death.

Avoidance mechanisms

Under HT conditions, plants exhibit various mechanisms for surviving which include long-term evolutionary phenological and morphological adaptations and short-term avoidance or acclimation mechanisms such as changing leaf orientation, transpirational cooling, or alteration of membrane lipid compositions.

Tolerance mechanisms

Some major tolerance mechanisms, including ion transporters, late embryogenesis abundant (LEA) proteins, osmoprotectants, antioxidant defense, and factors involved in signaling cascades and transcriptional control are essentially significant to counteract the stress effects.

Antioxidant Defense in Response to Heat-Induced Oxidative Stress

Tolerance to HT stress in crop plants has been associated with an increase in antioxidative capacity. Tolerant plants entail a tendency of protection against the damaging effects of ROS with the synthesis of various enzymatic and non-enzymatic ROS scavenging and detoxification systems.

Mechanism of Signal Transduction and Development of Heat Tolerance

Upon stress plants perceive the external and internal signals through different independent or interlinked pathways which are used to regulate various responses for its tolerance development (Figure 2).

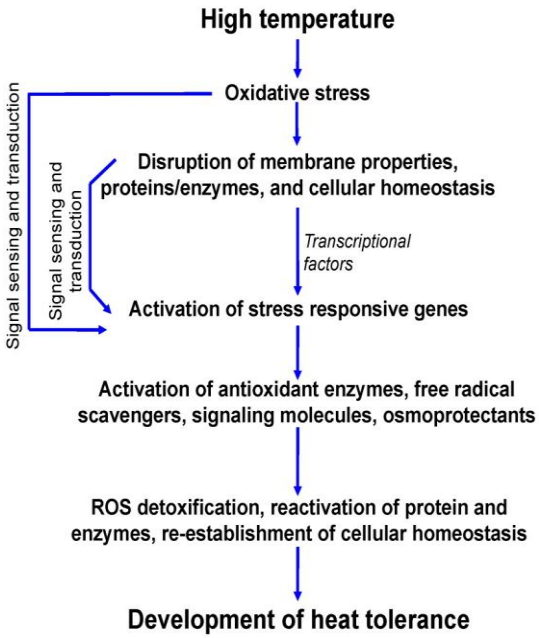

Figure 2. Development of heat tolerance in a plant through signal transduction mechanism.

Use of Exogenous Protectants in Mitigating Heat-Induced Damages

One of the ways to deal with adverse effects of heat stress may involve exploring some molecules that have the potential to protect the plants from the harmful effects of HT. Exogenous application of protectant such as osmoprotectants, phytohormones, signaling molecules, trace elements, *etc.*, have shown beneficial effect on plants grown under HT as these protectants has growth promoting and antioxidant capacity.

Heat-Shock Proteins (hsps): Master Players for Heat Stress Tolerance

Heat stress is responsible for the up-regulation of several heat inducible genes, commonly referred as "heat shock genes" (HSGs) which encode HSPs and these active products are very much necessary for plant's survival under fatal HT. High temperature induced constitutive expression of most of these proteins protect intracellular proteins from being denaturation and preserve their stability and function through protein folding; thus it acts as chaperones.

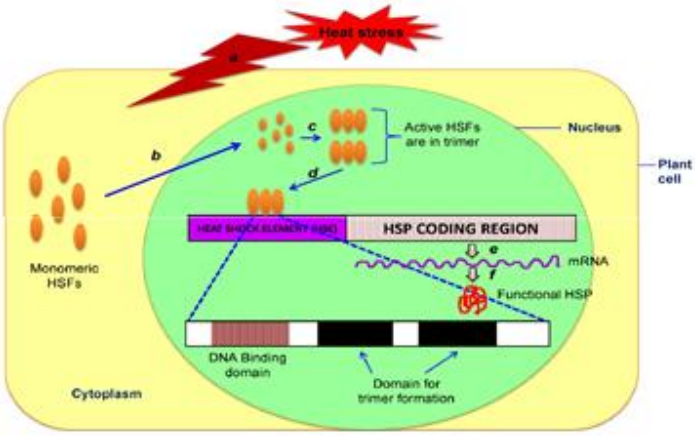

Figure 3. Regulatory mechanism of *HSPs*

Conclusion

The present rate of emission of greenhouse gases from different sources is believed responsible for a gradual increase in the world's ambient temperature, and is resulting in global warming. Therefore, plant responses and adaptation to elevated temperatures, and the mechanisms underlying the development of heat-tolerance, need to be better understood for important agricultural crops. HT effects currently carried out in different parts of the world are still limited to laboratory conditions and short-term studies only. Field experiments that explore different biochemical and molecular approaches and agronomic management practices are needed to investigate the actual HT responses and their effects on final crop yield.

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Unlocking the Potential of Fish / Animal Nutrition: Ameliorate Growth Performance and Nutritional Security through Feed Fortification with Additives

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Abstract

Animal nutrition is a critical component of livestock production systems, as it directly influences animal health, welfare, and productivity. The use of feed additives in animal nutrition has gained much attention in recent years as a means of enhancing animal performance and addressing nutritional deficiencies. Fish feed fortification with additives involves the inclusion of essential nutrients, such as vitamins, minerals and amino acids, in animal feed to enhance the nutrient content and improve animal health and growth. Animal nutrition plays a crucial role in ensuring food security and human well-being. Probiotics and prebiotics are commonly used to improve gut health, while enzymes can enhance nutrient digestion and absorption. Organic acids are used to reduce microbial contamination and improve feed preservation, while antioxidants are used to protect against oxidative stress and enhance shelf-life. This article gives insight into the viability of feed fortification with additives to augment fish/animal nutrition and facilitate sustainable livestock production. The authors expound on the underlying mechanisms that confer efficacy to these additives and furnish fundamental information regarding their usage. Feed additives hold promise as a prospective remedy for enhancing animal nutrition, curtailing environmental repercussions and satisfying the mounting need for superior feed.

Keywords: *Animal nutrition, Feed additives, Enzymes, Sustainable livestock production.*

Introduction

Feed additives are small quantities of substances that are incorporated into feed ingredients or diets to enhance or maintain their quality. These additives can serve as preservatives, binders, feeding stimulants, or even feed attractants. Specific ingredients or combinations are added to the primary feed mix to meet particular requirements and are generally used in small amounts. In aquaculture, feed accounts for somewhere between 50–80% of the production costs. One of the essential components of aquaculture is proper nutrition. The right diet and affordable production costs are essential for successful aquaculture. The price and quality of the feed additives and components that are employed throughout the feed formulation process determine the nutritional value and cost of the feed, respectively. Ingredients for feed include both organic and inorganic parts. To enhance the feed quality, the fish feeding efficiency, their health and overall performance, feed additives were added during the feed preparation. Most

feed additives, including antioxidants, immunostimulants, probiotics and antibiotics, are nonnutritive and are introduced to culture systems to enhance growth and water quality.

Feed manufacturers have started using functional feed additives to combat rising prices (Yousefi et al., 2019). There has been much research on the use of various additives in fish diets to reduce psychological stress. The additive type, in addition to the species component, is crucial in differentiating the stress response. In the literature, a variety of feed additives have been tested in various species, resulting in a range of physiological reactions that have not just focused on the stress system (Herrera et al., 2019). Feed additives improve growth performance, which can help the aquaculture industry become lucrative.

Furthermore, several kinds of research have shown that the better benefits of dietary inclusion of feed additives are connected with increased feed consumption, which likely enhances immunological response and increases weight gain. Feed additives were beneficial due to their special therapeutic characteristics and eco-friendly metabolism in the digestive system. It is primarily significant for aquaculture applications because of its involvement in immune response enhancement, binding site competition, antibacterial substance generation and nutritional growth performance.

Properties of feed additives

- Feed additives should not have any harmful effects.
- It should not react with feed ingredients.
- It should not alter the nutritional quality of the feed negatively.
- It should not reduce the feed's desirable qualities by affecting its taste, appearance, flavor and texture.
- It should be available in sufficient quantities at a reasonable cost.

Types of feed additives

There are two types of feed additives

- Nutritive feed additives- Vitamins, minerals and amino acids, etc
- Nonnutritive feed additives- Binders, preservatives, etc

Feed additives

- **Probiotics**
- **Prebiotics**
- **Binders**
- **Dietary amino acid**
- **Immunostimulant**
- **Antioxidant**
- **Probiotics**
- **Antibiotics**
- **Pigments**
- **Preservatives**
- **Chemoattractants and feeding stimulants**
- **Hormones**
- **Enzymes**
- **Vitamins and minerals**

Probiotics

Probiotics are living microorganisms administered into the gastrointestinal tract (GIT) with diet or water to promote good health by improving the internal microbiological balance (Amoah et al., 2019). Fuller (1992) revised the definition as "live microbial feed supplement which beneficially affects the host animal by improving its intestinal microbial balance. In aquaculture, however, *Vibrio* spp., *Bacillus* spp., lactic acid bacteria, yeast and microalgae are mainly utilized as probiotics for growth and survival enhancement and reduction of the pathogen. It is important, especially for early life stages, since their gut is sterile and adding probiotics helps build up beneficial bacteria faster. Probiotics have been proposed as an eco-friendly way of preventing disease in aquaculture since 2008 (Wang et al., 2008).

Prebiotics

Prebiotics are non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, thus improving host health. It is given as a feed for probiotics. A non-digestible dietary component known as a prebiotic positively influences the organism by selectively promoting the activity of one or a few specific bacteria in the gut. The use of prebiotics in rearing fish and shellfish has received less attention than other terrestrial species; despite the potential advantages to health and performance, the following factors have been looked upon in prebiotic research on fish and shellfish: growth, feed utilization, intestinal microbiota, cell loss, barrier properties to pathogenic bacteria and innate immune parameters like alternative complement activity, lysozyme activity, natural haemagglutination activity, respiratory burst, superoxide dismutase (SOD) activity and phagocytic activity (Ringø et al., 2010). The primary application of prebiotics, such as organic acids, is to sterilize feed that contains a variety of infectious and pathogenic organisms (Hinton et al., 1985).

Some of the prebiotics

Non-digestible carbohydrates, Some peptides proteins, Oligofructose, Transgalacto oligosaccharides (TOS), Lactulose, Isomalto oligosaccharides (IMO), etc.

Binders

Fish feed needs to be stable enough to endure typical handling and transportation without breaking. In addition, the fish feed has to be relatively water-stable. The starch found in the fundamental constituents of feed is gelatinized after cooking and serves as a binder in feed. Agar-agar, carboxymethylcellulose (CMC), bentonite, guar gum, lignin sulphate, plaster of paris, polyvinyl alcohol, sodium alginate and wheat gluten are among the substances used as binders used at a level of 2 to 8% to increase pellet stability (Hardy and Barrows, 2003). Heat-induced gelatinization of carbohydrates during diet preparation assists in the binding of the final feed. Any binder used in the production of fish feed pellets must be

i) It must be water stable for at least two hours.

ii) The binder must function as a source of carbohydrates in the feed and promote palatability.
iii) A binder must be inexpensive and easily available.

Binders are substances that are used in aquaculture feeds.

- ✓ To improve the efficiency of the feed manufacturing process by reducing the frictional forces of the feed mixture through the pellet dies, thereby increasing the output and horsepower efficiency of the feed mill.
- ✓ To increase pellet firmness and reduce the amount of fines produced during processing and handling.
- ✓ To improve water stability of feed.
- ✓ To minimize disintegration & loss of nutrients due to leaching.
- ✓ To improve the efficiency of the feed manufacturing process.

Classification of binders

Nutrient binders: Corn gluten, Cotton seed meal, Wheat gluten, Pre-gelatinized starch.

Non-Nutrient binders: Bentonite, Lignin sulfonate, Hemicellulose extract, Tapioca flour, Carboxymethylcellulose (CMC), Alginate, Agar.

Dietary amino acids

Providing amino acids (AA) for energy, development, protein synthesis and as substrates for essential metabolic processes, protein is the most expensive component of fish diets. AA engaged in cellular activities other than protein synthesis is referred to as functional AA. A lack or imbalance may hamper body metabolism and equilibrium in functional AA (Andersen et al., 2016). Essential amino acids (EAA) are added as a supplement to the feed to get a balanced AA profile. So supplemental EAA is added, like lysine and methionine. Using all the EAA, it is possible to lower dietary crude protein levels by 2-3%, which is a substantial saving for the farmer. The concept of an ideal protein blend from feedstuffs and feed additives will greatly help with decreasing the amount of nitrogen excreted in animal waste.

Immunostimulants

Disease-related issues have emerged to limit aquaculture's expansion in recent years. Pathogenic organisms have been spread across nations as a result of rising disease instances and, in particular, the unrestricted movement of live sea organisms. Due to these viral and bacterial epizootics, the shrimp farming sector in India and other Southeast Asian nations has experienced enormous financial losses. Immunostimulants are pharmacological substances that, whether administered alone or in combination with an antigen, activate the nonspecific immune system or the specialized immunological mechanisms, making animals more resistant to microbial and parasite infestations. A wide range of bioactive active molecules, including those with antimicrobial, antioxidant, immunostimulant, growth-promoting and anti-inflammatory properties, has been used to improve the health of aquatic animals. A novel technique has been

to use bioactive molecules in aquatic feed. This bioactive immunostimulant approach is dependable, reproducible and improves feed quality (Wang et al., 2017). It is an agent which stimulates the nonspecific immune mechanisms when given alone or through specific mechanisms. Hence, there are no environmental hazards and residual effects on fish which can be given orally or through the feed. Immunostimulants promote resistance to active infection by increasing general defensive mechanisms rather than stimulating particular immune responses. As a result, there is no memory component and the response will probably only last for a short time.

- ***Natural***: Ginger, turmeric, tulsi, garlic.
- ***Artificial***: Beta-glucan, levan, anthraquinone, sodium alginate.

Antioxidants

The energy value of a fat or oil is significantly reduced as a result of oxidative rancidity or lipid peroxidation. Unwanted oxidation in feeds can be prevented in a number of ways. It is important to take precautions to ensure that the components used in the feeds give appropriate margins of safety for the natural antioxidants lecithin and vitamins A and E. Feed should be made with as few unstable fats and oils or other pro-oxidants as possible when feasible. Commercial fish feeds have included antioxidants in the prior. Even though hundreds of chemicals have been studied, only a select number have demonstrated the qualities required to be used in finished feeds to avoid undesired feedstuff oxidations. In the absence of natural antioxidant protection, feedstuffs rich in PUFAs are highly prone to oxidative decomposition. It may cause a reduction in the nutritional value of the constituent lipids, protein and vitamins.

- Rancidity makes feeds unpalatable and generates toxic chemicals.

Properties of antioxidants

- Inexpensive
- Non-toxic
- Effective at low concentrations (0.001–0.02%)
- Capable of surviving processing

Commonly used antioxidants are;

Synthetic antioxidant

i) Ethoxyquine @ 0.015%.

ii) Butylated Hydroxyanisole (BHA) @ 0.2%

iii) Butylated hydroxytoluene (BHT) @ 0.2%.

Natural antioxidant

i) Vitamin E

ii) Vitamin C

Antibiotics

It is a bacteriostatic or bactericidal substance added to feed to treat disease. Some feeds can be formulated with antibiotics to treat Vibriosis and other bacterial infections. In general, it has been observed that antibiotics promote the growth of young animals rather than that of adults. Feeds made with vegetable proteins respond favorably to antibiotics decreasing or stopping pathogen activity, Getting rid of microorganisms that create growth-inhibiting toxins, promoting the growth of beneficial microbes that provide nutrients, lower the number of microbes that compete with the host for nutrition. Boost the intestine's ability to absorb nutrients (Hardyand Barrows, 2003). Routine uses in the feed are not recommended. Three antibiotics approved in the U.S. are sulfadimethoxine, sulfamethazine and tetracycline (oxytetracycline, OTC).

- OTC is commercially available as "medicated" fish (shrimp) feed, 1,500 mg/kg
- Flavophospholipol- 10-40 ppm
- Virginiamycin-100ppm
- Zinc Bacitracin- 100ppm

Pigments

Fishes have a variety of colours that are defined by pigment compounds deposited in their bodies. These pigment chemicals include melanin, nitrogenous bases, luminous proteins, and xanthophylls and anthocyanins (Price et al., 2008). Carotenoids have been included in diets of salmonids, crustaceans and other farmed fish, mainly as pigments to provide a desirable coloration to these cultured organisms. Consumers subconsciously relate product color to nutritive value, healthiness, freshness and taste. Therefore, color is a decisive quality criterion that has to be maintained and optimized. The most significant types of pigments in fish and crustaceans are carotenoids. Astaxanthin and canthaxanthin give the skin and eggs colour. Because they are unable to convert xanthophylls to carotenoids, high-value culture species like salmon and red sea bream must consume these pigments. These species are given carotenoid supplements using natural materials like paprika, krill products, shrimp, and crab processing waste containing the necessary pigments. Carotenoids may not only contribute to improving quality by enhancing color but could also help to create a better image in the minds of consumers of aquaculture products. Astaxanthin is added at 50 ppm and fed to shrimp for six weeks to improve colouration.

Examples:- Capsanthin, Lycopene, Beta-8'-apo-carotenal, Lutein, Cryptoxanthin Violaxanthin, Canthaxanthin, Zeaxanthin, Patent Blue V, Curcumin.

Preservatives

Susceptibility of individual feed ingredients and formulated feeds to oxidative damage (oxidative rancidity) and microbial attack on storage. Substances are added to the feed to control the rate of deterioration, particularly from fungal attacks under favorable conditions of storage are susceptible to the growth of microorganisms like fungi, yeast and bacteria. Feedstuffs and rations with an elevated moisture content (> 15%) are prone to microbial attack and Relative humidity of 70-90% and a temperature of 25^0C in the tropics favour rapid growth of microbes. *Aspergillus*, *Fusarium and Penicillium spp*. are associated with spoilage.

Antimicrobial preservatives

Propionic acid or Ca, Na or K salt - 0.1-0.25%, Sorbic acid or Ca, Na or K salt, Benzoic acid or Na salt, Acetic acid, Formic acid, Citric acid, Ascorbic acid or Ca or Na salt, Gentian violet, Potassium and sodium bisulphite, Potassium and sodium metabisulphite, Propylene glycol.

Chemoattractants and feeding stimulants

Synthetic chemicals or natural ingredients containing chemicals like free amino acids elicit feeding responses or induce animal feeding behavior and help improve food intake. Attractants are a mix of chemicals containing nitrogenous compounds, including

- Free amino acids
- Low molecular weight peptides
- Nucleotides related compounds
- Organic bases

Two types of feeding stimulants used in aquaculture feed

Natural ingredients: Squid meal, mussel flesh, shrimp meal and waste, short-necked clam flesh, marine polychaete worms, blood worms, certain terrestrial oligochaete worms, marine fish oils, fish meal, fish soluble, fish protein hydrolysates, soybean protein hydrolysates.

Purified or synthetic chemical derivative: Mixtures of L-aminoacids; amino acid mixtures including glycine, alanine, betaine, proline and histidine.

Hormones

Growth hormone, thyroid hormone, gonadotropin, prolactin, insulin, and different steroids are among the hormones that cause fish to develop. Growth promoters include steroid hormones like androgen, estrogen, progestogens, and non-steroidal hormones like thyroxin (Naiel et al., 2020). Various natural and synthetic hormones have been used in aquaculture for

- inducement of spawning,
- sex reversal,

- production of mono-sex population,
- growth enhancement.

Hormones responsible for fish growth are 17-alpha methyl testosterone, growth hormone, thyroid hormone, gonadotropin, prolactin, insulin and various steroid. Hormonal control is used to produce monosex cultures of fish to reduce reproduction & increase growth. Ex: Androgenic steroids (ethyltestosterone) fed to tilapia fry more than 90% of males.

Enzymes

The inclusion of anti-nutritional factors like phytate (mMyo-inositol-1,2,3,4,5,6-hexakisphosphates, the primary phosphorus storage form, is one of the main issues with the use of plant proteins in fish feed. Fishes lack intestinal phytases necessary for effective phytate hydrolysis during digestion; hence, up to 80% of the total phytase content in plants may be present in the form of phytate and is essentially unavailable to them. Therefore, much of the phytate-phosphorus is eventually excreted into the water, which may lead to pollution through algae growth. Enzymes aid in the improvement of the fish's inability to properly and efficiently digest its nutrition. Additionally, complex carbohydrates, collagen in skin and bones, and other feed components are all broken down by enzymes (Strobel et al., 2012). Biological catalysts, proteolytic and amylolytic enzymes are used. It improves the nutritional availability of feedstuffs. Feed enzymes have to be robust to withstand variations in pH and temperature. They should have high-temperature stability to withstand palletization. It should have a long shelf life. Phytase breaks down indigestible phytic acid (phytate) in cereals (rice bran, wheat), oil seeds and releases digestible phosphorus.

- Use of specific enzymes like **xylanase, pectinase and cellulose.** Protein levels in feed could be reduced and hence the cost factor also.

Feed Stimulants

Chemoattractants, such as free amino acids, betaine, and other naturally occurring components, including chemicals, are synthetic or natural compounds. The main flavour attractants are often thought to be extractive chemicals found in the muscles of crustaceans and mollusks. These attractants are a mixture of substances made of nitrogenous molecules, such as free amino acids, peptides with low molecular weight, nucleotides, related compounds, and organic bases. The food supplied must be appealing (i.e., scent or taste) in order to evoke an appropriate feeding response, depending on whether the animal in concern is a visual feeder or a chemo-sensory feeder. For example, whereas captive marine fish rely on sight to find food, they also rely on chemo-receptors placed in the mouth or on appendages such as lips, barbels, and fins. Dietary feeding stimulants must be used to induce an adequate and quick eating response in these farmed species. Furthermore, by employing feeding stimulants and boosting feed palatability, the time the feed spends in the water may be decreased, reducing nutrient leaching.

Aside from the feed additives listed above, there are others, like amino acids, antibiotics, and immunostimulants. L-lysine and DL-methionine are the most common synthetic amino acids used in feed supplements. These are used to compensate for deficits in a compounded diet as well as chemoattractants. Antibiotic use is prohibited since medicated feed poses health risks to consumers owing to residual buildup in the fish flesh and may also open the route for the emergence of drug-resistant bacterium strains.

Essential oils

Using herbal food additives can boost the immune system, increase feed consumption, and enhance performance by avoiding infections (Ezzat Abd El-Hack & Alagawany, 2016). Essential oil can be used as an alternative source of natural products to improve animal nutrition and prevent detrimental effects on animal health.

The most prevalent form of phytogenic compounds in aquatic feeds are feed additives, including aromatic plant essential oils. Essential oils are secondary metabolites produced by aromatic plants and are concentrated hydrophobic liquid molecules with a strong odour. Most of the plant's active chemicals are found in them, along with a range of volatile molecules such as terpenoids, aromatic components generated from phenol, and aliphatic components (Chakraborty et al., 2014) derived products that are added to the feed to boost animal performance.

Essential oil of peppermint (Talpur,2014) and cinnamon (Ahmad et al.,2011) appear to be potential options for improving growth performance, fish well-being and reducing microbial challenges in the gut. According to Zheng et al. (2009), diets enriched with oregano essential oil and its phenolic components carvacrol and thymol were demonstrated to increase growth in channel catfish. Following eight weeks, fish fed the diet supplemented with the commercial product (0.05%) had considerably greater ($P < 0.05$) weight increase, protein efficiency ratio, and enhanced FCR than fish fed the other diets.

Organic acids

Environment-friendly organic acids and salts commonly used as substitutes, such as acetic acid, formic acid, fumaric acid, lactic acid, propionic acid and citric acid. In combination, they act as excellent growth promoters (Balasubramanian et al., 2016). Feed conversion efficiency has been tested in salmonids, tilapia, and other fish species (Ng & Koh, 2017). Citric acid and salts are aquaculture's most studied organic acids for growth and weight gain (Zhang et al., 2016). Additionally, the benefits of citric acid with coupled amino acid-chelated trace elements have been explored as giant yellow croaker given high plant protein to digest by 0.8%-1.6% of citric acid (Chen et al., 2018).

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Climate Change: Fingerprint on Pest Population and Their Effect on Food Security

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Abstract

Climate change causes a major impact on agricultural production and food security, apart from that, the rising temperature and atmospheric CO_2 level cause a huge impact on pests (field and storage pests). Since temperature is the most important factor in pest population dynamics and phenology a study about the effect of climate change on pest population is needed, which has a direct impact on food securities by affecting agricultural production, food storage, and the food supply chain. Pests' metabolic rate tends to double for an increase in 10°C, elevated CO_2 concentration at the atmospheric level enhanced the consumption rate and alters the development time. The higher environmental temperature may produce higher resistive species to climate changes, in the case of storage pest the changes in climate condition highly influences the growth range and life cycle period of pests and mites. Major pests like cereal stem borers may move to temperate regions and cause huge losses in cereals, legumes, and other food crops. Integrated pest management (IPM) practices, modified cropping practices, adaptive management strategies and usage of pest as feed or protein intake can help to manage the overpopulation of pests.

Keywords: Climate change, Pest population, Food security, Greenhouse gases, Pest management.

Introduction

In the last 40-50 years climate change, caused a major change in the agricultural system; which had a direct impact on food production and the security of the food supply chain. The demand for agricultural production rises every year, accordingly by 2050 double the agricultural production is needed to overcome the increasing demand. Previous studies investigated the effects of climate change and associated conditions such as rising global temperatures, increased atmospheric CO_2 concentrations, heat waves, floods, drought, and other extreme events on agricultural production. The impact of climate variability on food security varies by region and society, for example, rising food insecurity caused by climate change in Sub-Saharan Africa was heavily driven by socioeconomic reasons rather than climatic change. Studies on the influence of climate change on crop productivity can show a partial picture of the relationship between food security and climate change, it is critical to

concentrate on the impact of climate change over it. Reduction in crop yield by climate variation is one part of the factor directly affecting food security, apart from that, the major biotic factors like pests and pathogens have effective control over the actual yield of crops, and control the food security in the agricultural field level, processing line, and food supply chain (Gregory et al., 2009). The elevated temperature causes a sudden outbreak of pests, so it is necessary to monitor the pest abundance and appearance in different conditions. This article provides a clear view of how climate change impacts the pest population and their impact on food security.

Effect of climate change on pest population

Climate change has a crucial role in atmospheric temperature, climate extremes, CO_2, and other greenhouse gases. Insects are poikilothermic organisms where the temperature is the most important factor that affects their growth cycle, behavior, and geographical distribution. The higher environmental temperature directly affects the population dynamics, distribution, reproduction, and survival rate of pests, whereas indirectly it alters the relationship between pest and their environmental or natural enemies (Sgrò et al., 2016). Other than the higher metabolic rate, increased temperature accelerates pest consumption, reproduction, population dynamics (survival, generation time, and population range), and distribution. Due to global warming, the pest growth rate in the tropical zone is expected to decline, while the growth rate in the temperate zone is expected to expand faster. In the case of rice, predicted decrease in pest population whereas for maize mixed response of pest population is expected.

The elevated CO_2 enhancement altered the C:N ratio of plants, which increased the consumption rate of pests and lengthened the development period. This had a greater influence on C3 plants than C4 plants, therefore C3 plants was positively affected by higher CO_2 and adversely impacted by insect response than C4 plants. Climate change affects the distribution pattern of insects where low temperature plays a major role, the pattern will vary based on the species-specific climate requirements. There are possibilities for an invasion of alien species either intentionally or unintentionally due to human activities. Climate change and its related effects can cause modifications in

- Diversity, behavior, and overpopulation of pest
- Environmental distribution
- Population dynamics
- Plant resistance against insects
- Pest outbreak and invasion

Impact of pest on crop production

The metabolic rate of pests tends to double for temperature rise of every 10°C, so a rapid change in the climate can cause sudden pest outbreaks and disease epidemics (Boggs, 2016). In optimal conditions, elevated CO_2 promotes the aphid population 10% earlier timing

of population peaks, 10% increase in winged forms, and the occurrence of flight phenologies before a month, which will enhance the spread of barley yellow dwarf virus where aphids act as a vector leads to the low yield. Changes in rainfall pattern by climate change favors a rapid population of *Agriotes lineatus* (wireworms), which is the major damaging pest in potatoes; alters the migratory pattern of desert locust (*Schistocerca gregaria*). The soybean cultivated at elevated CO_2 was damaged by up to 57% by pests like potato leafhopper, the Japanese beetle, the Mexican bean beetle, and the western corn rootworm. Although increased CO_2 has no direct effect on many insects' respiration, it does enhance heterotrophic respiration in pine beetles and creates competition for oxygen and nutrients between soil bacteria and insects. The elevated CO_2 helps to modify crop resistance against pests, for example, it resulted in a decrease in the expression of genes in soybean that make proteinase inhibitors, which have resistance against coleopteran herbivores; in white cabbage, the production of volatile defense compounds due to elevated CO_2 possess a specific deterrent against natural enemies (*Costesia plutellae*) of the diamondback moth (*Plutella xylostella*). Elevated CO_2 and temperature have a synergistic influence on plant secondary chemical synthesis, which has pharmacological implications for crop-pest interactions. For example, the higher concentration of nicotine in tobacco, and scopolamine in Jimson weed were identified in crops cultivated under higher CO_2 and temperature conditions (Gregory et al., 2009). But most of the environmental studies were focused on long-term climate change, but several pest incidences were registered in short-term climate change.

Effect of climate change on storage pest

Seasonal variations favor the life cycle and spread of storage pests in new environmental conditions. The native pest of lesser grain borer causes serious concern in the UK. Winter delays and rise in temperatures lead to shorter pest development periods, and the tolerance mechanism by pests varies based on the stage of pests, species, and region. *T. confusum* eggs and *Sitotroga cerealella* eggs, are the most sensitive to rising temperatures and CO_2, respectively. However, *O. surinamensis* larvae, *L. serricorne*, and *S. paniceum* adults have lower tolerance to high CO_2 concentrations (Moses et al., 2015). Developing countries like India, China, and Thailand already suffer from huge storage losses by storage pests irrespective of their higher crop production, the changes may develop highly resistive species. Mites and species like *Tyrophagus putrescentiae* (Schrank) have a high tolerance to temperature and have a maximum production rate in temperature above 30°C, which affect the high lipid/protein food and produce allergens; in addition to that seasonal variation also affects the mites population. Likewise, insects like *Ephestia cautella* (Walker), *Oryzaephilus surinamensis* (L.), and *Sitotroga cerealella* (Oliver) have up to 50% increase in their growth rate in elevated temperature conditions (Table 1). The infestation in storage grains and biological heating highly affects the quality of the stored products.

Crop loss is exacerbated by changes in geographical distribution and pest population, the major pests including cereal stem borers, beetles, mites, aphids, flies (whiteflies), and moth move towards higher temperature (temperate conditions) cause major damage to food grains, fruits,

and vegetables, which cause a loss in food production and food supply. Ultimately, climate change causes a major effect on food production and security, especially in developing nations where sustainable food production is necessary.

Effect of pest on food security

Food security is defined as "physical and economic access to take safe and nutritious food to meet the daily dietary need and food preference for a healthy life of peoples". Food security has several dimensions, including physical availability of food, financial and physical access to food, food utilization, and long-term stability of all other dimensions. The overgoing pest population affects the physical availability and access to food, for example approximately 10000 insect species responsible for 13.6% of annual crop loss. In India, the estimated annual crop loss by pest damage is 17.5% in eight major field crops. The variation in phenological pattern and distribution of species alters the interaction of species within communities, for instance, the carrot flies and *Delia radicum* emerge a month earlier than previously recorded and have complete four generations in one year. Global warming enhances earlier pest infestations, such as cotton bollworms; fall armyworms in maize, sorghum, and millet; and Tephritid fruit flies in fruit and other crops (Sharma, 2014). As a result, the impact of climate change on the insect population and life cycle poses a significant threat to food security.

Table. 1. Effect of temperature on growth rate and life cycle period of storage insect.

Pest	Optimum temperature (°C)	Enhanced growth rate (Per lunar month)	Life cycle period (Days)
Ephestia cautella	28-32	50	27-83
Oryzaephilus surinamensis	31-34	50	30-45
Sitotroga cerealella	26-30	50	35-50
Tribolium casteneum	32-35	70	26-48
Plodia interpunctella	26-29	30	50-65
Sitophilus oryzae	26-30	25	30-40
Trogoderma granarium	33-37	12.5	45-70

Way to effective pest management

Potential adaption methods are introduced to control the risk of existing and new pests on food production and security. The commonly used techniques are integrated pest management (IPM), alternate usage of pests as food, and monitoring climate and pest population. The Introduction of pest-resistant varieties, biopesticides, synthetic pesticides, and biological control with natural enemies are the key factors in IPM, it minimizes the negative impact on

the environment and improves the heterogeneous agroecosystems. Modified cropping practices and adaptive crop management practices reduce the field pest damage on crop yield. The impending trend of replacing protein intake with insect meat and transitioning to novel proteins obtained from insects, which are cultivated by supplying agricultural/food waste are promising ways for food sustainability and food security perspectives. For example, feeding *Acheta domesticus* with food waste, and using them as human or animal food helps in waste management, alternative food sources, and upcycling food systems (Vagsholm et al., 2020). The intake of insects should meet the safety concerns like total aerobic bacterial count, the presence of spore-forming bacteria, the presence of heavy metals like cadmium, and allergenic reactions. The proper standards and regulations for insect-based food can help to overcome these issues.

Conclusion

The rising global temperature and greenhouse gas levels adversely affect pests in both direct and indirect ways. The earlier infestation, the Introduction of alien pests, overpopulation, and the distribution of pests cause major crop losses at the field level. Storage pest is one of the biotic factors that affect the food in the food supply chain, the variation in insect growth rate, distribution, and resistance to environmental conditions highly affects the storage pest control mechanism and affects food security. The migration of insect species to temperate regions causes major damage to food crops (cereals, legumes), fruits, and vegetables. As a result, the development of robust technologies, effective pest management systems, and studies about pest/environmental relations need to be followed to safeguard crop production and food security.

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AMFI-SI-V2-17

Future of Aquaculture: Integrated Multi-tropic Aquaculture

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Abstract

Integrated Multi-Trophic Aquaculture (IMTA) is a sustainable form of aquaculture. IMTA involves the cultivation of multiple species of organisms in a single aquatic system. Research has shown that IMTA can reduce the environmental impact of traditional practices. It can also reduce waste and pollution and increase productivity.IMTA systems can be complex, requiring careful consideration of factors such as species selection, stocking density, and nutrient cycling..Additionally, the success of IMTA systems can be impacted by environmental factors such as water quality, temperature, and weather conditions.Another challenge is the regulatory framework for IMTA..While IMTA is gaining recognition as a sustainable aquaculture solution, regulations and policies related to IMTA can vary widely between jurisdictions..This can create uncertainty for farmers and limit the adoption of IMTA on a larger scale.Conclusion Integrated Multi-Trophic Aquaculture is a promising sustainable form of aquaculture that has the potential to address the environmental and economic challenges facing the aquaculture industry..IMTA offers several potential benefits, including reduced environmental impacts and increased

Keywords: IMTA, Aquaculture, Sustainable, Integrated.

Introduction

Aquaculture is a rapidly growing industry that has the potential to provide a sustainable source of protein for the growing global population. However, traditional aquaculture practices can have negative environmental impacts, such as water pollution and habitat destruction. To address these issues, Integrated Multi-Trophic Aquaculture (IMTA) has emerged as a promising solution.

Integrated Multi-Trophic Aquaculture (IMTA) is a sustainable form of aquaculture that has gained attention in recent years as a way to reduce the environmental impact of traditional aquaculture practices. IMTA systems involve the cultivation of multiple species of organisms within a single aquatic system, with the goal of creating a balanced ecosystem that maximizes the use of resources and minimizes waste.

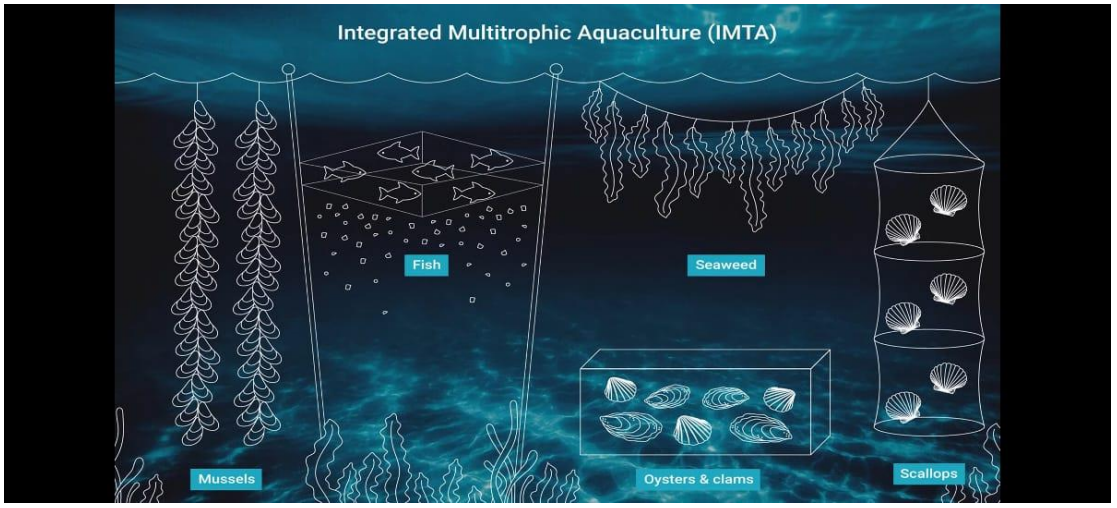
Research has shown that IMTA systems can be more efficient and environmentally-friendly than traditional monoculture aquaculture systems. For example, a study published in the journal Aquaculture showed that IMTA systems can reduce the amount of waste and improve water

quality compared to monoculture systems (Chopin et al., 2016).

IMTA systems can also have economic benefits, as they can create opportunities for the production of multiple high-value products within a single system. A study published in the journal Sustainability showed that IMTA systems can be economically viable and environmentally sustainable in different regions of the world (Troell et al., 2014).

Types of imta

Polyculture: This involves the cultivation of multiple species of fish or shellfish in the same tank or pond. The different species can occupy different levels of the water column and feed on different types of food, reducing competition for resources.



Integrated seaweed and shellfish culture: In this system, seaweed is cultivated in the water column while shellfish, such as mussels or oysters, are grown on ropes or nets suspended in the water. The seaweed provides a nutrient source for the shellfish, while the shellfish help to filter the water and remove excess nutrients.

Integrated finfish and bivalve culture: This involves the cultivation of both finfish and bivalves,

such as clams or scallops, in the same system. The finfish provide a source of nutrients for the bivalves, while the bivalves help to remove excess nutrients from the water.

Integrated fish and seaweed culture: This system involves the cultivation of fish and seaweed in separate tanks or ponds, with the seaweed providing a source of nutrients for the fish. The fish waste, in turn, provides a nutrient source for the seaweed.

Benefits of imta

Imta offers several potential benefits compared to traditional aquaculture practices. One of the most significant benefits is the reduction of environmental impacts. Imta systems can help to reduce waste and pollution by using multiple species to recycle nutrients and minimize the release of excess nutrients into the environment. Additionally, imta can help to reduce the use of antibiotics and other chemicals commonly used in traditional aquaculture practices.

Another potential benefit of imta is increased productivity. By cultivating multiple species in the same system, imta can make more efficient use of resources and space, leading to higher yields and reduced costs. Additionally, imta can help to diversify the range of species cultivated, reducing the risks associated with disease outbreaks or other environmental factors that can impact a single species.

Imta in india

The project was undertaken by india's central marine fisheries research institute (cmfri), working with fish farmers in moothakunnam, ernakulam.

Cmfri started the venture in december as part of its research initiative for developing a sustainable cage fish farming model suitable to kerala's ecosystem. In the first harvest among the three crops of the integrated farming, around one tonnes of green mussel was produced from 150 strings hung around four fish cages.the individual mussels grew to 72 g, which is a successful growth rate in mussel farming.

According to experts from the cmfri, a good harvest with better growth rate of green mussel showed that imta is economically feasible and well suited to kerala's conditions. They also observed that the fish inside the cage attained better growth and seaweed being cultured around the cage showed healthy status, with a fast growth rate.

Imta also helps to maintain environmental sustainability. "excess nutrients and carbon dioxide from the cage farm are directly or indirectly utilized by green mussel and seaweeds".

"cmfri has successfully developed a model of imta practice on open sea waters of tamil nadu which helps coastal people fetch increased income. The popularization of this innovative technology, in line with the increasing trend of adoption of cage farming technology, will help transform the lives of coastal communities.

Challenges in implementing imta

While imta offers several potential benefits, there are also several challenges associated with its implementation. One of the primary challenges is the design and management of imta systems. Imta systems can be complex, requiring careful consideration of factors such as species selection, stocking density, and nutrient cycling. Additionally, the success of imta systems can be impacted by environmental factors such as water quality, temperature, and weather conditions.

Another challenge is the regulatory framework for imta. While imta is gaining recognition as a sustainable aquaculture solution, regulations and policies related to imta can vary widely between jurisdictions. This can create uncertainty for farmers and limit the adoption of imta on a larger scale.

Conclusion

Integrated multi-trophic aquaculture is a promising sustainable form of aquaculture that has the potential to address the environmental and economic challenges facing the aquaculture industry. Imta offers several potential benefits, including reduced environmental impacts.

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AEROMONAS INFECTIONS: MOST COMMON CAUSE OF FISH DISEASES

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Abstract

Aeromonas species are opportunistic pathogens and can cause a variety of infections in freshwater fishes including fin rot, body rot, hemorrhagic septicemia, and ulcerative dermatitis. There are many species of Aeromonas that can cause disease in fishes, but some of the most common are *Aeromonas salmonicida*, *Aeromonas hydrophila*, *and Aeromonas sobria*, *Aeromonas veronii*, *Aeromonas jandaei* etc. Aeromonas strains have been tracked down in various sorts of food, like meat, fish, vegetables and handled food varieties. Aeromonas bacteria are common in both fresh and salt water. They have been separated from freshwater pond waters, streams, lakes, swamps, dregs, chlorine water, water dispersion frameworks, drinking water, and leftover waters, particularly during hot months in more prominent numbers. They are often associated with fish diseases, but can also be found on healthy fish.

Keywords: *Aeromonas Infections*, *Fish Diseases*, *Aeromonas salmonicida*, *Aeromonas hydrophila.*

Introduction

Aeromonas species are Gram-negative, facultatively anaerobic, rod-shaped bacteria that are found in water and soil. They are motile and have polar flagella. Aeromonas bacteria are common in both fresh and salt water. They are often associated with fish diseases, but can also be found on healthy fish. Aeromonas species are opportunistic pathogens and can cause a variety of infections in freshwater fishes including fin rot, body rot, hemorrhagic septicemia, and ulcerative dermatitis. There are many species of Aeromonas that can cause disease in fishes, but some of the most common are *Aeromonas salmonicida*, *Aeromonas hydrophila*, and *Aeromonas sobria*, *Aeromonas veronii*, *Aeromonas jandaei* etc. Motile Aeromonas as pathogenic bacteria can kill up to 80–100% of fish within 1–2 weeks causing substantial economic losses, due to high mortality rates and worsened quality of produce in fishery farms, mainly for commercial carp farming.

Fish species affected from Aeromonas infections

These microbes are liable for infections and mortality of various fish; basically, such species as carp, tilapia, rainbow trout, earthy colored trout, eel, roost, catfish, goldfish, and salmons.

Survival of bacterium

The individuals from the Aeromonas family are omnipresent, water-borne microorganisms. They have been separated from freshwater pond waters, streams, lakes, swamps, dregs, chlorine water, water dispersion frameworks, drinking water, and leftover waters, particularly during hot months in more prominent numbers. The quantity of disconnects from drinking water is by and large low contrasted with its numbers tracked down in food.

Aeromonas strains have been tracked down in various sorts of food, like meat, fish, fish, vegetables and handled food varieties. Possibly they could address a difficult issue in food, as many strains can develop at temperatures of a typical cooler, at a pH of 4-10 and in presence of higher centralizations of salts. Moreover, it has been shown that they can deliver exotoxins at low temperatures.

Disease outbreaks

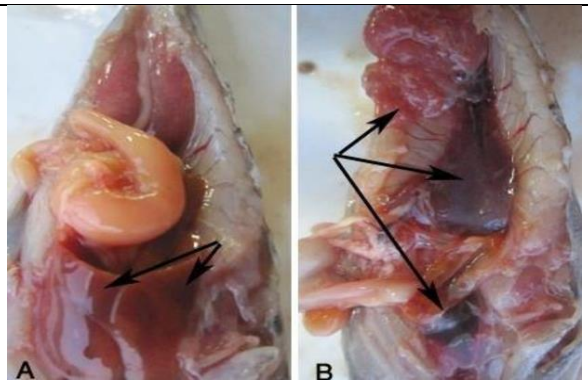
- Among the most prevalent bacteria in freshwater aquatic habitats are mobile aeromonads. They can be found in brackish waters as well, though less commonly when the salinity rises above 15 ppt (about half the salinity of seawater). Because aeromonads are facultative, they may utilise the nutrients in the water and endure for extended periods of time without a host fish.
- They are most common in water ways that are rich in organic matter, such those in ponds and other aquaculture systems. These bacteria can also be isolated from pond mud, aquatic plants, some protozoan parasites, the skin and intestines of healthy fish.
- Disease development is accelerated by environmental stressors, particularly those connected to poor water quality conditions. High water temperatures, high ammonia and nitrite concentrations, pH disturbances, and low dissolved oxygen levels are some of these contributing elements.
- Aeromonas infections are more common in warmwater and temperate species than in coldwater fish. Infections can occur in any age fish, but losses are usually most severe in fry and small fingerlings.

Clinical signs & symptoms

- It is common for fungus or the columnaris bacteria to be found in skin lesions brought on by aeromonads. Despite having extensive ulceration, fish that are just affected by skin lesions can continue to eat and survive for long periods of time.

- Small haemorrhages within scale pockets are the starting point of skin lesions, which can quickly spread to wider areas. Ulcers eventually develop and affected scales fall off.
- External symptoms of an Aeromonas infection might also include exophthalmia (popeye), abdominal distention (abdominal enlargement), and pale gills.
- The internal organs may appear swollen, crimson, pale, or with a mottled pattern of deep red haemorrhage dotted with pale patches of tissue necrosis or disintegration.
- Organs with severe tissue necrosis weaken and are susceptible to harm when touched. The intestinal system will normally be empty of food, swollen, and loaded with mucus that may be crimson or hazy yellow.
- The abdomen may contain clear, murky, or crimson fluid. There will be a lot of green bile in the gall bladder.

		
Fig. 1 Fin Rot	Fig. 2 Skin Redness	Fig. 3 Scale Erosion

	
Fig. 4 Septicaemia	Fig. 5 A) Enlarged liver with hemorrhagic spots. B) Intestinal haemorrage, swollen kidney and distended gall bladder.

Mortalities: -

- This bacteria is very influential in freshwater fish farming and often causes disease outbreaks with high mortality rates (80-100%) in a short time (1-2 weeks).
- The harmfulness level of *A. hydrophila* can kill fish contingent upon the poison delivered. The pathogenicity of *A. hydrophila* contamination happens on the

grounds that it is impacted by a few harmfulness factors, for example, cytotoxin, protease, S-layers, and Aerolysin.

- Aerolysin (aerA) has been characterized as one of the destructiveness markers to recognize the pathogenicity of the Aeromonas strain.

Pathogenic species of Aeromonas for fishes: -

Several studies and findings reported that following species of Aeromonas are responsible for most disease outbreaks in fishes: -

- *Aeromonas salmonicida*
- *Aeromonas hydrophila*
- *Aeromonas sobria*
- *Aeromonas veronii*
- *Aeromonas jandaei*

Prevention and Control: -

- Disease outbreaks of Aeromonas can be controlled with good water quality, proper sanitization, proper feeding and controlling the stress causing factors for fishes.
- Use of Benzalkonium chloride 80% for 3 days with dose rate of 2 PPM and 500 ml. of per acres of pond.
- Treatment is currently limited to two antibiotics, Terramycin® with dose rate of 2.5-3.75 g/100 lb of fish per day for 10 days in feed, and oxytetracycline with dose rate of 50 mg/kg of fish per day for 5 days.

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Tank-based cultivation of edible seaweeds in India

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Abstract

Marine seaweeds have been attracting the attention of both consumers and researchers in recent days because of their enormous nutritional and industrial properties. Seaweeds are autotrophic plants also called macroalgae that are edible in Asia, especially in Indonesia, Philippines, China, and Korea, and recently in Europe, the USA, and Australia. The high rate of lipids, proteins, and fibre content of seaweeds is an advantageous one. Their bioactive molecules play a major role in the pharmaceutical, nutraceutical, and cosmetics industries. The daily usage of seaweed has been increasing day by day, but their wild harvest rate does not meet their requirements. Hence, on-shore seaweed cultivation was initiated several decades ago in some Asian countries, and subsequently, such culture methods have been followed in some other countries. On-shore cultivation would provide a large algal quantity at a specific time interval, but when it comes to edible purposes, on-shore cultivation fails to provide contamination-free, and nutritionally rich seaweeds. Therefore, the land-based tank cultivation practise could provide an opportunity to cultivate seaweed without contamination and also to make it possible to enhance their nutritional compounds under laboratory conditions initially. Natural calamities may not affect the cultivation of seaweed in tanks. It would ensure the continuous supply of raw materials to consumers and industries. This study will focus on the seaweeds, as to importance of land-based seaweed cultivation is essential, the advantages of tank cultivation, how to select the seaweeds for tank cultivation, the methods of plantlet preparation, and the indoor and outdoor cultivation in tanks, basic applications of tank cultivated seaweeds; and the challenges during tank cultivation.

Keywords: Edible seaweeds, Land-based cultivation, Tank cultivation, Nutritional value.

Introduction

Diverse types of macro-algae which are distributed ubiquitously in marine environments, in all the temperate and tropical regions of the world, are called seaweeds. They are autotrophs and play a vital role in the marine aquatic food web. Most of such seaweeds are found to be distributed in the inter-tidal and sub-tidal areas. The seaweeds are classified into three major groups viz., Phaeophyta (brown algae), Rhodophyta (red algae), and Chlorophyta (green algae) and these algae possess huge quantities of primary metabolites (proteins, lipids, and carbohydrates) and such metabolites form raw materials for various industries viz., fodder, food, agriculture, biotechnological, cosmetics, and pharmaceuticals [2]. During the past many decades, seaweeds were the traditional daily food to humans in many coastal states, maritime

countries. And their consumption rate was increased when the algae was found to be a source of protein and dietary fibre (with a low lipid level). Over a period, the seaweeds gained popularity as a raw material for a variety of applications in industrial sectors.

The consumption of seaweeds (*Laminaria ochroleuca* and *Sacchoriza polyschides*) would improve the bone health, muscle function, and influence the metabolism in humans through their associated minerals, trace elements, and vitamins (A, K, and B12). Ruan et al. have opined that the marine-algae showed a variety of medicinal properties like anti-inflammatory, antioxidant, anti-cancer, antiviral, antidiabetic, and antifungal characteristics upon the regular consumption. Seaweed cultivation is a sustainable practice to save their diversity in the wild. To date, there are several seaweed cultivation technologies being developed for their on-shore cultivation (for commercial purpose). In India, floating bamboo rafts and mono-line methods are considered to be the most suitable technologies for seaweed cultivation in open sea. Hence, there is an urgent need to develop an appropriate methodology for seaweed culture in the open sea (with high tidal and wave actions) and also in land-based system. India has developed a tube net method for seaweed cultivation of *Gracilaria edulis*, *Gracilaria dura*, *Kappaphycus alvarezii* in such high tidal amplitude places.

Global scenario of seaweed production:

The world seaweed production from both wild collection and cultivation was 32,386 million tonnes in 2018. The total seaweed production mostly covered through the cultivation 97.1% and the balance was obtained from wild collection. The Asian continent is responsible for 99.51% of total global-seaweed production, where China is the highest producer around 18,575 million tonnes and India stands last at around 5300 tonnes.

In Asia, the countries like Indonesia, South Korea, and the Philippines produce a reasonable quantity of seaweeds (next only to China through cultivation). Seaweed production was found to be increased from 10.6 million tonnes to 32.4 million tonnes during the period of 2008–2018, which is three times higher than before. Likewise, 4 million tonnes (wet weight) were produced by Indonesia in 2010, but its production rate jumped to 11 million tonnes/year during 2015–2018, due to the rapid expansion of culture of Kappaphycus alvarezii and Eucheuma spp farming. Japanese kelp (35%), Eucheuma spp. (29%), Gracilaria spp. (11%), Undaria pinnatifida (7%), Porphyra spp. (6%), and Kappaphycus alvarezii (5%), among others, contributed nearly 90% of total global seaweed production. It is expected that the Asian countries such as China, Korea, Japan, Philippines, and Indonesia would contribute up to 100,000 tonnes (by farming) in the future. But, outside Asia, the wild–harvest is still contributing more than through farming (to their total seaweed production) and such continuous wild-harvest would affect their future stocks. Recently, both in Western and eastern countries, the brown and red algae have been chosen for pre-commercial cultivation, that has already been practiced in Asian countries like China, Korea, Japan, Philippines, and Indonesia. The interest in seaweed cultivation has been increased due to its demand for edible purposes and their applications in polysaccharide industries. The seaweed cultivation methodology may change among the different countries in relation to environmental factors.

Need for land-based edible seaweed cultivation:

The regular monitoring of water quality such as pH, salinity, temperature, nitrate, phosphate, microbial load, etc. is very much essential during seaweed culture. Since most of the edible seaweeds are acclimatized to their native conditions, they are largely influenced by environmental characteristics like pH, salinity, nutrients, temperature, and solar radiation. If the environmental conditions are favourable for seaweeds, their growth would be significant with a notable contribution from nature. However, the environmental conditions are not stable always and the loading of nutrients (phosphate and nitrate) and other parameters may vary based on the climate and season. The ex-situ method of culture is the method of growing edible seaweeds on land where the cultivator can continuously monitor the growth indicators. This type of cultivation is devoid of environmental threats such as storms, food, and other natural disasters. The algal growth can be enhanced (so as to meet our needs) with the addition of nutrients (phosphate and nitrate) and by providing the appropriate parameters like light and salinity. Thus, the land-based edible seaweed cultivation provides some advantages which are not available through any other methods of cultivation. Onshore edible seaweed cultivation has some seasonal problems in relation to changes in the temperature, bacterial infection, and salinity. Unexpected weather event in coastal areas is one of the biggest problems (during the cultivation of edible seaweed in the open sea). But it can be carefully handled if we adapt the land-based culture of edible weeds. For eco–friendly economic development, land-based seaweed farming is a preferable method (to open-ocean cultivation). The land-based edible seaweeds cultivation could be considered as the suitable method (if the number of by-products is high) for generating high quality biomass, that would be suitable to produce high-value functional products and edible recipes.

Cultivation of edible seaweeds in tanks:

Since the late 1980s, the tank-cultivation of edible seaweeds has been practiced in USA, and in Canada by experimental basis. Subsequently, this type of tank cultivation was followed in many European and Asian countries like Israel, Chile, Germany, Mexico, Japan, Korea, and China. The production rate of seaweeds is high in tanks (per 1 m2 of water surface) than through the other cultivation methods and mostly seaweeds are cultivated in tanks for purifying the effluents (along with some other organisms) to obtain valuable co-products like prostaglandins, and agarose which provides additional value in scientific and medicinal research. Demetropoulos and Langdon carried out an experimental study on the culture of gastropod mollusc abalone which was fed with the tank cultivated seaweeds. Hence, tank-cultivated seaweeds are efficient to be used as fodder without any change in the nutritional parameters.

Many studies were earlier carried out in large concrete tanks of ten cubic meters-size (Sylt Island in Germany, December 2007) to get a huge quantity of biomass (Palmaria palmata) and some of them were carried out in plastic tanks (for experimental purpose). However, some researchers have stated that the commercial scale culture of green seaweeds in tanks involves the high-power consumption along with expensive equipments and materials. The culture of seaweeds in tanks on a commercial scale requires high power inputs along with expensive

materials and operative instruments. The fragmented thalli, plantlets, and spores are utilized to conduct an intensive seaweed farming and it can be considered as stock material for future cultivation. The maintenance of optimal light intensity, photoperiod, and nutrients in the media are highly essential for cultivating the seaweed in tanks. The light intensity and photoperiod can be regulated by filters, screens, and an additional lamp. The depth of the tank, density of seaweed, and uniform movement of the seaweeds (from the bottom to the surface) must be focused on. Using a compressor to provide air injection and water flow can trigger the seaweed rotation in tanks. The temperature of the cultivation site can be controlled by cooling with the help of an air conditioner, and bypassing the water through a cooling. Commercial fertilizers are playing a major role in the tanks-based cultivation, if used in optimal concentrations it should be exchanged in a regular interval along with water exchange. Some studies have been carried out on seaweed farming by providing CO2 to enhance their growth and the results were quite interesting. Regulation of salinity of the culture–medium could be achieved by the addition of sea salts to the distilled water. The sea salts are the best option due to the pressure of all essential nutrients and minerals. Previously, most of the studies have been carried out in natural seawater, that possessed an enormous amount of nutrients along with the trace elements.

Types of culture tanks and their advantages:

Many types of culture–tanks are available in the market, and some of them can be used for seaweed cultivation. The type of tank being chosen is a very important factor in tank cultivation. The tanks can be classifed according to their size and material. The main features of the tank should be facilitation of proper aeration, light, nutrient circulation, and easy cleaning of the tank. Land-based cultivation may use diferent types of cultivation systems in terms of shape (round tanks, D-ended tanks, and raceways)

Selection of seaweeds for tank cultivation:

The tank-based seaweed cultivation was started during the 1970s in Canada, and now many countries have adopted land-based seaweed cultivation, after the recognition of the fact that seaweed is an important raw material for much bio-based food and application-oriented products. The major advantages of tank culture are it would produce high yield than the other methods without toxins; and also meets sustainable agricultural productivity without the influence of environmental issues like cyclones, eutrophication, and other natural calamities. Seaweed selection for tank cultivation depends. mostly on two factors: (1) local availability of the type of species and (2) what the end-product is from the cultivated biomass. These two factors mostly decide the seaweed–selection for the cultivation in tanks.

Mostly, the seaweeds which are going to be used for edible purpose should be robust and free from contamination. The edible seaweeds like Ulva fasciata, U. lactuca, U. intestinalis, and Monostroma sp., were tried for tank raceway ponds and other land-based system in last two decades.

Recently, outdoor spray cultivation is developed for Ulva fasciata, Ulva compressa, and Hypnea musciformis by Neori et al. They have tried land-based systems especially in tanks to

obtain toxin-free biomass along with protein content. The gas exchange in the atmosphere was reportedly higher in the spray cultivation system when plants like seaweeds were immersed/floated in a surface area or few millimetres depth. When compared to the other edible green seaweeds, the Ulva sp. consists of a high number of nutritional properties. At the same time, tank cultivation of Ulva is not a successful venture in India.

Table 1 Types of tanks and their advantages and dis-advantages which can be used possibly in land-based seaweed cultivation

Sl.No.	Type of tank	Mode of tank	Advantages	Disadvantages
1.	Raceway pond	Concrete	Easy to handle and harvest	Immovable, corrosion, aging
2.	Round shape tank	Concrete	Easy to maintain	More chances of corrosion
3.	D-ended tank	Concrete	Useful when there is a lack of space	More chances of corrosion
4.	Steel tank	Steel	Hard to break	Corrosion during saline water usage
5.	Plastic lined tank	Reinforced plastic bag	In-expensive replacement for metal or ferro-cement tanks	The continuous replacement may be necessary
6.	Fiberglass tank	Glass-reinforced plastic tank	Affordability, durability, lightweight, and ease of customization	Poor resistance to temperature on long-term basis
7.	Polyethylene tank	Polyethylene	Easy to handle, and maintain and leakproof	Careful installation is required to extend the life

Ulva, an edible green alga, contains a high percentage of protein (16–22%), carbohydrates (43–60%), and ash content (12–18%) as dry matter, as well as a variety of minerals and vitamins. And if we adapt a tank cultivation methodology for Ulva, it would be helpful for the commercial cultivators and farmers (to ensure a continuous supply of Ulva biomass for value-added product preparations). Cultivation of Ulva show many advantages, like a faster growth rate (than through the other commercially cultivated seaweeds); it can grow in highly polluted waters with high ammonium absorption; and it can be maintained with high stocking density.

Methods followed for the green seaweed cultivation:

For sustainable tank cultivation of seaweed, the constant supply of enough germling materials/plantlets are considered to be the most important factor. Because, the quality of plantlets' material reflects the quality of the fnal product (like edible recipes) and their associated by-products. Methods of germling preparation and production play a crucial role in

successful seaweed farming in tanks. The commercial cultivation of edible seaweeds can be possible by the whole thallus (vegetative) method and spore method. The whole thallus method is considered as a traditional method by multiplying the edible seaweeds. The long-time cultivation through this whole thallus method would lead to the loss of their vigour. To overcome this problem, the spore method is available to produce healthy germlings. The advantage of the spore method is very feasible to produce healthy germlings in a short period of time. Many advantages are available in the spore culture method of Ulva when it comes to tank cultivation. The asexually derived germlings would lead to reduced variability among them. Further, the quality of biomass produced (through the spore culture method) ensures less chance of losing its vigor. And the quantity of germlings would fulfil the requirement when done on a commercial scale in tank cultivation.

The germlings produced by the spore method are not affected while are they maintained in controlled conditions. The germling's production is also possible throughout the year (through this spore culture method) when the mother plant is available for spore shedding. Ohno [58] stated that large-scale edible seaweed cultivation still depends on artificial seeding and is limited only to Monostroma. If we develop the life history patterns of seaweeds, it would enhance and simplify the artificial seeding process.

Requirements to setup the tank cultivation facility:

In India, land-based seaweed cultivation can be an important alternative method to enhance the livelihood of fisherfolks as well as a promising method for the constant supply of seaweed biomass to the concerned industries. Maintenance of the land-based edible seaweed cultivation systems requires the following essentials to fulfil a full-fledged continuous process. Fiberglass reinforced plastics (FRP)-tanks are essential to maintain the plantlets in outdoor and indoor systems, and their size must be 100 L to 5000 L. For day-to-day operations, plumbing accessories such as PVC pipes, aeration tubes, control valves, agitators, aeration motors (with the desired HP capacity), water-sucking pumps, and chillers are also required. The water inlet and outlet facilities are essential, and the inlet water should be equipped with both UV and sand filters (to avoid contaminants and epiphytes). The proper power supply is essential without stoppage. The aeration and air-conditioning systems support healthy plantlets and germlings. The water is also essential in tank cultivation. Skilled manpower is essential for operating the machines, exchange of water, inoculation, harvesting and dry the plant materials, and other human-related tasks. The cleaning materials are essential for cleaning tanks and other culture vessels. The seaweed culture tanks are mostly affected by epiphytes and other cyanobacteria, hence the removal of the such unwanted organisms is essential.

Challenges in tank cultivation:

There are some issues that needs to be resolved to achieve the landmark in seaweed cultivation in tanks. It would be a basic initial step to start this kind of business. There is a need for high investment to develop the infrastructure (construction of tanks, buildings, sheds, providing electrical supply, installing water pumping, and aerator systems). Maintenance of seaweed culture farms and their regular operations like cleaning, water exchange, plantation,

harvesting, and the post-harvesting process is needed/required. Like this process, the farm requires skilled or highly skilled manpower to maintain the activities in a full-fledged manner. And most importantly, procuring culture land is a serious challenge for tank cultivars. Getting land (along with good water facilities) is very difficult, as most of the coastal lands are government owned. Providing an electrical supply is essential for pumping water in the tanks, aeration, providing lights, and shifting of materials from one place to another. Hence, an uninterrupted power supply is essential for such activities. In coastal areas, getting an uninterrupted power supply is a difficult task, henceforth a power generator, or solar power panel, is essential for maintaining a cultivation farm in an active manner. Mostly, we face certain issues regarding the scarcity of labor, particularly skilled and semi-skilled labourers.

Most of the ocean-based seaweed cultivation has been thwarted by conflicts with local stakeholders and fishermen as it competes against land-based facility development. The land-based seaweed farming is quite expensive when infrastructural development is costly. Trying to get assistance from the technical and engineering departments for designing and constructing a land-based seaweed farming facility is partially unsuccessful so far. It is because of the rare development of such facilities. Till now, the details of land-based seaweed farming are lacking and we need to develop the proper methodology and refine the technology for the design of the culture tank, seeding type, harvesting type, and the post-harvesting process.

Need to focus on land-based cultivation:

Upscaling of algal biomass is a major target in land-based cultivation systems (without any contamination). Hence, the yield of biomass at a daily rate in certain areas is needed via land-based systems. In the case of edible seaweed, protein content should be high. The experiments and research need to be focused on the enhancement of nutritional composition (as compared to wild seaweeds). The caragenophytes' cultivation must focus on the storage of hydrocolloids (agar, alginate, and carrageenan), bioactive compounds (prebiotics, phenolics, and oligosaccharides), and other functional food components enhancement. Also, the right combination of antibiotics must be worked out to eradicate the growth of epiphytes in the tanks. The crucial parameters that need to be focussed on while cultivating the seaweeds in tanks. Before starting of the cultivation optimization is essential. The successful progress of tank cultivation would be evaluated by the cost of inputs and outputs, and environmental impacts with reference to their daily operations. The inputs are basically classified in three categories; electrical power supply, manpower engagement, and other resource management. Electrical inputs include pumps, blowers, lights, and cranes; manpower engagement includes seeding, harvesting, drying, rinsing, processing, and other daily operations; and other resource management inputs providing of nutrients like nitrogen, phosphorus, vitamins, and trace elements. Transportation input also plays a vital role in land-based cultivation systems. Proper transportation arrangement is essential for the rapid shifting of seed materials, shifting of final products, etc. The outputs are classified based on how many products are to be harvested by wet weight (kg/week) and how many quantities are to be processed (products-kg/week). The environmental impacts of tank cultivation are to be classified in relation to energy usage, excessive nutrient discharges into the river or nearby aquatic ecosystems, and the rate of

greenhouse gas emissions. The energy usage is based on the manpower and natural energy that are to be utilized for day-to-day activities.

Research needs and future direction:

The seaweed communities play a major role in CO2 absorption in marine vegetative community because they are autotrophic and produce more organic matter through photosynthesis (than they consume through ecosystem respiration). Duarte et al. stated that 2.48 million tons/year of CO2 were consumed by seaweeds and through their farming activities. In 2014 the global seaweed production was 27.3 million tonnes, and their carbon capture was 100%, with a production of 24.8% carbon dry weight. Even yet, the estimated 173 Tg C year−1 global wild seaweed CO2 uptake is only 0.4% of this upper limit and this may increase up to 60% by the end of 2050. Therefore, CO2 absorption by seaweed farming in the open sea, as well as land-based systems, cannot represent an emission reduction measure at the current rate and through the projected potentials for future. These comparisons, on the other hand, may be considered matters based on the cultivation that was initiated in various global locations in an open sea and land-based system. The carbon footprint and CO2 sequestration through land-based seaweed farming are not yet fully documented, and future studies should focus on the same. Water quality is one of the prime factors in seaweed cultivation especially while they are processed in tanks. When the nitrogen content of seawater is high, the growth rate of seaweeds peaks. Hence, maintaining proper nitrogen along with proper water quality characteristics is a major concern in seaweed cultivation in tanks.

However, Jaiswar et al. delivered the standard optimized physicochemical characteristics (25 psu salinity; 25 °C of temperature; 60 and 5 µmol of nitrate and phosphate; 50 µmol m2 s−1) for the cultivation of Ulva lactuca in indoor conditions but not in tanks. Hence, to cultivate Monostroma sp. in tanks 35 psu salinity, 25 °C temperature, 14:10 h L:D photoperiod, 60 µmol m−2 s−1 light intensity is considered as optimum in indoor conditions. The operational cost of edible seaweed cultivation in tanks has yet to be determined, and some reports claim that Ulva is being cultivated in the open sea (of shore) using the long line method. One tonne of dry material costs € 1019, and 20 tonnes of dry material can be produced per hectare per year, and this cost includes labor, shipping, and storage. Energy consumption for land-based cultivation of edible seaweeds was deliberated for Ulva intestinalis using a pilot scale photobioreactor system and there are no reports for tanks and pond cultivation. 22.05 kWh day−1 electricity is required with 1280.3 W to operate 180 h to produce 3.0 kg m−2 fresh biomass of U. intestinalis in the pilot scale photobioreactor.

Conclusion:

The land-based edible seaweed cultivation is an alternative way to fulfil the requirements for seaweed-based products once the cost of production gets reduced. Also, land-based edible seaweed cultivation provides scope for new species that are not available in the wild throughout the year. As a result, land-based cultivation attracts entrepreneurs by providing new and commercially important seaweed as a raw material for food-based by-products. In the future, quality biomass is essential to produce high-value functional goods. Nowadays, the seaweed-

based market and the cultivation industry are seeking for higher production at lower inputs and lower investment. Hence, the entry-level industries are on the safer side and invest their money in promising methods and products during initial ventures. The new innovation with easy handling is essential to provide benefits to the cultivars and also for the industries.

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STABLE BOUNDARY LAYER METEOROLOGY FOR CROP GROWTH

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Abstract

The atmospheric boundary layer over land experiences a clear diurnal cycle driven by the incoming solar radiation. During the evening transition period, the earth's surface radiation budget turns negative due to long-wave radiative loss and so the surface cools to a temperature below that of the air above. Consequently, the potential temperature increases with height, producing a stable boundary layer (SBL). SBLs prevail at night, but also during daytime in winter in mid-latitudes, in Polar Regions, and during daytime over irrigated regions with advection. The SBL is governed by a multiplicity of processes such as turbulence, radiative cooling, the interaction with the land surface, gravity waves, katabatic flows, fog and dew formation. Despite extensive earlier research, these processes and their interactions are not sufficiently understood, primarily because of their diversity and their general non-stationary, which prevent an unambiguous interpretation of observation. This ambiguity is a major obstacle to the development of model parameterizations.

Keywords: *Radiation, dew formation, boundary layer interaction, transition period*

STABLE BOUNDARY LAYER (SBL)

A stable boundary layer occurs when the vertical (potential) temperature gradient in the boundary layer is positive. This is usually associated with the heat flux and the associated buoyancy flux FB being negative at the surface, *i.e.*, h/LMO>0. However, stable boundary layers may also occur in in cold fronts. When, the boundary layer is significantly cooler than the air above is the major reason for occurrence of cold fronts. In these cases, the Richardson number Ri>0 with Ri defined as

$$Ri = \frac{\frac{\partial \Theta^{-}}{\partial z}}{\frac{\partial U}{\partial z}}$$

Where,

Θ is the average speed and U is the average potential temperature. Buoyancy forces prevent the vertical displacements of fluid components, coherent structures in convective and neutral flows.

Relationship between Thickness and Temperature Gradients in SBL

Thickness is a measure of how warm or cold a layer of the atmosphere is, usually a layer in the lowest 5 km (17,000 feet) of the troposphere; high values mean warm air, and low values mean cold air.

Table. 1. Scale of the Layer with Height

Scale roughness layer	Boundary layer height (m)
Roughness layer planetary	0.0–0.1
Turbulent surface layer	0–10
Boundary layer	0–1000
Troposphere	0–1 × 10^4
Stratosphere	1 × 10^4

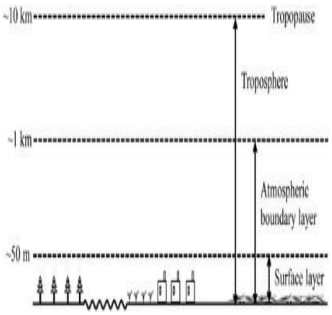

Figure 1. Layer height of atmosphere

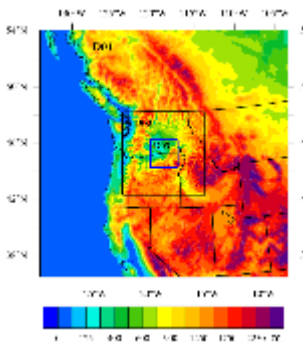

Figure 2. Convective boundary layer during preciptation

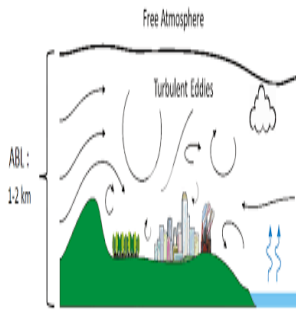

Figure 3. Schematic picture of Atmospheric Boundary Layer (ABL).

Measuring tendency of SBL

Despite all attempts, it is still difficult to measure stable boundary-layer (SBL) turbulent characteristics. Since, the SBL is typically non-stationary and the turbulence is uncertain. Recent research has shown that depending on the stability strength, stable circumstances can be categorized into at least two separate scaling regimes. As stability rises, the heat flux falls until it reaches a critical point, beyond which turbulence becomes local, intermittent, frequently disconnected from the surface. It is challenging to measure and simulate stable and very stable cases due to the wide range of phenomena present in the turbulence parameter values that are extremely close to the observational errors.

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AGRONOMY AS AN OPTION FOR CLIMATE CHANGE MITIGATION

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Abstract

Climate change is one of the biggest challenges faced by humanity today, and it poses a threat to food security and agricultural production worldwide. Agronomy, which is the science of crop production and soil management, has a significant role to play in mitigating the effects of climate change. Agronomic practices such as conservation agriculture, cover cropping, crop rotation, and reduced tillage have been found to reduce greenhouse gas emissions and enhance carbon sequestration in soils. These practices also contribute to improved soil health and water conservation, which are important for climate change adaptation. In addition, the use of precision agriculture technologies, such as remote sensing, precision planting, and variable rate fertilization, can reduce the extend of inputs required and improve the efficiency of production, further reducing greenhouse gas emissions. Thus, agronomy has a vital role to play in climate change mitigation and adaptation in agriculture. The adoption of sustainable agronomic practices can contribute significantly to reducing greenhouse gas emissions, enhancing carbon sequestration, and promoting food security. However, to maximize the potential of these practices, it is important to address the challenges and limitations associated with their implementation and to promote the adoption of climate smart agronomy practices mitigating its effects through enhancing productivity, adaptation, and mitigation, ensuring food security, reduce greenhouse gas emissions, and promote sustainable agriculture.

Keywords: Conservation Agriculture, Cover Cropping, Carbon Sequestration, Precision Agriculture, GHGs

Introduction

Climate change is occurring since the time immemorial but the accelerated rate of change mainly due to anthropogenic activity is one of the greatest challenges facing the world today, and it is already having a significant impact on agriculture (IPCC, 2014; FAO, 2021). Rising temperatures, changes in rainfall patterns, and extreme weather events are all affecting crop yields and soil health, which in turn threatens food security and livelihoods for millions of people. Agronomy, the science of crop production and soil management, has an important role to play in mitigating the effects of climate change on agriculture (Seppelt et al., 2022). By adopting practices that promote soil health, conserve water, and reduce greenhouse gas emissions, farmers can help to build resilience to climate change and contribute to global efforts to reduce emissions.

CLIMATE CHANGE IMPACTS ON AGRICULTURE

Climate change is a global phenomenon that is having significant impacts on agriculture. Rising temperatures, changes in rainfall patterns, and extreme weather events are affecting crop yields, soil health, and water availability. These impacts are threatening food security and livelihoods for millions of people around the world. Higher temperatures can lead to heat stress, reduced photosynthesis, and lower yields. Changes in rainfall patterns can also affect crop yields, with droughts and floods having significant impacts on crop growth and development (USDA, 2021). Pests and diseases are also becoming more widespread and damaging as a result of climate change.

Changes in temperature and rainfall patterns can alter soil moisture, which can affect nutrient availability and soil structure. Soil erosion is also becoming more common as a result of extreme weather events, which can lead to nutrient loss and reduced soil fertility. Additionally, changes in soil temperature and moisture can affect soil microbial communities, which play a critical role in nutrient cycling and plant growth (Wu et al., 2022). Changes in precipitation patterns and increased evaporation rates are affecting water availability and quality. Droughts and heat waves are becoming more frequent and severe, leading to water scarcity and reduced crop yields (Table. 1). Flooding is also becoming more common, which can lead to soil erosion and nutrient loss. Additionally, changes in water temperature and nutrient levels can affect aquatic ecosystems and the quality of water for human consumption.

Agronomy practices for climate change mitigation

Agronomic management practices have a significant role in mitigating the impacts of climate change. Agriculture is one of the major contributors to greenhouse gas emissions, but it also has the potential to sequester carbon and reduce emissions.

***Conservation agriculture*:** It involves reducing or eliminating tillage to conserve soil moisture, reduce soil erosion, and increase soil organic matter. By reducing the need for tillage, conservation agriculture can also reduce the use of fossil fuels and the emissions associated with soil disturbance (Jat et al., 2019a). In addition, conservation agriculture can increase the amount of carbon stored in the soil, helping to mitigate greenhouse gas emissions.

Crop diversification: It is the phenomena of bringing out desirable changes in the existing cropping pattern towards a more imperative and sustainable one. Planting a variety of crops to reduce pest and disease pressure, improve soil health, and provide a more diverse range of food and income sources (Jat et al., 2019b). By increasing the diversity of crops grown in a particular area, it can also help to reduce the risk of crop failure due to extreme weather events, such as droughts or floods.

Precision agriculture: It is the new generation technology to optimize the use of inputs, such as fertilizer and water by utilising GIS, GPS and remote sensing technology and to minimize the environmental impacts of agriculture. By using precision agriculture practices, farmers can

reduce the use of inputs, increase crop yields, and minimize the emissions associated with agricultural practices (Padhan et al., 2021a).

Table. 1. Effect of climate change on agriculture

Effect of Climate Change	Remarks
Reduced crop yields	Global crop yields are projected to decline by 1.8% per decade due to climate change. (IPCC, 2014)
Shifting planting and harvest seasons	In the United States, planting and harvest seasons for crops such as corn and soybeans have shifted earlier by 5-10 days over the past 30 years due to climate change. (USGCRP, 2018)
Increased frequency and severity of extreme weather events	Extreme weather events such as floods, droughts, and heatwaves have caused significant crop losses, particularly in developing countries. (FAO, 2021)
Decreased soil fertility and health	Climate change has led to increased soil erosion, salinization, and acidification, negatively impacting soil health and fertility. (IPCC, 2014)
Changes in pest and disease pressure	Rising temperatures and changing precipitation patterns have altered pest and disease pressure, affecting crop yields and quality. (USDA, 2021)
Reduced water availability and quality	Climate change has led to decreased water availability in some regions, particularly in arid and semi-arid regions, as well as changes in water quality due to increased runoff and erosion. (FAO, 2021)

***Agroforestry*:** Integration of trees into agricultural landscapes to improve soil health, provide shade for crops, and sequester carbon along with providing a range of ecosystem services, such as improving soil fertility, reducing erosion, and providing habitat for wildlife. By sequestering carbon in woody biomass and soil organic matter, agroforestry can help to mitigate greenhouse gas emissions.

Cover cropping: It involves planting a crop that is grown primarily for its ability to improve soil health and protect soil from erosion vis-à-vis increasing the soil organic matter, improving soil structure, and reduce the need for tillage. By improving soil health and reducing erosion, cover cropping can help to mitigate the impacts of climate change.

Policy measures: Governments can provide support for sustainable agriculture practices, such as subsidies for conservation agriculture, agroforestry, and crop diversification. Policies that promote the use of renewable energy, such as solar or wind power, can also help to reduce greenhouse gas emissions and mitigate the impacts of climate change on agriculture.

There are also other strategies that can help to mitigate the impacts of climate change on agriculture. For example, research and development can help to develop new crop varieties that are more resilient to climate change, and that can produce higher yields with less water and fertilizer. Climate-smart agriculture approaches can also help to increase agricultural productivity while reducing greenhouse gas emissions. Furthermore, the benefits of agronomy practices for climate change mitigation are not limited to agriculture. By sequestering carbon and reducing greenhouse gas emissions, these practices can also have broader benefits for the environment and society as a whole. For example, agroforestry can provide habitat for wildlife and improve air and water quality, while cover cropping and conservation agriculture can reduce erosion and improve soil fertility. Overall, agronomy practices have the potential to play a significant role in mitigating the impacts of climate change on agriculture by adopting sustainable practices such as conservation agriculture, agroforestry, cover cropping, crop diversification, and precision agriculture, farmers can reduce their environmental footprint while also improving soil health, increasing yields, and contributing to climate change mitigation efforts.

Climate smart agronomy (csa)

Climate smart agronomy (CSA) refers to a set of practices and technologies that enable farmers to adapt to the changing climate while enhancing productivity and reducing greenhouse gas emissions. The concept of CSA is based on three key principles (Figure 1): productivity, adaptation, and mitigation (Barasa et al., 2021).

Benefits of CSA

The adoption of CSA practices has numerous benefits for sustainable agriculture. These benefits include:

- Improved productivity and food security
- Enhanced resilience to climate change effects
- Reduced greenhouse gas emissions
- Improved soil health and fertility
- Reduced soil erosion and water pollution
- Diversification of income sources

Agronomic practices: producer as well as mitigator

Agronomic activities such as land use change, tillage, and fertilizer application can release greenhouse gases (GHGs) such as carbon dioxide, nitrous oxide, and methane into the atmosphere. However, agronomic practices can also be used to sequester carbon in the soil and reduce GHG emissions from agricultural activities (Figure 2). Agriculture is a significant contributor to GHG emissions, accounting for approximately 10-12% of global anthropogenic emissions. The primary sources of emissions from agricultural activities are livestock and soil management practices. Livestock is

responsible for the majority of methane emissions, while soil management practices such as tillage and fertilizer application are responsible for nitrous oxide emissions. Agriculture also contributes to deforestation, which releases carbon dioxide into the atmosphere.

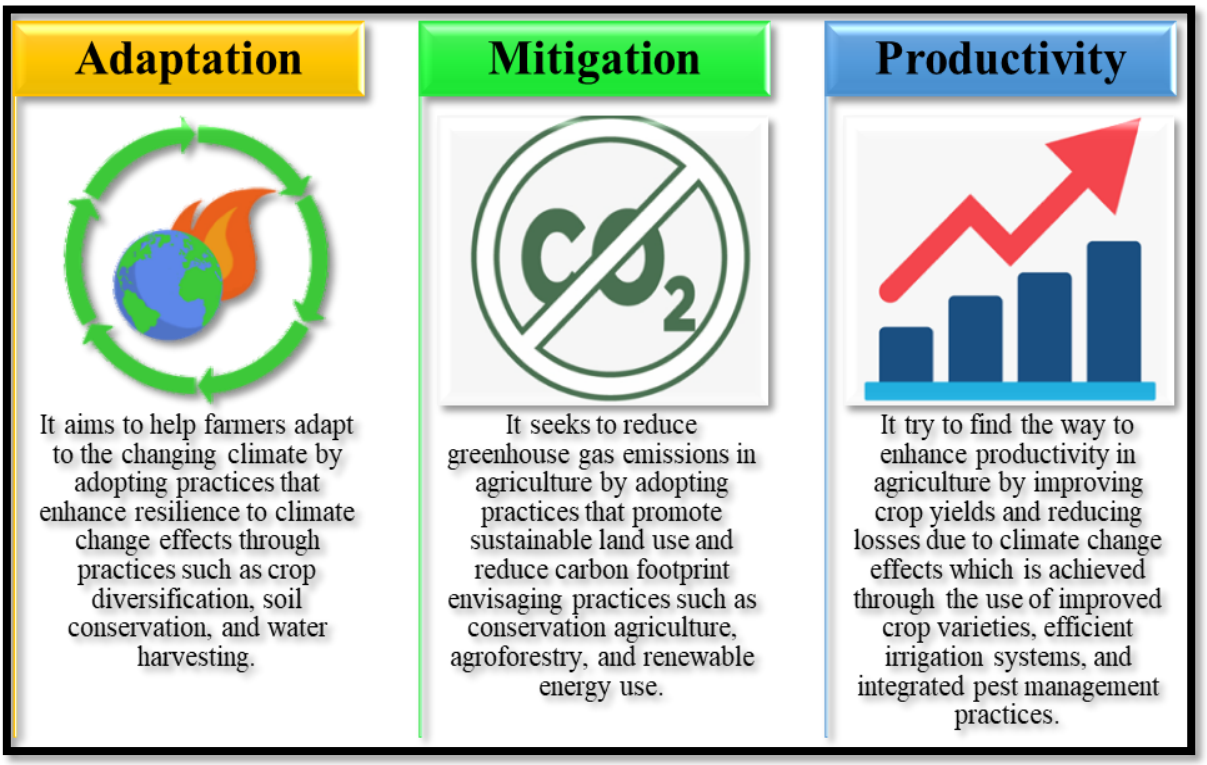

Figure 1. Three pillars of climate smart agronomy

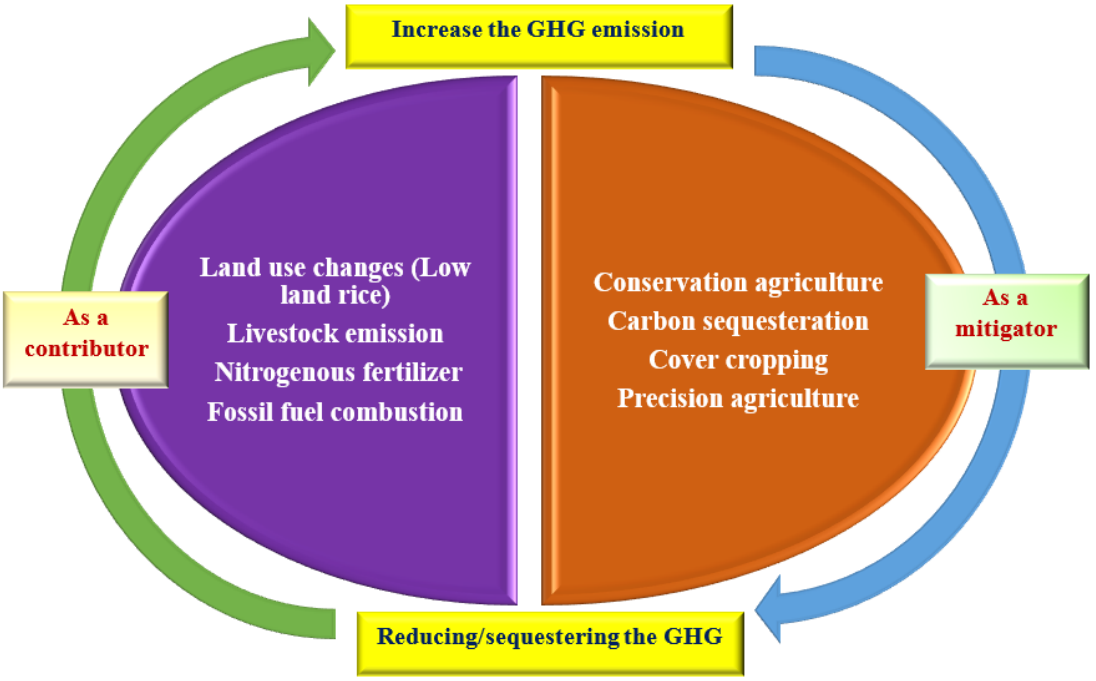

Figure 2. Agronomic practices as a contributor and mitigator to climate change

Agronomy practices can help mitigate climate change by reducing emissions and sequestering carbon in the soil. Conservation tillage, for example, reduces soil disturbance, increases soil organic matter, and sequesters carbon in the soil. Cover crops also increase soil organic matter and fix atmospheric nitrogen in the soil, reducing the need for synthetic fertilizers and reducing GHG emissions. Nutrient management practices, such as using organic fertilizers and precision farming techniques, can also reduce GHG emissions by reducing fertilizer use and improving fertilizer efficiency (Padhan et al., 2021b). Crop rotation can also reduce GHG emissions by improving soil health and reducing the need for synthetic fertilizers and pesticides. Agroforestry, the integration of trees into agricultural systems, can sequester carbon in the soil and reduce soil erosion. Integrated pest management, using a combination of cultural, biological, and chemical methods to manage pests and diseases, can reduce the need for synthetic pesticides and improve soil health. Precision agriculture, using technology such as GPS and sensors to optimize inputs (Shyam et al., 2021), can reduce waste and improve efficiency, resulting in reduced GHG emissions. Therefore, agronomic practices are the contributor as well as mitigator of climate change.

Conclusion

Agronomic practises are essential for reducing the impact of climate change on agriculture. By enhancing soil carbon sequestration, lowering nitrous oxide emissions, and lowering methane emissions from livestock production, greenhouse gas emissions from agriculture can be lowered. Due to a lack of resources and knowledge, smallholder farmers may have trouble implementing sustainable agronomy practises. Governments, extension agencies, and other stakeholders can offer assistance, money, and support to farmers so they can successfully implement these practises. Stakeholders can create a more sustainable and resilient agriculture sector that can address the challenges of climate change while ensuring food security and enhancing livelihoods by giving priority to climate wise agronomy practises.

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MICROPLASTICS IN AQUACULTURE: A GROWING CONCERN FOR FOOD SAFETY AND ECOSYSTEM HEALTH

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Abstract

Microplastics are small plastic particles that are increasingly being recognized as a major threat to aquatic ecosystems. Aquaculture is a rapidly growing industry that is also at risk from microplastics. Microplastics can enter aquaculture systems through a variety of sources, including plastic pollution, fish feed, and aquaculture equipment. Once in the system, microplastics can be ingested by aquatic organisms, leading to a range of negative impacts on their health and well-being. The effects of microplastics on aquaculture systems can include reduced growth and reproduction rates, altered behaviour, and increased susceptibility to disease. In addition, microplastics can accumulate in the tissues of aquatic organisms, including those that are consumed by humans, leading to potential human health impacts. Effective management of microplastics in aquaculture requires a multi-faceted approach, including reducing plastic use, proper waste management, and the adoption of best practices for managing microplastics in aquaculture systems. There is also a need for continued research to better understand the impacts of microplastics on aquatic organisms and ecosystems, as well as the development of new technologies and practices for mitigating the impacts of microplastics. Overall, it is clear that urgent action is needed to address the threat of microplastics in aquaculture, in order to ensure the sustainability of this important industry and the health of aquatic ecosystems.

Keywords: *Microplastic, Aquaculture, Aquatic Ecosystem, Human Health*

Introduction

Since the early 1950s, when large-scale industrial manufacturing first began, plastic output has significantly risen. Plastics are used in almost every face of daily life. The durability of plastic items is one of their most admired features. Environmental contamination occurs in freshwater, marine, and terrestrial settings when this characteristic is paired with poor waste management. Products made of plastic will gradually deteriorate over time, especially if they are exposed to UV light from the sun and high temperatures. This deterioration will cause the material to break down into smaller sizes, ranging from the macroscopic to the microscopic, and finally into nanoplastics, which are currently undetectable dimensions.

Different environmental matrices have contained small plastic particles known as microplastics, which are often described as being 5 mm or less in their longest dimension (atmosphere, soils, freshwater and marine) Microplastics have been discovered in beaches, shelf and deepwater sediments, as well as surface and subsurface waters in both freshwater and marine ecosystems. Additionally, numerous aquatic species of creatures, including commercially significant fish and invertebrates, have been seen to consume microplastics.

Microplastic in aquaculture

Microplastics are small plastic particles that are less than 5 millimeters in size. These particles can be found in various environments, including the ocean, where they can pose a threat to marine life. In aquaculture, microplastics can enter the food chain through various pathways and have the potential to impact the health of aquatic organisms.

Microplastics can enter aquaculture systems through several routes, including the use of plastic equipment such as pipes and nets, plastic packaging materials, and microbeads in aquafeed. These particles can also be introduced through wastewater discharges from sources such as urban runoff and industrial activities.

The growing concern of microplastics in aquaculture

Aquaculture is the fastest-growing sector of food production in the world. The global aquaculture industry produced 114.5 million metric tons of seafood in 2020, with an estimated value of USD 263.8 billion. However, the growth of aquaculture has also raised concerns about its environmental impact, including the release of pollutants and waste into the water.

One of the emerging concerns in aquaculture is the presence of microplastics. These small plastic particles can enter the aquaculture system through various pathways, including plastic equipment such as pipes and nets, plastic packaging materials, and microbeads in aquafeed. The increasing use of plastic in aquaculture operations is exacerbating this problem.

Impact of microplastic on aquaculture

Microplastics can have various impacts on aquatic organisms in aquaculture, including:

1. Bioaccumulation: Microplastics accumulate in fish and other seafood tissue, causing health effects when consumed by humans. The accumulation of microplastics also affects the overall health and reproductive success of aquatic organisms.
2. Chemical toxicity: Microplastics may contain toxic additives and absorb toxic chemicals from the surrounding environment. These toxic chemicals can be released when microplastics are taken by aquatic organisms, causing health effects such as reproductive problems, developmental disorders and damage to the immune system.
3. Ingestion: Microplastics can be mistaken for food by fish and other aquatic organisms, leading to ingestion. This can cause physical damage to the digestive system and blockages, leading to malnutrition, reduced growth, and even death.

4. Alterations in Behaviour and Physiology: Exposure to microplastics can result in changes in behaviour, physiology, and metabolism in aquatic organisms. These changes can impact their ability to survive and reproduce, ultimately affecting the overall health and productivity of aquaculture operations.

Practices to manage microplastic in aquaculture operation

Managing microplastics in aquaculture operations is critical for protecting the health of aquatic organisms and ensuring the sustainability and safety of our food supply. Some best practices for managing microplastics in aquaculture operations:

1) Reducing Plastic Use: The first step in managing microplastics in aquaculture operations is to reduce plastic use. This can be done by using alternative materials for equipment and packaging, such as biodegradable or compostable materials.
2) Proper Waste Management: Proper waste management is essential for preventing microplastics from entering the water. Aquaculture operators should implement proper waste disposal practices, such as recycling or incinerating plastic waste, to prevent it from entering the environment.
3) Monitoring and Detection: Regular monitoring and detection of microplastics in aquaculture systems can help identify potential sources and hotspots of contamination. This can be done through water sampling, sediment analysis, and visual inspection of fish and other aquatic organisms.
4) Choosing Sustainable Feed: Aquaculture operators should choose sustainable feed that does not contain microbeads or other microplastics. This can be done by selecting feed that is free from plastic additives and ingredients.
5) Rinsing Equipment: Equipment used in aquaculture operations should be regularly rinsed to remove any microplastics that may have accumulated. This includes nets, pipes, and other equipment that come into contact with the water.
6) Education and Awareness: Education and awareness programs can help raise awareness among aquaculture operators and consumers about the risks of microplastics in aquaculture. This can help promote the adoption of best practices for managing microplastics in aquaculture operations.

Conclusion

The threat of microplastics in aquaculture is an urgent issue that requires immediate action. Microplastics pose a significant risk to the health and well-being of aquatic organisms and the environment, as well as to human health through the consumption of contaminated seafood. To effectively manage microplastics in aquaculture, it is necessary to adopt a holistic approach that involves reducing plastic use, proper waste management, and the adoption of best practices for managing microplastics in aquaculture systems. The future directions in research and management of microplastics in aquaculture should focus on understanding the impacts of microplastics, developing detection and mitigation strategies, developing sustainable feed, and stakeholder engagement. It is essential that all stakeholders, including aquaculture operators,

regulators, consumers, and researchers, work together to address this issue. By taking action now, we can prevent further harm to aquatic ecosystems and ensure the sustainability of the aquaculture industry for future generations.

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Social Extension for technology dissemination for Dryland agriculture

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Abstract

The role of social media is accelerating day by day in every sphere of life. With the ever-increasing internet connectivity and cheaper tariff, mobiles and computers have penetrated in the hinterland of India. The story of Dryland areas is no different when it comes to the role of social media in disseminating the agricultural technologies. Social extension in form of whatsapp. Facebook, youtube have become an important tool in reaching farmers in India.

Keywords: *Dryland, Extension, Social Media*

In extension, role of social media is accelerating day by day. With the ever-increasing internet connectivity and cheaper tariff, mobiles and computers have penetrated in the hinterland of India. The story of Dryland areas is no different when it comes to the role of social media in disseminating the agricultural technologies. Social media refers to the means of interactions among people in which they create, share, consume and exchange information and ideas in virtual communities and networks. Kaplan and Haenlein (2009) define social media as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0 and that allow the "creation and exchange of user-generated content." Social media offers a unique way of communicating with the public because of the content that individuals can choose to engage with or not imagine that it is on a bulletin board. One of the big advantages of social media is that someone can directly respond to what you share with them. A negative is that while once something is posted it is archived and accessible far into the future, it can be quickly forgotten by those who read it because so many people have a flood of content funneling through their social media accounts.

Social media can play important role in following four dimensions

1. Networking (Farmer – Farmer) via social media platforms
2. Industry Knowledge, Extension & Marketing (Farmer – Agricultural Industry)
3. Consumer Engagement (Farmer/Industry – Consumer)
4. Crisis communication

Whatsapp

In the recent years, Whatsapp has become a potent tool in dissemination of information. WhatsApp offers several advantages over these mobile agricultural information services. It is a form of a social media tool that enables one to many and many to many types of conversation and sharing information and facilitating discussion (Andres and Woodard, 2013). It has become the most preferred mode of communication among the smart phone using farmers. One can

share information in multiple forms ranging from text-based messages to audios, visuals; audiovisual and even web links making it an information enriched platform. Additionally, information sharing is possible at any place and at any time without worrying about background disturbances (Thakur et al.,2017). This tool is simpler and easy to use, has low internet data requirements, and is increasingly popular in rural India."Shetkari Mitra" (farmers' friend) a whatsapp group in Yavatmal, Maharashtra, has become a popular method for sharing information on agriculture. M. S. Swaminathan Research Foundation's Village Resource Centre, created this group with over 130 farmers from different villages, who use Whatsapp. Through this group, information is shared on agriculture, marketing, animal husbandry and government schemes.

Facebook

Facebook provides users with an interactive Web page-like format to share information, photos, articles, and Web links. This venue makes it easy to post a message that can be shared with small or large communities of users. Messages, photos, and video clips can be posted easily for interested audiences (i.e., Facebook friends). Facebook attracts followers who are organizations or individuals interested in the creator's postings. Extension educators may find it useful to communicate information regarding upcoming events, celebrations, informational pieces, and publications. A recent study about how farmers use media found that 42% of farmers who use Facebook and Twitter are using it every day. Whether sharing personal stories or using the sites as news sources, farmers are making their presence known online. Like Facebook, Kalgudi is operating in the Telangana, Andhra Pradesh etc where it is providing a platform for the farmers and other stakeholders to share a common platform.

YouTube

YouTube is a popular video-sharing venue online that attracts millions of users daily. Extension educators find it useful to disseminate educational messages, video, and TV news clips for the global audience (Kinsey, 2010). Sharing a link to a YouTube video is simple and can easily be attached to an email message. Visual literacy (reading and writing) is heightened for users in this interactive venue (Educause Learning Initiative, 2006). Viewer demographics (country, state, age, and gender) can be tracked, and data can be collected regarding the way the viewer found the video and information about the length of time the user browsed the Web site. YouTube's popularity makes it an attractive tool for Extension due to its viral nature, ease of use, and accessibility by audiences of all ages. Indian council of agricultural research and its various institutes have their youtube channels where they are regularly uploading the videos. Farmers and extension professionals can downloads videos on important practices directly.

Podcasts

Podcasts are brief audio or video messages created by an individual or group and readily available on the Internet. Messages created with audio-only include the voice of the Extension educator vocally sharing his or her educational message. Audio podcasts are available at a variety of Web sites, including iTunes. Some podcasts feature enhanced video, meaning the

video includes voice recording, music, pictures, and/or animation. Podcasts are useful for demonstrating how to perform a task or sharing essential research-based information. Podcasts can easily be uploaded online for sharing with the global community using video-sharing Web sites. Because users are usually well versed at locating, downloading, and playing videos that are available online, little or no instruction is generally needed. Extension educators can publish demonstrations, seminars, or workshops through podcasts (Xie & Gu, 2007).

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EFFECT OF DRIP IRRIGATION IN RICE CULTIVATION

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Abstract

Drip irrigation is the most efficient and one of the best irrigation practices in the case of rice cultivation. Because it makes farmers independent from the uncertainty of rainwater. In Indiaaround 54% of cultivated land is rainfed. From the environmental perspective, it could reducethe methane and CO2 emissions from the rice field.

Keywords: *Drip irrigation, Yield, Crop water requirement, Water scenario*

Introduction

Drip irrigation is the slow, even distribution of low-pressure water to soil and plant rhizosphere via plastic tubing placed at the root zone of the plants. It is an alternative to irrigating crops via sprinklers or furrows. Crops with high or low water requirements can employ drip irrigation. Rice is one of the most important cereal food crops in India. It feeds more than 60% of the population. It covers around 23% of the total agricultural crop area and production is around 120 million tons in FY 2020-21 and it will be around 555 million tons in 2035 (Riaz, Zaman; 2006). But the problem is we mostly practiced flood irrigation techniques and for this, so much water is needed. For the production of 1 Kg of rice, almost 2500 litres of water is used. That's why as a solution we can use drip irrigation which gives more yield and less water use.

Water scenario of India

India has only a 4% share of global freshwater resources to fulfill the needs of 18% of the world population (World bank, 2022). Per year around 80% of water is received during monsoon season but due to limited water harvesting infrastructure, only 1/3rd of this precipitation can be utilized and the rest creates runoff losses. Another source of water is groundwater, and the agriculture sector alone used 89% of it for irrigation and other practices,that's why the water table is getting down at an alarming rate of 0.3 meters per year. In India, nearly 54% of cultivated land is rainfed, for that in most cases farmers are dependent on rainfall and if it does not happen that will ruin their crops along with their life. For farming likerice cultivation, it needs a huge amount of water in the traditional flood irrigation method. So,if we want to change this harsh condition we have to adopt new technology like dripirrigation which is much more water efficient and also at the same time gives a higher yield.

A brief Introduction to drip irrigation

Drip irrigation or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. It is the most efficient water and nutrient delivery system for growing crops. In places with limited water supplies or in circumstances requiring precise control of water delivery, such as in agriculture, landscaping, and home gardening, this method of irrigation is frequently used. A pump or other water source supplies water to the main conduit in a conventional drip irrigation system. Then, a number of smaller tubes or hoses that are attached to the primary pipeline are used to disperse the water. The tubing has emitters fitted along it at regular intervals, which are tiny devices that release water drops. It is possible to precisely manage the application of water by adjusting these emitters torelease a certain volume of water every hour. Compared to other irrigation techniques, drip irrigation provides a number of benefits. Water is provided directly to the plant roots, minimizing water loss from evaporation or runoff, making it potentially more efficient. Because water is only provided to the plants and not the surrounding soil, it can also aid in reducing weed growth. Drip irrigation systems can also be automated, giving users precise control over water delivery schedule and volume, which can assist save labour and time costs.

Types of Drip irrigation system

There are mainly 2 types of drip irrigation system-

a. **Surface drip system:**

It is direct application of water to the soil's surface using drip irrigation. The method is simple and easy to maintain which makes it more popular.

b. **Sub-surface drip system:**

In subsurface drip irrigation, the lateral is positioned close to the plant root zone area beneath the soil. Through the emitters, water is gradually supplied below the surface in this irrigation system. These systems have become more widely accepted as a result of the significant reduction of earlier clogging issues. A sub-surface drip system may have a longer operationallife while causing little disruption to crop cultivation or other cultural practices.

Drip irrigation in rice cultivation

For rice cultivation, Drip irrigation is the most efficient way of water utilisation. The amount of irrigation water required under drip irrigation is the lowest i.e., almost 258mm and the highest value was 365 mm and in conventional irrigation systems it was found to be 600 mm (Sarkar et al, 2018). The water requirements under drip irrigation were less as compared to conventional (flooding) irrigation. Because of the stagnant water condition of rice fields, it contributes 12% of global methane emission but if we adopt drip irrigation it will decrease bya significant level.

Necessity of Drip irrigation in current scenario

Rice (Oryza sativa L.) is the most important staple food in the world. It is specially grown in eastern and southern Asia. It may be produced in a wide range of conditions and is often successful where other crops would not. Nature's gift to humanity, water, is not always unlimited and free. Only around 1520 million cubic kilometres of water are present in the universe, with 97% of that being ocean and seawater, 2% being frozen arctic waters, and only1% being water in lakes, rivers, and underground reservoirs that can be carried about and used directly by humans (Shaker, 2004). However, rice cultivation, considered to be the largest user of water resources, uses around 50% of the water resources utilised in all economic activities (Fan et al., 1996; FAO, 2010).

Cost of a drip irrigation system

Installation cost of drip irrigation system depends on several factors like size of the area,type of crop, type of soil, quality of water, level of automation etc. In India it costs between 45000 rupees to 60,000 rupees.

Government subsidy for drip irrigation in India

States are able to obtain the money through NABARD (National Bank for Agriculture and Rural Development) loans at 3% below the cost of funds, with the remaining 3%funded by the central government. Small and marginal farmers will receive subsidies worth 55% of theindicative unit cost under the PMKSY (Pradhan Mantri Krishi Sinchayee Yojana), while other farmers will receive subsidies worth 45% of the indicative unit cost.

Conclusion

For agriculture, water is the most important factor, especially in rice cultivation with the conventional method i.e. flood irrigation, there is a huge amount of water loss. From this, wecan see that almost 62% of the water has been saved in drip irrigation, and production has also increased by 125%. Through all of this farmer's income will increase by around 50%. So,obviously drip irrigation is the most efficient way of irrigation but the drip irrigation system requires good and proper management and in this system, the initial cost is very high to maintain and it may be difficult for farmers.

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Flower Colours and Dyes: New Way of Commercialization in Floriculture

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Abstract

Floriculture is considered to include the cut flowers, potted plants, and ornamental bedding plants and garden plant industries. The only other major group are caroteniods, which provide principally yellow colours, with some oranges and reds. Other classes much less in importance in relation to flower pigmentation are chlorophyll (greens), quinones (occasinoal red and yellow) and betalains alkaloids (giving yellow, red and purple colours in centrospermae). India is a major exporter of herbal dyes mostly due to ban on production of some of the synthetic dyes and intermediates in the developed countries due to pollution problem. India's total export for natural dyes is worth 41.31 USD Million in 2020-2021. which when compared to the previous year's export stats has increased by 4.01%. It was concluded that very few serious attempts have been made to generate new information on the use of natural dyes. We can get different shades of colour using different mordants and the colour fastness, wash fastness properties also can be improved by different treatments procedure, hence it can be used in small scale as well as in large scale industry

Keywords: *Pigmentation, Centrospermae, Alkaloids.*

Introduction

India is richly endowed with vast variety of natural flora and it is estimated that there are some 500 varieties of plants that can yield natural colours. Floriculture is considered to include the cut flowers, potted plants, and ornamental bedding plants and garden plant industries. A survey report reveals that 40% of the total productions of flowers are unsold and wasted everyday which are thrown away or dumped somewhere. These wasted flowers can be used in various ways & we can get wealth from waste materials, i.e. value added. Flower colour is largely due to the presence of pigments present in chromoplast or cell vacuoles of floral tissues.

The only other major group are carotenoids, which provide principally yellow colours, with some oranges and reds. Other classes much less in importance in relation to flower pigmentation are chlorophyll (greens), quinones (occasional red and yellow) and betalains alkaloids (giving yellow, red and purple colours in centrospermae).

Why flowers have colour?

Flowers that are bright in colour are meant to attract birds, bees and other insects in order to help the plants reproduce i.e. pollination. Bright colours or dull colours are fixed in the genetics of a flower. Pigments are responsible for colour in plants. Pigments are the molecules that absorb specific wavelength of light and reflects all others. Pigments are coloured substances produced by a plant.

Pigments in plants are:

- Chlorophyll
- Carotenoids
- Anthocyanin
- Betalains
- Quinones

The various uses of these flowers are:

a) Used in textile industry
b) Herbal gulal
c) Used as bio-fertilizers
d) Using these dyes in food industry.
e) Xanthophyll pigment present in marigold petals are dried and used to feed in poultry farms, as it is used to increase the colour of the yolk.
f) Tinting
g) Colourful candles.

Commercialization of natural dyes in India:

India is a major exporter of herbal dyes mostly due to ban on production of some of the synthetic dyes and intermediates in the developed countries due to pollution problem.

India's total export for natural dyes is worth 41.31 USD Million in 2020-2021. which when compared to the previous year's export stats has increased by 4.01%. Natural dyes are exported from India majorly to United Arab Emirates, Nepal, Japan, Indonesia, Republic of Korea, for which the combined export value from India to these countries stands at 16.26 USD million, which is 34.1% of total India's export for this commodity.

Natural dyes obtained from plants i.e. Berry, flower, bark, leaf, seed etc. Herbal dyes being natural tend to be softer and their range of tones is very pleasant. At present total market of herbal dyes is to the tune of US $ 1 billion and is growing tremendously at the rate of 12% per annum. Per capita consumption of dyes is 400 g to 15 kg in developed and underdeveloped countries for their utility in paints, inks, textiles, polymers etc.

There are basically 2 types of dyes used:

A) Synthetic dye
B) Natural dye

A) Synthetic dyes:

They are chemically manufactured. These days environmental protection has become a challenge for the textile industry because it utilizes a lot of chemicals for colouration of textile materials. These chemicals are harmful for both human as well as environment. Synthetic dyes suffer from several draw-backs. Some of the synthetic dyes which are even carcinogenic and mutagenic have been banned.

B) ***Natural dyes:***

Natural dyes are obtained from natural sources like root, bark, leaf, fruit, wood, seed, flowers, etc. Many natural dyestuff and stains were obtained mainly from plants and dominated as sources of natural dyes, producing different colours like red, yellow, blue, black, brown and a combination of these.

Commercialization in Chhattisgarh

- On march 07, 2021, ahead of the festival of colours (Holi), women of self-help group in Balrampur district of Chhattisgarh have made powders of various colours using different parts of the plants. These women are being trained at the Agriculture science centre of balrampur. The group is making herbal colours with the help of beetroots, spinach among others.
- Under agricultural university, through 15 KVKs and self-help group, herbal gulal was manufactured and retailed. With the help of these KVKs , various women self-help group, preapared 54 quintal of herbal gulal, from which 25 quintal herbal gulal retailed about 6.75 lakh rupees income.
- With the collaboration of KVKs and self-help group, sindoor, haldi, lal bhaji, palak, beetroot, flower of palash, flower of sem and other flowers as well as the colourful leaves of vegetables are mixed in different proportion to make natural herbal gulal. These natural dyes are being mixed with arrowroot (tikhor powder).

Table. 1. Some Flower colour and its pigments

S.NO.	FLOWER	COLOUR	PIGMENTS
1	Marigold	Yellow	Xanthophyll
2	Bougainvillea Glabra	Pink	Betalains
3	Amaranthus Caudatus	Red	Betalains
4	Salvia	Scarlet	Pelargonidin
5	Verbena	Mauve Violet	Delphinidin
6	Calendula	Orange	Carotenoid
7	China Rose	Red	Anthocyanin
8	Saffron (Stigma)	Dark Yellow	Carotenoid
9	Golden Rod	Yellow	Flavanoids glycosides
10	Hollyhock (Petals)	Red, Violet	Anthocyanin

Figure 1. Marigold

Figure 2. Bougainvillea

Figure 3. Saffron

Figure 4. Used in food industry as food colour

Figure 5. Used in textile industry

Figure 6. Herbal Gulal

Conclusion

- Due to increasing awareness among people about the harmful effects of synthetic dyes, products made from natural materials are gaining popularity. As natural dye shows non-toxic, nonallergic effects and results in less pollution as well as less side effects, it become a thrust area in the field of textile dyeing research.
- There has been a resurgence in the use of plant originated dyes, along with the general tendency of turning to nature.
- One of the major imperatives to the use of natural dyes is the knowledge gap. Very few serious attempts have been made to generate new information on the use of natural dyes. Most of the research in this area is carried away by the emperical information reported in literature that does not have any scientific reasoning or basis.

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Post-Harvest Management

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Abstract

Even though approximately a third of the fruits and vegetables (FV) produced in sub-Saharan Africa (SSA) are lost before being consumed, this sector of horticulture is growing. Depending on the crop, FV postharvest losses in SSA range from 30 to 80%. High levels of poverty, unmet hunger needs, and malnutrition are only a few of the economic and food security setbacks brought on by a lack of postharvest management expertise and technology, such as temperature control to sustain the cold chain, value addition, and packaging. Applications of postharvest technology, including as the use of ethylene, 1-methylcyclopropene (1-MCP), and temperature control, have demonstrated their ability to lower postharvest losses of FV on a global scale. Additionally, both chemical and non-chemical techniques can be used to control pathogenic microorganisms and spoilage, particularly in the case of ready-to-eat FV items. SSA might benefit from the use of postharvest technology such controlled ripening, edible coating, temperature control, and chemical treatment procedures to minimize FV postharvest losses, improve food and nutritional security, and reduce poverty. An efficient post-harvest handling system's main responsibility is to ensure that the harvested product reaches the customer while meeting expectations of the market and consumers regarding volume, quality, and other product and transaction features, such as nutrition, food security, and product safety. Managing or controlling post-harvest losses of agricultural products required careful cultivation, transportation, and packing, storage, processing, sorting, and cleaning. Decreased post-harvest food losses are therefore a crucial part of guaranteeing future global food security.

Keywords: - *Fruit*, *Vegetable* , *Post Harvest* , *Technologies*

Introduction

Postharvest losses refer to the measurable loss of quantity and quality of food crops during harvesting, storage, transportation, processing, marketing and preparation before consumption. It occurs throughout the value chain as a result of technical and managerial failures during harvesting, handling, transport, processing, packaging, marketing and distribution. Postharvest losses affect the environment and climate because the production, processing and transportation of fruits and vegetables (FV) produce unnecessary greenhouse gases that ultimately end up as losses

PV production in SSA in 2014 is approximately 34.22 and 31.95 million tons. Postharvest FV losses in SSA range from 30 to 80% depending on the nature of the crop, while worldwide postharvest losses are estimated at 30%. However, one of the goals of sustainability is to reduce post-harvest losses to report that aging, water loss, physical deterioration, rough

handling, poor packaging, poor temperature control and lack of training are the main causes of postharvest PV losses in SSA. Weak market infrastructure, such as open and unorganized markets without warehouses common in SSA, also cause large losses.

The handling of food from the farm to the fork or table is referred to as postharvest management. This includes harvesting, transportation, handling, storage, processing, and value addition. Post-harvest loss poses a serious risk to farmer incomes, food security, and the effectiveness of the world food system. A third of the food produced worldwide is thought to be lost or squandered. In Sub-Saharan Africa, post-harvest losses are estimated by the Food and Agricultural Organization (FAO) to be worth roughly $4 billion annually, out of an annual grain crop value of US$27 billion generated in the years 2005-2007. Various sites of intervention, various value chains, different technologies (a multidimensional problem in terms of the technology), and value chains embedded in underdeveloped and underdeveloped agricultural systems are significant components of the post-harvest loss conundrum.

The term "postharvest loss" refers to the amount and quality of a food output declining from harvest to consumption. Losses in quality can occur when a product's acceptability, edibility, or nutrient/calorie content are compromised. Developed nations tend to experience these losses more frequently. Quantity losses are those that cause a product's quantity to be lost. Quantity loss is more frequent in underdeveloped nations. According to a recent FAO research, food waste volumes are larger globally in downstream phases of the food chain in high-income nations than they are in low-income regions, where they are higher in upstream phases.

Value of Postharvest Development and Research

Postharvest research has a variety of benefits for both health and food security. Post-harvest food losses are decreased by new storage methods including biological pest control and controlled environment storage. A compelling case has been made by a number of writers in flavour of investing greater resources in postharvest research and development in poor nations. Less than 5% of the funding for agricultural research is dedicated to postharvest research fields, even though minimizing postharvest losses of previously produced food is more environmentally friendly than expanding output to make up for these losses. Postharvest activities have not received much attention from international research organizations (CGIAR, FAO, ACIAR, IDRC, GTZ, CIRAD, NRI, USAID) until recently, even though research on the improvement of agricultural production has received considerable attention and funding. The heavily unbalanced distribution of money to production vs postharvest themes cannot be justified, given the important contribution of postharvest research to CGIAR goals such as poverty reduction, food security, and sustainability, as well as in light of high rates of return. Since postharvest research has received very little funding thus far, when barriers and bottlenecks are eliminated, there is the potential for significant effects. Therefore, it would be preferable to review present financing priorities and give a greater percentage of resources to the postharvest region.

Technologies to Minimize Post-Harvest Losses

FV is metabolically active, maturing and aging changes that must be controlled to maintain quality and extend shelf life. The implementation of postharvest techniques has shown measurable reductions in postharvest losses worldwide and can be a strategic way to reduce poverty, hidden hunger and malnutrition in SSA They have also improved the horticulture industry to meet FV's local and international demand for nutrition and food security. The choice of technology depends on the type of crop, climatic conditions, affordability and ease of use. At the same time, proper post-harvest handling techniques should be followed to avoid damage and bruising in FV. Postharvest practices are designed to slow ripening and senescence changes, thereby minimizing crop damage and microbial growth. Some postharvest technologies include chemical and physical methods that effectively reduce microbial contamination. Physical methods include modified atmosphere packaging (MAP), nanocomposite packaging, active and smart packaging. Other emerging technologies include cold plasma, irradiation, ultrasound, and combined methods.

Post-Harvest Changes in the Physicochemical Composition of Fruits and Vegetables

After fruits and vegetables are harvested, a variety of changes may take place because the tissues are exposed to environmental factors that regulate the pace of degradation.

Some of the factors that cause spoilage of fruits and vegetables include: -

i. The product's moisture content.
ii. The environment's relative humidity.
iii. Product temperature, outside temperature, and heat produced by the product.
iv. Physical, mechanical, and physiological damage. Microorganisms, such as fungus or bacteria, decompose things.

Contamination by Microbes in Recently Harvested

Given that interior tissues of many fruits and vegetables are densely populated with nutrients, such as carbohydrates, proteins, vitamins, and minerals, they offer the perfect environment for the development and survival of microbes. Vegetables have a pH that is close to neutral, which provides bacteria with the best conditions for growth. By imparting an unfavorable smell and scent to the newly cut fruits, this may also provide suitable conditions for the onset of fermentation. To prevent the development of anaerobic reaction, the concentration of O2 and CO2 in the surrounding environment should not be less than 2% and more than 5%, respectively. Freshly cut fruits and vegetables respond more significantly to oxygen concentration than CO2 concentration. However, anaerobic bacteria, lactic acid bacteria, and yeasts are particularly resistant to carbon dioxide. Gram-negative bacteria and fungi are especially susceptible to CO2. The reduction in respiration caused by rising CO2 concentration reduces browning and microbial development on some freshly cut fruits and vegetables. Therefore, the ambient oxygen and carbon dioxide levels should be at a substantial level for freshly cut fruit and vegetables.

Conclusions

Postharvest Management, also known as harvesting, transporting, handling, storing, processing, and value addition, refers to the management of products from farm to fork or table. A particularly efficient technique to decrease the amount of land needed for production and/or increase food availability is to minimize postharvest crop losses. Postharvest technology have a variety of benefits that can improve food security. The amount of food that is accessible for consumption by farmers and underprivileged rural and urban customers can be increased if PHL is reduced. In order to boost food availability and accessibility, production must be raised together with distribution and loss reduction. Decreased post-harvest food losses are therefore a crucial part of guaranteeing future global food security. In general, considerable contributions to global food security might be made through reducing food loss.

Due to several health advantages, consumption of fresh fruits and vegetables that are ready to eat (RTE) has grown. Processing of fruits and vegetables requires the correct post-harvest processing procedures, such as washing, sanitation, cutting, and dipping treatments. Historically, different chemicals like sodium hypochlorite and other acids as disinfection agents have been employed to reduce the microbiological contamination of fruits and vegetables. However, these substances produce cancer-causing chlorinated compounds that are harmful to human health. In order to ensure safety and increase the shelf life of fresh-cut fruits and vegetables, enhanced processing processes, packaging materials, and alternative sophisticated sanitization procedures may be used. This improves the shelf stability of fruits and vegetables and lowers the microbial burden. A notion of smart packaging, in addition to this sophisticated packaging material like the MAP, aids in extending shelf life and determining product quality, respectively. The cutting-edge packing material helps keep produce fresh without chemical processing or cooling.

Through the whole value chain, the use of postharvest technologies, such as the use of ethylene to promote and delay ripening, and 1-MCP, can considerably lower FV postharvest losses. Controlled ripening is advantageous, particularly at busy times and while travelling long distances. The majority of tropical FV are climacteric and temperature-sensitive, therefore maintaining the cold chain and temperature control is necessary. Additionally, combining approaches is more advantageous for reducing post-harvest losses on FV, especially with FV that has had minimum processing. Increased safety of FV and adherence to quality requirements for domestic and international markets will result from the use of postharvest technologies including controlled temperatures, sanitizing chemicals, edible coating, and controlled ripening.

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Engineering Photosynthesis Mechanism to Tackle the Present-Day Climate Change

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Abstract

Designing crops to withstand the climate change is the current day challenge to address the rising temperature and carbondioxide levels. Plants hold the necessary photosynthesis mechanism within providing the needed energy for plant growth. While multiple efforts in creating agronomic adaptations such as intercropping, change in spacing, plant architectural changes added to enhance the photosynthetic potential of the plant, genetic interventions form the solutions with larger impact. Transformation techniques to engineer the photosynthetic mechanism through manipulating the RUBISCO enzyme, photochemical responses or shifting the entire C_3 cycle into C_4 create the pliable possibilities. Efforts underway are being designed to further introspect the photosynthesising ability of the plant to eventually tackle the climate stress while producing enhanced biomass and yield benefits.

Keywords: Photosynthesis, Transformation, RUBISCO, Photochemical responses, C_4 cycle

Introduction

In the present era of climate change, one major contributor to the destructive irreversible damage occurring comes from the greenhouse gases. Globally, carbondioxide (CO_2) accounts for 65% of the emissions from the industrial and fossil fuels while 11% is contributed from the cultivated lands [IPCC, 2014]. Over a long period, the CO_2 concentrations shuffled around 300ppm while the pre-industrial era created the momentum to enhance the levels currently hovering around 400ppm. These levels are yet to rise further due to the direct human effects creating impacts over the biodiversity and are directly linked to the current day global warming [Bereiter et al, 2015].

Afforestation has been a well-known contributor in tackling the climate change impacts. While plants contribute via sequestering carbondioxide and acting as a reservoir through the process of photosynthesis, there has been recent interests in extending the plants innate ability for further benefit. Photosynthesis in plants is a process through which plants create their needed food reservoir utilising the atmospheric carbondioxide in the green factories of the cells releasing oxygen (O_2) as their by-products. Sunlight acts in providing the impetus for the chloroplasts energising the electrons along the thylakoid membrane in the Calvin Benson cycle. RUBISCO (Ribulose-1,5-bisphosphate carboxylase/oxygenase) owes the responsibility in CO_2 fixation recycling itself for further cycles. This process of synthesis in the plant cell contributes in the carbondioxide utilisation from the atmosphere.

While photosynthesis has been a part of the plants' mechanism, the rise in climate impacts push for manipulating this mechanism thus, improving the plant's carbondioxide intake and utilisation. Possible routes to enhance this ability are:

a. Enhancing the ability of RUBISCO enzyme
b. Optimising the photochemical response in the plant
c. C_4 cycle transformation into the C_3 crops:

a. Enhancing the ability of RUBISCO enzyme:

RUBISCO is the major photosynthesising enzyme in the plants which evolved in the CO_2 rich atmosphere. Past effort to optimise this enzyme complex started with understanding the reaction mechanisms in this complex for synthesising the glucose, while the recent trends are skewed to evolve the CO_2 competence. Being a large hexadimeric complex it poses the difficulty to engineer the components within governed by nucleus and chloroplast genes [Maliga et al., 2011]. Efforts in *Flaveria* created a single amino acid change thus converting a C_3 compartmentalisation into C_4. The C_4 adoption owes to enhance the CO_2 utilisation by eliminating the photorespiration losses as in case of C_3 [Whitney et al., 2011]. Introduction of cyanobacterial regulatory genes controlling the RUBISCO enzyme which create carbondioxide concentration, also showed the possibility of improved photosynthesis and vegetative growth in tobacco plants equal to the wild species. In this species the transgenic regulatory genes through chloroplast transformation altered the expression of this hefty enzyme [Ochhialini et al., 2016]. These aspects depicted the insights in extending further research in optimising the expression of this complex in manipulating photosynthesis.

b. Optimising the photochemical responses in the plant:

Plants hold a reactive mechanism to reflect back the excess heat received by the plant to the atmosphere termed as photoprotection. Under this process, the genes expression tend to switch on upon crossing the limiting photoperiod receptance. Efforts to silence these genes in tobacco upon transformation tended to enhance the yielding potential of the plant above 20% by modifying the genes from the photosystem-II. Also, transforming the antenna or the light receiving complex would rather increase the receptivity and utilisation minimising the photoprotection [Blankenship et al, 2011].

c. C4 cycle transformation into the C3 crops:

The transition from C3 to C4 plants requires the evolution of both morphological and physiological traits. Among these, the differentiation of photosynthetically active vascular bundle sheath cells, modification in the biochemistry of several enzymes, and increased intercellular and intracellular transport of metabolites are of pivotal significance.

The road for c4 rice:

Recently an attempt is underway to increase the rice yield potential by engineering an efficient C4 type photosynthesis into rice. For this, a set of genes which regulate leaf anatomy and biochemical processes have to be inserted into rice and expressed in an appropriate manner which is currently not possible solely by conventional plant breeding techniques.

Initial attempts were made to generate hybrids between closely related C3 and C4 plants by conventional crossing. With the advent of transformation technology there were numerous attempts to introduce C4 photosynthetic genes into C3 species. Four enzymes of the C4

photosynthetic pathway were successfully introduced into rice although no photosynthetic gains were observed. C4 rice consortium was conceptualized and established which began the practical work of C4 rice engineering since 2009- desire to engineer a full Kranz two cell type mechanism in rice photosynthetic pathway were successfully introduced into rice although no photosynthetic gains were observed. C4 rice consortium was conceptualized and established which began the practical work of C4 rice engineering since 2009- desire to engineer a full Kranz two cell type mechanism in rice

In rice more than 90% of the total chloroplasts are located in mesophyll cells (MCs) within the leaf whereas, in C4 plants both MCs and bundle sheath cells (BSCs) possess equal numbers of chloroplasts. This is because in C3 plants, the entire process of photosynthesis takes place in MC, but in C4 plants the process of photosynthesis is compartmentalized into MC and BSC.

Based on the study of the evolution of C4 from C3 species and the associated changes, the following modifications are essential to establish a functional C4 photosynthetic pathway in rice.

1) Increase the number and size of chloroplasts in bundle sheath cells of rice
2) Reduce the vein spacing thereby increasing the vein density in the leaf
3) The activity of the Calvin cycle should be significantly reduced in MC and greatly enhanced in the BSC of rice
4) The photorespiration in mesophyll cells has to be greatly reduce [Lin et al, 2020]

While the efforts are underway yet certain drawbacks such as availability of specific promoters and uncertainty in the gene expression are impeding the shift.

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Evaluation Of Rice Genotypes Under Low Phosphorous Soils To Identify The Tolerant Lines

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Abstract

Rice is life for many people in Asian countries. Phosphorous is one of the major nutrients useful for the optimum growth and development of the many crops, including rice. Even though this element is present in soil in enough quantity, it may not be available to the plants in the field. The reason behind is reduction of phosphorous use efficiency as the phosphate form of fertiliser P may bind to organic matter or chemicals applied from the outside in the soil. One of the main problems limiting rice yield is phosphate (P) shortage in the soil. Deficiency of the Phosphorous element may lead to stunted growth of the plant and narrow leaves, significant in reduction in the plant growth and number of panicles, panicle length, number of total grains of the panicle, grain yield per plant, root and shoot length of the plant and appearance of the plant type. Along with the above said symptoms, Phosphorous deficiency may leads to delay in the flowering and maturity period of the crop. In severe cases flowering may not be seen in the crop and may observe non- productive tillers and may observe panicles with chaffy grains. Developments of tolerant cultivars are the feasible strategy to deal with the low phosphorous tolerance in rice crop. Thus, this article is helpful to identify P-stress-tolerant rice genotypes using different methodologies like relative tillering ability, stress tolerance indices and ANOVA.

Keywords: Low P soils, Stress Indices, Rice, Phosphorous deficiency

We need to finalize the material which has to be screened under low phosphorous plot. The selected material needs to sow in the nursery beds. 21-30 days old seedlings used to transplant in both control condition plot (normal plot, where available P is 30ppm) as well as low phosphorous plot (available P is <3ppm). Seedlings should grow with proper spacing and recommended package of practices in the field level to proper establishment of the plants. We should take care that P fertiliser should not apply to the low phosphorous plot. After collecting the yield data from both low P and normal conditions, data was subjected to the selection criteria for identifying the stress tolerance promising genotypes.

1. We can identify the tolerant lines based on productive tillers recorded in low phosphorous and normal plot conditions by using relative tillering ability.

Relative tillering ability: It is the ratio of number of productive tillers under stress (low P plot) to the non-stress (normal) condition and it is expressed in percentage.

$$\text{Relative tillering ability} = \frac{\text{Number of productive tillers under low P}(< 5kgP/ha)}{\text{Number of productive tillers under normal P(25kgP/ha)}} \times 100$$

If the percentage of relative tillering ability is 80-100%, then it is considered as tolerant entry, if it is 60-79%, then it will be recorded as moderately tolerant entry, if the relative tillering ability percentage is 40-59 %, it will be moderately susceptible, if the percentage is 20-39%, it is considered as susceptible entry, if the relative tillering ability percentage is 0-19%, it can be considered as highly susceptible entry.

2. The grain yield per plant from stress and normal condition plot was used to identify the tolerant lines by using different stress indices.

Stress Indices followed to identify low P tolerant lines:

SI. No	Index name	Formulae	Reference
1	**Stress tolerance index (STI)**	STI= $\frac{Y_{PYS}}{(\bar{Y}_P)2}$	Fernandez, 1992
2	**Stress tolerance (TOL)**	TOL= Y_P-Y_S	Rosielle and Hamblin, 1981
3	**Stress susceptibility index (SSI)**	SSI=$\frac{1-YS/YP}{1-\bar{YS}/YP}$	Fisher and Maurer, 1978
4	**Yield stability index (YSI)**	YSI =$\frac{YS}{YP}$	Bouslama and Schapaugh, 1984
5	**Yield reduction ratio (YRR)**	YRR= $1-\left(\frac{Ys}{Yp}\right)$	Golestani Araghi, and Assad, 1998
6	**Yield index (YI)**	YI=$\frac{Ys}{\bar{Ys}}$	Gavuzzi *et al.*, *1997*
7	**Mean productivity (MP)**	MP= $\frac{(Yp+Ys)}{2}$	Rosielle and Hamblin, 1981
8	**Geometric mean productivity (GMP)**	GMP= (Yp×Ys)0.5	Fernandez, 1992
9	**Percent yield reduction (YR)**	YR= $\frac{Yp-Ys}{Yp}$×100	Yaseen and Mahli, 2009

Where, YP is grain yield under normal soil P condition (P60), YS is grain yield under low soil P condition (P0), and are the mean grain yield of respective genotypes under P60 and P0 conditions.

Based on the results obtained from the above said stress indices, we can identify the entries which are tolerant in low phosphorous soil conditions.

3. Along with the above said criteria, pre-harvest observations like plant height (cm), number of productive tillers, number of total tillers, panicle length (cm), flag leaf length

(cm), flag leaf width (cm) and post-harvest phenotypic observations like number of filled grains per panicle, number of chaffy grains per panicle, 1000 seed weight (g), grain yield per plant (g), spikelet fertility (%) recorded for the cultivars under stress (low phosphorous) and normal conditions can subjected to analysis by using R software studio (*version* 3.5.2) to understand the phenotypic response of the cultivars along with the checks.

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Organic Production in Vegetables – A Way To Create Healthier Ecosystem

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Abstract

There are innumerable health hazards posed by the conventionally grown crops due to the presence of higher pesticide residues, heavy metals and also genetically modified organisms. In cereals and pulses where the moisture level is maintained around eight per cent, the presence of pesticide residue is very minimum and has been found to disappear over a period of time due to storage, whereas in the case of vegetables and fruits the moisture level is more than 90 per cent and the availability of pesticide residue is maximum and the produce is to be consumed within a reasonable time because of the perishable nature. Organic cultivation besides protecting the environment, has a greater socio-economic impact on a nation. Soil-boosting practices that are the foundation of organic agriculture also help sequester more carbon in soil compared to non-organic systems. Soil invertebrates are critical to carbon sequestration, because they are responsible for the formation of soil components that are essential to building soil organic carbon. Organic farms are required to build healthy soil and crops that make them better able to adapt in a changing climate. Organic farming promotes resiliency by boosting soil's ability to retain water and the natural nutrients found in healthy soils. By increasing organic matter in soil continuously over time, organic agriculture improves water percolation by 15-20%, replenishing groundwater and helping crops perform well in extreme weather like drought and flooding.

Keywords: organic, carbon, resiliency, nutrients

Importance of organic farming

Organoleptic studies have shown that vegetables like tomato and potato tastes better when grown organically. Likewise, the fruits had a better taste, flavor, texture and juicier when compared to conventionally grown ones. Similarly, organically grown okra and carrots were found to possess better quality attributes like taste, flavor and sugar content than those grown conventionally. Excessive nitrate intake is posing a serious threat to human health. Leafy vegetables, in particular, accumulate more nitrates followed by root vegetables and potato. Studies have confirmed that organically produced vegetables like potato, carrot, cabbage beetroot, celery, leak, parsley and lettuce contain lesser levels of nitrates and higher levels of vitamin C content when compared to conventionally grown vegetable crops. Similarly, it has been found in studies that organically grown vegetables accumulate higher content of total sugars, minerals like phosphorous and magnesium and phenolic compounds in vegetables like carrot, potato, spinach, brinjal, lettuce and cabbage. Organically grown vegetables like sweet

pepper and brinjal exhibited higher levels of phenolic compounds, peroxidase and capsidol activity offering resistance to diseases.

Sustainable Organic Farming

Sustainable agriculture provides a potential solution to enable agricultural systems to feed a growing population within the changing environmental conditions. For successful organic farming maintaining soil health by addition of organic residues is imperative. Soil health is not only maintaining the carbon content in the soil but also maintaining a balance between carbon and nitrogen which is the most important factor that determines the nutrient availability besides the population dynamics of the microflora in the soil. Organic farming sustains, maintains and enhances the quality of ecosystem. Because fossil fuel-based fertilizers and most synthetic pesticides are prohibited in organic farming, it has a significantly lower carbon footprint. The production of these farm chemicals are energy intensive. Studies show that the elimination of synthetic nitrogen fertilizers alone, as is required in organic systems, could lower direct global agricultural greenhouse gas emissions by about 20%. Meanwhile, fumigant pesticides – commonly used on crops like strawberries and injected into soil – emit nitrous oxide (N2O), the most potent greenhouse gas (Das *et al*., 2020).

Carbon Sequestration

Conventional vegetable farming has been shown to turn down the levels of soil organic carbon. The characteristics of this agricultural system include high-intensity tillage, exposed soil, and the high usage of chemical fertilizers, pesticides, and water for irrigation. Organic farming is an agricultural system that uses natural inputs to increase soil fertility, without using chemical fertilizers or pesticides. Organic farming systems can accelerate soil carbon by recycling organic matter. The impact of soil management practices on soil C is best observed in regards to the active or labile C fraction, which plays an important role in providing nutrients for plants. Assessing the organic C levels in the soil are key to studying carbon sequestration because the distribution of the labile C fraction in the lower regions of the soil has implications for carbon storage.

Organic farm management results in higher levels of carbon sequestration compared to conventional agriculture because an increase in carbon sequestration is associated with a rise in levels of organic C in the soil. It can also be influenced by the continuous provision of organic matter as fertilizer in organic farming, which increases the amount of biomass in the soil. Organic material undergoes decomposition in the soil, resulting in mineralization and the formation of a relatively thick material called humus. Humus is composed of cellulose, lignin, and protein, and generally has an organic C content of 58 percent. Therefore, applying organic fertilizer increases the amount of humus in the soil, which also improves levels of carbon.

Labile carbon in the soil is very active, so it is easily transported down the soil profile, accumulating in the root zone. It plays an important role in increasing carbon storage within the soil. The higher organic carbon levels in the soil were particularly in the form of labile carbon, which has the potential to increase farm profitability by improving soil fertility and nutrient availability. Furthermore, the use of manure compost as an alternative to chemical fertilizer

affect the rise of organic carbon storage and increase financial benefits for farmers. Organic farming is a method of vegetable production to assist reduce global warming by improving carbon sequestration and encourages sustainability. Multiple meta-analyses comparing thousands of farms nationwide have shown that organic agriculture results in higher stable soil organic carbon and reduced nitrous oxide (N2O) emissions when compared to conventional farming. (Madagoudra and Lokesh, 2021)

Status of organic farming in vegetables

Organic cultivation has a significant role to play in maintaining the soil fertility by boosting the microbial flora of the soil. This can substantially lead to increase in yield, plant composition as well as nutritional quality. Organic treatments resulted in higher carrot root production compared to conventional treatments. The yield of cabbage and tomato grown under organic practices yielded better than that grown under conventional system. Better results in terms of fruit yield in vegetables could be attributed to the fact that organic amendments of soil changed the soil dynamics as well as the plant composition and nutritional quality. Organic inputs can proportionately increase the microflora which in turn facilitates production of substances such as citrate and lactate which combine with soil minerals to increase the availability of mineral nutrition to the plant roots. Higher levels of iron and magnesium were recorded in vegetable crops like carrot, beetroot, lettuce, kale, leek, turnip, onion, celery and tomato when grown organically. Experiments on tomato, celery and kale have shown higher vitamin C content when they are grown under organic practices than when grown under traditional systems of cultivation. On an average, the vitamin C content of organically grown vegetables is 27% more when compared to the conventionally grown vegetables.

Organic certification

In India, the National Programme on Organic Production (NPOP) has provided the regulatory framework while National Project on Organic Farming (NPOF) is involved in providing support for expanding the area under certified organic production. Organic product certified by NPOP can be exported to Europe, Sweden and USA. To meet the domestic demands, NPOP notified under Agriculture Produce Grading, Marketing and Certification Act (APGMC) comes to play lead role.

1. An organic production or handling system plan. All information requested in the application shall be completed in full i.e. name, addresses, details of contact person, telephone number of the authorized person etc.
2. The names of organic certification body to which application is previously made and outcome, non-compliance noted if any, copy of such records and reason for applying shall be given.
3. Any other information necessary to determine the compliance with the standards specified.
4. The prescribed registration fee, one time inspection fee, one time travel cost shall be paid by the operator along with the application form.

Inspection

Initial field inspection shall be fixed at a reasonable time so that the operator can demonstrate compliance or capacity to comply with the standards while conducting inspection of land, facilities and activities. Such initial onsite inspection shall be delayed up to six months from the date of registration so as to give time for the operator to comply with required standards including record keeping. All onsite inspection shall be conducted only in the presence of operator or an authorized representative of the operator who is knowledgeable about the operation. However, this requirement does not arise in the case of unannounced / surprise inspections. There shall be one annual inspection and additional inspection shall be fixed based on the risk assessment carried out during initial inspection.

Organic certifying agencies

1. Tamil Nadu Organic Certification Department (TNOCD), Tamil Nadu
2. Indian Organic Certification Agency, Kerala
3. Uttaranchal State Organic Certification Agency (USOCA), Uttaranchal
4. Rajasthan Organic Certification Agency (ROCA), Rajasthan
5. Chhattisgarh Certification Society, Chhattisgarh
6. Natural Organic Certification Agency, Pune
7. ISCOP (Indian Society for Certification of Organic Products), Tamil Nadu

Constraints in organic farming

1. Market development, particularly domestic sector continues to be one of the biggest challenges in organic farming.
2. Lack of infrastructural facilities for post-production practices also pose a challenge as it sets a constraint in meeting the organic standards.
3. Cost involved in certification process and the extensive documentation procedure is a major setback.

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Hydroponic Fodder Production: Need of the Hour

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Abstract

Green fodder plays an important role in the feeding of dairy animals, thereby providing the necessary nutrients for the production of milk and the health of dairy animals. The shrinkage of grazing and fodder generating land has been caused by rapid urbanization and mining areas. Due to the year-round non-availability of quality green fodder, milk producers are forced to use additional concentrates for optimal milk production. Non-accessibility of irrigated land for the production of fodder, higher labor costs, and limited land holdings have left milk farmers with many milk production challenges. It is very clear that sustainable technology will be the main driver of the dairy industry in the years to come with the decrease of cultivable land and the depletion of natural resources.

Keywords: Green Fodder, Hydroponics, Milk Production, Dairy.

Introduction

One of the alternatives is hydroponic fodder to complement the meager pasture capital to meet this growing demand for green fodder. Two Greek words originate from the word hydroponics:' hydro' meaning water and 'ponos' meaning labor, i.e. working water. Hydroponic green fodder can be grown both in massive, advanced, automated, environmentally controlled commercial systems or in low-cost systems where the climate is suitable for the production of fodder. In the absence of soil, fodder seeds use tap water or nutrient-enriched solutions for plant nourishment. Often known as fresh fodder cookies, sprouted fodder or sprouted grain or alfaculture, hydroponic fodder.

Today, hydroponics is used in extreme climates such as deserts, poor-soil areas or urban areas where conventional agriculture has been pushed by high land costs. The development of hydroponic fodder is possibly ideally suited to semi-arid, arid and drought-prone regions of the world suffering from chronic shortages of water or in areas where there is no irrigation infrastructure. For farmers whose soil is rocky and infertile, hydroponic fodder production is a blessing. It is a viable alternative technology for landless farmers for the development of fodder that is friendly to farmers. Hydroponics can be used to produce foods such as maize, barley, oats, sorghum, rye, alfalfa and triticale.

Advantages

Efficiency: The efficiency of the output of fodder is surprisingly improved by having the optimum environment. Since it is applied directly to the roots and is often recycled and used many times, hydroponic systems eliminate water wastage. The water should be safe, however, because during the growth cycle, bacteria and fungi proliferate during recycling. Therefore, it is suggested to go for the filtering of infrared.

Space: Hydroponic systems need much less time and energy than traditional systems, which makes urban dwellers with limited yard space suitable for the former. In hydroponic fodder, the plant root systems are far smaller than in traditionally grown fodder, which means higher plant numbers per unit of room.

Use of pesticides, insecticides and herbicides: In a controlled environment without soil, hydroponic fodder is grown and is thus not vulnerable to soil-borne diseases, pests or fungi, thus reducing the use of pesticides, insecticides and herbicides.

Fodder yield: Under a hydroponic system, plants mature faster and more evenly than a conventional soil-based system. The yield of hydroponic maize fodder on a fresh basis is 5-6 times greater than that obtained in traditional farm production and is more nutritious (Naik et al., 2014).

Fodder quality: A rich source of vitamin A, vitamin E, vitamin C, thiamin, riboflavin, niacin, biotin, free folic acid and anti-oxidants such as β-carotene is hydroponic food (Finney, 1982; Cuddeford, 1989; Naik et al., 2015)

Impact on animal production: Saidi and Abo Omar (2015) noted that there was no effect on feed consumption, body weight change, milk yield, and milk composition of hydroponic barley fodder (HBF); however, HBF had positive effects on the health, mortality, conception rate, and abortion of ewe. The hydroponic fodders are highly digestible, palatable and animal-loving.

Need of Hydroponics Technology:

In the state's traditional green fodder output, hydroponics technology is needed to resolve the following constraints.

1) Small holdings of land among dairy farmers

2) Non-availability of fertile land for the production of fodder

3) Scarce resources for irrigation, fencing and land preparation are

Hydroponics Technology

Instead of soil, it is a science of growing plants in nutrient-rich solutions and can be used effectively to eliminate strain from the land to produce green feed for livestock. In order to grow, plants need three things: water, nutrients, and sunlight. Hydroponics is a straightforward way of providing all these nutrients to optimize the growth of plants without the need for soil

under controlled environmental conditions. Technology has been tested for producing high-quality nutritious green fodder for dairy animals on different crops such as maize, sorghum, barley, oats. In addition to this, hydroponics can be used for optimum growth in seven days for the production of wheat grass, paddy saplings, etc. Fodder obtained from hydroponics consists of grass, compared to just stem and leaves in conventionally grown fodder, with seeds, roots, stem and leaves.

Hydroponic innovative technology for dairy business

- To grow green fodder without fungal growth at a broader temperature (15° C - 32° C) and humidity (70 -80 percent) range.
- Friendly with the environment.
- Free fodder from pollution.
- Saves water and employment
- Fodder cultivated is extremely palatable and nutritious
- Animal health and reproductive efficiency are improved by fodder.

Advantages of Hydroponics

- Conservation of water - maximum water use efficiency.
- Less land requirement
- Less labour requirement
- Less time requirement in fodder production
- Green fodder round the year
- Increasing of nutritive value of fodder
- Natural feed for animals
- Enhancement of milk production
- Minimizing loss of fodder

Conclusion

Non-availability of suculent grass land is available for a shorter duration of the year, non-availability and higher cost of land, minimum use of fodder-producing areas for livestock feeding, will internally provide more land for other crops, thus increasing the economy and sustainability of the land. Hydroponically, the method of growing green fodder enables the regulation of climatic conditions for optimum growth with guaranteed daily production. In developing countries, high initial investment in fully integrated commercial hydroponic systems is not a success. Low-cost hydroponic systems, on the other hand, have been built by the use of locally accessible infrastructure where there is an acute shortage of fodder and water; local irrigation systems are not well established; transport and fuel costs are high; and there are extreme seasonal shifts in fodder prices.

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Success story, Rashtriya Krishi Vikas Yojana Goa state co-operative milk producers' union ltdcurtiponda, Goa-404301 production of hydroponic green fodder for eco-friendly and sustainable milk production.

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Embryo Rescue Technology: An approach for deliverance of wild progenies

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Abstract

Wild relatives of crop species act as a store house of the many advantageous genes and alleles controlling desirable traits like high nutritional quality and resistance to biotic and abiotic stress. Embryo rescue is an *invitro* technique that has been used to rescue the embryos from wild crosses that do not fully develop naturally. Embryo rescue technique used in tissue culture has proven to be of greater value to the breeders. The success of this techniques depends on isolating the embryo without injury, formulating a suitable nutrient medium and inducing continued embryogenic growth and seedling formation. Currently, embryo rescue holds great promise for not only effecting wide crosses but also for obtaining haploid plants and it is also useful in understanding embryo morphogenesis and precocious germination.

Introduction

Wild relatives of crop species harbour the beneficial genes/alleles controlling desirable traits such as biotic and abiotic stress resistance and high nutritional quality. These traits should be introgressed to the cultivated varieties. Transfer of desirable traits from tertiary genepool is difficult due to post fertilization barriers. Tissue culture techniques such as embryo rescue come to picture in rescuing the hybrid F_1s.

Wild relatives of crop species contain the advantageous genes and alleles controlling desirable traits like high nutritional quality and resistance to biotic and abiotic stress. These characteristics ought to be introduced into the cultivated varieties. Post-fertilization barriers make it challenging to transfer desirable traits from the tertiary genepool. In order to rescue the hybrid F1s, tissue culture techniques like embryo rescue are used.

Growth of any species during its embryonic stage, in an artificial medium in order to enhance its likelihood of survival is called embryo culture. It involves the culture of immature embryos to rescue them from unripe or hybrid seeds which fail to germinate.

The term “embryo rescue” refers to *invitro* techniques whose purpose is to promote the development of an inherently weak, immature or hybrid embryos into a viable plant. One of the oldest and most effective *invitro*, or tissue culture, processes used with plant species is embryo

rescue. Various methods that encourage the development of an immature or weak embryo into a viable plant are referred to as embryo rescue. These procedures are often used for producing plants from hybridizations that normally produce inviable seed. The method used to save the most embryos is called embryo culture, in which the embryos are removed and placed directly onto culture media.

Embryo rescue plays an important role in modern plant breeding. *Invitro* techniques for the culture of protoplasts embryos have been used to create new genetic variations in the breeding line.

Whole ovules or ovaries may occasionally be placed into culture because small embryos are extremely challenging to remove without damaging the small seeded species or very young embryos frequently use ovary and ovule culture. The probability of success for all embryo rescue procedures rises as the embryos mature, but cultures must be started before the embryos die. One of the main reasons for using in ovule embryo rescue is to regenerate inherently weak, immature or hybrid embryos that otherwise would not develop into viable mature plants.

Types of embryo culture

1) Immature embryo culture.

2) Mature embryo culture.

Immature embryo culture or embryo rescue technique:

Culture of immature embryos to rescue the embryos of wild crosses is used to avoid embryo abortion and produce viable plants.

It requires complex media which includes special amino acids, hormones, growth regulators, Macro and micro elements, pH of the medium, vitamins, carbohydrates, culture Environment etc.

Mature embryo culture:

It is culture of mature embryo derived from ripe seeds. It requires simple medium.

Some species produce sterile seeds which may be to incomplete embryo development. Such embryo can be cultured and viable seedlings can be cultured and viable seedlings can be produced.

This culture is done when embryos do not survive in vitro and to eliminate the inhibition of seed germination.

Culture medium:

The culture medium is the source of nutrition for embryos developing in vitro as part of the embryo rescue process and, as such, represents a critical factor in determining the success rate.

In general, low, concentrations of auxins have promoted normal growth, gibberellic acid has caused embryo enlargement and cytokinin's have inhibited growth. In addition to supplying vitamins and amino acids to the medium natural extracts often also supply growth regulators.

Since embryos vary in their physiological and developmental characteristics at different stages, different types of growth media, including different basal media are used for the embryo rescue. Basic requirements for the embryo development are MS macro elements, sucrose, pH ranges 5-7, My-inositol, Ms minor, Fe-EDTA, Agar, IAA etc.

Plant growth regulators (PGRs) are not only important for embryo rescue when added to the embryo culture medium, but also exhibit an effect when sprayed onto the plant at the pre-blooming and blooming stages.

Embryo rescue procedures:

It is the most used embryo rescue procedure is embryo culture, in which embryos are excised and placed directly on to culture medium.

Pods from controlled pollination of greenhouse or field grown plants is collected prior to the time at which embryo abortion is thought to occur. Since embryos are in a sterile environment, disinfestation of the embryo itself is not required. In some cases, the entire ovary is surface – sterilized.

The embryo will be placed directly into culture after its excision so that it does not become dry, for heart -shaped and younger embryos, the embryo should be excised with the suspensor intact.

Applications of embryo rescue:

- The most common application for embryo rescue in breeding is rescuing inherently weak embryos.
- Through embryo rescue, the abortive embryos can be cultured to viable embryos and subsequently normal plantlets can easily be obtained.
- Overcome of seed dormancy and to determine seed viability.
- Study the relationship between embryo and endosperm.
- Shorting of breeding cycle.

The hybrids raised through culture have been utilized for:

Phylogenetic studies and Clonal propagation.

Genome analysis, Transfer of useful agronomic traits from wild genera to the cultivated crops.

To raise synthetic crops and for germplasm conservations.

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Recent developments in Crispr variants

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Introduction

Genome editing (GE) is a technique which introduces DNA mutations in the form of insertions and/or deletions (indels) or base substitutions in target sequences. GE comprises various techniques, such as the use of zinc finger nucleases (ZFNs), transcriptional activator-like effector nucleases (TALENs), and the most recently developed clustered regularly interspaced short palindromic repeat (CRISPR). Although the discovery of artificially designed mega nucleases followed by ZFNs and TALENs successively increased the genome-editing efficacy, targeting different sites in the genome required re-design or re-engineering of a new set of proteins. The difficulty in cloning and protein engineering ZFNs and TALENs partially prevented these tools from being broadly adopted by the scientific community (Malzahn *et al.*, 2017). The endogenous CRISPR system requires two short RNAs: the mature crRNA and a trans-activating crRNA (tracrRNA). The crRNA is composed of the part that serves as guiding sequence and another part base pairs with the tracrRNA. Both crRNA and tracrRNAs are required to form the Cas9 protein–RNA complex that cleaves DNA with DSBs at target sites, these double-strand breaks (DSBs) trigger DNA repair pathways, such as non-homologous end joining (NHEJ) to introduce frameshift mutation for gene knock out (KO) or homologous direct repair pathway (HDR) for gene substitution or gene knock-in (KI) through supplied DNA template (Adli *et al.*, 2018).

CRISPR variants

There are two classes of CRISPR systems, each containing multiple CRISPR types. Class 1 contains type I and type III CRISPR systems that are commonly found in Archaea. Class 2 contains type II, IV, V, and VI CRISPR systems (Agarwal *et al.*, 2021). Although researchers repurposed many different CRISPR/Cas systems for genome targeting, the most widely used one is the type II CRISPR-Cas9 system from *Streptococcus pyogenes*. Because of the simple NGG PAM sequence requirements, S. pyogenes' Cas9 (spCas9) is used in many different applications. However, researchers are still actively exploring other Cas9 variants from other species other than *Streptococcus pyogenes* and also non Cas9 proteins to overcome limitations like PAM restrictions, off-target effect and reduced target specificity. (Song *et al.*, 2021). Some of the recently discovered ones, such as Cpf1 proteins from *Acidaminococcus sp.* (AsCpf1) and

Lachnospiraceae bacterium (LbCpf1), in contrast to the native Cas9, which requires two separate short RNAs, Cpf1 naturally requires one sgRNA. Furthermore, it cuts DNA at target sites 3′ downstream of the PAM sequence in a staggering fashion, generating a 5′ overhang rather than producing blunt ends like Cas9. Banakar *et al.* (2020) compared efficacies of three Cas9 (WT Cas9 nuclease, HiFi Cas9 nuclease, Cas9 D10A nickase) and two Cas12a nucleases (AsCas12a and LbCas12a), using the rice phytoene desaturase (PDS) gene as a target site and concluded LbCas12a had a higher editing efficiency than that of WT Cas9 and HiFi Cas9.

Cas13 is a recently identified CRISPR effector and CRISPR/Cas13 can target specific viral RNAs and endogenous RNAs in plants cells. The Cas13 system has high RNA target specificity and efficiency. Cas13 was also used to direct ADAR2 deaminase for the modification of RNA (changing adenosine to inosine) in human cells for the recovery of functional proteins to halt disease progression. Recently, CRISPR/Cas13a has been considered as an entirely new CRISPR type that belongs to class II type VI. Due to the presence of higher eukaryotes and prokaryotes nucleotide-binding (HEPN) domains, it is associated with RNase activity. The CRISPR/LshCas13a system has been used to create resistance against potyvirus (an RNA virus) in plants, which indicates that this system can be used in agricultural and biotechnological applications. Aman *et al.* (2018) used CRISPR/LshCas13a to stably engineer *Arabidopsis thaliana* for interference against the RNA genome of Turnip mosaic virus (TuMV) and concluded that CRISPR RNAs (crRNAs) guiding Cas13a to the sequences encoding helper component proteinase silencing suppressor (HC-Pro) provide better interference compared to crRNAs targeting other regions of the TuMV RNA genome.

Base Editing and Prime Editing

Base Editing (BE) is the most recent and a quite different GE system, which introduces precise and highly predictable nucleotide changes at genomic targets without any requirement for donor DNA templates, DSBs, or dependency on HDR and NHEJ. This BE utilizing cytidine deaminases which generate specific C to T alterations by using DNA mismatch repair pathways. Adenine base editors, developed by fusion of an evolved tRNA adenosine deaminase with SpCas9 nickase (D10A), generates the conversion of A,T to G,C when directed by sgRNAs to genomic targets in human cells (Komor *et al.*, 2016).

Base editing can efficiently install the four transition mutations (C→T, G→A, A→G, and T→C) without requiring DSBs, but cannot perform the eight transversion mutations (C→A, C→G, G→C, G→T, A→C, A→T, T→A, and T→G), such as the T•A-to-A•T mutation needed to directly correct the most common cause of sickle cell disease. In addition, no DSB-free method has been reported to perform targeted deletions or targeted insertions. Targeted transversions, insertions, and deletions are therefore difficult to install or correct efficiently. So novel technology called Prime editing, a 'search-and replace' genome editing technology (Anzalone *et al.*, 2019) that mediates targeted insertions, deletions and all 12 possible base-to-base conversions without requiring DSBs or donor DNA templates. Butt *et al.* (2020) used prime editing technology by targeting rice ACETOLACTATE SYNTHASE (OsALS) for herbicide

resistance, this ALS gene catalysis the initial step common to the biosynthesis of the branched chain amino acids and is primary target site for herbicides like Bispyribac sodium. A single amino acid change (W548L) in ALS by prime editing results in a BS-resistant phenotype.

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Due to its robustness and flexibility, CRISPR is becoming a versatile tool with applications that are transforming not only genome-editing studies, but also many other genome and chromatin manipulation efforts, these alternative application areas are largely possible because of the programmable targeting capacity of catalytically inactive dead Cas9 (dCas9), which cannot cleave DNA but can still be guided to the target sequence. While WT Cas9 enables genome editing through its guidable DNA cleavage activity, catalytically impaired Cas9 enzymes have been repurposed to achieve targeted gene regulation, epigenome editing, chromatin imaging also.

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CLIMATE SMART AQUACULTURE

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Abstract

With the ever-increasing population in today's world with limited resources, we need different methods to be able to provide nutrients in a sustainable manner. The most effective method to tackle this problem brought aquaculture to light which now became one of the fastest-growing industries all over the world. Climate change is having significant impacts on aquaculture, which is already facing challenges from overfishing, pollution, and habitat destruction. Warmer ocean temperatures, increased ocean acidity, and changing weather patterns are affecting the growth, survival, and reproduction of fish and shellfish, which can result in reduced yields and increased disease outbreaks. Rising sea levels can also cause flooding and saltwater intrusion, which can damage infrastructure and crops. In addition, extreme weather events, such as hurricanes and typhoons, can cause significant damage to aquaculture facilities, leading to economic losses and food insecurity. To adapt to these impacts, the aquaculture industry is exploring climate-smart practices such as improving water management, using more sustainable feed sources, and adopting new technologies to monitor and manage production systems.

Keywords: sustainable aquaculture, IMTA, Aquaculture Stewardship Council, RAS, US National Oceanic and Atmospheric Administration (USNOAA)

Introduction

Climate change is having a significant impact on the world's oceans and the fisheries and aquaculture industries that depend on them. According to FAO (2015), an integrated approach for developing technical, policy, and investment conditions to develop sustainable agricultural development that goes along with climate change is termed ad climate smart aquaculture. Climate-smart aquaculture is a rapidly growing approach to seafood production that seeks to mitigate the impact of climate change on aquatic ecosystems, while simultaneously improving the efficiency and profitability of fish and shellfish farming. By adopting practices that reduce greenhouse gas emissions, optimize the production efficiency, and enhance the resilience of aquatic ecosystems, climate-smart aquaculture can provide a low-carbon and sustainable source of protein for a growing global population. This approach not only helps to reduce the impact of climate change on aquaculture, but also supports the long-term sustainability of the industry and the communities that depend on it.

Impact of climate change on aquaculture

Climate change is expected to have significant impacts on aquaculture, which is the farming of aquatic organisms such as fish, shellfish, and seaweed. Some of the factors that are directly affecting aquaculture production are as follows;

1. Temperature: Rising water temperatures can affect the growth and reproduction of aquatic organisms. Changes in water temperature can also alter the timing of reproduction, leading to mismatches with natural cycles and reduced yields.
2. Ocean acidification: As carbon dioxide dissolves in seawater, it increases acidity, which can have negative impacts on shellfish and other organisms that build shells or skeletons.
3. Changes in ocean currents: Changes in ocean currents can affect the distribution and abundance of species, which can impact aquaculture operations.
4. Extreme weather events: Climate change is expected to increase the frequency and intensity of extreme weather events such as hurricanes, cyclones, and typhoons. These events can damage aquaculture infrastructure, disrupt production, and cause loss of stock.
5. Sea level rise: As sea levels rise, low-lying aquaculture operations may become inundated, leading to production losses or complete farm failure.

Principle of climate-smart aquacuture

The main principles of climate-smart aquaculture include reducing greenhouse gas emissions, optimizing production efficiency, and enhancing the resilience of the ecosystem. In order to do that climate-smart aquaculture relies on several methods such as improving feed efficiency, selecting low-emission feed ingredients, and reducing the use of fossil fuels. It also aims to optimize production efficiency by reducing waste, improving water quality, and implementing integrated farming practices. Another key principle of climate-smart aquaculture is enhancing the resilience of the ecosystem. This includes measures such as monitoring water quality, managing fish and shellfish diseases, and reducing the impact of invasive species. By adopting climate-smart aquaculture practices, fish and shellfish farmers can improve the sustainability of their operations, increase their profitability, and contribute to a more sustainable global food system.

Examples of climate-smart aquaculture practices include integrated multi-trophic aquaculture (IMTA), which involves farming multiple species that complement each other in terms of nutrient cycling and waste management and recirculating aquaculture systems (RAS), which allows for more efficient water use and reduce waste discharge.

Current status of climate smart aquaculture in the world

Climate-smart aquaculture is gaining popularity and momentum around the world, as more countries and businesses recognize the need for sustainable seafood production that is resilient to the impacts of climate change. For example, the European Union has set ambitious targets

for sustainable seafood production, with a goal of increasing aquaculture production by 45% by 2030. Many countries in Europe are investing in RAS systems and other sustainable technologies to reduce the environmental impact of aquaculture. The United States and Canada are also investing in climate-smart aquaculture, with a particular focus on RAS systems and sustainable feed sources. The US National Oceanic and Atmospheric Administration has a "Sea Grant" program that provides funding for research and development in sustainable aquaculture practices. While aquaculture is still a relatively small industry in Africa, there is growing interest in climate-smart aquaculture as a way to provide food security and economic opportunities. Several countries in Africa are investing in sustainable aquaculture practices and developing their domestic aquaculture industries.

Current status of climate smart aquaculture in asia

Asia is the largest producer of aquaculture products in the world, and many countries in the region are adopting climate-smart practices. For example, China has invested heavily in RAS systems, and Japan is a leader in the development of land-based aquaculture.

Climate smart aquaculture is still a relatively new concept in India, but there is growing interest and investment in sustainable aquaculture practices. The use of sustainable feeds is a key component of climate smart aquaculture, and Indian aquaculture farmers have been shifting towards alternative feeds, such as plant-based protein and insect-based feeds, to reduce their reliance on fishmeal and fish oil, which are sourced from wild fish. Integrated farming systems, such as combining fish farming with rice cultivation, have been increasingly adopted to enhance the sustainability of aquaculture. This approach produces fish and provides valuable nutrients and organic matter to the rice paddies, reducing the need for chemical fertilizers. The Government of India has launched several initiatives to promote sustainable aquaculture practices. The National Fisheries Development Board (NFDB) is supporting research and development of sustainable aquaculture practices, while the National Bank for Agriculture and Rural Development (NABARD) is providing financial assistance to farmers for adopting climate-smart aquaculture practices. Certification programs like the Aquaculture Stewardship Council (ASC) are gaining traction in India. ASC certification ensures that the aquaculture practices used are environmentally sustainable and socially responsible.

Upcoming challenges for climate smart aquaculture

Climate-smart aquaculture has vast potential as it is designed to be environmentally sustainable, socially responsible, and economically viable while adapting to and mitigating climate change. However, there are several challenges that need to be addressed to achieve these goals:

1. Limited availability of suitable sites: Finding suitable sites for aquaculture is becoming increasingly difficult due to competing land use, pollution, and other environmental constraints.

2. Access to finance: The cost of developing climate-smart aquaculture can be high, and financing can be a challenge, especially for small-scale producers who may not have access to traditional lending institutions.
3. Technical capacity: Developing and managing climate-smart aquaculture requires technical knowledge and skills that may not be readily available in many areas.
4. Lack of infrastructure: Adequate infrastructure, such as roads, electricity, and water supply, is essential for successful aquaculture operations. However, many areas lack the necessary infrastructure to support aquaculture development.
5. Market access: Access to markets is essential for the success of aquaculture operations. However, many small-scale producers have limited access to markets, which can limit their ability to generate income and sustain their operations.
6. Regulatory frameworks: Clear and effective regulatory frameworks are needed to ensure that aquaculture operations are environmentally sustainable, socially responsible, and economically viable. However, in many areas, regulatory frameworks are inadequate or poorly enforced.

Addressing these challenges will require collaboration between governments, industry, and civil society to develop and implement policies and practices that promote sustainable and climate-smart aquaculture.

Future of climate smart aquaculture

The future of climate-smart aquaculture is promising, with many innovative technologies and practices being developed and implemented. Some of the key trends and developments in this area include the use of sustainable feed as one of the biggest challenges in aquaculture is finding sustainable feed sources that do not contribute to overfishing or deforestation. In the future, we are likely to see more use of alternative feeds such as insects, algae, and even by-products from other industries. Also, the adoption of recirculating aquaculture systems (RAS), Integration with renewable energy, genetic improvement, and selective breeding can reduce the need for antibiotics and other chemicals, making aquaculture more sustainable. Also, the use of big data and AI as data analytics and AI can help optimize production, reduce waste, and improve the overall efficiency of aquaculture operations. This can lead to more sustainable and profitable practices.

Conclusion

In Conclusion, climate-smart aquaculture is a rapidly growing field that aims to produce seafood sustainably and reduce the environmental impact of aquaculture. By adopting innovative technologies and sustainable practices, such as recirculating aquaculture systems, integrated farming, and sustainable feeds, we can produce more fish with fewer resources and reduce greenhouse gas emissions, nutrient discharge, and other environmental impacts. Climate-smart aquaculture also has the potential to provide economic opportunities and contribute to food security, particularly in developing countries. However, there are still many challenges to be

addressed, such as ensuring the availability and affordability of sustainable feeds and improving the social and economic performance of aquaculture farms. To fully realize the potential of climate smart aquaculture, continued research and investment are needed, as well as policies and incentives that support sustainable practices. By working together, governments, businesses, and stakeholders can create a more sustainable and resilient aquaculture industry that benefits both people and the planet.

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LEVERAGING CHATBOTS FOR SMART SUSTAINABLE FISHERIES AND AQUACULTURE

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Abstract

This article discusses the role of chatbots in the digital transformation of the fisheries and aquaculture sector. Chatbots are computer programs that interact with users using natural language and predefined algorithms. The chatbots use artificial intelligence and natural language processing to understand human speech or text and reply from a database. In fisheries, chatbots can be used for a variety of purposes such as providing information and assistance, gathering market intelligence, ensuring traceability and transparency, providing customer service, engaging with stakeholders, and providing training and education. They can also provide real-time information on weather conditions, sea state, and other environmental factors that can affect fishing operations, and can help with compliance with fishing regulations, catch and quota management, and stock assessment. Overall, chatbots can help to build sustainable fisheries and aquaculture by leveraging digitized data and technical advancements, including IoT, machine learning, data science, and AI. The article also discusses the history of chatbots and the types of chatbots based on response-generation methods. The importance of chatbots in different sectors is increasing because they are cheaper to make compared to other equipment and apps.

Keywords: Chatbots, Artificial Intelligence, Capture Fisheries, Culture Fisheries

Introduction

With the explosion of digitized data and technical advancements, ICT plays a critical role in achieving digital fisheries and aquaculture using digital devices and Artificial Intelligence (AI) to build sustainable fisheries and aquaculture. In the era of internet of things (IoT), machine learning, data science, and artificial intelligence (AI), chatbots have crucial roles to play in catalyzing the economic development and social well-being. Because, the chatbots are revolutionizing different sectors starting from day-to-day life to corporate business arenas. A study by Juniper Research in 2019 reported that retail sales resulting from chatbot-based interactions will reach $112 billion by 2023 which shows the importance of these technologies in the future. Basically, Bots or Chatbots refers to the computer programs or software applications that interacts with users using natural languages with the help of predefined set of

algorithms. It interacts with its users through instant speech or text through artificially created human language patterns. The main technology in creating chatbots are artificial intelligence and natural language processing. To make user interface more convenient, a sophisticated set of algorithms and machine languages are used to understand human speech or text and reply from the database. The chief purpose behind the development of chatbots are to create an easy Human Computer Interaction (HCI) to emulate chat communication between a human user and a computer, using natural language which help the users to obtain timely and efficient assistance or information directly by speaking, typing, and pointing to the chatbots. Different terms have been used for a chatbot such as: chatterbot, machine conversation system, virtual assistant, dialogue system, digital agent and the conversational interfaces. Chatbots that are used to uncover and share knowledge and expertise within a business more quickly, as well as dramatically minimize errors. Artificial intelligence techniques such as image moderation, natural language understanding (NLU), natural language generation (NLG), machine learning, and deep learning are used by these Intelligent Chatbots. Chatbots have a lot of potential in the fisheries and aquaculture sectors.

Genesis of Chatbots

The term "ChatterBot" was first coined by Michael Mauldin who created the first Verbot named Julia in 1994 to describe conversations. But the entry of chatbots dated back in 1960s which was introduced for entertainment purposes to mimic dialogs and entertain the users. ELIZA is considered as the first chatterbot in the history developed by Joseph Weizenbaum in 1966 to demonstrate the interaction between human and computer by asking questions and responding back with answers. The main idea behind developing ELIZA is the keyword matching. During the seventies and eighties, there were many research carried out and improved versions of chatbots had been developed. A rapid progress was noticed with the Introduction of graphical user interfaces, improvement of data-mining, machine-learning techniques, artificial intelligence, and processing tools the chatbots have become popular with many commercial applications. And recent years the voice driven assistants by technology giants are gaining momentum viz. Apple's Siri (2011), Microsoft's Cortana (2015), Amazon's Alexa (2015) and Google's new Assistant (2016). These advancement in the technologies and updates in the chatbots will be surely having a wide array of utilities in different sectors of the world. In India although the bots are introduced in several sectors but a full-fledged operation with complete automation are still on the way but soon the country will surely cope up with the technological advancement. The major reason for the increase in demand for chatbots is that it is cheaper to make compared to other equipment and apps.

Chatbots: Working Principles

The chatbots works to understand the queries from the user and generate relevant response to answer the queries. Basic chatbots scan the user input sentences for broad keywords, skim through their prepared list of replies, and respond with relevant answer. Modern chatbots, on the other hand, rely on artificial intelligence (AI) and natural language processing

(NLP) to identify intention of customer from the context of their input and respond appropriately. Basically, chatbots consist of 7 components viz.:

1. **Natural language processing**: Natural language processing (NLP) convert user text and speech into structured data to a machine language. NLP consists of the following processes:
   a) Tokenization/Lexical analysis: It is the process of breaking down a string of words into smaller "tokens" depending on their meaning and link to the rest of the sentence.
   b) Normalization/Syntactic analysis: is the process of checking words for typos and changing them into the standard form. For example, the word “tmrw” will be normalized into “tomorrow”.
   c) Entity recognition: the process of looking for keywords to identify the topic of the conversation.
   d) Semantic analysis: the process of inferring the meaning of a sentence by understanding the meaning of each word and its relation to the overall structure.

2. **Natural language understanding**: Natural language understanding (NLU) is a subfield of NLP which focuses on understanding the meaning of human speech by recognizing patterns in unstructured speech input. NLU solutions have 3 components: Dictionary to determine the meaning of a word Parser to determines if the syntax of the text conforms to the rules of the language Grammar rules to break down the input based on sentence structure and punctuation NLU enables chatbots to classify users’ intents and generate a response based on training data.
3. **Knowledge base:** A knowledge base is a library of information that the chatbot relies on to fetch the data used to respond to users. Knowledge bases differ based on business needs. For instance, the knowledge base of an e-commerce website chatbot will contain information about products, features, and prices, whereas a knowledge base of a healthcare chatbot will have information about physicians’ calendars, hospital opening hours, and pharmacy duties. Additionally, some chatbots are integrated with web scrapers to pull data from online resources and display it to users.
4. **Data storage:** Chatbot developers may choose to store conversations for customer service uses and bot training and testing purposes. Chatbot conversations can be stored in SQL form either on-premise or on a cloud.
5. **Dialog manager**: A dialog manager is the component responsible for the flow of the conversation between the user and the chatbot. It keeps a record of the interactions within one conversation in order to decide how to respond. For instance, if the user says “I want to order strawberry ice cream” and then within the conversation says “change my order to chocolate ice cream”, the dialog manager will enable the bot to detect the change from “strawberry” to “chocolate” and change the order accordingly.
6. **Natural language generation**: Natural language generation (NLG) is the process of transforming machine-produced structured data into human-readable text. After understanding users’ intent, NLG has 6 steps to generate a response:

i. Content determination: Filtering existing data in the knowledge base to choose what to include in the response
ii. Data interpretation: Understanding the patterns and answers available in the knowledge base
iii. Document planning: Structuring the answer in a narrative manner
iv. Sentence aggregation: Compiling the expressions and words for each sentence in the response
v. Grammaticalization: Applying grammar rules such as punctuation and spell check
vi. Language implementations: Inputting the data into language templates to ensure a natural representation of the response.

7. **User interfaces:** Conversational user interfaces are the front-end of a chatbot that enable the physical representation of the conversation. They are classified into text-based or voice-based assistants. And they can be integrated into different platforms, such as Facebook Messenger, WhatsApp, Slack, Google Teams, etc.

Types of Chatbots

Chatbots can be divided into six types based on the response-generation method namely;

1. **Menu/button based chatbots:** It is the most basic type of chatbots and these are glorified decision tree hierarchies presented to the user in the form of buttons similar to the automated phone menus. In many organizations, these chatbots are primarily employed to answer Frequently Asked Questions (FAQs). However, when it comes to delivering the user to the intended value, these chatbots are the slowest.
2. **Linguistic/Rule based chatbots:** This type of chatbots create conversational automation flows using if/then logic to generate responses based on predefined conditions and responses. Because they demand rigidity and specificity, these chatbots have limited customization capabilities, but they are dependable and less prone to go off the tracks.
3. **Keyword recognition-based chatbots:** Unlike menu-based chatbots, keyword recognition-based chatbots can listen to what users type and respond appropriately. To determine how to offer a suitable response to the user, these chatbots use customizable keywords and an AI application-Natural Language Processing (NLP). Furthermore, some AI-based chatbots improve themselves by using user data as additional training data to increase their knowledge bank and enhance their responses.
4. **Machine Learning chatbots:** Machine Learning (ML) and Artificial Intelligence (AI) are used by these chatbots to recall discussions with specific users in order to learn and evolve over time. Chatbots with contextual awareness, unlike keyword recognition-based bots, are smart enough to self-improve based on what users are asking for and how they are requesting it.
5. **Hybrid chatbots:** To understand users and generate responses, hybrid chatbots use both rules and natural language processing (NLP). The databases of these chatbots are easy to customize, but they have fewer conversational skills than AI-based chatbots. The hybrid chatbot model combines the simplicity of rules-based chatbots with the complexity of AI-bots to provide the best of both worlds.

6. **Voice bots:** With virtual assistants like Apple's Siri and Amazon's Alexa, voice bots have been on the increase for the last couple of years. With vernacular conversational interfaces, a voice-activated chatbot provides seamless interactions directly to the end customer.

The characteristics of chatbots are depicted in figure 1.

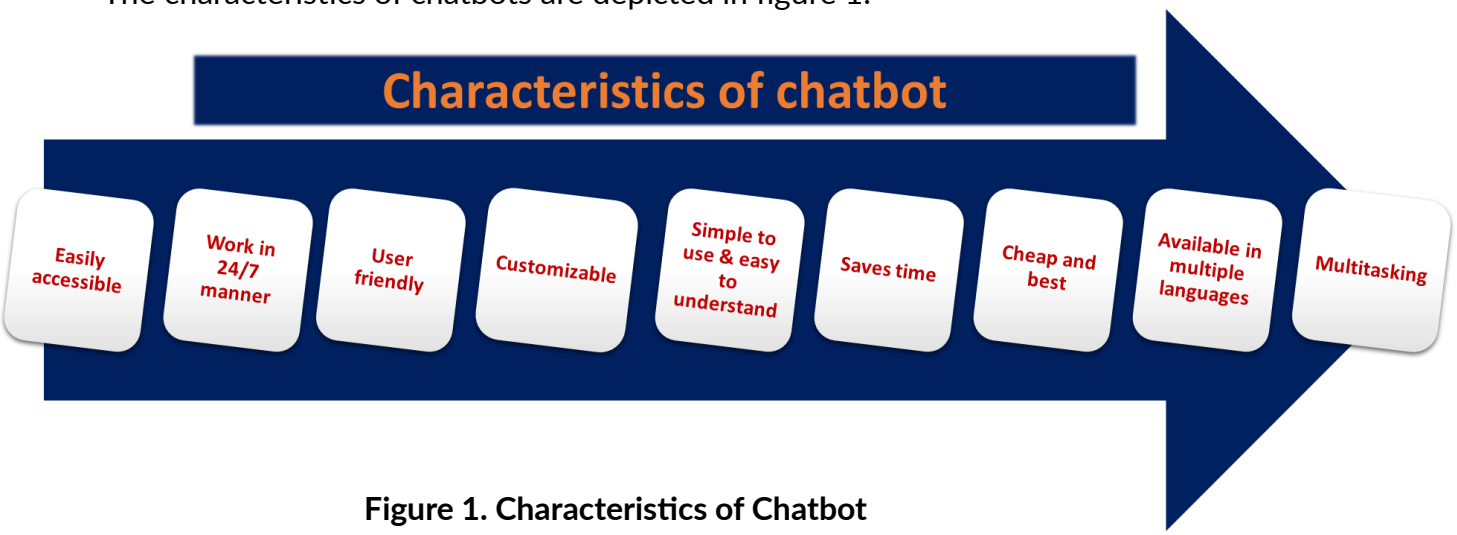

Figure 1. Characteristics of Chatbot

Scope of chatbots in fisheries

Fisheries and aquaculture that has been progressing over the years meeting the supply needs and contributing towards the global economy. The sector provides significant food security and economic growth and is projected to expand for feeding 9.6 billion human population by 2050, further ascertaining the significance of the sector. To cope with providing increased yields while maintaining sustainable fish populations, new technologies like Artificial Intelligence (AI) and Internet of Things (IoT) creates both new opportunities for information and data processing. Digital Platform based on AI and IoT, is aiming to change the current scenario of the sector. Fisheries and aquaculture with improved technology could well suit as the next feasible alternative for expanding production and thus meeting global demand and providing livelihood security. With the integration of chatbots with IoT and using AI and machine learning algorithms, the culture of high-end fish species can be improved by reducing the cost of production as it minimizes the labour requirement and increases the precision. Usually, chatbots are used for various functional purposes in dialog systems, including customer support or knowledge acquisition with the help of natural language processing systems. In fisheries and aquaculture which is a labor-intensive sector, chatbots can play this role with more precision & accuracy. Chatbots integrated with AI and automation can help in multiple fisheries activities like harvesting, processing, marketing, potential fishing zone alerts, supply chain management etc.

General Utilities of Chatbots in Fisheries

1. Information and assistance: Chatbots can provide quick and accurate answers to common questions about fisheries regulations, permits, and other related information. They can also assist with tasks such as filing reports and renewing licenses

2. Market intelligence: Chatbots can be used to gather real-time data on fish prices, market trends, and other information that can be used to optimize aquaculture and fishing operations and improve business decision-making
3. Traceability and transparency: Chatbots can be used to provide consumers with detailed information about the origin, species, and sustainability of fish products. They can also be used to trace fish products along the supply chain and ensure compliance with regulations
4. Customer service: Chatbots can be used to provide quick and efficient customer service, handling customer queries and complaints, and providing information on the availability of products
5. Stakeholder engagement: Chatbots can be used to engage with various stakeholders in the fisheries industry, including government agencies, fishing organizations, and conservation groups
6. Training and education: Chatbots can provide educational information and resources to assist fisher/fish farmer and other industry workers with training and professional development

Utilities of Chatbots in Capture Fisheries

1. Management and conservation of fish stocks: AI-powered models can help fishery managers to better understand and predict the dynamics of fish populations, including migration patterns, spawning seasons, and population growth rates. This information can be used to develop more effective conservation and management strategies for sustainable fishing
2. Monitoring and enforcement of fishing regulations: AI-powered technologies, such as satellite imagery and drone-based monitoring systems, can help to monitor and enforce fishing regulations, including detecting illegal, unreported, and unregulated (IUU) fishing activities more effectively
3. Improving the efficiency and sustainability of fishing operations: AI-powered technologies can help to optimize fishing operations by providing real-time data on weather conditions, sea state, and the location of fish populations, allowing fishermen to make more informed decisions and to reduce fuel consumption and bycatch
4. Traceability of fishing products: AI can also help to improve traceability in the seafood supply chain by using techniques such as image recognition to identify fish species and track products from the point of capture to the consumer. This can help to ensure that seafood is sustainably sourced and to combat IUU fishing
5. Fishing regulation compliance: Chatbots can provide information on fishing regulations, including catch limits, closed seasons, and restricted areas, and assist with compliance, such as filing reports and renewing licenses
6. Catch and quota management: Chatbots can be used to track and manage the number of fish caught by vessels and assist in adhering to quota set by the authorities.

Utilities of Chatbots in Culture Fisheries:

1. Farm management: Chatbots can be used to provide farmers with real-time data on water temperature, pH levels, dissolved oxygen levels, and other parameters that are critical for the

health and growth of aquatic organisms. They can also be used to control and monitor feeding systems, aeration, and other farm equipment

2. Smart disease detection and management: Chatbots can be trained to identify signs of disease and infection in aquatic organisms, track fish health, and to provide farmers with recommendations for treatment
3. Smart Feed management: In an aquaculture system, nearly 60% of the operational cost goes for feed. Hence, precision and accuracy in feeding can increase the profit. Chatbots can be used to assist farmers with feed formulation and management, by providing information on nutritional requirements, ingredients, and sourcing options. It plays a great role in reading the fishes through vibration-based sensor and acoustic signals so that the feed will be distributed more precisely and accurately
4. Smart aeration system: A smart aeration system using chatbots could be an innovative solution for managing and optimizing the aeration process in aquaculture ponds. The chatbot integrated with sensors and other monitoring equipment could act as a virtual assistant for farmers, providing real-time data and insights on the performance of aerators, as well as offering recommendations for adjusting aeration rates for improving efficiency and reducing energy consumption. It has a potential to improve the efficiency, reliability, and sustainability of aquaculture system, while also reducing operating costs and improving overall performance
5. Inventory & Supply chain management: Chatbots can be used to automate and streamline many aspects of the inventory and supply chain management process, from tracking inventory levels to ordering supplies and managing deliveries. Chatbots can enable organizations to check inventory levels. For example, bot can return the most current inventory numbers for a SKU. Customers and suppliers can also track the present status of the shipment by typing the delivery number. It is a useful solution for managing the complex logistics involved in the production and distribution of fish and fish products
6. Harvest planning: Chatbots can be used to assist farmers with planning and scheduling harvest dates, considering factors such as growth rate, market demand, and weather conditions
7. Resolving farmer queries: Farmers can chat with chatbots on their farm problems and get solutions. There are intelligent personal assistants such as Alexa, Siri, and Cortana currently working successfully in other sectors. Similar bots can be developed exclusively for aquaculture sector
8. Prediction and forecast: Based on historical data and predictive algorithms, chatbots can forecast changes in water quality, feed consumption, disease, growth rate and yield and alert farm managers to potential issues.

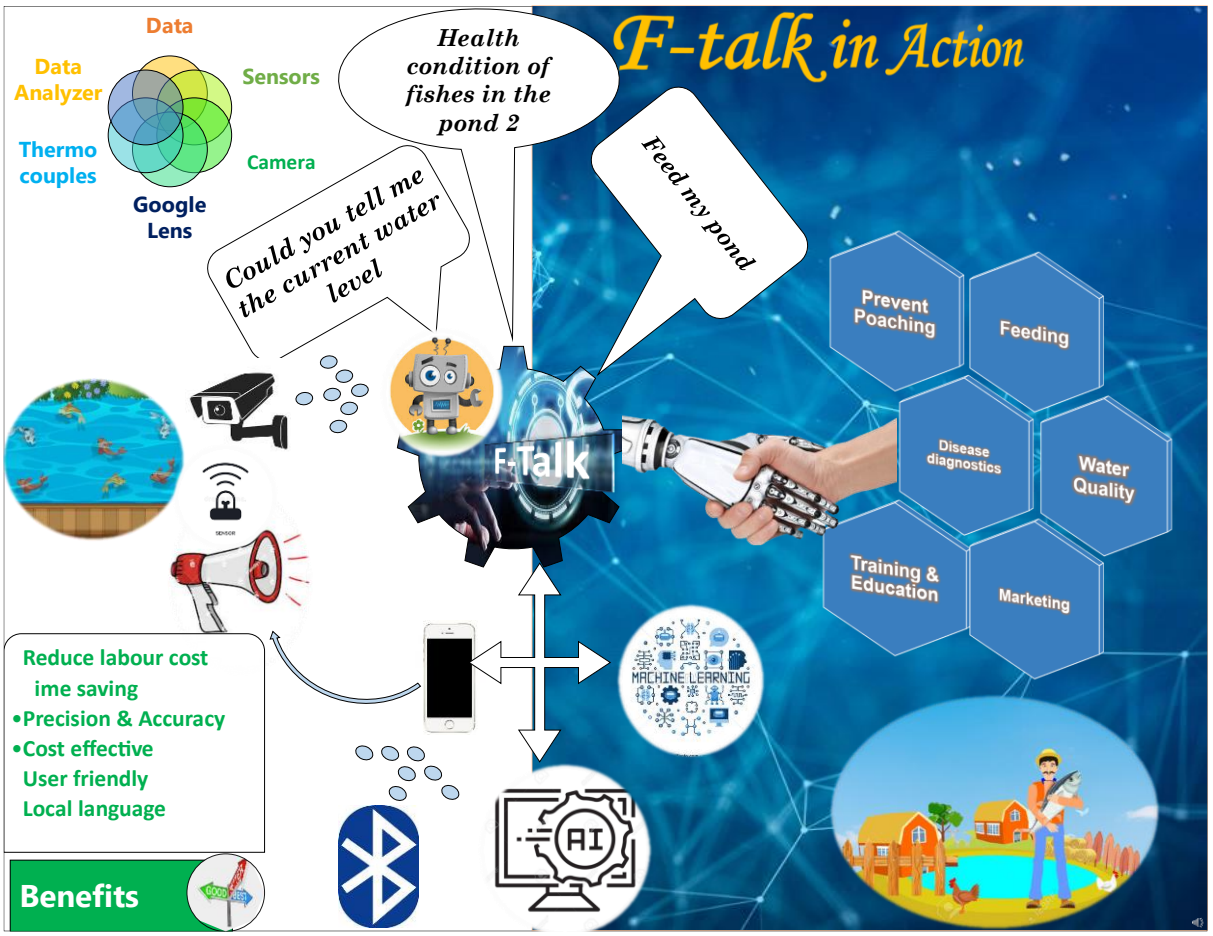

Figure 2. Conceptual framework on chatbot (F-talk) use in aquaculture

A conceptual framework on use of chat bot (F-talk) in aquaculture sector is depicted in figure 2. This chat bot works similarly like Amazon Alexa, Google assistant, Apple Siri etc. With the help of AI, machine learning, camera, sensors & other equipment's, F-talk chatbot can be used to monitor the farming activities like feeding, water exchange, medication etc. over voice which enables the farmer to save time and money. F-talk also provides helpful information like the farming information's, weather updates, market information's, answer questions and control your smart farm.

Way forward

The potential benefits of AI-powered chatbots in fisheries are clear, including improved resource allocation, increased labour productivity, and better environmental sustainability. However, there is a need for increased technical and educational spending in the fisheries and aquaculture industries to fully realize these benefits. To achieve this, it is important to popularize these technologies among multiple stakeholders and encourage collaboration and investment in the development of new chatbots exclusively for the fisheries sector. Integrating other technologies such as big data, artificial intelligence, and blockchain can further enhance the capabilities of chatbots in fisheries. In order to move forward, the industry needs to embrace

innovation and adaptation, just as it has done throughout history in response to changing needs and opportunities. Ultimately, the use of AI in fisheries and aquaculture is a necessary step forward in meeting the growing global demand for food and increasing food security in the face of climate change and other challenges. The integration of computer vision technology also presents a significant opportunity for fisheries and aquaculture. Computer vision can be used to monitor fish populations, detect disease outbreaks, and improve feed management. The increased availability and affordability of computer vision technology means that it is becoming an increasingly viable option for small-scale fisheries and aquaculture operations, as well as larger commercial operations. However, the adoption of these technologies will require some shifts in the industry. This may include changes in training and education programs to help farmers and other industry stakeholders develop the skills needed to effectively use these technologies. It may also require changes in regulatory frameworks to ensure that the use of these technologies is safe, sustainable, and ethical. In summary, the potential benefits of AI-powered chatbots in fisheries are significant, but the industry needs to invest in the development of these technologies and embrace collaboration and innovation to fully realize their potential. By doing so, fisheries and aquaculture operations can become more efficient, productive, and sustainable, while meeting the growing global demand for food and increasing food security in the face of climate change and other challenges.

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Breeding by design to tailor climate resilient varieties

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Abstract

Climate change leads to extreme calamities such as floods, drought and pest and disease intensification, which greatly affects agriculture. In order to combat these effects, climate resilient varieties capable of sustaining extreme climatic conditions needs to be developed. Firstly, QTLs/genomic regions controlling various traits of agronomic interest should be mapped and subsequently allelic variations of these superior traits should be deciphered. Knowing the contribution of all alleles to the phenotype will aid in predicting the phenotype based on genotypic results with higher accuracy. Best strategy to know the allelic variation and its effects are association mapping, which will extract all the possible allelic variation present in available genetic resources and use of marker haplotypes improves the information gained compared to single marker analysis. Breeding by design is the integrative approach to design superior varieties which combines all the favorable alleles of agronomic interest. Identified markers will aid in selection of precise recombination events which collates superior alleles of agronomic interest next to each other. Use of this methodology gives the privilege of excluding phenotyping in all the season as markers are intensively used. Extensive phenotyping can be done only with the eventually obtained superior varieties at the end of breeding programme. Overall, breeding by design forms the potential approach to develop climate resilient varieties which combines superior agronomic traits.

Keywords: Breeding by design, markers, phenotyping, superior agronomic traits

Introduction

Climate change greatly impacts agricultural production. Major consequences of climatic change comprises of extreme climatic phenomena such as flood, drought, cyclonic storms and intensification of diseases and pest attack. The most important reason behind the calamities like floods and drought is the rise of inter-annual variation of rainfall caused by climate change (Panda et al., 2023). As agriculture is mainly dependent on rainfall, any vagaries in it will lead in direct loss of quantity and quality of agricultural produce. To circumvent this problem, climate resilient varieties capable of performing better under adverse climate are necessary.

Marker assisted selection

Molecular breeding techniques come in rescue by aiding in the development of varieties. Application of markers in breeding accelerates selection by reducing the number of generations, improves the accuracy of selection and resource use efficiency. Marker assisted selection (MAS) such as marker assisted backcrossing utilizes linked marker data alongside phenotypic data to improve the efficiency. Marker assisted backcrossing is one of the widely used and successful MAS method, which involves transferring desirable traits to the adapted cultivars using molecular markers. The main disadvantage of this method is that it cannot develop completely new variety instead only rectifies one/few defects in the adapted variety.

To design climate resilient varieties, a combination of primary and secondary traits of agronomic interest should be improved. Advances in applied genomics and the possibility of generating large-scale marker data sets provide us with the tools to determine the genetic basis for all traits of agronomic importance. The foremost step in tailoring a variety is to identify QTLs/genomic regions controlling agronomically important traits. Mapping population for the traits of interest is pivotal in mapping studies. Various QTLs controlling agronomically important traits in different crops are enlisted in Table 1, which can be used for further introgression.

Table 1: List of QTLs controlling agronomically important trait

Crop	QTLs	Traits	References
Rice	*QRy2*, *QRy9*, *QRy9* *QRsf5*, *QRsf8*, *QRsf9*	Relative yield per plant Relative spikelet fertility	Yue *et al.* (2005)
Soybean	*qPH6*, *qPH19-2*	Plant height	Ren *et al.* (2005)
Maize	MQTL1.1	Drought stress	Sheoran *et al.* (2002)
	MQTL 1.2, MQTL 1.3	Heat stress	
	MQTL 1.4, MQTL 1.5	Salinity	

Many segregating populations such as F_2, Backcross population, DH, RILs forms the basic population for mapping. Among many mapping populations, best possible one is chosen based on the purpose, trait of interest and available resources. Mapping relies on deciphering the association of phenotype with the molecular marker nearest to the trait locus.

Prediction of phenotype based on the QTLs is difficult as entire allelic variations are not captured. Deciphering all the allelic variations underlying the agronomically relevant traits in the available genetic resources and assessment of their effects are essential. Biparental population can only identify biallelic variations and overall allelic variations for the trait cannot be entirely dissected. To serve this purpose, association mapping can be utilized, in which natural population is used to map all possible alleles controlling the trait considering historical recombination. Thereby it captures minor and major effect QTLs controlling the trait of interest. Instead of single/few markers, use of marker haplotype improves the efficiency and helps in complete capture of all the allelic variations and assesses the effect of these alleles. This data will aid in the development of highly saturated genome with markers which will lead to determine all allelic variation at any point in the genome there by leads to the prediction of

phenotype with genotyping results. QTL mapping for superior alleles and genetic dissection of germplasm resources for potential parental materials are two prerequisites in "Breeding by Design" (Gai *et al*., 2012).

Breeding by design

Breeding by design is a method developed by Peleman and van der Voort which utilizes humongous amount of genotypic and phenotypic data to tailor varieties *in silico*. Superior varieties with agronomically important traits controlled by favorable alleles can be designed. It is a crop design utilizing favorable/superior alleles from different genetic resources available in that species. Extensive knowledge on map positions of all loci controlling agronomic trait of interest, allelic variation and their effects on phenotype will enable to obtain combination of favorable alleles at all loci. This information would enable in selecting recombination events that align favorable alleles next to each other using flanking markers (Peleman *et al*., 2003). This also helps in reducing linkage drag and obtains recombination of superior alleles.

Detailed programme should be laid out to generate mosaic genotypes of superior alleles by crossing lines. Selection of parents and designing the crosses are the preliminary steps to initiate a breeding plan. After setting up a defined crossing plan, breeding by design can be used to identify superior progenies from the QTL allele information. Markers linked to QTLs will aid in identification of desirable recombination events.

Enormous amount of data generated through this process enables breeders to come up with more refined breeding strategies. Software tools and statistical methodologies have brought this strategy within reach. Phenotyping is difficult when evaluating for complex traits such as water logging tolerance, drought tolerance etc. Under such circumstances breeding by design method is much desirable as phenotypic selection can be omitted and focused on selection based on marker data. Extensive phenotypic evaluation should be done only for eventually obtained superior varieties at the end of the breeding programme.

Optimal utilization of natural plant genetic resources will create great opportunity to assess allelic variations, their effects and creates new possibilities to subsequently use these traits to develop new varieties. Breeding by design is the potential crop improvement methodology. Its potential can be compared to GMO strategies as it is resource efficient and is acceptance by public is not questioned.

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ZERO BUDGET NATURAL FARMING- A WAY TOWARDS SUSTAINABILITY IS MYTH OR REALITY!

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Abstract

The foundation of the Indian economy has always been agriculture. Today, more than half of the population relies on agriculture and related services for a living. To lessen the nation's reliance on food imports, India's agriculture has changed from subsistence to commercial cultivation. Additionally, it has changed to accommodate the varied nutritional needs of a population that is expanding quickly. Each year, it becomes increasingly difficult for agriculture to accomplish its main goal of feeding the globe due to several obstacles. Rural regions are home to the majority of the world's impoverished population, and agricultural development has been successful in rescuing rural households from poverty and famine. Zero Budget Natural farming (ZBNF) is essentially a form of organic farming that substitutes biological insecticides for fertilisers based on chemicals. The terms credit and costs are used in a budget. ZBNF's discoverer, Subhas Palekar, provided a number of ideas, guiding concepts, and techniques regarding ZBNF techniques. The most well-known ZBNF pillars- Jeevamrita, Beejamrita, Acchadana, and Whapsa. This article discussed the impact of a zero budget in great detail. Physical, chemical, and biological soil fertility is achieved through natural farming. The economy and potential for using organic fertilisers in the agriculture industry were also looked at.

Keywords: *Jeevamrita, Beejamrita, Acchadan, Zero-budget.*

Introduction

The name "Zero Budget Natural Farming" (ZBNF) refers to a farming technique in which agricultural plants are grown and harvested at no or minimal expense. A back to the basics agrarian movement is helping to increase the popularity of the ZBNF concept, which was first put forth by Maharashtrian agriculturalist Padmashri Subhash Palekar in the middle of the 1990s as an alternative to the Green Revolution's methods based on chemical fertilisers, pesticides, and intensive irrigation. Zero Budget Natural Farming (ZBNF) is an alternative low-input, climate-resilient farming method that has emerged in India and throughout the world to lower input costs and increase yields for farmers from locally available sources/inputs by doing away with chemical fertilisers and enhancing soil fertility (Bharucha et al., 2020). According to Palekar's research, the price of external inputs like

fertiliser and pesticides is the main driver of farmer debt and suicides globally. The high cost of production and high interest rates on credit might be greatly decreased by using traditional farming techniques. Zero Budget Natural Farming (ZBNF), also known as Zero Budget Spiritual Farming, is a recently popular agricultural practise among farmers as a result to the detrimental consequences of chemical farming (ZBSF). In southern India, especially in Karnataka, where it initially developed, it has achieved widespread success (Kumar. N, 2012). It is currently expanding so quickly and actively throughout India. As the name suggests, zero budget natural farming is a type of farming where there are no costs associated with cultivating and harvesting the plants. This indicates that farmers do not need to buy pesticides and fertilisers to ensure the crops grow healthily. The technique calls for using readily available natural biodegradable materials, contemporary technology, and traditional agricultural techniques based on scientific knowledge of ecology. The Food and Agriculture Organization of the United Nations claims that a zero-budget natural farming is an alternate way to substantially reduce farming expenses, which might help break the debt cycle of farmers throughout the world (Singh et al., 2018).

1.2 Palekar's six years of thorough investigation led to the following Conclusions:

1. The only manure from nearby Indian cows is useful for re-enriching the depleted soil. It is less effective to use the dung from Jersey and Holstein cows. You may also utilise the dung from bullocks or buffaloes if the local cows' dung runs out.
2. The black-coloured Kapila cow's dung and urine are thought to have supernatural properties.
3. Make sure the urine and cow dung are as old as feasible and that the manure is as fresh as possible to get the most use out of them.
4. Ten kilos of local cow dung must be applied monthly to an acre of soil. One cow may help fertilise 30 acres of land each month since they produce an average of 11 kg of manure every day.
5. Additives include urine, jaggery, and dicot flour.
6. The cow's manure is more helpful to revitalising the soil the less milk it produces (Babu, 2008).

ZBNF is symbiotic in nature and self-nourishing (Subash Palekar) (Palekar, 2014)

1. Fundamental Pillars of Zero Budget Natural Farming

Jeevamruta/Jivamrita/Jeevamrit- are used as preventative treatments for bacterial and fungal illnesses. This may be kept for a year and used for irrigation or foliar spray applications (Khadse and Rosset, 2019). It may be made in a 250-litre plastic barrel by adding 10 kg of fresh cow dung, 10 litres of native cow urine, 2 kilogramme of Jaggary, 2 kg of pulse flour (besan, chickpea flour), and 150 g of undisturbed forest or bund soil to 200 litres of water and properly mixed. Barrel should be kept in shade with a gunny bag, cotton fabric, or plastic mosquito nett covering them. Twice daily, in the morning and evening, stir the mixture for 5 to 10 minutes with a wooden stick. Jeevamrit can be used up to 12 days after preparation and is suitable for application on the ninth day. Other

beneficial microorganisms already present in the soil are attracted to and stimulated by the Jeevamrit culture combination (Khadse and Rosset, 2019). One acre of land requires 200 litres of Jeevamrit. Use irrigation water or a 10% foliar spray to apply once every two months.

Beejamrit/Beejamruta/Bijamrita- For treating seed, seedlings, and young planting material, use beejamrit. Young roots can be protected from fungus, soil-borne illnesses, and seed-borne illnesses with its help. It may be prepared by hanging 5 kg of locally produced fresh cow dung in 20 litres of water for 12 hours after being wrapped in a cloth and taped together. Take one litre of water, add 50 grammes of lime to it, and let it sit overnight. To remove material, squeeze this bundle of cow dung three times in water. Stir the mixture well before adding the soil from the unaltered bunds or forest. 5 litres of local cow pee should be added along with the lime water, and the mixture should be well-stirred. The seeds can be treated using Beejamrit. Any crop's seeds are mixed with bijamrita, let too dry in the shade, and then sown. Leguminous crop seeds are simply dipped and immediately dried. Bijamrita, like Jivamrita, has certain helpful bacteria that are useful for plant protection as well as for promoting plant growth and development (Rao et al. 2022).

Mulching or Achadana- The process of mulching involves adding cover crops, dried leaves, or agricultural residue to the top soil. It prevents soil erosion, enhances soil aeration, maintains soil moisture, boosts soil water retention capacity, promotes soil fauna, improves soil nutritional status, and inhibits weed development (Smith et al., 2020).

Whapasa / Water vapour- When both air and water molecules are present in the soil, the situation is referred to as whapasa. In order for plants to grow and develop properly, the soil must have adequate aeration. It increases soil aeration, which raises humus content, soil structure, and good water holding capacity, all of which are best for agricultural plant development, especially during dry spells (Khan et al. 2022).

2. Other Practices followed under Natural Farming-

Crop rotation and intercropping- Intercropping is the simultaneous cultivation of two or more distinct crops on the same plot of land. It leads to greater solar radiation gathering, better use of land and other resources, less evaporation and erosion, etc. In the event that their primary crop fails, it aids farmers in increasing their revenue or ensuring their survival. Cropping system diversification is another crucial ZBNF technique because it disrupts pest and disease habitats and prevents their accumulation.

Plant Defence- When pest and disease outbreaks occur, only zero budget natural farming is allowed to apply bio-pesticides (such as "Neemastra," "Agniastra," "Bramhastra," etc.) to prevent the plants from reaching economic harm levels. Aphids, jassids, mealy bugs, white flies, and other insects that are airborne as well as soil- and seed-borne illnesses and pests are effectively controlled by them.

Cow Dung- Only native Indian cows' (Bos indicus) faeces are advised for use in ZBNF activities since these animals have 3-5 crores more beneficial bacteria than foreign breeds (Kumar et al. 2020). According to Palekar, foreign breeds' faeces contain a lot of dangerous bacteria, fungi, and other diseases whereas Indian breeds are effective for crop

cultivation. 30 acres of land may be farmed by one breed of indigenous cattle from the area. Therefore, proponents of ZBNF advise farmers to use the dung and urine of their native Indian cows for ZBNF and those of foreign breeds for the production of biogas or fuel rather than combining the faeces of Indian and foreign bovine breeds.

3. Plans and policies of the government for ZBNF

Through the National Agricultural Development Plan and the committed programmes of the traditional agricultural development plan, India's legislature will advance natural farming in the country from 2015 to 2016. By 2024, Andhra Pradesh hopes to be the first state in India to adopt only natural farming, according to a plan that was launched in 2018. By converting 60 lakh farmers in the state to ZBNF practises, it seeks to cultivate 80 lakh hectares of land chemically. Government has set up institution for Natural farming such as National Centre for Organic and Natural Farming is a nodal organization for promotion of organic farming under INM Division, Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India under Soil Health Management component of National Mission on Sustainable Agriculture (NMSA). NCOF came into force in 2004, for implementing National Project on Organic Farming (NPOF) along with its Regional Centres. National Centre for Organic Farming has been renamed as National Centre for Organic and Natural Farming (NCONF), Ghaziabad in March 2022 with five Regional Centres for Organic and Natural Farming (RCONFs) located at

Regional Centre	Zone
Ghaziabad	North Zone
Bengaluru	South Zone
Bhubaneshwar	East Zone
Nagpur	West and Central
Imphal	North East zone

The revised mandate of National Centre for Organic and Natural Farming (NCONF) will be as under: -

1) Management and oversight of NCONF's Office for National and Regional Centers

2) Building the ability of stakeholders to promote chemical-free agriculture systems including organic, natural, and regenerative farming across the nation.

3) To serve as a national knowledge repository for different organic and biological fertilisers and to evaluate market demand, supply, and the nation's production units' capacity for such organic and biological inputs.

4) To serve as a national information repository for sustainable natural, organic, and other chemical-free agricultural systems, best practises, and natural and organic farming success stories.

5) To fulfil the requirements of the Fertilizer Control Order, 1985 by acting as the nodal quality control laboratory for the examination of bio-fertilizers and organic fertilisers (FCO).
6) To create criteria and procedures for assessing different organic agriculture inputs.
7) To provide infrastructure for agrochemical residue testing, training, screening, monitoring, and quality evaluation of organic and natural farming goods.
8) To create, maintain, and update a nationwide database of organic and natural farming producers, processors, input factories, and farmers that implement these practises.

4. Natural farming with no budget and farmer income

The primary attribute of zero budget natural farming is that it has no production costs and requires no initial input purchases from farmers.

1) In comparison to traditional farming techniques, zero budget natural farming used just 10% of the water that was used by the former.
2) It encourages the usage of an indigenous Indian breed of cow on 30 acres of land, enabling farmers to generate profits earlier than anticipated.
3) According to Palekar, one may earn Rs. 6 lakh per acre in irrigated regions and Rs. 1.5 lakh in non-irrigated areas with Zero Budget Farming.
4) It is stated that Zero Budget Natural Farming is appropriate for all types of crops since it covers all agroclimatic regions.
5) Farmers can profit from higher yields in the first year alone. Since farmers don't need to take out loans to acquire any farming supplies, zero budget farming is also thought to relieve some of their financial burden.
6) Farmers should anticipate to make more money per acre, and there may be fewer villagers moving to cities.

Criticism faced by Zero Budget Natural Farming

In the scientific world, the idea of Zero Budget Natural Farming is not widely received. Scientists from the National Academy of Agricultural Sciences noted that there is no scientific support for the practises utilised in zero budget farming, hence India cannot rely on it. Contrary to what the name would imply, the farming method does require a minimal amount of input. Compared to the breeds now in use, maintaining the native cow breed is challenging. The crops grown by Zero Budget Natural Farming will face another obstacle to organic certification, which might make it impossible to sell the products to organic companies.

Advantages and Disadvantages of Zero Budget Natural Farming

Advantages	Disadvantages
• Natural farming with no budget lowers the initial investment for farmers, the revenue of farmers naturally rises. • Cow dung raises the soil's value and the soil ecosystem becomes better. • It is readily accessible locally and packed with nutrients. • Cow dung bacteria break down organic substances in soil to create soil nutrient for plants. It used less water and power.	• This kind of farming is practised in limited regions of India. • This farming practise is under discussion and evaluation involves little scientific data. • It is a very unclear and uncertain form of farming. • This agricultural method is employed in very few places. • Certification system is yet to be developed

5. Conclusion

Zero-budget farming is both economical and ecologically beneficial. Costs for seeds, fertiliser, and plant-protection chemicals are reduced as a result. Crop leftovers are consistently retained, which aids in preserving the soil's health. The control of pests and illnesses is another important aspect of low-budget natural farming crop production methods. There is no evidence to refute the assertion that ZBNF has been developed with a highly positive mindset to serve the agricultural community, despite the controversies and opponents' points of view. It has been successful in reviving a number of small-scale farmers around the country. Prior to making a recommendation, the claim must first be thoroughly evaluated or validated scientifically. For this, several studies conducted by neutral, independent organisations such to examine ZBNF's effects on the health of the soil, land, and environment, the socioeconomic condition of farmers, and the nation's food security, multi-locational trials by impartial, independent agencies like ICAR are desperately needed.

How to Move Forward: A few state governments in our nation started to endorse this idea. The government of Andhra Pradesh has unveiled a number of programmes to help 3000 farmers adopt ZBNF. NITI Aayog is one of the leading advocates of the ZBNF approach. The Andhra Pradesh Government's experience is also being closely watched to determine whether or not ZBNF needs more public financing assistance. The ZBNF method, used by some basmati and wheat farmers in India, is also being

studied by the Indian Council of Agricultural Research, which is assessing its effects on productivity, economics, and soil health, including soil organic carbon and soil fertility. If found to be effective, an institutional mechanism will be set up to spread the technology among farmers. ZBNF, an ecologically sustainable farming approach, is without a doubt the best way to accomplish chemical-free farming, but more research must be done to convincingly demonstrate that ZBNF is a great way to increase farmers' incomes and ensure the nation's food security. Our farmers have been engaged in natural farming for a long time, but they are gradually adopting the most recent technology, which has improved both the position of our nation's food security and the revenue of farmers. Before applying techniques that have not been scientifically established, it is thus required to undertake the appropriate trials for a suitable amount of time.

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International Year of Millets

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Abstract

In India 86 per cent of farmers are small and marginal who are facing financial insecurities. Indian women and children are facing malnutrition and hidden hunger problems. In the upcoming decades, the world agriculture production could decrease due to climate change. To address these major ongoing issues, the role of millets as a smart food is inevitable. The United Nations has designated 2023 as the 'International Year of Millets'. This was suggested by the Indian Government. Millets are in the news these days because of their high nutritional value and other benefits. Due to their high nutritional value, millets are referred to as "nutri-cereals". Millets are nutritionally superior, having a low glycemic index, having low carbon and water footprint. The government has hiked the Minimum Support Price of Millets, which came as a big price incentive for farmers. Government should also make provisions to introduce millets in the Public Distribution System to increase the demand for millets and run mid-day meal scheme in schools on large scale basis to eliminate the hidden hunger among the children. Government should also provide incentives and subsidies to new start-ups to promote millet based value-added food production.

Keywords: Public Distribution System, Minimum Support Price, Nutri-cereals

Introduction

The United Nations has designated 2023 as the 'International Year of Millets'. This was suggested by the Indian Government. Millets are in the news these days because of their high nutritional value and other benefits. Due to their high nutritional value, millets are referred to as **"nutri-cereals".** In addition to a plethora of health benefits, millets are also good for the environment with low water & input requirement. Despite being a staple food source for hundreds of millions of people worldwide, its production is declining now.

In light of this, the Indian government suggested that 2023 be designated as the International Year of Millets. It was endorsed by Members of FAO Governing Bodies and at the 75th Session of the UN General Assembly (UNGA). More than 70 nations voted in favour of the resolution creating the International Year of Millets.

#IYM2023 will be an opportunity to raise awareness of, and direct policy attention to the nutritional and health benefits of millets and their suitability for cultivation under adverse

and changing climatic conditions. The Year will also promote the sustainable production of millets, while highlighting their potential to provide new sustainable market opportunities for producers and consumers.

International Year of Millets

The objectives of declaring 2023 as the International Year of Millets are as follows:

- Elevate awareness of the contribution of millets to food security and nutrition.
- Inspire stakeholders on improving sustainable production and quality of millets.
- Draw focus on enhanced investment in research and development and extension services to achieve the other two aims.

What are Millets?

- Millets are a group of cereal grains belonging to the Poaceae family, sometimes referred to as the grass family.
- Millets were among the earliest plants to be domesticated; they have been a traditional food source for hundreds of millions of people in Sub-Saharan Africa and Asia for more than 7,000 years, and they are today grown all over the world.
- The most popular millet variety is pearl millet, an important crop in Africa and India. Other significant crop species include finger millet, proso millet, and foxtail millet.
- They are considered ancient grains and are consumed as food for humans, animals, and birds.
- India is the world's leading producer of millets.

Geographical Conditions for Millet Growth

- Millets are often cultivated in tropical and subtropical climates up to an altitude of 2,100 m.
- It is a heat-loving plant, and 8 to 10°C is the minimum temperature needed for germination.
- For optimum growth and good crop production, a mean temperature range of 26–29°c is ideal.
- It is cultivated in areas with 500–900mm of annual rainfall.
- Kodo Millet has a high-water requirement and thrives under conditions of 50–60 cm of rainfall.
- Soil: Millet can handle a certain level of alkalinity and adapts well to a variety of soils, from extremely poor to highly rich.

- Alluvial, loamy, and sandy soils with adequate drainage are the best types of soil.
- Kodo millet may be produced on rocky and gravelly soil, such as those found in hilly areas.

Significance of Millets

- ***Nutritionally Superior:***
  - Millets are less expensive and nutritionally superior to wheat & rice owing to their high protein, fibre, vitamins and minerals like iron content.
  - Millets are also rich in calcium and magnesium. For example, Ragi is known to have the highest calcium content among all the food grains.
  - Millets can provide nutritional security and act as a shield against nutritional deficiency, especially among children and women. Its high iron content can fight high prevalence of anaemia in India women of reproductive age and infants.
- ***Gluten-free a low Glycemic Index:***
  - Millets can help tackle lifestyle problems and health challenges such as obesity and diabetes as they are gluten-free and have a low glycemic index (a relative ranking of carbohydrate in foods according to how they affect blood glucose levels).
- ***Super Crop at Growing:***
  - Millets are Photo-insensitive (do not require a specific photoperiod for flowering) & resilient to climate change. Millets can grow on poor soils with little or no external inputs.
  - Millets are less water consuming and are capable of growing under drought conditions, under non-irrigated conditions even in very low rainfall regimes.
  - Millets have low carbon and water footprint (rice plants need at least 3 times more water to grow in comparison to millets).
- ***Initiatives Taken by Government:***

  Initiative for Nutritional Security through Intensive Millet Promotion (INSIMP)
  - **Increase in Minimum Support Price (MSP):** The government has hiked the Minimum Support Price of Millets, which came as a big price incentive for farmers. Further, to provide a steady market for the produce, the government has included millets in the public distribution system.
  - **Input Support:** The government has introduced provision of seed kits and inputs to farmers, building value chains through Farmer Producer Organisations and supporting the marketability of millets.

Conclusion

The timely need to educate consumers, producers, actors throughout the value chain, and decision-makers on the variety, nutritional value, and ecological benefits of millets can strengthen connections between the food, agriculture industries and conservation. Against this backdrop, the decision to declare 2023 the 'International Year of Millets' assumes great significance and is bound to have a positive impact on the awareness, production, and consumption of millets throughout the world.

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Rainbow trout-A Highflier of Nutrient Ensuring Food Security and Human Health

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Abstract

Rainbow trout *(Oncorhynchus mykiss)* is the most remunerative aquaculture species in the Indian Himalayas, and its contribution towards livelihood and food security in the coldwater regions is gradually expanding. They are primarily cultured in earthen or concrete flow-through raceways or ponds in a conventional manner. At present, the total annual production of rainbow trout in India is said to be 2500 tonnes, with an average unit productivity of 10-15 kg/m3. Compound feed for the private and public trout farms comes from the state fisheries department operated feed mills in Jammu and Kashmir and Himachal Pradesh, as well as few commercial feed manufacturers in recent times. As trout aquaculture is heavily dependent on the quality of the feed given, the composition and physical properties of the feed, mode of preparation and application strategy is the key to success. For humans, fish and fishery products are found to have an important dietary role owing to its high nutritional quality. Food security can be defined as secure access to enough food at all times for everyone. A person needs adequate health, good environment, and food for their survival, which is therefore closely linked to the economic and social health of a nation, society and individual. Rainbow trout ensures food security due to its faster growth, hardiness, high flesh quality (Figure. 2.) and market value. O. mykiss has gained significance as one of the most important cultured fish in the world and at present aquaculture of the fish is more popular in its introduced form rather than native form.

Keywords: Food security, nutrition, rainbow trout, amino acid, fatty acid, vitamin, mineral.

Nutritive superiority of rainbow trout

The content of essential amino acids, long chain polyunsaturated fatty acids (n-3 and n-6 PUFA) and minerals are high in fish products, whereas the cholesterol content of these products is low. Due to the reported health benefits of long-chain omega-3 fatty acids (eicosapentaenoic acid - EPA, 20:5n-3 and docosahexaenoic acid DHA, 22:6n-3) in preventing various chronic diseases like coronary heart disease, rheumatoid arthritis, neurotic disorders in infants, cancer, hyper-glycemia, psoriasis, multiple sclerosis and inflammation, people are getting attracted towards a diet rich in fish. It is important to note that long-chain n-3 PUFAS cannot be synthesized readily by human beings and hence required through diet, more in case of developing foetus, infants, adolescents and pregnant and lactating women.

(A) Amino acid profile

About a kilogram of trout fillet contains sufficient amino acids to produce 33% of the recommended daily intake (RDI) for proteins. It also provides 8% of recommended daily intake for fats and gives 118 calories. Protein content of rainbow trout is of high quality and comprises balanced amino acid composition with high levels of proline (96.37mg/g crude protein), aspartic acid (85.23mg/g crude protein), tyrosine (83.84mg/g crude protein) glycine (69.87 mg/g crude protein), serine (66.63mg/g crude protein), arginine (65.26mg/g crude protein), isoleucine (64.56mg/g crude protein) and tryptophan (61.63mg/g crude protein). It has been reported that amino acids in rainbow trout has high nutritive value along with other health benefits such as blood cholesterol reduction, anti- mutagenicitiy, prevention of coronary heart disease and treatment of obesity. Reports on the cytotoxic activity of aspartic acid, glutamine, proline, glycine and leucine against cancereous cells have also been presented by researchers. Various other amino acids like glycine, alanine, arginine, serine, isoleucine and phenylalanine together with proline has a very important role in re-growth and tissue healing Amino acids such as tyrosine, methionine, histidine, lysine and tryptophan are known to serve as antioxidants. **Sabetian *et al.* (2012)** reported seventeen different amino acids in rainbow trout meat, 8 essential amino acids and 9 non-essential amino acids. Essential amino acids were isoleucine. Phenylalanine, lysine, leucine, threonine, tryptophan and valine. Rainbow trout meat includes all of the essential amino acids. It clearly indicates that rainbow trout (O. mykiss) fillet has well-balanced and high quality protein in the respect of essential and non-essential amino acids ratio. **Dezhabad *et al.* (2012)** studied amino acid profile of rainbow trout (mean + SEM, 452 + 15.5 g) and found that glutamic acid (3.60g/100g), is present in the highest amount among all the amino acids. The amount of essential amino acids in rainbow trout was found to be 9.98g/100g.

The most abundant amino acid (g/100g muscle) was proline followed by aspartic acid, tyrosine, glycine, serine, arginine, isoleucine, tryptophan, alanine, threonine, leucine, glutamic acid, valine, lysine, methionine, phenylalanine and histidine. Free amino acids like glutamic acid, aspartic acid and glycine impart flavor to fish **(Capillas and Moral 2004**). Glutamine is known for its ability in functioning of various organ systems. **Christina *et al.* (1999).** Table.1. Nutrient requirements of rainbow trout.

(B) Proximate composition profile

Yesilayer & Genc (2013) documented that Oncorhynchus mykiss contain protein (17.9%), lipid (4.3%), moisture (75.6%) and ash (2.1%). The results of proximate analysis of muscle tissue of cultured O. mykiss by **Mashaii *et al.* (2012)** indicated that it contained moisture 74.18 - 77.05 %, crude protein 17.05 18.53 %, total fat 2.35 - 5.13 %, ash 1.31 - 1.7 % and carbohydrates 0.51 - 2.32 %. **Celik *et al.* (2008)** analyzed the proximate composition of rainbow trouts (O. mykiss) and found that it contains 71.65% moisture, 19.60% protein, 4.43% lipid and 1.36% ash. Ozden (2005) found similar levels of moisture (76.23 %), protein (18.57%), lipid (3.71%) and ash (1.47%) for rainbow trout. Their results indicated that rainbow trout has a good content of unsaturated fatty acids, protein and minerals. (Figure 1.)

(C) Mineral profile

The cooked fish provides recommended daily intake of 3% calcium, 7% iron and copper, 4% magnesium and zinc, 19% phosphorus, 6% potassium, and 2% sodium. Among various minerals, potassium (1447.0mg/100g) is found in higher concentration (1447 mg/g) followed by Ca (359.33 mg/100g), Na (208 mg/100g), Fe (5.17 mg/100g), Zn (1.7 mg/100g), Se (1.6 mg/100g) and Mn (0.1 mg/100g). Minerals like potassium is important in maintaining optimal bone density, in checking Rickets and Osteomalacia during early development and later growing stages. This indicates that rainbow trout is beneficial for human health. The primary roles of essential minerals include maintaining of colloidal system and regulation of acid- base balance. Minerals are also essential for the functioning of various hormones, enzymes and enzymes activators. Proper amount of iron in diet is very helpful in preventing a major health problem called anemia. Good amount of iron (5.17mg/100g is present in the muscle of rainbow trout and zinc level found in rainbow trout was 1.79mg/100g of muscle which is enough to maintain fitness in humans. Zinc deficiency can cause several health hazards such as growth retardation, immunological abnormalities, appetite loss and skin changes. Selenium act as an antioxidant and its content in rainbow trout was found to be 1.66 mg/100g which is higher than those in sea bass (0.227 mg/ kg), turbot (0.473mg/kg), flounder (0.371 mg/kg). Apart from this, selenium has a very important role in providing protection against cancer.

(D) Fatty acid profile

Muscle and liver of O. mykiss which intake high levels of fat has higher omega 3 levels. Various factors like environment, diet, species, maturity period, sex, size, age of the fish, rearing conditions and geographical location may cause significant variation in the total lipid and fatty acid composition of fish. Fatty acids can be used as biomarkers. Pollutants can be accumulated in fatty tissues and therefore bioaccumulation can be accessed through lipid/fatty acid analysis Fatty acid proves to be a useful mean for distinguishing fish and invertebrate species despite of individual variation within species. EPA and DHA have important role in prevention of human coronary artery diseases. The American Heart Association recommends approximately 1.0 g/day of EPA and DHA, or two servings of fatty fish per week for diminishing the mortality rates from coronary heart disease. **Sarma *et al.* (2011)** reported that among the different fatty acids, total monounsaturated fatty acids (MUFA) were the highest (35.88%) in rainbow trout followed by saturated (34.51%) and polyunsaturated fatty acids (31.39%). The most abundant fatty acid in rainbow trout was palmitic acid (63.28%) followed by stearic acid (22%). Oleic (67.69 %) and palmitoleic acid (22.85 %) were the dominant monounsaturated fatty acids. Among PUFAs, linoleic acid (C18:2n-6) DHA (C22:6 n-3), linolenic acid (C18:3n-3). arachidonic acid (C20:4n-6) and EPA (C20:5 n-3) were found at 43.93%, 20.52%, 15.42% 7.65% and 7.45% respectively. DHA and EPA have an important function in human nutrition. Linoleic acid has a role in the biosynthesis of arachidonic acid. Arachidonic acid is the precursor of prostaglandins and thromboxanes that are helpful in blood cloting and healing process. It also has a role in growth process. In the same study it was reported that DHA, arachidonic acid and EPA accounted for

20.52%, 7.65%, and 7.45% of total PUFAs in muscle of rainbow trout. The long chain omega-3 and omega-6 fatty acids which are commonly called PUFA and their ratios (omega-3/omega-6) are also important for the fatty acids composition. Thus rainbow trout has been suggested as a key component for a healthy diet for humans. **Stancheva *et al.* (2010)** investigated that the trout (12.30 g/100 g raw tissue) could be designated as a high fat fish. Oleic acid (40%) was the highest among PUFA followed by palmitoleic acid (16.12%). In analyzed fish samples, the total sum of omega-6 acids was 25.44% of total fatty acids and the sum of omega-3 fatty acids was 15.64% of total fatty acids. The predominant fatty acids in the group of PUFAS were linoleic acid (5.81 %). A precursor with omega-6 and omega-3 series in the diet of fish assists them to synthesize any type of fatty acids. The fatty acids present in their dietary lipids of fishes highly influenced the fatty acids composition of tissue lipids in fish. The predominant fatty acids in rainbow were found to be palmitic acid, oleic acid, and docosahexaenoic acid (DHA, C22:6n-3). Linoleic acid (18:2n-6) was found to be in the range of 7.0- 1 1.9g per 100g lipid. The major n-6 polyunsaturated fatty acid (PUFA) in Rainbow trout was Linoleic acid which was responsible for the n-3 per n-6 PUFA ratios of 1.8-3.6. However, DHA content in rainbow trout varied from 13.8 to 27.8g per 100g lipid and EPA varied from 4.2 to 7.3g per 100g lipid.

(E) Vitamins profile

Fish contain both water soluble and fat soluble vitamins. Vitamin A in aquatic animals is stored in hepatic region which is comparable to that of mammals and birds. Fatty or semi fatty fishes are excellent source of Vitamin D, the concentration of which is in the range of 500-3000 IU/100g. Vitamin E occurs as Tocopherol in the fish meat. Vitamin K, also called the anti-haemorrhage factor, is also present in fish. Vitamin B complex can also be obtained by fish. Though, Vitamin E is present in fish only minute quantities; a typical value is 12 ug/100 g. But the studied samples had often notable amounts of Vitamin E. Frozen storage had significantly reduced the vitamin E content of fish. The samples of O. mykiss stored at -12°C compared with -18°C show more Vitamin E loss. The reduction of off-flavors and lipid oxidation in fish fillets can be managed by increasing the concentration of Vitamin E from 300 to 1,500mg/kg (which contain 30% lipid). The edible portion of rainbow trout contains highest amounts of alpha-tocopherol followed by retinol and cholecalciferol.

Table .1. Nutrient requirements of rainbow trout

Protien/Energy components		Non-Energy components	
Amino acids (% dry diet)		***Fat soluble vitamins***	
Arginine	1.5-2	A (mg/kg)	0.75
Histidine	0.8	D (ug/kg)	40
Isoleucine	0.8-1.1	E (mg/kg)	50
Leucine	1.5	K (mg/kg)	not determined
		Water soluble vitamins (mg/kg)	
		Thiamin	1

Lysine	1.8-2.4	Riboflavin	4
Methionine + cystine	1.1-1.4	Vitamin B_6	3
Phenylalanine + tyrosine	1.8	Pantothenic acid	20
Threonine	0.8-1.1	Niacin	10
Tryptophan	0.3	Biotin	0.15
Valine	1.3	Folic acid	1
Fatty acids (%)		Choline	800-1000
18:3 n-3	0.7-1.0	Myoinositol	300
n-3 LC-PUFA	0.4-0.5	Vitamin C	20-50
18:2 n-6	1.0	***Macro -minerals (%)***	
Digestible energy (kJ/g)	17.6	Calcium	not required
Protein (%)	40-50	Phosphorus	0.7
Lipid (%)	16-24	Magnesium	0.05
		Trace elements (mg/kg)	
		Copper	3
		Iodine	1.1
		Manganese	12
		Selenium	0.15
		Zinc	15

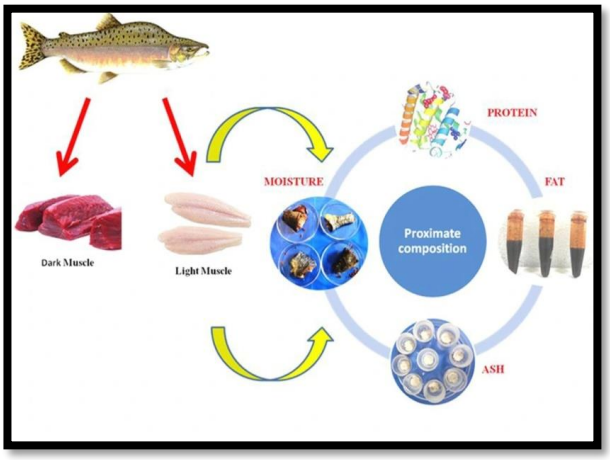

Figure1. Proximate analysis

Figure.2. Flesh quality

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Weed Management Under Changing Climate

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Abstract

Long-term modifications to weather and temperature patterns are referred to as climate change. Weeds are unwanted and undesirable plants that negatively impact human welfare by interfering with the use of land and water resources. They may alternatively be called "plants in the wrong place." Weed management is an important component of plant protection improving the production potential of crops. It includes management of the weeds in a way that the crop sustains its production potential without being harmed by the weeds. Weed management is done through the mechanical, cultural and chemical means. Weed control strategies may become more challenging as a result of the major impact that climate change has on weed growth and spread. The distribution range of weed species can be expanded by changes in air temperature and rainfall patterns, which can also change how they affect crops. In addition, changed climatic factors like temperature and precipitation have a direct impact on the species makeup of arable weeds. To effectively control weed populations, it is essential to comprehend how climate change affects weed growth and spread. To effectively manage weeds under changing climate conditions, integrated weed management approaches can be used. Integrated weed management involves combining different agronomic practices to manage weeds, reducing reliance on any one weed control technique. In addition to integrated weed management approaches, the use of climate-resistant crops and cultivars can also be an effective strategy for weed management. Adoption of precision agriculture techniques is another strategy that can be used for weed management under changing climate conditions.

Introduction

Long-term modifications to weather and temperature patterns are referred to as climate change. Such changes may occur naturally as a result of variations in the sun's activity or significant volcanic eruptions. However, since the 1800s, human activity has been the primary cause of climate change, mostly as a result of the combustion of fossil fuels like coal, oil, and gas. By trapping the sun's heat and boosting temperatures, greenhouse gas emissions produced by burning fossil fuels behave as a blanket over the planet. Methane and carbon dioxide are the principal greenhouse gases responsible for climate change. These result from using fuels like petrol or coal to heat buildings, respectively. Carbon dioxide can also be released during land clearing and forest logging. Agriculture, oil and gas operations are major sources of methane emissions. Energy, industry, transport, buildings, agriculture and land use are among the main sectors causing greenhouse gases.

Climate scientists have demonstrated that over the past 200 years, almost all of the global warming has been caused by people. The earth is warming faster than it has in at least

the last two thousand years due to greenhouse gases caused by human activities like the ones outlined above. The Earth's surface is currently around 1.1°C warmer on average than it was in the late 1800s (before to the industrial revolution) and warmer than it has ever been in the previous 100,000 years. The last four decades have been warmer than any decade since 1850, with the most recent decade (2011–2020) being the warmest on record. Many believe that rising temperatures are the main effect of climate change. But the story doesn't start with the temperature increase. Changes in one place might have an impact on changes in all other areas since the Earth is a system in which everything is interconnected. Intense droughts, water scarcity, destructive fires, rising sea levels, flooding, melting polar ice, catastrophic storms, and a decline in biodiversity are currently some of the effects of climate change.

The production and delivery of food in the modern era contribute significantly to greenhouse gas emissions: 14% of all greenhouse gas emissions are directly attributable to agriculture, and decisions on how to manage rural land more broadly have an even greater impact. Currently, deforestation contributes an additional 18% of emissions. A historical perspective must be taken into account in this situation: According to Dr. Rattan Lal, a professor of soil science at Ohio State University, over the past 150 years, 476 billions of tonnes of carbon have been released from farmland soils as a result of improper farming and grazing practises, as opposed to 'only' 270 Gt released from the burning of fossil fuels. 200 to 250 Gt of carbon have been lost from the biosphere as a whole in the previous 300 years, according to a more generally used estimate. Regardless of the precise number, the loss of forests, biodiversity, faster soil erosion, loss of soil organic matter, salinization of soils, pollution of coastal waters, and

acidification of the oceans have all contributed to these losses in "living carbon potential." Climate change can also be severely exacerbated by changes in land use. The atmosphere may contain more carbon as a result of large-scale changes like deforestation, soil erosion, or machine-intensive farming techniques. Agriculture and the natural environment are both impacted by soil erosion brought on by water, wind, and tillage. One of the most significant (and maybe the least well-known) effects is soil loss of today's environmental problems.

Weeds are unwanted and undesirable plants that negatively impact human welfare by interfering with the use of land and water resources. They may alternatively be called "plants in the wrong place." In agricultural lands, woodlands, aquatic systems, etc., weeds compete with the desirable and helpful plants, and they pose a serious problem in non-cropped areas like industrial sites, road and rail lines, air fields, landscape plantings, water tanks, and waterways, etc. All land and water resources must be managed for weeds to be controlled, but agriculture is most affected. Weeds generate more losses to agriculture than any other type of agricultural pest. Weeds account for 45% of the entire yearly loss in agricultural produce, followed by insects 30%, diseases 20%, and other pests. Weed management is an important component of plant protection improving the production potential of crops. It includes management of the weeds in a way that the crop sustains its production potential without being harmed by the weeds. Weed management is done through the mechanical, cultural and chemical means.

The impact of climate change on weed management techniques

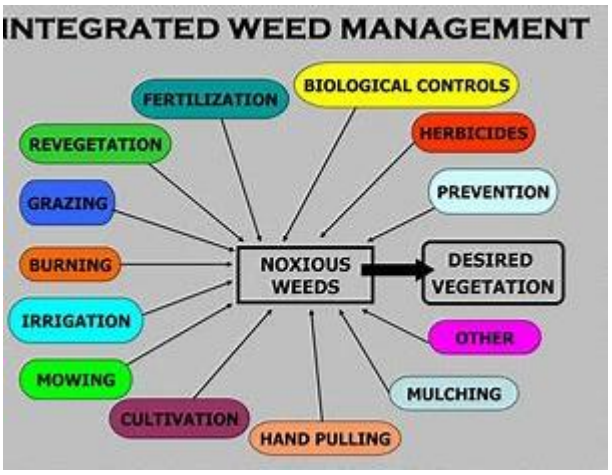
Weed control strategies may become more challenging as a result of the major impact that climate change has on weed growth and spread. The distribution range of weed species can be expanded by changes in air temperature and rainfall patterns, which can also change how they affect crops. In addition, changed climatic factors like temperature and precipitation have a direct impact on the species makeup of arable weeds. To effectively control weed populations, it is essential to comprehend how climate change affects weed growth and spread.

Extreme weather conditions like floods and droughts can have a big impact on weed control strategies. These occurrences may change the timing and efficacy of weed control measures, making weed population management more challenging. Long-lasting droughts, for instance, can promote weed development and lessen the efficiency of herbicides, but flooding can obliterate weed seeds and make weed management more difficult. Therefore, when creating weed management methods, it's crucial to take the potential effects of extreme weather events into account.

To adapt to the changing climate and effectively manage weed populations, it is necessary to develop adaptation strategies. These strategies may include increased landscape connectivity to support biodiversity, which can present opportunities for increased weed invasion. Additionally, agronomic practices may need to be adapted to account for changes in temperature and precipitation patterns. While the impacts of climate change on weed management are still unclear in many cases, it is important to consider the potential impact of climate change on weed populations and develop effective strategies to manage them.

Strategies for weed management under changing climate conditions

Integrated weed management



Climate change has significant impacts on weed communities, making weed management more challenging. To effectively manage weeds under changing climate conditions, integrated weed management approaches can be used. Integrated weed management involves combining different agronomic practices to manage weeds, reducing reliance on any one weed control technique. This approach has been found to be effective in achieving sustainable weed control. Regularly controlling weeds in areas such as fence lines, field edges, irrigation ditches, and roadsides can also reduce weed seed dispersal into fields. Therefore, adopting integrated weed management approaches can help farmers manage weeds in a changing climate and maintain crop productivity.

Use of Climate-resistant cultivars

In addition to integrated weed management approaches, the use of climate-resistant crops and cultivars can also be an effective strategy for weed management. Climate-resistant crops and cultivars are adapted to highly variable, extreme climate conditions and can withstand the challenges posed by changing climate conditions. However, it is important to note that weeds may also adapt to changing climate conditions, potentially reducing the efficacy of weed management techniques. Therefore, it is crucial to continually monitor and adapt weed management strategies to ensure their effectiveness.

Precision Farming

Adoption of precision agriculture techniques is another strategy that can be used for weed management under changing climate conditions. Precision agriculture involves using technology to monitor and adjust crop management practices based on real-time data. This approach can improve the accuracy and efficiency of weed management practices, reducing the use of herbicides and other inputs. Experts expect the adoption rates of precision agriculture techniques to almost double in the next decade. Therefore, introducing or developing precision agriculture techniques can be an effective strategy for weed management under changing climate conditions.

Area Coverage

Agri Business Management
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Agricultural Economics
Agricultural Engineering
Agronomyc
Dairy
Entomology
Environmental Science
Fisheries
Food Processing &
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Technology
Genetics & Plant Breeding
Horticulture
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