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Role of Native Strains of Rhizobium in Pulse Production

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The world today faces a tough challenge, for ensuring food security with provision of balance diet for everyone. Overcoming hunger and malnutrition in the 21stcentury means increasing food quantity as well as quality, while making sure we produce food sustainably and efficiently. Pulses have been a secondary choice, mostly confined to the rainfed ecology. Over the last four years, the on-going National Food Security Mission (NFSM) has been converged with multi– pronged strategies to enhance the production and productivity of pulses in the country. Thanks to government's comprehensive policy, there has been a leap frog in production since 2016-17, where in 'Five Year Roadmap' was adopted. The production of pulses to the tune of 25.23 million tonnes during 2017-18 is close to self-sufficiency in pulses (Annual report on pulses, 2016-2017). The country is now confident of meeting the projected demand of 35 million tonnes by 2030. An improvement in pulses production technology can reduce the cost of production and ensure higher productivity resulting in affordable prices to consumers.

To achieve this target the consumption of nitrogenous fertilizer is increasing., Between 1960 and 2009 global fertilizer consumption increased tenfold by 10.8 Mg (metric tons) per year to 113 million Mg per year. Nitrogenous fertilizer applied through inorganic sources results in increase in yield but simultaneously promote sizable nitrogen loss, while addition of nitrogen through biological processes enhance more soil available nitrogen as well as crop yield. The biofertilizers, when applied as seed or soil inoculants, multiply and participate in nutrient cycling and leads to crop productivity. Generally, 60% to 90% of the total applied fertilizer is lost and the remaining 10% - 40% is taken up by plants. Hence biofertilizers can be important component of integrated nutrient management systems for to sustaining agricultural productivity and a healthy environment. The application of N fertilizer quickly inhibits both the formation and N fixation activity of nodules. Many agricultural soils contain a high level of residual N which limits legume nodulation and N fixation. Furthermore, farmers frequently apply N fertilizer to the seed bed of legumes to help with crop establishment. This practice is likely to inhibit legume nodulation until the soil N supply has been depleted. Therefore, understanding of how legumes sense and signal their N supply status to regulate nodulation is of fundamental importance for developing more sustainable agriculture using lower inputs of chemical fertilizer. In leguminous plants, bioinoculation with *Rhizobium* as a substitute for costly N fertilizer contributed for crop growth stimulation. Thus emphasis should be given for establishment of efficient symbiotic N_2 – fixation in legume. Different field studies indicated that the legume seed, inoculated with *Rhizobium* culture increased the crop yield from 20-80% and thebeneficial effect on the subsequent crop yield also observed significantly. On a global basis these symbiotic association between legume and *Rhizobium* may reduce about 70 million tons of atmospheric nitrogen to ammonia per annum.

The utilization of native *Rhizobium* as inoculants promote ecologically sustainable management of agricultural ecosystem and enhance legume production due to their growth promoting traits and adaptability to soil and environmental stress. Furthermore, crop production using inoculants could be cheaper and more affordable to the resource – poor smallholder farmer. The ability of native strains to interact positively with the resident soil micro biota and their adaptability to the local agroecological climatic conditions often elucidates their superior performance over the exotic commercial strains. The present study contributes to the understanding of the native rhizobial population diversity nodulation. This will contribute to the development of future course of action for cultivation technology so as to enhance production and improve grain quality of such an important pulse crop. The study also provides important information regarding the nodulation patterns, presence or absence of root modulating bacteria in agricultural soils and suitable strains for augmentation in rhizobia deficient soils.

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Papaya Mealy bug (*Paracoccus marginatus*) Management in Horticultural Crops

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Introduction

Mealybugs (coccids) belong to the insect order homoptera and the super family coccoidea. They cause direct damage by way of feeding and in addition they also inject toxic saliva, excrete honey dew paving way for the growth of sooty mould fungus giving an ugly look resulting in poor quality of the produce. It also causes yellowing of leaves and malformation of affected portions due to salivary infection. They also cause indirect damage by way of spreading many viral diseases by acting as vector. The presence of red ants causes the nuisance while harvesting fruits/nuts in mango, coconut, guava, citrus, cotton, ornamentals, flower and medicinal crops etc. The honey dew also causes the sooty mould due to capnodium growth and it reduces the photosynthesis (Vijay and Suresh, 2013).

Of the known 35 families under Coccoidea, 20 families are recognized only in India of which, pseudococcidae is widely prevalent (Williams, 2004). However, at times mealy bug infestation may occur within the vegetative shoot apex and may be extremely difficult to detect. This ability of mealybugs to form dense colonies particularly with in the shoot apex often makes chemical control of this pest quite difficult.

Among the various coccids *Phenacoccus solenopsis* (solenopsis mealybug) has been recorded causing economic damage to many crops. Now a days it cause recent outbreak of many crops. In India, losses have been reported for cotton, bhendi, gingelly, sunflower, brinjal, chrysanthemum, marigold and tuberose (Suresh and Mohanasundaram, 1996). Its reducing yields 50 to 100 per cent. The other mealy bugs are *Maconeliococcus hirsutus* (Green) (Grapevine mealybug), *Phenacoccus solani* (Solanum mealy bug), *Phenacoccus madeirensis* (Green) (Maderia mealybug), *Nipaecoccus viridis* (Green) (lebbeck mealybug), *Coccidohystrix insolita* (Green) (Brinjal mealybug), *Dysmicoccus brev*ipes (Ckll.) (Pine apple mealybug), *Rastrococcus iceryoides* (Green) (Icerya mealy bug), *Paracoccus marginatus* (Ckll.) (Pappaya mealybug) and *Planococcus citri* (Risso) (Citrus mealybug) cause a severe damage by reducing the photosynthesis of the plant due to honeydew secretion and sooty mould attack in agricultural and horticultural crops (Ben-Dov, 1994). Among them papaya mealy bug cause serious damage in horticultural crops due to polyphagous in nature.

Morphology

Mealy bugs are white to pink in colour and measure 3-4 mm in length. *Paracoccus marginatus* adult female body oval, somewhat rounded in lateral view; dark green almost black; 9-segmented antennae; legs red; covered by thin, white, mealy wax, with dark dorso submedial bare spots on intersegmental areas of thorax and abdomen, these areas forming 1 pair of dark longitudinal lines on dorsum considerably in size of 4.5 mm length and 3.45 mm wide. Ovisac well developed ventrally; with 18 pairs of lateral wax filaments, posterior pairs longest, up to ¼ th length of the body.

Biology

Reproduction is mostly parthenogentically. The mature female lays eggs in an egg sac of white wax, usually clusters on the twigs, branches, or bark of the host plant but sometimes on the plants leaves and terminal ends, egg sac contain as many as 600 eggs majority of female resulting in explosive outbreak due to shortened life cycle and higher reproductive rate. Egg is creamy white in colour, slender in shape, varying from 0.3-0.4 mm in length. Eggs development takes between 3 and 9 days. Eggs hatch into nymphs called crawlers and are very mobile. In appearance, three nymphal instars in female and four in males which lasts for 22-25 days. The last instar of the male is an inactive stage with wing buds within a cocoon of mealy wax. Individual mealy bugs may take as long as 30 days to grow through all the nymphal stages under normal conditions.

Mode of Transport

Non-infected plants can be infected from infected plants as juvenile mealybugs can crawl from an infected plant to another plant. Small 'Crawlers' are readily transported by wind, rain, birds, ants, clothing and vehicle and may settle in cracks and crevices, usually on new plants. The wax, which sticks to each egg, also facilitates passive transport by equipments, animals or people. The female mealybug is not active and unable to fly. In fact, humans are great friends helping in transport of mealy bugs.

Symptoms of attack

Infested growing points become stunted and swollen. Heavy clustering of mealybugs can be seen under leaf surface giving the appearance of a thick mat with waxy secretion. They excrete copius amount of honey dew that attracts ants help in development of black sooty mould which inhibits the plants ability to manufacture food. Both nymphs and adults suck the sap from leaves causing withering and yellowing of leaves. It severely affects the stems due to development of dense colonies. In guava serious attack results in retarded growth and yellowing of leaves by the way of feeds on soft tissues and injects saliva that causes curling and contortion of leaves.

Fig. 1: Papaya mealybug infestation in Guava

Management

Mealybug control often involves the control of care taking ants that are important for the proper development of mealybugs. Management of mealybugs, it is important to know the species present as management programs for the various mealybugs may differ. Plant protection products are of limited effectiveness against mealybugs because of their habit of hiding in crevices and the presence of wax covering of its body. Management of mealybugs involves the following tactics.

Cultural control

Crop residues in previously infested fields should be removes and burnt. Crop residues and grass left in the field may harbor mealybug populations which may invade the new crop. Field borders should be free from weeds and debris that may support mealybugs between plantings. Weeds also provide alternate weed host for ant populations between periods where mealybug infestations are small. Removal of alternate weed host *viz., Parthenium hysterophorus. Abutilon indicum. Triaunthema postulacastrum, Amaranthus viridis etc.* in and nearby crop. Can't grow the same families of crop in and nearby field.

Biological control

Biological control is considered the most effective long-term solution to the mealybug infestation because the parasites nd predators are self-perpetuating, persist even when the mealybug is at low population densities, and they continue to attack the mealybugs, keeping populations below economic injury levels. Biological control by release of natural enemies has proved very successful. Among the biological control agent's introduction of *Cryptolaemus montrouzieri*, *Anagrus pseudococci*, *Harmonia, Leptomastix dactylopii, Scymnus coccivora*, *Hypoapsis sp*., *Verticillium leccanii* and *Beauveria bassiana* are effective in managing the infestation. *Hypoaspis* is a small mite that feeds on crawlers. The entire population of mealybugs may not be suppressed by coccinellids. There is a need to integrate other control tactics along with conservation and augmentation of coccinellids to manage mealybugs. *C. montrouzieri* is commonly called the australian lady bird beetle or the mealybug destroyer. The larvae feed on mealybug eggs and young crawlers. The life span of the *C. montrouzieri* is two months. During this time, the mealybug destroyer can lay up to 400 eggs. It is capable of eating 3,000- 5,000 mealybugs in various life stages. Biological control in grapes includes one to three releases of *C. montrouzieri* at 10 per tree or @ 5,000 beetles /ha, two times in a season especially during august – September and December-January.

Release of imported encyrtid parasitoids such as *Acerophagous papayae, Anagyrus loecki* and *Pseudoleptomastix mexicana* is being currently used to manage papaya mealybug. Among them *A. papayae* was successfully eliminated the papaya mealy bug population. It attacks the mealy bugs in two ways. The adult wasp punctures a mealybug and extracts fluid from the wound. The female wasp feeds on the fluid of the drying mealybug, which provides nutrient to wasp's eggs for development. Fully developed adult wasp comes out of the mummy of the mealybug by cutting a circular hole in the end of the mummy and crawls out.

Chemical control

Any insecticides used against mealybugs should be carefully selected to avoid injury to natural enemies. Pest monitoring: Crawler is the most susceptible stage to identify the crawlers in earlier stage easily to manage the insecticides under field conditions. Plant protection products are of limited effectiveness against mealybug because of its habit of hiding in crevices, and the waxy covering of its body. Most granular insecticides are ineffective, therefore systemic insecticides are used to control heavy infestations. Spray profenophos 50 EC @ 2 ml/l (or) dichlorvos 76 EC @ 2 ml/ l (or) acephate 75 SP @ 2g/lit, chlorpyriphos 20 EC @ 2ml/l (or) Imidacloprid 17.8 SL @ 0.5 ml/l (or) Thiamethoxam 25 WDG @ 0.5 ml/l (or) FORS @ 25g/l (or) Buprofezin 25 SC @ 0.75 ml/l (or) Azadirachtin 1% @ 2ml/l (or) dimethoate 30 EC @ 2ml/litre of water at 15 days interval.

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Decline of Entomofauna- An Overview

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Introduction

Insects are hexapod invertebrates and the largest group within the phylum Arthropoda belongs to class Insecta. Insects excel all other animals in both diversity and magnitude and it would be impossible to come across in any other group of animals the type of intimate relations the insects exhibit with men and his belongings. Globally, an average estimate suggested that, there are around 5.5 million insect species, of which about 1 million insect species were found and described. Hence, over 50 per cent of all described eukaryotes are insects. Now a day's various factors and human interventions lead to continuous reduction or defaunation of vertebrate and invertebrate species which ultimately ends in global, local or functional extinction of animal populations or species from ecological communities. In 2017, atleast 66 insect species extinctions had been recorded in the previous 500 years, which generally occurred on oceanic islands. According to Bayoa and Wyckhuys (2019), huge rates of decline may lead to the extinction of 40 per cent of the world's insect species over the next few decades. Noteworthy, biomass losses occurred between 98% and 78% for ground-foraging and canopy-dwelling arthropods over a 36 year period, with respective annual losses between 2.7% and 2.2% in rainforest (Listera and Garcia, 2018). Among the Holometabola insects, several economically important orders such as Lepidoptera, Hymenoptera and Coleopteran already lost a gradual proportion of species in terrestrial ecosystems. Among the insects, hymenopterans are considered as the largest and diversified beneficial insects with nearly 2.5 lakh described species and important group of pollinating insects. Hallmann *et al*. (2017), estimated a seasonal decline of 76% and mid-summer decline of 82% in flying insect biomass over the past 27 years. Reason behind that decline as apparent regardless of habitat type, while changes in weather, land use, and habitat characteristics.

Pollinators decline

Pollinators play an important role in maintaining plant diversity by transferring pollen from the anthers to the stigma of the flower, enabling the flower to set seeds and fruits. Though this process is carried out by a variety of animals, insects like bees, flies, butterflies, moths, wasps, beetles and some other insect orders encompass the majority of pollinating species. It is estimated that worldwide, 35 per cent of crop production is mainly dependent on insect pollination. Further it has also been reported that about 15 per cent of the hundred principal crops are pollinated by domestic bees, while at least 80 per cent by the wild bees. A dramatic decline of upto 50 per cent of bee colonies have been suffered worldwide. According to Gallai *et al*. (2009), more than 40 % of honey bees have been disappeared during the last 25 years in India. However, this is only reliable data on decline of honey bees in India. In United Kingdom (UK) and Netherlands, 71 per cent of butterfly species have decreased and 3.4 per cent wild flowering plants became extinct over the past 20 years. The highest net loss compared to native flowering plants (28% decrease in 40 years) and birds (54% decrease over 20 years) (Pannure, 2016).

Defaunation

Change in habitat is the main and large proportion factor for insect declination (49.7%) followed by pollution (25.8%), biological factors (17.6%) and climate change (6.9%) triggering the losses for insect declination (Bayoa and Wyckhuys, 2019).

Habitat change

Habitat change is an immediate consequence of human activities. In the past and recent centuries increasing amounts of land is being transformed to provide dwellings, facilitate transportation, urbanization (11%), agricultural conversion (24%) and deforestation (9%) at the expense of various natural habitats. However, majority of insect declines occurred, when agricultural practices were moved from traditional to intensive and industrial scale production brought about by the Green Revolution during 1960s. Agricultural intensification includes stream channel, draining of wetlands, modification of floodplains and removal of riparian canopy, resulting in homogenization of water stream microhabitats and alteration of aquatic insect communities. In recent decades, urbanization has taken over agricultural land across the globe, causing the disappearance of natural vegetation or biodiversity with the replacement of artificial habitats.

Pollution

Pollution is the second major factor of arthropod declines. Sources of pollution include fertilizers (10%) and synthetic pesticides (13%) used in agricultural production, sewage and landfill leachates from urbanized areas and industrial chemicals. In terms of toxicity, pesticides are considered as the most toxic to all insects and herbicides reduce the biodiversity of vegetation within the crops and in surrounding areas through drift effects that indirectly affects the arthropod species. Apart from pesticides, the introduction of synthetic fertilizers also plays a major role of pollinator losses. Aquatic species such as dragonflies have also been affected by the eutrophication of surface waters, caused by excessive fertilizer use in rural areas. The impact of industrial chemicals (*e.g.*, heavy metals, persistent halogenated hydrocarbons) lead to global declination of stoneflies, mayflies and caddisflies which can be imputed to man-made pollutants discharged into streams and rivers

Biological factors

Parasites and pathogens are involved in the collapse of honeybee colonies. The global spread of mite (*Varroa destructor*) and the small hive beetle (*Aethina tumida*) pose a threat for the apicultural industry because they can also transmit viral diseases. The human-assisted introduction of exotic species for biological control can also contribute to a decline of endemic insects through processes such as competitive displacement. The introduction of invasive plants had negative effects leading to a reduction in the overall abundance, diversity and fitness of different organisms, including insects.

Climate change

Global warming is one of the important causes for insects and bees decline, sometimes it has a positive impact on tropical and subtropical insects as they can be easily adopted and develop in temperate regions by changing their favorable habitats. In contrast, insects of tropical regions have more narrow thermoregulatory adaptations and get acclimatized to increased temperature. Hence, global warming has increased the population of certain butterflies in northern Europe (Bayoa and Wyckhuys, 2019). Global warming has certainly reduced the range of some dragonflies, stoneflies, bumblebees and some pollinators.

Impacts on ecosystem

Pollination**:** Insect pollination is needed for 75 per cent of all the world's food crops which nearly contributed to 10 per cent of the economic value of the world's entire food supply. In the last 30 years, the abundance of pollinators appears to be strongly declining globally. Therefore, reduced pollination further reduces seed production and population regeneration.

Economic impact*:* The losses of pollinators were found to vary widely across crop categories. Globally, vulnerability was high for fruits (23%), vegetables (12%), nuts (31%), edible oil crops (16%) and beverages and narcotic crops (39%), lower for pulses (4%), spices (3%) and nil for cereals, tuber and sugar crops (Gallai *et al*., 2009).

Nutrient cycling: The diversity of invertebrate communities, have higher impacts on decomposition rates and nutrient cycling water quality**.** Defaunation has its impact on global declines in amphibian populations with increased algae and detritus biomass which reduced the nitrogen uptake and whole stream respiration.

Human Health: Defaunation will affect human health in many other ways, *via* reductions in ecosystem goods and services including pharmaceutical compounds, livestock species, biocontrol agents, food resources and disease regulation.

Conclusion

Pollution and habitat change are the important factors of arthropod declines. In particular, the crop production practices such as synthetic pesticides are a major factor of insect losses in recent times. Unless a change in our ways of crop production practices and using inputs, insects will reach a phase of extinction in a few decades. Habitat restoration is the only way of mitigation and limit reduction of entomofauna. Some of the tactics like 'ecological engineering' used to maintain and conserve pollinators and insects with their natural enemies. Hence, in cultivation practices, using biological control agents instead of pesticides management, we can avoid the decline of non-targeted species and at the same time cost effective management can also be attained. On reducing the contamination by limiting the use of toxic chemicals we can maintain aquatic insect biodiversity. There is still a gap between insect species abundance and diversity of basic information. Unless this gap is bridged, the clear-cut results regarding the disappearance of insects and nontarget species could not be predicted in India.

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Crop Insurance: Need, Advantages and Nature in India

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Need of Crop Insurance

Every year, in one a part of India or the opposite food crops are suffering from natural calamities, "Crop yield instability is that the normal condition and agriculture continues still to be which the farmer's fortunes are exposed, is practically the same as before. In fact, good years and bad years, wet weather and drought or floods and frost, low yields and bumper crops are to be expected in mixed succession. The total loss due to natural calamities (like flood, drought and plant diseases) is estimated as high as Rs. 1,000 crores every year. The man behind the plough has to be assured that he will be compensated for such loss in crops. Otherwise, he cannot be drawn into the campaign to increase productivity of land under his plough,"

The need for shielding the farmer from natural hazards arises for the subsequent reasons:

(1) In our country Nature has always been unthinkable. "She is unpredictably generous to one state and disconcertingly bad-tempered to another. This fickleness of weather in several parts of the country upsets the whole agricultural economy, and makes one part bountiful, while the other starves."

(2) Droughts, floods, locusts, plant diseases, weeds have always been a big enemy to our agriculture by destroying crops and thereby reducing farmers' income.

(3) Majority of the holdings are tiny, from which the farmers get marginal surplus in good years and incur heavy deficits in the bad ones.

(4) Farming is more hazardous than the other enterprise. The weather can make all the difference between success and failure. Consequently, many farmers, particularly the tiny ones, feel shy of adopting new techniques.

The fear of loss is so overwhelming that even when convinced of the gain accruing from the application of science and technology, they prefer to go along the traditional track of low productivity. Once free of fear by crop insurance they will quicken the pace to high productivity.

The Fourth Plan reported, "many problems are there to the farmers by failure resulting from drought, floods and other natural disasters. This risk is likely to get accelerated under conditions of large investments in fertilizers, pesticides, improved seeds and other inputs which are proposed to be used on a large scale during the Fourth Plan. One of the important means of alleviating distress arising out from natural calamities might be the organisation of crop insurance."

Advantages of Crop Insurance

- It provides protection to farmers against losses caused by failure and thereby ensures stability in farm income,
- It also strengthens the position of co-operatives and other institutions that finance, agriculture to the extent it enables the farmer members to repay their loans in years of crop failure,
- By protecting the economic interest of the farmers against possible risk or loss, it accelerates adoption of latest agricultural practices,
- It minimizes the matter of rural indebtedness, which is traceable to the frequent failure of crops,
- It also reduces, to some extent, government expenditure incurred on relief measures extended to satisfy the havoc caused by natural calamities,
- It may act as anti-inflationary measure, by locking up part of the resources in rural areas.

Speaking of the various advantages flowing from the crop insurance, a politician of the U.S. Federal Crop Insurance Corporation said that it's "fundamentally for the aim of making catastrophic insurance and is meant to insure a minimum return to the farmer which enables him to stay in business in case of severe loss. The justification for the govt insurance isn't alone the necessity of protection, of the individual farmer and his continued income and buying power. This affects vitally like labour, industry, trade, banking and therefore the entire community of which the farmer may be a part."

According to S. K. Patil, "Crop insurance is the Mangna Charta of the Indian agriculturists. It will mitigate rural poverty and can change the psychology of the Indian farmer during a radical manner."

Nature of Crop Insurance

Crop insurance makes up the loss or damage to growing crops resulting from a spread of causes like hail or drought frost, flood and disease. The cultivators pay a premium and protection is given to them on an equivalent basis as in other insurance. When the production from an insured acreage falls below the insured coverage, the tiller is entitled to an indemnity.

Coverage and premium rates are settled on the basis of productivity and susceptibility to risk of the lands under cultivation in the same, area. Besides an all-risk crop insurance, there are three other main sorts of insurance to hide the danger from fire, hail and flood.

Scenario of Crop Insurance in India

The very idea of crop insurance in India was initiated about 30 years ago, when a Sub-Committee on "Land Policy, Agricultural Labour and Insurance," inter alia, had recommended a national scheme of cattle and' crop insurance with agriculturist, the village or the district and therefore the nation collectively contributing to its successful operation.

The first absolute step towards introduction of the insurance scheme was initiated by the govt. in 1948, when a special officer Dr. G.S. Priolker was appointed to research a scientific and scientific a basis for formulating an experimental pilot scheme.

Dr. Priolker in his Report, 1949, recommended a pilot scheme covering 4 crops, (cereals, cotton and sugarcane). In Tamil Nadu (Paddy and cotton), Maharashtra and Gujarat (cotton), M. P. (cotton, wheat and rice) and U.P. (wheat, rice and sugarcane) were suggested for experimentation.

The financial responsibility of the State Governments was to the extent of paying:

(a) Entire expenses of administration,

(b) Direct subsidy, and

(c) Operating deficits.

The scheme was examined by an expert committee, which suggested the introduction of the scheme at 12 centres. In 1952 the four States of Maharashtra and Gujarat, Uttar Pradesh, Tamil Nadu and M. P. were asked whether they would be able to implement the scheme by sharing 50% cost on State level organisation.

While M.P. was willing to try the scheme if the entire cost were borne by the Centre, the other States were not willing to undertake it. The scheme was later examined by the FAO Working Committee meeting at Bangkok in 1956. Experts in insurance and agriculture considered it preferable for doing implementation. On account of financial stringencies, however, the Government of India decided to defer the introduction of the scheme.

Punjab Experience

In 1961 Punjab Government decided to implement a modified version of the pilot scheme in certain selected areas of Punjab. According to the scheme, two of the four major crops like wheat, gram, cotton and sugarcane are to be taken care of.

It is compulsory, that's to mention, all the cultivators who grow any two of the insured crops will need to participate within the scheme. All natural hazards are covered under the scheme. For the purpose of indemnities and premium rates a block is divided into a number of areas homogeneous regarding soil, cultivation practices and production risks. Indemnities and premium rates are to be fixed separately for each crop and each homogeneous area.

Crop failures are to be visualised objectively and if the indemnities become payable in respect of an insured crop, every cultivator growing that crop within the area will get subsidies whether or not he suffered loss of yield in respect of that crop. Indemnities are payable when the seasonal yield calls below 75% of the traditional yield. The maximum subsidy to be paid just in case of total loss of crop are going to be 50% of the traditional yield.

The premium rates for a crop in a given area will be such that the premia collected over a number of years balance the indemnities payable over that period. Seasonal yields for the determination of indemnities will be fixed by an objective method of crop-cutting experiments by the field staff provided under the scheme. The administrative cost of the scheme will be shouldered by the Govt. The scheme is to be administered by a Crop Insurance Board which can include agricultural exports and insurance experts as members.

The Punjab scheme has several limitations. The key principle of insurance requires that indemnity will correspond with the loss but the Punjab farmer, under this pilot scheme is assured of indemnity irrespective of his having suffered an actual loss or not Premium rates have been fixed in, such a way that, collected over a number of years, the amount will balance the indemnities payable over the period.

If his presupposes that the farmer will have to shoulder the losses due to natural calamities, this might make the farmers feel that they are bearing a new tax burden, a feeling that should be avoided. The administrative cost which is to be shared by the Central and therefore the State Govts, on a 50: 50 basis are going to be about Rs. 7 lakhs per year, which comes to about 17.5% of the premia collected.

The cost seems to be on the very high side. Nevertheless, within the Third Plan, a sum of Rs. 40 lakhs were allotted for the purpose. The programme might be put into operation due to the constitutional hitch insurance being a central 'subject, a State Govt. cannot run even a pilot scheme without an enabling legislation by the Parliament. Therefore, in July, 1967, a Bill known as a Crop Insurance Bill was drafted and the pilot scheme for the introduction of compulsory crop scheme was forwarded to the State Governments for support.

Punjab has collected requisite data in selected area. The scheme covers wheat, gram, cotton and sugarcane, and will be extended to cover other crops and other areas in the State. During the Fourth 5-year Plan, crop insurance scheme was extended to other States and union territories. Legislation was organised for the introduction of crop insurance on a compulsory basis by the States. To give credit money to the scheme, a Crop Insurance Fund of about Rs. 100 crores have been contemplated.

The main difficulty in introducing crop insurance scheme is that the non- availability of essential data like loss rates in several year, heavy financial resources, bad luck of experienced and trained personnel.

There are certain areas in some States where pilot schemes can be introduced. For example, we could suggest 2 or 3 districts in Punjab, Tamil Nadu, Maharashtra and Gujarat for selected crops. More particularly, crop insurance is often experimented within those areas where the crop loan system has been introduced and met with a hit.

Conclusion to Crop Insurance Scheme

To conclude, it may be said that one of the basic objectives of our economic planning is to step up farm production. This can be achieved by adopting crop insurance schemes. Crop insurance schemes will assure the farmers that they're going to be compensated for losses against natural calamities. These schemes won't only spread the losses geographically but also spread them over the time. Therefore, the earlier the scheme is put into operation, the better it will be for the farmers and for the nation.

Artificial Cloud Seeding: An Alternative to Get Rains

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Introduction

Meteorological conditions influencing ground-based glaciogenic cloud seeding are cloud temperature, cloud liquid water, and ice crystals formation within, below or above the super-cooled cloud. Cloud temperature is a key parameter to activate the ice nuclei condensation and the rate of diffusional snow growth are highly temperature dependent. Clouds composed of liquid water droplets at temperatures below 0°C (super-cooled clouds) contain large numbers of tiny water droplets that are too small to precipitate. Hence, common practice of cloud seeding has positive impact on the amount of precipitation from clouds. When the water droplets inside clouds are too small or less, we can introduce the artificial ways to create ice crystals and thereby facilitate the formation of precipitation, weather phenomenon called as artificial rain making (Givati and Rosenfeld, 2005).

The Desert Research Institute found that 8 to 15 per cent increase in snowpack by cloud seeding. Evidence of cloud seeding study is that, seeding on super-cooled orographic clouds (clouds that develop over mountains) has seasonally increased the precipitation by about 10 per cent (Huggins, 2009). The California Department of Water Resources estimated that an average snowpack increases of 4 percent in their research on 2013. All these researches have given more interest to global scientists to further explore on the technology.

Approaches

The intention of rainfall enhancement techniques is to convert the super-cooled water droplets into precipitation sized ice particles that then fall to ground as either rain or snow. According to Cotton (1982), there are theoretical approaches to precipitation enhancement by the seeding of super-cooled clouds, namely,

1. Static seeding
2. Dynamic seeding
3. Hygroscopic seeding

Static seeding

The hypothesis of static cloud seeding is that the introduction of an "optimum" concentration of ice crystals may enhance the efficiency of precipitation by converting the reservoir of super-cooled water droplets into precipitation sized particles. Therefore, additions of ice nuclei materials into the clouds may result in precipitation. Static cloud seeding is the eldest one and still being practiced by many even today. It consists of spreading dry ice or silver iodide into the cloud to provide crystals which can condense surrounding moisture (Schaefer, 1946).

Dynamic seeding

Dynamic cloud seeding is practised based on the hypothesis of sudden release of the latent heat of fusion when a super-cooled cloud (ice + heat= water) is rapidly glaciated through seeding increases the buoyancy of the cloud and boost vertical air currents, this in turn generates deeper and more vigorous cloud that produces more rain. Several dynamic cloud seeding experiments have been conducted in the USA, the most notable of which was the Florida Area Cumulus Experiment, FACE. The results of these experiments were about 13-15% in Israeli and positive effects of 18% - 24% were found subareas of the experiment. (Bruintjes, 1999).

Hygroscopic seeding

Hygroscopic seeding method is introducing hygroscopic particles like salts through the flares or explosive in the lower portion of the cloud that readily takes water by vapour diffusion in super saturated clouds. This method is mostly suitable for tropical climate regions.

Chemicals used

The most common chemicals involved in cloud seeding are:

- Silver Iodide
- Potassium Iodide
- Dry Ice (Solid Carbon Dioxide)
- Liquid Propane
- Urea
- Salt - Sodium Chloride

Silver Iodide (Agl), solid inorganic compound is the "weapon of choice" for the cloud seeding industry. AgI nuclei is usually produced when combustion of an acetone solution from ground-based generators. Approximately 50,000 kg are used for cloud seeding annually, each seeding experiment consuming 10–50 grams. Liquid propane**,** which expands into a gas has also been used. This can produce ice crystals even at higher temperatures compared to silver iodide. After promising research, the use of hygroscopic materials such as table salt and talcum powder are becoming more popular (Hill and Ming, 2012).

Instruments

Ancient instrument used for cloud seeding are ground generators, plane, or rocket launchers. New technology instruments are aircrafts, drones and howitzers and depicted in Fig. 1a & 1b respectively.

Criteria of Cloud seeding

The main criteria of cloud-seeding are, when and how to apply the chemicals and on which clouds to be targeted. The criteria is including the account of their temperature, thickness and convective patterns, and the way that the winds flow into and out of them. The best cloud to shoot for seeding is orographic clouds, which are produced when air is forced upwards over mountain ranges. Such clouds are short-lived, relatively shallow and contain much water (French *et al.*, 2018).

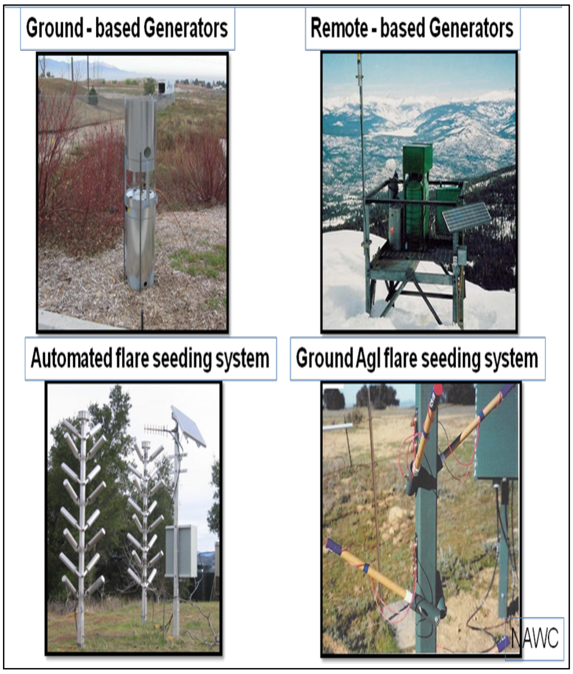

Fig. 1a: Ancient instrument Figure

Fig. 1b: New technology instruments

For successful artificial rains, the following conditions are necessary:

- Cloud formation in super cooled condition
- Large spread of clouds
- Upward movement of clouds with wide spread
- Ideal conditions on earth's surface to accelerate the process of cloud formation.

Protocols of cloud seeding

- Maintaining of logbook, indicating the number of seedable clouds, seeded clouds and reasons there off for not seeding by the Meteorologists at Radar Station.
- Threshold value of Decibel (dbZ – Radar Reflectivity) is to be decided.
- Threshold value of Vertical Integral Limit (VIL) is to be decided.
- Necessity of filling the proforma by the pilot about the kind of clouds he has seen physically, the kind of clouds seeded and the reasons there off for not seeding if necessary.
- Meteorologists should decide the number of flares to be fired, or the pilot in the field of experiment.
- How much time is needed between now casting and actual flying for seeding?

Suitable Clouds

Ordinary cumulus clouds are most often found in the sky that are too small to produce any worthwhile rains by seeding. American meteorologist Chuck Doswell has explained that the rain at the ground through seeding typical should be target on a fairly large cloud which is 10 km tall and 10 km in diameter. Substantial work has also been conducted in the past regarding the dispersion and transport of seeding material in both convective and orographic clouds. Many of the potential rain-bearing clouds in tropical and semi-tropical countries are convective in nature and their tops often not exceeding the height of the freezing level (Doswell, 1985).

Conclusion

It may be concluded that cloud seeding operations are boon to the farmers especially where rainfed agriculture is followed and cloud seeding is an opportunity to fill the reservoirs paving way towards increasing the ground water levels at favourable conditions. Apart from rain making, we can save lot of crops by suppressing the hail storms well in advance during the pre-monsoon showers along with the advantage of dissipating the profuse rainfall during the floods. In the context of more droughts and floods due to climate change, cloud seeding techniques can be effectively to augment the adverse effects and will help the society in a multipurpose way.

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Fruit Fly Life Cycle and It's Management

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Introduction

Drosophila melanogaster is one of the small insect pests which is commonly found near unripe and rotted fruits. It has been in use for over a century to study genetics and behavior. Thomas Hunt Morgan was the preeminent biologist studying *Drosophila* early in the 1900'. Drosophila derived from Greek word drosos means dew loving. They belong to the Drosophihidae family; and are most frequently know as fruit flies or often called vinegar, wine or pomace flies. Their main distinguishing character is to stay on fruit, which are ripped or rotten. There is another related family tephritidae , their members are also called as true fruit flies or fruit flies. Drosophilae are different from them. They mainly feed on unripe or ripe fruit. Many species of Drosophila are agriculture pests, especially the Mediterranean fruit flies. Their breeding takes place in numerous types of rotten vegetation and mycological materials, comprising barks, flowers, fruits, mushrooms and slime fluxes. However, the maggots of *D. suzukii* act as the pests and feed on fresh fruit. Furthermore, several species attract to lure of mushrooms and fermented bananas but others deny attracting to every type of bait.

The mango fruit flies are believed to be the single largest crop damage in India. It accounts for about 27% of harvesting loss. The flies attack semi ripe and mature fruits during the months of April and May. Other fruits like guava, citrus, peach, sapota etc are also susceptible to this pest attack. Damage is caused both by adults and maggots. Adult female punctures the rind of near ripe fruits with its needle like ovipositor and lays eggs.

Symptoms

- Considerable damage can occur inside the fruit before any obvious infestations are visible.
- Discolored patches on the skin of fruit are the most obvious signs of infestation.
- Symptoms found on the fruit and vegetables can be very similar to those caused by native flies such as the Queensland fruit fly (*Bactrocera tryoni*).

Pest identification

D. melanogaster multiple mutants (clockwise from top): brown eyes and black cuticle (2 mutations), cinnabar eyes and wildtype cuticle (1 mutation), sepia eyes and ebony cuticle, vermilion eyes and yellow cuticle, white eyes and yellow cuticle, wildtype eyes and yellow cuticle.

Color: *D. melanogaster* is dull tan to brownish yellow or brownish black; eyes usually bright red. Larvae are nearly white, except mouth hooks which are black and the tips of the abdominal breathing pores which are yellowish.

Characteristics: An *D. melanogaster* adult small fruit flies have antenna with a feathery bristle; wings with thickened front margins intersected in two places.

Size: Small fruit fly and vinegar fly adults are about 1/8 in long including wings.

Maggots: the legless yellowish maggots after hatching bore and feed on fruit pulp and on maturity come out of the fruit, drop on the ground and pupate deep under the soil. Thus the maggots destroy the pulp making it foul smelling and discoloured. Infested fruit develop brown rotten patches on them fall to the ground ultimately.

Life Cycle

Fruit flies lay their eggs near the surface of fermenting foods or other moist, organic materials. Upon emerging from an egg, the tiny larvae continue to feed near the surface of the fermenting mass. One female will lay about 500 eggs. The entire life cycle from egg to adult can be completed in less than two weeks. The entire lifecycle from egg to adult can be completed in about a week. Fruit flies lay their eggs near the surface of fermenting foods or other moist, organic materials.

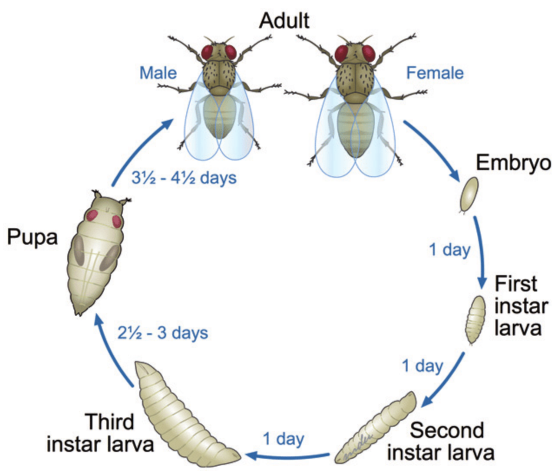

Fig. 1: Life cycle of fruit fly Drosophila

The whole life cycle of the fruit fly Drosophila is relatively rapid and takes only approximately 10-12 days at 25 C. The Drosophila development is divided into various stages: embryo, larva (first instar, second instar and third instar), pupa and adult.

Damage symptoms

- Maggots feed on the pulp of the fruits.
- Oozing of resinous fluid from fruits.
- Distorted and malformed fruits.
- Premature dropping of fruits and also unfit for consumption.

Management practices

- Removal and destruction all the affected fruits help to reduce the infestation.
- The fruits if covered with polythene or paper bags may escape infestation.

- Collect the fallen infested fruit and dispose them by dumping and burying in 60 cm deep pits.
- Plough the interspaces in the orchard during summer to expose flies puparia to kill them under hot sun rays.
- Install methyl eugenol traps at 6 nos./acre.
- Insecticide fogs such as CB80 or PT 565 Pyrethrum Aerosol can be sprayed into the air to kill adult winged Fruit Flies. A simple 3 second spray into the air with the products will kill most Fruit Flies within the area.
- Spraying with malathion 50 EC at 2 ml/L or neem-based formulation at 5ml/L of water starting from flowering to harvesting stage at an interval of 21 days for effective management of the pest.
- Spraying with methyl parathion (metacid) 50 EC at 1 ml/L or can also control this pest.
- Spray 80 ml of fanvalerate with 150 liters of water and spray it at the end of the week when the fruit is ripe. After the spray of fanvalerate, pluck the fruit on the third day.
- Recently it was reported that T. drosophilae presents a parasitization preference for *D. suzukii*, as also shown in this study, probably because of the difference in dimensions in comparison to *D. melanogaster*
- The parasitic wasp has gone through rigorous testing and Walton is awaiting a permit to raise and release the wasp in large numbers.

Life Cycle and Management of Varroa Mite (*Varroa destructor*)

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Introduction

Varroa mite is a native parasite of *A. cerana* throughout Asia, it has been reported as causing damage in both temperate and tropical Asia. The overall effect of varroa infestation is to weaken the honey bee colonies and thus decrease honey production. This parasite occasionally in *A. mellifera*, and more frequently in *A. cerana*, heavy infestation cause absconding. This mite is found all over the world, except Australia and New Zealand. In addition to causing damage through feeding upon lipids of larval and adult honey bees, Varroa mite also spread the several viruses, with deformed wing virus being most prevalent. Varroa destructor is causing of colony collapse in *A. mellifera* (L.) colony.

Symptoms

Varroa causes injuries to honey bees by direct feeding. The adult female of mite pierces the adult bees soft inter segmental membrane with their own pointed chelicerae and sucks the bee's haemolymph (blood). The adult bee and larvae are damaged if the infestation is very severe. The honeybee colony being infested with *Varroa* mites is called *varroosis*. If more than one parasitic mite infests or damaged the brood cell the brood decays or deformations occur including shortened abdomen or deformed wings symptoms. If very little quantity of mite infests a cell symptom may not be directly visible although the bee's life-span is considerably shortened as compared to healthy bees. Moreover, the bee's behavior is also disturbed, e.g. in orientation or gathering food and foraging behavior also very effected. *Varroosis* is a multi-factorial disease.

Life cycle

Varroa mite life cycle has two phases. The first phase called as the phoretic phase and second phase is called as reproductive phase. In this phase mites will ride on adult worker bees and drones also, feeding on their whole-body fluid. If there is brood for the mites to parasite, this phase lasts 5-11 days. Otherwise, it can last as long as 6 months, during which the mites will spread disease as they hop from host to host. The mites then move onto brood as they enter their second, reproductive phase. After entering the cell, they move underneath the larva to feed on prepupa. The female lays her first egg 60 hours after the cell is capped, then one every 30 hours. Up to a half dozen will reach maturity within a week, feeding on the bee, impeding its development, and exposing it to disease. They mate, then adult females will leave the cell with the damaged bee, transferring to other bees, and the cycle begins again.

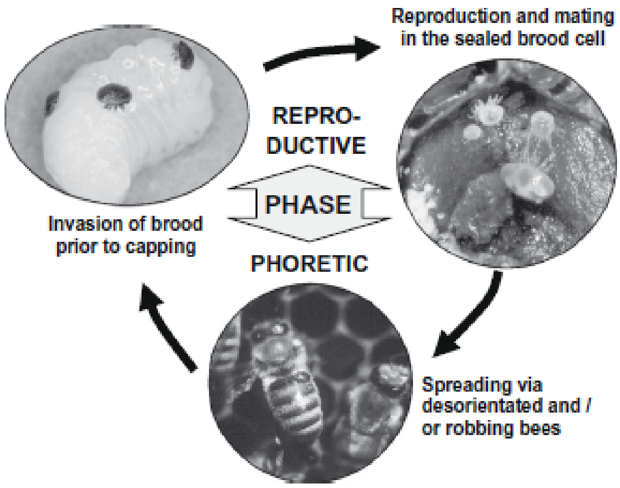

Fig. 1: Life Cycle of the Varroa mite

Management

Soft Chemicals

Organic acids, essential oils, and hop beta acids are important soft chemicals because these are naturally found in nature. These chemicals do not have chemical residues in hives like wax and etc. If these types of chemicals are used in the hive/bee's boxes, it is recommended to apply soft chemicals and less residual impact of bees.

Formic acid

Formic acid mainly found in the venom of honey bees and is a natural component of honey. This type of chemical is commonly used in India as well as across the world, because at high concentrations, they penetrate the wax capping and effectively kills reproducing mites all over the colonies. Some limitation is that the use of formic acid is mainly temperature dependent and can cause damage to the colony if temperatures higher than 85F because it can increase brood mortality and the potential for queen loss. When used below 50F, formic acid results in low efficacy.

Oxalic acid

Oxalic acid is a mostly naturally-occurring compound found in plants, such as rhubarb, kale, beets, and spinach. As a chemical for mite control, oxalic acid can be used in two formulations: vapor and dribble form. Because it does not penetrate the capping of cell, oxalic acid is most effective during brood less periods making it a useful component to an integrated varroa control program as a winter or early spring method. However, it should not be used as a stand-alone treatment. If overdose or used at regularly, oxalic acid can harm bees by crystalizing in the midgut of larvae, larval mortality also increases, and reducing brood area and reduce the egg laying of queen and nursing activity also reduced.

Lactic acid

Lactic acid is clearly better tolerated by bees and does not cause problems in warmer climatic zones. The disadvantage is that every single comb must be extracted to spray the bees with the acid. The dosage applied per comb side is 8 ml of 15 percent acid. This treatment can be repeated two times at intervals of seven days.

Thymol

Essential oils are natural compounds distilled from plants. The most popular essential oil for varroa mite control is thymol (from a thyme plant). While thymol treatment can effectively control mites on adult bees, it cannot penetrate the cell cappings, so does not control mites in brood cells. Efficacy of thymol is dependent on colony strength as well as ambient conditions. During treatment, the workers react by emptying cells near the product so this treatment can reduce the overall area of brood in colonies when applied in the spring. In addition, thymol treatment can induce robbing behavior and increase aggressiveness of colonies.

Hops beta acids

Potassium salts of hops beta acids are derived from the hops plant and it is safe for use any time of the year, even during the honey flow. However, it is more effective as a mite control treatment when there is less brood because it does not go through the cell capping. Use during brood rearing requires multiple applications.

Hard Chemicals

Chemical control of varroa mites can be achieved through the use of various acaricides/miticides. Synthetic miticides are generally effective, killing up to 95% of the mite population. Historically, fluvalinate and coumaphos have been the most widely used mite treatments, but mites have developed resistance to these chemicals and residues persist and accumulate in wax. While these two hard chemicals are wrong impact on bees. Miticide residue in wax can harm bees directly and makes bees more susceptible to nosema disease. In addition, these residues can be found in bee products. Synthetic chemicals should be a last resort for beekeepers practicing IPM.

Amitraz

The most popular synthetic/artificial acaricide is amitraz {sold in market as Apivar (R)}. Amitraz does not, in its original form, persist as a contaminant of honey or wax. However, some metabolites of amitraz have been found to persist and there is a synergistic effect of amitraz and viruses that has been linked to increased bee mortality. In addition, resistance to amitraz has been documented, so its efficacy must be monitored closely.

Locusts Attack and Its Control by Soil Pesticide

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Introduction

Locusts belong to the family *Acrididae.* These are collections of certain species of short horned grasshoppers. Taxonomically, there is no distinction between grasshoppers and locusts. The notable difference being, locusts have big hind legs that help them to jump or hop. Usually, they show a solitary lifestyle. But sometimes they become abundant and change their habit from solitary to becoming gregarious. This change in lifestyle is observed when there is abundant greenery as a result of rain after a period of dry spell. Under such conditions, locusts breed abundantly as a result of release of serotonin in their brain and they can sense one another around them. This is called the gregarious phase of locusts.

Fig. 1: The plague of locusts (Source: thehindu.com)

There are also various phenotypic changes in locusts during this phase which includes change in body size, colour, body shape and even change in size of the brain. This is what is called phenotypic plasticity i.e. ability of an organism to change in response to stimuli or inputs from the environment. It is also known as phenotypic responsiveness, flexibility or condition sensitivity.

Destruction to crops

According to FAO, locust swarms are now developing across East Africa, Yemen, Iran, Pakistan and India. These areas have been warned to be on high alert and their growth is threatening crops in India. Countries like Kenya, Ethiopia and Somalia, continue to face an "unprecedented threat to food security and livelihoods". They fly very rapidly and in swarms of millions. They can remain in air for a long time and also cover huge distances. They can cause massive crop damage. According to an estimate, a swarm of locusts covering just a square kilometer could damage up to a 100 ton of crops daily. The Australian Plague Locust Commission estimates that on an average, nymphs of locust can per day eat 100-450 mg of green vegetation and adults can eat 0.2 g of green vegetation per day.

Locusts eat green and tender tissues of any plant material ranging from rice, wheat, cotton, vegetables and others. In Indian states, locusts have caused a huge destruction starting from Rajasthan, Madhya Pradesh, Maharashtra and parts of Punjab, Haryana, Bihar and Uttar Pradesh. The whole crop is wasted if green tender parts of a crop are damaged. According to an estimate by FAO, a swarm of just 1 square kilometer can consume as much food as would be eaten by 35,000 people (or six elephants) in a single day.

Fig. 2: Destruction caused by locusts (Source: thehindu.com)

Control of locusts attack

The corona virus pandemic along with locust attack is posing a great challenge for the farmers who are battling the insects using sprayers, pesticides, and drones. Mostly countries are combating the locust attack by spraying organophosphate chemicals which are applied by vehicle mounted or aerial sprayers. In certain regions, drones are used for controlling it. The resource poor farmers are going out at night to battle against the insects wearing masks and some basic protective clothing. But, for a Hyderabad based farmer, spraying of chemicals was not acceptable. Padma Shree award winner Chintala Venkat Reddy is a very innovative farmer who uses organic techniques of soil and nutrient management. He does not use any chemical fertilizers, insecticides or fungicides in farming. He has received an international patent for his various techniques.

Reddy told that "One must understand the anatomy of insects like a locust to know what will attract them and what will repel them. Locusts do not have a liver so they cannot digest clay contents. If they don't have anything to feed on in my field, they will avoid and deroute." This was the basic principle used by him.

Procedure for making the soil pesticide

- From about two inches depth of the field, collect 15 kg of topsoil and completely sun dry it.
- Now, separately sundry 15 kg subsoil from four feet depth. This preparation should be done in peak summer months. This quantity can vary. But the ratio should be

maintained at 1:1. We can dry the mixture in bulk and use it as and when required to spray. But the conditions must be completely dry for storage.

- Now, mix the topsoil and subsoil in 200 liters of water, once they are completely dry.
- After mixing it with the help of a stick, the mixture is allowed to settle for about half an hour till mud settles at the bottom.
- Now, filter the top water with a cloth or sieve and spray on the crop. Spraying should be done within four hours of the mud settling. The mud settled at the bottom need not be discarded. It can be reused as a root application for the crops.
- Spraying with this soil-based pesticide must be done at least once every 7 to 10 days. For vegetables, it should be done once every four days for best results.

Reddy told Telangana Today that, "Farmers can also spray water first and take the subsoil in dry form and sprinkle or distribute it like fertilizer. That will stick to the plants and also saves the sprayers from jamming". Reddy had already experimented by spraying light muddy water on his grape plants. In about two days, the death of insects occurred and he also used it on other crops with equally good results.

Conclusion

In the middle of the corona virus pandemic, locust outbreak has cost a huge loss to the standing crops. It is a real threat to the economy of India and its effective control is the need of the hour. Keeping in view the current environmental state, integrated and environmentally safer solutions should be used to deal with the upsurge of these pests. For immediate control, soil pesticide spray is a viable option. But, for a longer term, the central government also needs to start certain schemes and policies that provide insurance to farmers, producers and local community dwellers against this uprising pest.

Biofumigation in Crop Protection

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Introduction

Biofumigation is incorporating the soil amendment (fresh plant material, manures) into the soil, which in turn produces organic compounds during the development of succeeding crop species thus helping to defend against pests and pathogens. Biofumigation is one of the important tools and cost-effective methods in crop disease control. This method is simple, alternative to chemicals which control pests, soil borne pathogens including *Fusarium* spp and *Phytopthora* spp and nematodes. This biofumigated soil also has increased activity of beneficial bacteria and fungi supporting the plant growth and defense against stress conditions. Biofumigation materials improve soil organic matter, nitrogen, phosphorous and potassium content; improve soil temperature and physiological performance of the crop. Basically, biofumigation is a non-chemical soil disinfection method.

Biofumigation In Eco-Agriculture

In agricultural crop protection, chemical control is currently dominant, but most of the regulatory guidance is moving towards eco-agriculture and conservation agriculture. In the case of pest and disease management, it requires sustainable management and conservation of biodiversity. The main principle of agro-ecological crop protection (ACP) as stated by Deguine et al. (2017) is to prevent and reduce the risk of pest infestations or outbreaks. Habitat management which is an important factor under ACP involves planting permanent ground cover, flower strips, and plants to attract natural enemies. Creating unfavorable habitat for the pest and pathogens, favorable habitat for the natural enemies and biocontrol agents is possible by introducing biodiversity in the agro-ecosystem than monocropping. Crops belonging to Brassica family (cabbage, cauliflower, mustard etc), Moringaceae, Capparidaceae are majorly used as biofumigant crops. These crops contain secondary metabolites like glucosinolates. During the decomposition of crop residues, the metabolite breaks down into thiocyanates, isothiocyanates and others. The predominant breakdown product isothiocyanates have biocidal activity on harmful fungi, bacteria, nematodes and weeds.

Biofumigation, in addition to pest and disease management improves soil physical, chemical and biological properties by altering the soil texture enhancing water infiltration and water holding capacity. The community structures of the beneficial microorganisms are known to increase. The acids from the decomposition of green manures help in release of minerals for the succeeding crop. Biofumigation prevents wind erosion and surface run-off. More importantly it increases nitrogen content of the soil. Since biofumigation provides vegetative cover, weeds, population of nematodes and soil-borne pathogens are kept under control.

Components of Biofumigation

***Crop rotation**:* Sequential cultivation of crops belonging to different botanical family in the same land is known as crop rotation. Crop rotation with biofumigation crops helps to improve soil health and effectively manage pest and diseases. The non-host plants leave the pests and pathogens under starvation. However, choice of the crops should be made in such a way to avoid outbreak of new pests and pathogens. According to Flint and Roberts (1988), crop rotation is used to manage the pest population and its mobility due to non-availability of host and thus limitation in the infestation source.

Incorporation of biofumigants: Mustard family crops are incorporated after cultivation for the purpose of converting glucosinolates to isothiocyanates. To achieve higher amount of release of this breakdown metabolite, water is supplied to ensure complete hydrolysis. Covering the soil with plastic mulch is followed since some of the isothiocyanates are volatile in nature. Yield of crops was found to be increased due to incorporation of mustard family plants in the soil.

Cover and green manure cropping: Green manure crops are basically planted between the main crops. They generally act as natural soil cover enriching nitrogen, improving microbial activity, protecting the land from erosion, controlling weeds, controlling pests and pathogens by acting as non-host plants. Everts (2002) reported that the cover crops can reduce population of infectious bacterial and fungal pathogens by breaking their life cycle. Sorghum is known to reduce soil inoculum of bacterial blight to the succeeding crop. Cover crops also act as host for natural enemies (predators and parasitoids). The natural enemies migrate from harvested winter crop to the spring planted crops. Growing of clover and cereal rye is known to reduce infestation of cabbage fly. Larkin and Griffin (2007) reported that the mustard plants can suppress common scab pathogen (*Streptomyces scabies*) in potato. Population of the wilt pathogen *Verticillium dahiliae* (infective propagules) was found to be reduced to great extent when mustard, canola, and radish were grown.

Trap crops: Trap crops are used as one of the pest management measures to deviate pests and protect the main crop from infestation. When these plants are chopped and incorporated in the soil, they release metabolites to kill soil-borne pathogens. Jaffee et al. (1998) suggested that specific Brassica species can be used as trap crops for nematode management.

Biofumigation Crops

Brassica species: White mustard (*Sinapis alba*), yellow mustard (*Brassica hirta*), Indian mustard (*Brassica juncea*), black mustard (*Brassica* nigra) are used as biofumigation crops for the management of weeds and wilt causing pathogens. Mustards contain high levels of glucosinolates. Radish is known to control cyst nematodes in the soil. Rapeseed species such as *Brassica napus* and *Brassica rapa* are used for management of nematodes as well. Turnip, in addition to nematode and pest control, facilitates water infiltration by forming numerous micro-channels in the soil. Brassica rapa gives effective control of bacterial wilt caused by *Ralstonia solanacearum* in tomato. Mustard can control *Fusarium* wilt in beans and

Phytopthora fruit rots in other crops. Soil-borne pathogen, *Rhizoctonia solani* which has a broader host range gets significantly reduced by the decomposing *Brassica juncea* plant tissues. The volatile chemicals from biofumigation crops control *Fusarium oxysporum, Rhizoctonia solani, Botrytis cinerea, Cladosporium fulvam, Pythium ultimum* and *Sclerotium rolfsi*. Incorporation of green cover crops suppresses *Verticillium* in potato, *Pythium*, *Fusarium* and *Rhizoctonia* in beans, *Pythium* in lettuce, *Aphanomyces* rot in onion, *Pythium*, *Rhizoctonia* and *Fusarium* root rot in peas and *Fusarium* in carrot. Biofumigation using Brassica species crops can eliminate weeds to the range of 20-90%. Incorporating meadow foam (*Limnanthus alba*) seed meal in the field limits the weed growth upto 90%. Allyl isothiocyanates can inhibit the growth of weeds like redroot pigweed.

Non-Brassica species: Decomposition of crop residues of barley, wheat, oats show inhibitory effects on soil-borne plant pathogens and nematodes. Strong nematicidal activity is observed in Sudan grass and sorghum. Onion releases volatile sulphur compounds such as thiosulfinates which are converted into disulfides during decomposition. Dimethyl disulphide (DMDS), dipropyl disulphide (DPDS), diallyl disulphide (DADS) have potential of inhibiting various fungal pathogens including *Colletrotrichum*, *Fusarium* etc. DMDS has toxic effect on termites. Metabolites released from garlic residues in moist soils inhibit weeds such as black nightshade, common purslane and banyard grass.

Conclusions

Removal and destruction of crop residues is part of the integrated pest and disease management in agricultural crops. This is recommended if the standing crop is affected by pest, disease or nematode outbreak. However, if the standing crop has not experienced such infestations, incorporation of residues in the soil can serve as effective pest and disease management strategy for future crops. The understanding of the contribution of metabolites and fermented products of the crop residues to the soil needs further exploration. Complete profiling of metabolites of every crop residue in the soil through metabolomics can help to strengthen the basic information in this subject. Although the release of metabolites from crop residues is slower, it can provide a long-term beneficial effect. Crop rotations with Brassica species crops are necessary in a cropping pattern to control pest and diseases since these crops are best suited for biofumigation, thanks to their biochemical composition. More research and optimization of crop residue management are critical for the success of agro-ecological crop protection in a non-chemical way.

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Status and Constraints in Indian Fruits and Vegetable Export

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Introduction

The diverse climate in India ensures production of all varieties of fresh fruits and vegetables. Still the demand for fruits and vegetables has been constantly increasing. The increasing trend of agricultural trade of at global level benefits the developing countries the promotion of rural development, agricultural exports and economic growth (Barbier, 2000). India being an agricultural country has a large potential for foreign trade. The geographical location with good logistic and suitable climate placed India in a favorable position for growing a variety of fruits and vegetables around the year (Sexana *et al*., 1990). India is producing around 85 million tons of fruits and 170 million tons of vegetables every year. The present situation demands considering Agriculture as the major economic and commercial activity to enhance growth and national economy. The huge production base of fruits and vegetables provides excellent export opportunities for India. Despite this advantage, India's share in the global market is insignificant and accounts for only 1.7 per cent of the global trade in vegetables and 0.5 per cent in fruits.

The horticulture sector is strongly believed to be the future for agriculture through fruits and vegetables export. The major concern during policy making is much oriented towards economic and political risks as the farmers of the country are heavily dependent on local markets and industries. All India Technology of Horticultural Crops had identified the problems in fruits and vegetables which discouraged the farmers from undertaking large-scale cultivation of fruits (Navadkar, 2004). The fresh fruit export from India is very small owing to a number of constraints and any solution would lead to realization of vision to the enhancement of exports in the near future (Chandra and Kar 2006). Owing to these creeping problems in the sector a study the constraints faced by the producers and exporters of major fruits and vegetables in India are identified. The producers and exporters of fruits and vegetables are facing several problems and are categorized as production and trade related here.

Constraints in fruits and vegetables export

There exists a close sense of belonging between farmers producing fruits and vegetables for export and the exporters. It is inevitable to know the problem of producer which is a complementary to the export sector. Hence the problems of producer in the course of production of fruits and vegetables are made and the constraints are listed according to its merits.

Problems encountered by farmers

The constraints faced by the sample farmers are furnished in Table 1. The most important constraint identified by the fruits and vegetables growers is the inability to meet the quality requirements for export. This is one of the frequent problems in fruits and vegetables export; so to say the importing countries propose particular quality specification for each commodity. This has resulted in farmers could not cater distant market for want of increased net price. The second major constraint ranked by the sample farmers is poor storage and transport facilities as most of the fruits and vegetables are perishable. Dependency on pesticide usage, lack of institutional supports and lack on information on organic cultivation are the other important problems encountered by the farmers.

It is noteworthy to infer that the production problems are spelled little by the farmers compared to facilitative constraints. On the whole the importance of quality produce to meet the requirements of importing countries. It also reveals the high demand for organic products especially mangoes in Germany, France, Netherland and U.K. The pesticide consumption of 39.73 thousand tons during 2005-06 in India has reached 52.98 thousand tons in 2011-12 (Indira Devi et al. 2017). Hence efforts are needed to reduce the usage of pesticides to make fruits and vegetables accepted by the European markets.

Table 1. Constraints of Fruits and Vegetables Farmers

Sl. No	Problems	Rank
1	Inability to meet quality requirements for export	I
2	Poor storage and transport facilities	II
3	Dependency on pesticide usage	III
4	Lack of Institutional supports	IV
5	Lack of information on organic cultivation of fruits and vegetables	V

Problems encountered by exporters

The problems faced by the exporters of fruits and vegetables are presented in Table 2. It could be seen from Table 2 that the poor infrastructure facilities are the most important problem faced by the exporters. It was reported that timely infrastructural facilities namely reefer vans, pack houses, quality packing materials, cool chain, Controlled Atmosphere (CA) containers are not adequately available for export. Lack of standardization on post-harvest handling iss the second most important problem expressed. This shows the need for standardization of protocol and training on post-harvest handling and Controlled Atmosphere (CA) and Modified Atmosphere (MA) storage facilities. The third important problem is the documentation procedure for export. The other problems include collision among commission agents and auctioneers and unavailability of market information and strategies.

Table 2. Constraints of Fruits and Vegetables Exporters (n=40)

Sl. No	Problems	Rank
1	Poor infra-structure facilities	I
2	Lack of standardization on post-harvest handling	II
3	Tedious documentation procedures for export	III
4	Collision among commission agents and auctioneers	IV
5	Unavailability of market information and strategies	V

Conclusion

It could be concluded that the export share of major fruits and vegetables to the total production is found to be low except onion. The important constraints faced by fruits and vegetables growers are the inability to meet the quality requirements for export and poor storage and transport facilities. The poor infrastructure facilities and lack of standardization on post-harvest handling are the major problems faced by the exporters. This is in line with the findings of Usha *et al.* (2014). Hence, it is suggested suggest that there is a need for linking production and export activities in order to achieve the best results in terms of productivity, quality and value addition.

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Jet streams- A Conceptual Review

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Introduction

Jet stream are a band of long, narrow, high-speed winds that generally blow from west to east across the globe particularly in the middle and upper troposphere or lower stratosphere (8 to 15km vertically). Mostly, the main jet streams are formed near the altitude of the tropopause and are moving as westerly winds, characterized by strong vertical shearing action, which is thought to be largely responsible for clear air turbulence (Shapiro & Keyser, 1990).

Wasaburo Oishi (Japanese meteorologist) detected the jet stream during 1920's from a site near Mount Fuji when he tracked pilot balloons (used to determine atmospheric conditions) as they moved upward into the atmosphere. Flyers consistently noticed westerly tailwinds excess of 160 km/hr in flights. Similarly, in 1944 a team of American meteorologists in Guam, including Reid Bryson, had enough observations to forecast very high west winds that would slow bombers (Lewis, 2003).

Horizontal differences in temperature causes the movement of air due to horizontal pressure gradient that drives geostrophic and gradient winds. Jet streams are positively correlated with horizontal temperature differences and encircle the Earth in meandering paths, shifting position as well as speed with the seasons. During the winter their positions are nearer the equator with higher speed than during the summer (Matthew, 2018).

Types of Jet streams

Region of both the Northern and Southern hemispheres are facing various jet streams, although the jet streams of northern hemisphere are more forceful due to greater temperature variations. Generally, two group of jet streams are created in the upper atmosphere viz., Permanent jet streams (Subtropical jet stream and Polar front jet) and Temporary Jet Streams (Tropical Easterly Jet or African Easterly Jet and The Somali Jet) (Krishnamurthi and Bhalme 1976). The details of these jet stream formations are detailly given below of this paper.

Sub-tropical jet stream (STJ)

- Sub-tropical Jet Streams used to develop during winter and early spring seasons with a maximum speed of 300 knots. These jets give predominantly fair weather in areas they pass over and sometimes they used to drift northward and merge with a polar-front jet. The formation of sub-tropical jet stream is detailly explained below.
- The sub-tropical jet streams are produced due to Coriolis force and temperature difference between tropical and sub – tropical regions where the velocity of the earth rotation produces a greatest deflective force in the atmosphere. As a result of this

rotation, the rising air deflected to right in the northern hemisphere and to the left in the southern hemisphere at about 30° latitude which spreads out northwards and southwards, moves faster than the latitudes over which it is blowing and it becomes concentrated as the subtropical jet streams (Figure 1).

- During winter, nearly continuous STJ are produced in both the hemispheres which exists in southern hemisphere all the years whereas, intermittent in the northern hemisphere and during summer it migrates to northern side.
- The STJ was one of the last tropospheric features discovered by direct human observation and can be temporarily displaced when strong mid-latitude troughs extend into subtropical latitudes. When occurrence of these displacements, the subtropical jet could merge with the polar front jet creating Cloudbursts. These type of jet streams are closely connected with the Indian and African summer monsoons.

Polar front jet (PFJ)

- Polar front jet (PFJ) are also called as midlatitude jet streams, a belt of world's most powerful upper level wind force moves generally in westerly direction and forms in the junction between the Ferrell and Polar cells. As a consequence of formation of these jets manifest themselves as front, unstable and breakup into Rossby waves.
- Polar Front jet stream is a fast-flowing air at the boundary between the troposphere and stratosphere and more variable position than the sub-tropical jet. In summer, its position shifts towards the poles and in winter towards the equator whereas, in winter, jets are stronger and more continuous.
- It greatly influences the temperature difference of two different air masses lying close to 50°-60° N/S region is where the polar jet located. It determines the path, speed and intensity of temperate cyclones (Fig. 1). The polar jet streams used to form several miles deep and more than 100 miles wide, with the strongest winds typically 8 to 16 km above the ground. These types of jet stream are typically more common in North America and Europe.

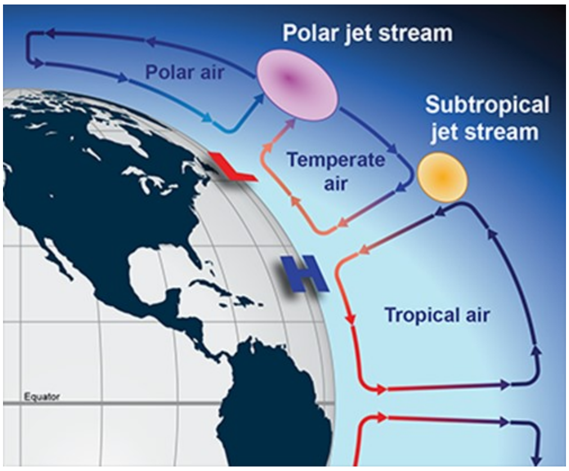

Fig. 1: Polar and Sub-tropical Jet Streams **(Source: http://www.weather.gov/)**

Temporary jet streams

Permanent jet streams (polar and subtropical jet streams) are the best known and most studied at world level whereas, other jet streams are also formed when wind speeds crossed above 94 km/hr in the upper atmosphere at about 9 to 14.5 km above the ground surface. Most important temporary jets are Polar night jets, Somali Jet and The African Easterly jet.

Polar night jet streams

- PNJS are also known as the stratospheric sub-polar jet streams and it is developed at the height of 30 km during winter, become very strong due to the steep temperature variations in the stratosphere around the poles and moves westerly but the velocity decrease during summers and the direction becomes easterly.
- It causes the circulation of polar vortex and warmer air could only move along the edge of the polar vortex, but not enter it.

The Tropical Easterly Jet or African Easterly Jet

- High velocity winds in the lower troposphere called as low-level jets (LLJs) or Tropical Easterly Jet (TEJ) the well-known prominent of these is the African Easterly Jets and it is found near the latitude between 5° and 20°N. These unique and dominant feature of the northern hemisphere is observed over southern Asia and northern Africa during summer months (Figure 2).
- TEJ are upper level easterly wind that are fairly persistent in position, direction, and intensity which starts in late June and continues until early September. The strongest development was noticed at about 15 km above the earth surface over Indian Ocean.
- It's existence is found quickly after the Sub Tropical Jet (STJ) has shifted to the north of the Himalayas (Early June) and during the south Asian summer monsoon it induces secondary circulations that enhance convection over South India and nearby ocean thus causing strong southwest monsoon **(**Hastenrath and Stefan, 1985**).**

The Somali Jet

- Among the most well-known of the tropical LLJs is the Somali Jet, a low-level south westerly jet, formed the Arabian Sea of India in the summer months and the coast of Somalia. Somali jet supported the movement of the southwest monsoon towards India which originates close to "Mascarene high" near Madagascar in the southern hemisphere being intense from June to August (Figure 2).
- Boos and Emanuel (2009) examined the onset of Somali jet and the associated monsoon and observed that the Jet onset is accompanied by a large (100 W/m2) increase in surface enthalpy flux over the Arabian Sea that increases in deep tropospheric ascent. It is a major cross-equatorial flow from the southern Indian Ocean to the central Arabian Sea.

Influence of Jet Streams on Weather

- Helps in maintenance of latitudinal heat balance by mass exchange of air and influence the mid-latitude weather disturbances. When jet streams are interfering with surface wind systems cause severe storms.
- Jet streams influence the path of temperate cyclones thereby influence the distribution of precipitation**.** Also, an influence on movement of air masses is observed which may cause prolonged drought or flood conditions over the earth system. Eg: Polar vortex cold wave over North America in 2014 winters.

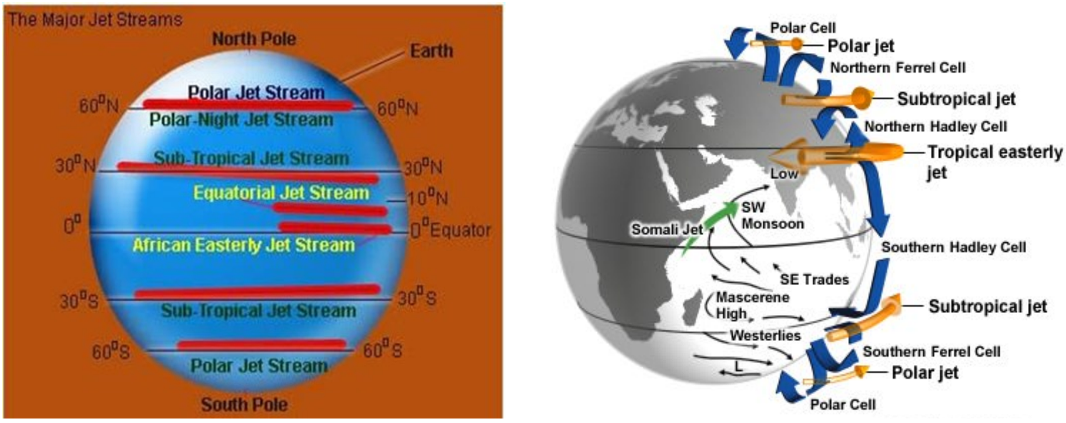

Fig. 2: Somali Jet **(Source:** www.pmfias.com **)**

Role of Jet Streams in Indian Rainfall

1. Winter Rainfall: Transport the western disturbances (temperate cyclones) originating over the Mediterranean Sea and brings rain to north western part of India.
2. Southwest monsoon – withdrawal of STJS from the south Himalayas decides the onset of SW monsoon in Indian sub-continent.
3. Tropical cyclones – Easterly jet stream steers tropical depressions and cyclones from the Pacific Ocean towards Indian Ocean and brings rainfall over the east coast regions.

Conclusion

From the above context it is concluded jet streams, which are discontinuous in time, space and with notable wind speed and elevation variations, is a westerly circulating air flow that tends to push the cold wind from upper atmosphere to the surface of the earth. During the process, dry winds from this high-pressure area start blowing towards the low-pressure area. After reaching the Oceans through the westerly flow under the influence of Ferrel's cell they form north east monsoon which gives rainfall.

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Seed Priming – A Tool for Sustainable Agriculture

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Introduction

Effective germination of seed is crucial for agriculture. The emergence and growth of plant species are initially based on the seed quality. A good quality seed, in a good soil yield higher. The use of other inputs such as manures, pesticides, fertilizers etc. are based upon the seed quality used. Seed forms a key tool in ensuring food security and act as a carrier in technology adoption. Quality seed must possess some important traits including high physical and genetic purity, higher germination percentage, increased vigour and free from pest and diseases. Many adverse conditions including climate change may lead to failure of the crop. Some effective strategy must therefore be adopted for successful crop growth. Among them seed priming is a vital technique aiding the successful establishment of crop growth. Seed priming is a physical technique where the seeds are subjected to controlled hydration and drying for enhancing the sufficient pre-germination metabolic process for quick and rapid germination. The seeds are partially hydrated and retained under a specified temperature, moisture and aerated condition for a particular time period. Priming forms feasible and economic technique for uniform germination and growth (Pawar *et al.,* 2018)**.**

Benefits of Seed Priming

- Faster and uniform seed germination
- Helps to overcome thermo dormancy
- Alleviate diverse effects caused by various stresses
- Aids to overcome the chromosome damages induced by aging
- It minimizes soil borne diseases
- Increases the viability of low vigor seed
- Overall enhances the growth and yield of the crop

Seed Priming Phenomena

After sowing, usually the seeds remain in soil for some time for absorbing water and nutrients required for their growth. In seed priming technique this time is reduced and the seed germinate quickly and uniformly. Added to the hydration, the priming also decreases the seed sensitivity to the external environmental factors. Priming regulate the seed germination under 3 stages *viz.,* imbibition, germination and the growth (Fig 1). During imbibition stage, water uptake promotes the respiratory activities and protein synthesis through mRNA. The second stage is the initiation of various physiological process like mitochondrial synthesis, protein synthesis and alternation in the soluble sugars related to germination. The crucial factor during priming are the controlled uptake of water during second stage before emergence and the growth of the radical from seed coat in the last stage. The second stage are much sensitive for the environmental factors than the last stage. Therefore, during seed priming seeds that had passed through second stage can germinate under varied environmental conditions.

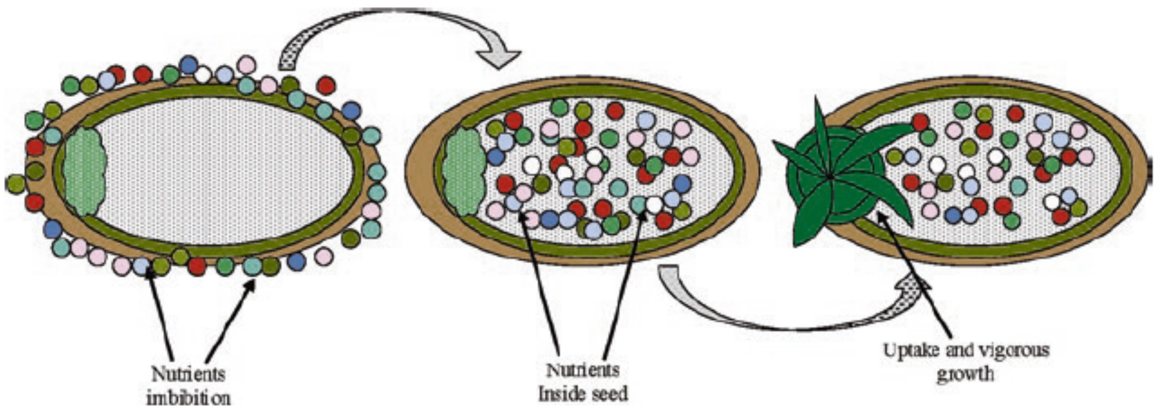

Fig 1: Seed Priming Phenomena (Waqas *et al.,* 2019).

Methods of Seed Priming:

There are several priming techniques that are been practiced (Raj *et al.,* 2019). Some of the priming techniques are as follows:

1) *Hydropriming*

In this, the seeds are soaked in the water for some specific duration. This technique is mostly used in dry farming areas. Here the water entering the seeds is influenced by the seed tissue affinity for water. Hydropriming are cheap and ecofriendly in nature. The key factors in hydropriming are water soaking duration, volume of water and the temperature at which the priming is performed

2) Halopriming

The seeds are soaked in the inorganic salt solutions (NaCl, KCl, etc,) during halopriming. These salts might exert some direct or indirect effects on nutrition. It promotes uniform and better performance of the crop even under some adverse conditions. Added it also tolerates salinity through enhanced Ca^{2+} and K^{+} accumulation, reduced Na^{+} accumulation and increased osmosis by proline accumulation

3) O*smopriming*

Osmopriming also termed as osmoconditioning involves the soaking of seeds in osmotic solution like polyethylene glycol, mannitol, glycerol, sorbitol etc. Seeds uptake the water slowly due to the lower water potential in the osmotic solution permitting the seed imbibition. Generally osmotic potential of priming solution ranges from – 1 to -2 MPa but differs with duration and species in the priming solution.

4) Solid matrix priming

In this method the seeds are incubated in solid insoluble matrix such as peat moss, vermiculite, diatomaceous earth, sand, charcoal and clay with limited water quantity conferring slow imbibition. The materials that are used as matrices should have low matrix potential, low water holding capacity, should stick to bed surface and non-toxic to the seeds

5) Biopriming

Biopriming combines the seed inoculation with the beneficial microorganisms and regulate the hydration of seeds for the biotic and abiotic stress management. During biopriming microorganism proliferates, colonize and produces PGRs (Plant Growth Regulators). Biopriming also favors seed germination and safeguards from seed and soil borne diseases. The beneficial microorganisms can colonize and proliferate in the rhizosphere and supports the plant both directly and indirectly.

6) Hormonal priming

Hormopriming or hormonal priming involves the treating of the seeds with various hormones that increases growth and development of seedlings. Hormones that are commonly used includes auxin, abscisic acid, kinetin, gibberellins, ethylene, salicylic acid and polyamines

7) Nutripriming

Here the seeds are primed with nutrient solution to improve the seed quality by enhancing the seed nutrient content. Micronutrients are vital for the plant growth as it involves in 2 key process namely photosynthesis and the respiration that aid in overall growth of the plant.

8) Nano priming

It is a new seed priming method with the nanoparticles like iron oxide, zinc oxide, silver nanoparticle, titanium dioxide etc. Nutrient or fertilizer applied to the plants are not taken up by them as they get drained off or broken down by the exposure to water and light. Nanoparticulate nutrient/material deliver to the plants provides restricted and adequate nutrient use at the specific site required for the plant growth.

Conclusion

The technique of seed priming is considered as the best solution for problems related to germination that too when the seeds are under favourable condition. Over last few decades, priming seeds offers effective, realistic and smart option for an effective plant growth. It is environmentally safe and can be easily adapted by farmers and are beneficial in numerous ways. Added, all the priming protocols would not lead to significant germination and growth where some inappropriate techniques can cause protective protein degradation. Hence, there must be an extensive research for selecting a specific priming protocol for different species in relation to germination and growth in various environmental conditions.

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High-Throughput Plant Phenomics (HTTP) for Crop Improvement

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Introduction

Improving plant genetics and breeding is one of the best ways to increase the productivity of major food and feed crops worldwide. However, the discipline of crop improvement must evolve to meet the increasing challenges of climate change Moreover, some predictions suggest that crop yields must approximately double by 2050 to adequately feed an increasing global population. Modern techniques for crop improvement rely on both DNA sequencing (genotyping) and accurate quantification of plant traits (phenotyping) to characterize germplasm and experimental populations to identify useful genes/QTLs. Despite recent advances in genomics, a lack of suitable phenotyping data (phenomics data) has led to poor results in gene/QTL discovery, limiting progress in genomics-assisted crop improvement programs. Therefore, acquisition of high-throughput, effective and comprehensive trait data needed to understand the genetic contribution to phenotypic variation has become an acute need Sustaining and increasing crop yields with the advantages afforded by modern genetics tools now depends on rapid advancement of phenomics.

More noticeably, sustainable plant productivity to provide sufficient food for the increasing human population has become a thorny issue to scientists in the era of unpredictable global climatic changes, appearance of more tremendous or multiple stresses, and land restriction for cultivation. Thus high-throughput phenotyping platforms allowed screening of large plant populations, germplasm collections (core collections) breeding material and phenotypic trait acquisition coupled with decreased labour input achieved by automation, remote control and data (image) analysis pipelines amenable to high-throughput. To further these efforts, the International Plant Phenomics Initiative was also launched. Progress has been already made, but more research is required to fully utilize genomics and molecular breeding tools in crop improvement This review article aims to: i) highlight the importance of phenomics and phenotypic constraints in crop improvement in the genomics era, ii) review the status of phenomics platforms and facilities worldwide, iii) highlight the use of high-throughput phenomics platforms for trait dissection in different crop plants and discovery of genes/QTLs for variety of traits in different crop plants, and (iv) highlight the need for sharing of phenomics databases and phenotypic data for crop improvement.

One of the important highlights in this issue is the review of the benefits brought by high-throughput sequencing technology, which is also known as next-generation sequencing

(NGS). It is not so difficult to recognize that its application has allowed us to carry out biological studies at much deeper level and larger scale.

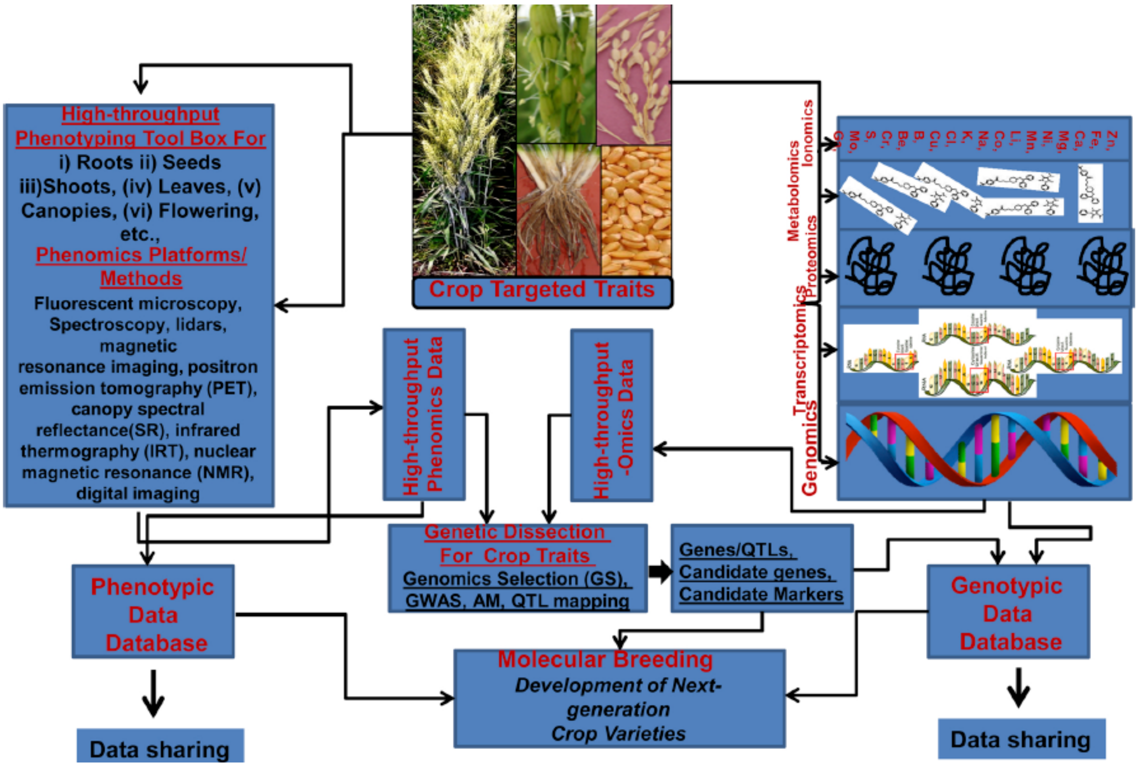

Fig. 1: Holistic view of role of crop phenomics in crop improvement.

The phenomics bottleneck

Unprecedented recent developments in next-generation DNA sequencing technologies have resulted in tremendous progress in unravelling and understanding crop genomes, thus shifting the plant science research bottleneck from genomics to phenomics. This shift has driven the need and efforts for the development of high throughput, non-invasive phenotyping technologies able to capture trait phenotypic data that can be linked to genomics information for crop improvement Despite these advances, our ability to collect reliable phenotypic data still lags behind the current capacity to generate high-throughput molecular genotyping data resulting in a "phenotypic bottleneck", which is currently hindering plant breeders from making fast progress.

Effective phenotyping

Effective phenotyping means increasing the accuracy, precision, and throughput of measurements, while reducing costs (cost-efficient/affordable**)** and minimizing labour through automation, remote sensing, data integration, and experimental design. Cost-efficient phenotyping is developing rapidly due to decreases in cost of equipments such as environmental sensors, and smartphone embedded applications for mobile imaging to capture images and crop performance datasets both under controlled environments and in the field. Too few studies present QTL derived under experimental conditions that are subsequently also of relevance to crop productivity. For instance, in wheat QTLs/genomic regions have been identified for agronomic and physiological traits in environments encompassing drought, heat, and well-irrigated conditions and efforts have been made in the study to normalize the confounding effects phenology and growth habit.

The phenotyping environment and its control

The environment plays a crucial role in plant phenomics since most of the important traits in plants are quantitative in nature and highly influenced by environmental factors. Further, plant breeders aim to develop crop varieties with good buffering and stability that perform well under different environmental conditions. Therefore, appropriate documentation of the experimental environmental conditions (*e.g*. rainfall, temperature, photoperiod and soil characteristics) is essential for any crop phenomics strategy. These genetic/environment interactions significantly contribute to the phenotypic variation explained by complex quantitative traits like yield, drought and quality traits like grain protein content. For highly heritable traits such as grain weight, G×E does not play a major role but main effect genes play major role in controlling grain weight.

Plant phenotyping platforms and initiatives

The area of plant phenotyping is continuously progressing, with invasive, low throughput phenotyping methods being replaced by high throughput, non-destructive methods. Rapid developments in non-destructive inexpensive sensors and imaging techniques over the last decade have revolutionized crop phenomics . Current implementations of non-destructive high-throughput phenotyping platforms include the use of sophisticated technologies such as: i) infrared thermography and imagery to scan temperature profiles/transpiration; ii) fluorescent microscopy/spectroscopy to assess photosynthetic rates; iii) 3D reconstruction to assess plant growth rate and structure; iv) light detection and ranging (LIDAR) to measure growth rates; v) magnetic resonance imaging and positron emission tomography to measure growth patterns, root/leaf physiology, water relations, and/or assimilate translocation properties; vi) canopy spectral reflectance for monitoring dynamic complex traits; vii) nuclear magnetic resonance for monitoring the structure of tissues, mapping water movements, and monitoring sucrose allocation;

Phenotyping platforms in trait phenotyping: some examples

The variety of high-throughput phenomics methods/platforms that have been developed over the past decade have been used for phenotyping of a variety of plant traits including growth, phenology, physiology, disease incidence, insect damage, drought tolerance and for recording data on different plant organs such as roots, seeds and shoots. For example using different phenotyping platforms, data has been recorded in high-throughput and automated manner for plant height, leaf growth parameters including leaf area, area of canopies, photosynthesis, photosynthesis efficiency, chlorophyll content, leaf nitrogen content and canopy height in different plant species including wheat, maize, barley , rice, pea, Arabidopsis, potato, canola, and soybean among others. High-throughput methods have been also used to study plant responses to various types of abiotic stresses (drought, heat, cold tolerance, salinity, Nitrogen limitation, and UV light). Drought tolerance is considered one of the most important complex quantitative traits and many phenomics approaches have been used to understand the nature of drought tolerance. The approaches range from osmotic balance in hydroponics, to conveyer systems in glass house, to rainout shelters in the field.

Examples of phenomics platforms for trait phenotyping in plants like Growth traits, phonological traits and physiological traits *viz.,* ., Microsoft Excel-based macro, a tool called "LEAF-E", Light Curtain arrays (LCs), TRiP (Tracking Rhythms in Plants). Biotic and abiotic stresses (drought, heat, cold tolerance, salinity, nutrient-starving, UV light; low N-stress) software's *viz*., Hyperspectral imaging (HSI), Hyperspectral absorption-reflectance-transmittance imaging (HyperART) Therefore high-throughput platforms /methods developed like hyperspectral imaging (HSI) are considered promising non-invasive sensor techniques in order to accelerate and to automate classical phenotyping methods

Integrating high-throughput trait phenotyping with genomics

The evolution of high-throughput phenomics platforms during the last decade has revolutionized trait phenotyping by helping in recording data effectively and cost-efficiently. The data generated was used in trait dissection using a variety of approaches like QTL interval mapping, association mapping, candidate gene association studies, genome-wide association studies, QTLseq and genomic selection leading to discovery of genes/QTLs for important targeted traits. The rice automatic phenotyping platform (RAP) was used for high-throughput screening of recombinant inbred line (RIL) mapping population combined with genome-wide association studies (GWAS) that led to the identification of 141 associated loci, 25 of which were previously known genes such as the Green Revolution semi-dwarf gene, SD1

Phenotype databases & data sharing:

Advances in analysis of genome sequencing data has benefited greatly due to the publically available genomics databases [11]. Several genomics and proteomics databases are available where DNA sequence and protein sequence data are continuously being stored and shared by researchers world-wide. However, the recording of trait data in highthroughput manner is still not routine and it is important to note that even after collection of effective phenotypic data from hundreds of plants from multiple locations and replications; there is no public repository for the deposition of this raw data. Similarly, crop specific databases have been developed including: (i) Phenome Networks (http://phnserver.phenomenetworks. com), and LycoTILL (http://www.agrobios.it/tilling/index. html) for tomato, (ii) Oryza Tag Line software (OTL) (http://urgi.versailles. inra.fr/OryzaTagLine), Rice Mutant Database software (RMD) (http://rmd.ncpgr.cn), Tos17 (http://pc7080.abr.affrc.go.jp/phenotype), and OryGenesDB (http://orygenesdb.cirad.fr/index.html) for rice, (iii) SCRI Barley Mutants software (http://bioinf.scri.ac.uk/barley/) for barley, (iv) Maize GDB software http://www.maizegdb.org/rescuemu-phenotype.php) for maize

Conclusion

In summary, with recent progresses in biological and biotechnological areas, especially rapid development of advanced technologies in biological system modelling, functional genomics, computer-based analysing tools, genetic engineering and molecular breeding, biological control and biotechnological applications in agriculture have brought about an extraordinary revolution and have been considered the most powerful approaches in maintaining or even increasing crop yield.

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