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Phloem Restricted Trypanosomatid: An Emerging Microscopic Pathogen of Tropical Region

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Introduction

The phloem restricted trypanosomatids are a flagellate protozoan commonly called as *Phytomonas* which are grouped under the phylum *Euglenozoa*. They differ from other protozoan members in genomic, mitochondrial and cytological organization and have more characters of animal. Strong evidences support that some flagellate protozoa cause disease in plants although their pathogenicity could not yet be determined via Koch's postulates similar to phytoplasma and some RLO's. The presence of flagellate protozoa (= flagellates) in the latex - bearing cells (laticifers) of the laticiferous plant was first observed by Lafont in Mauritius in 1909 in *Euphorbia*. Implication of flagellate protozoa as etiological agents in plant disease was discovered by Stahel in 1931. The plant parasitizing protozoa were placed under a separate genus *Phytomonas* and the species described by Lafont was named as *Phytomonas davidi*. The new genus *Phytomonas* was suggested by Donovan in 1909.

Scientific Classification of *Phytomonas*

Kingdom: Protozoa
Phylum: Euglenozoa
Class: Kinetoplastea
Order: Kinetoplastida
Family: Trypanosomatidae
Gemus: *Phytomonas*

General Characteristics of *Phytomonas*

- They have a definite long, oval or spherical body of size ranges between 5 x 250µm size.
- Vic Kerman, 1976 defined *Phytomonas* as flagellates with digenetic life cycle in plants and insects, retaining the promastigote form throughout (anterior end terminating in a flagellum which is free from the cell body).
- The genus *Phytomonas* reside in the phloem sieve tubes of non-lactiferous plant like coconut, oil palms, red ginger and coffee. Most of the lactiferous inhabiting *Phytomonas* are not considered to be pathogenic except *P.francai* which causes empty root in cassava.
- They can be grown on specialized culture media. The phloem inhabiting *Phytomonas* was first grown in media containing cultured insect cell for generations and then grown on cell free media.
- The plant-infecting *Phytomonas* seem to be transmitted by root graft and by insects of the families *Pentatomidae, Lygaeidae* and *Coreidae*.
- *Phytomonas elmassiani* (on milk weed), *P. brancrofti* (on ficus), *P. leptovasorum* (on coffee), *P. francai* (on cassava) and *P. staheli* (on coconut and oil palm) are some of the parasitic protozoa reported respectively from plants belonging to Asclepiadaceae, *Moraceae*, *Rubiaceae, Euphorbiaceae* and *Palmaceae*.

Mechanisms of infection caused by *Phytomonas*

The actual mechanism by which the protozoa cause disease in plant is not clear. *P. francai,* a laticifer inhabiting protozoa produces enzyme to degrade pectin and cellulose in the laticifer ducts of root and result in empty root disease with poor development of root system and a general chlorosis in cassava plants. However, the non-laticifer or phloem inhabiting *Phytomonas* block the transport of photosynthates to roots and cause phloem necrosis in coffee, hart rot disease in coconut and the Marchitez suppressive (sudden wilt or wither) in oil palm.

Some of the economically important diseases caused by Phloem Restricted Trypanosomatid (*Phytomonas*)*:*

1. **Phloem necrosis of coffee: *Phytomonas leptovasorum:*** Symptoms: Infected trees show sparse yellowing and dropping of leaves. At the end, only the young top leaves remain on bare branches. Roots show die back and the tree dies in the diseased palms, the roots and trunk exhibit multiple divisions of cambial cells and production of a zone of smaller and shorter (abnormal) phloem vessels next to the wood cylinder. The bark is firmly attached to the wood and cannot be separated from it. Trees wilt and die within 3 to 6 weeks during dry season. It can be transmitted through root grafts but not through green branch or leaf grafts. Pentatomid insects of the genus *Lincus* also transmit the disease.
2. **Heart rot/ Lethal yellowing or bronze leaf wilt of Coconut**: ***Phytomonas staheli***: Symptoms: Include yellowing and browning of the tips of the older leaves that subsequently spread to the younger leaves. Recently opened inflorescence become black, unripen nuts fall off and roots begin to rot. Petioles of older leaves may break and spear becomes necrotic. At this stage apical region of the crown rots and emits foul odour. Diseased trees will die within few months of appearance of the external symptom. Pentatomid insects of the genus *Lincus* and *Ochlerus* transmit the disease.
3. **Sudden wilt or Marchitez sopresiva in Oil palm: *Phytomonas staheli:*** Symptoms: It includes browning of tips of the older leaves, which subsequently spread to the younger leaves and eventually become ashy gray. The plant growth slowdown, fruit bunches discolour, rot or falloff and the whole tree die within a few weeks due to rotting and deterioration of root tips and root system. They occur widely in the phloem sieve elements of roots, leaves and inflorescences of infected trees. Pentatomid insects of the genus *Lincus* and *Ochlerus* transmit the disease.
4. **Wilt and decay of red ginger: *Phytomonas staheli:*** Symptoms: It includes browning of tips of the older leaves, which subsequently spread to the younger leaves and eventually become ashy gray. The plant growth slowdown and the whole plant die within a few weeks due to rotting and decaying of rhizomes.
5. **Empty root of Cassava: *Phytomonas francai:*** Symptoms: Diseased plants have poor root system and small slender roots with no starch. The above aerial parts of the plants exhibit general chlorosis and decline. Diseased plants contain numerous flagellate protozoa in the laticifer ducts but not in the phloem. It can be transmitted through stem grafts. Pentatomid insects of the genus *Lincus* also transmit the disease.

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2. PLANT PATHOLOGY

Role of Mycorrhizal Fungi for Improving Plant Health

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Mycorrhizal fungi association widely varied in structures and functions, but the Arbuscular Mycorrhizae (AM) are the most common interactions. Six genera of arbuscular mycorrhizal fungi have been recognized based on morphological characteristics of a sexual spores and also based on various biochemical studies as well as molecular methods. Further, various criteria have been used for the identification of AMF like hyphal character, auxiliary cells subtending hyphae, spore or sporcarp ontogeny, morphology, germination, shield spore wall, biochemical, molecular and immunological characteristics. Few species of host roots synthesize a yellow pigment when colonized by mycorrhizal fungi which is considered as a sign of infection. AMF are zygomycetous belonging to the genera *Glomus, Gigaspora, Sclerocystis, Acaulospora, Entrophospora* and *Scutellospora*.

Mycorrhizal fungi are a major component of the agricultural natural resource and they are members of the fungus kingdom. A symbiotic association of fungus and roots has been discovered in Monotropa Hypopity by Franciszek Kamienski (1881). The studies of the Polish botanist Frank 1885 had initiated worldwide interest on a fungus-root (Myco-rhiza) Also, he gave the name *MYCORRHIZA* to the peculiar association between root trees and ectomycorrhizal fungi. The AMF play an important function in the reduction of plant pathogens like *Rhizoctonsa solani, Pythium altimum, Phytophthora* species, *Ralstonia solanaceaum*, *etc.*

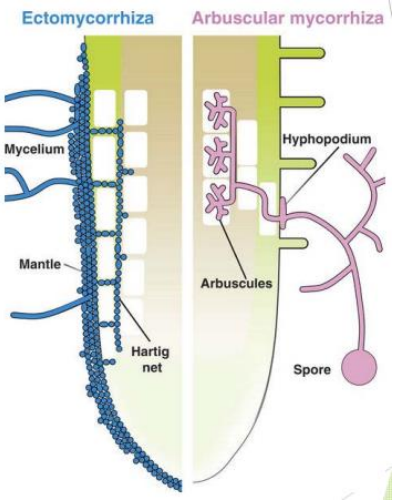
Types of Mycorrhizal Fungi

Seven different types of mycorrhizal tungi association have been recognised and the most important ones are:

Endo-mycorrhizae

Endo-mycorrhizae represent a group of fungi that are associated with most agricultural crops and provide biological protection against soil-borne diseases. They occur in most ecosystems of the world and are found in many important crop species (wheat, maize, rice, grape, soybean and cotton) and horticultural species roses, petunias and lilies) (Peterson et al., 2004), AMF are obligatory biotrophs feeding on the products of their live plant host and those fungi are not specialized to their potential hosts. The host plant receives mineral nutrients from outside the roots depletion zone via the extraradical fungal mycelium, while the AMF obtains photo-synthetically produced carbon compound from the host.

Many endomycorrhizal fungi form terminal or intercalary vesicles in the root cortex. When the vesicles are expanded the thin walled structures, which are not septum and it's contain a large quantity of lipids. They may be oval, spherical, or lobed in shapes and may become thick walled and resting spores. The term arbuscular mycorrhizae replaced the earlier term vesicular arbuscular mycorrhizae (VAM) because some endomycorrhiza produce vesicles, but all form arbuscules only.



Ecto-mycorrhizae

Ecto-mycorrhizal (ECM) fungus forms a thick mantle structure within the intercellular spaces of root cortex and a sheath around the feeder root acting as an interface for channeling of nutrients from the plant to the fungus and vice versa. Ectomycorrhizal fungi do not penetrate living cells in host roots, but can only surround them. The extensive mycelium produced by ectomycorrhizal may function in transferring nutrients directly from the decaying leaves.

They are most common in ornamental and forest trees species in the family *Pinaceae, Myrtaceae, Salicaeae, Dipterocarpecae, Fagaceae* and *Gentum* plants. Ectomycorrhizas are distinguished by the presence of mantle and the hartig net. Hartig net develops in cortical cells or epidermal cells. Hartig net consists of branch systems which can provide a large surface contact between cells of the two symbionts. Other types of mycorrhizal fungi include (Ecto-endo Mycorrhiza, Ericoid Mycorrhiza, Monotropoid, Arbutoid mycorrhizas and Orchid mycorrhiza).

Functions of Arbuscular Mycorrhizae (AM) Fungi:

- Mycorrhizal fungi offer protection against soil borne pathogens (bio-control agents).
- Increase soil's water & nutrition holding capacity.
- Improve soil porosity and permeability.
- Develop soil microenvironment, promote higher microbial activity and nutrient cycling.
- Increase roots establishment and survival at seeding or transplanting.
- Improve the plant's mineral absorption capabilities, access many extra nutrient sources share with colonized plants.
- Increase plants resistance ability to soil diseases, virus, drought & salt stress and pests etc.
- Increase plants root system healthy development.
- Produce more vigorous and healthy plants. Increase plant establishment and survival at seeding or transplanting.
- Increase yields and crop quality.
- Improve drought tolerance, allowing watering reduction.
- Enhance flowering and fruiting.
- Optimize fertilizers use, especially phosphorus. Increase tolerance to soil salinity.
- Reduce disease occurrence.
- Contribute to maintain soil quality and nutrient cycling.
- Contribute to control soil erosion Hyphal networks are very efficient at exploring the soil and bringing in phosphate, zinc and ammonium.

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3. SOIL SCIENCE

Micronutrients Deficiencies and Its Management in Coconut

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Micronutrients

Boron

Boron deficiency is caused by insufficient boron in the soil. It may be caused by soil drying and high soil pH, while temporary boron deficiency is caused by heavy leaching. Symptoms always occur on newly emerging leaves, and remain visible on these leaves as they mature and are replaced by younger leaves. One of the earliest symptoms of boron deficiency on coconut palm is leaf wrinkling and manifested as sharply bent leaflet tips, commonly called "hook leaf". These sharp leaflet hooks are quite rigid and cannot be straightened out without tearing the leaflets. Leaves have a serrated zigzag appearance. One of the most common symptoms of boron deficiency is the failure of newly emerging spear leaves to open normally. In a chronic stage, multiple unopened spear leaves may be visible at the apex of the canopy. Boron deficiency also occurs in inflorescence and nuts. The inflorescence and nuts are become necrotic.

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Correction measure

Application of borax/sodium tetraborate 0.2% (2 g/l of water), (75-100 ml/seedling), borax/ sodium tetraborate/octaborate 15-20 g/plant.

Zinc

Zinc deficiency is characterized by formation of small leaves wherein the leaf size is reduced to 50%. Leaflets become chlorotic, narrow and reduced in length. In acute deficiency, flowering is delayed. Zinc deficiency will also lead to button shedding. Its occurs mostly in saline soils.

Correction measure

Soil application of $ZnSO_4$ @ 10 kg/acre.

Iron

Iron deficiency usually appears on palms growing in poorly aerated soils or those that have been planted too deeply. Water logged soils and deep planting effectively suffocate the roots and reduce their effectiveness in taking up nutrients such as iron. The main symptom of iron deficiency is chlorosis or yellowing between the veins of new leaves (uniform chlorotic new leaves as the deficiency progresses, the tips become necrotic and leaf size reduced).

Correction measure

Application of $FeSO_4$ 0.25 to 0.5 kg/tree/year.

Copper

Coppery bluish leaf.Rolling of terminal leaves due to loss of turgor. Leaves appear to be bleached grey. Fail to produce flowers.

Correction measure

Soil application of $CuSO_4$ @ 10 kg/acre.

Manganese

The newest leaves of manganese deficient palms emerge chlorotic with longitudinal necrotic streaks. As the deficiency progresses, newly emerging leaflets appear necrotic and withered on all but basal portions of the leaflets. This withering results in a curling of the leaflets about the rachis giving the leaf a frizzledappearance ('frizzle top'). On new leaves of manganese-deficient palm, necrotic leaflet tips fall off and the leaf has a signed appearance. In severely manganese deficient palms, growth stops and newly emerging leaves consist solely of necrotic petiole stubs.

Correction measure

Soil application of $MnSO_4$ @ 10 kg/acre

Nutrient management

Coconut has unique feature among the plantation crops in that it flowers and fruits throughout the year. Therefore, its requirement of water and nutrients should be supplied throughout the year. Nutrient exhaust from one hectare of coconut ranged from 92 to 149 kg N, 12 to 20 kg P and 119 to 183 kg K. This clearly indicates that K and N are required in higher quantities for coconut production.

Regular manuring from the first year of planting is essential to achieve higher productivity. For coconut 20 - 50 kg organic manure should be applied per palm per year with the onset of south west monsoon, when soil moisture content is high. Different forms of organic manures like compost, farm yard manure, bone meal, fish meal, blood meal, neem cake, groundnut cake etc. could be made use for this purpose. Apply fertilizers and manures in circular basins at a radius of 2.0 m from the base of the palm and 10 cm deep, opened after the onset of southwest monsoon.

4. HORTICULTURE

Health Benefits of Mushroom

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Introduction

Mushrooms have been used as nutrients by many communities due to their taste and nutritional content. The ancient Romans called “the food of the gods” and the first Egyptians called the “gifts from God of Osiris” and Chinese called it “the elixir of life”. In the history of humanity, mushrooms have been consumed as food, especially during the rainy season. Approximately 1000 species of mushrooms are classified as edible worldwide.

Mushrooms, which serve as a good source of food for human beings for centuries, have high nutritional value due to the vitamins and minerals they contain. In a study on an edible mushroom species, it was found that 88-90% water, 3-8% protein, 0-3% fat, 4-9% carbohydrate, 1-2% ash (calcium, phosphorus, iron, copper, chlorine, sodium, zinc, manganese and bromine) in trace amounts; B vitamins A and B complex vitamins B1 (Thiamin), B2 (Rhiboflavin), B3 (pantetonic acid), B5 (Nicotinic acid), vitamins.

Health Benefits of Mushroom

Weight Management - It is found that substituting red meat with white button mushrooms can help enhance weight loss. Dietary fiber plays an important role in weight management by functioning as a "bulking agent" in the digestive system. Mushrooms contain two types of dietary fibers in their cell walls (beta-glucans and chitin) which increase satiety and reduce appetite, making you feel fuller longer and thereby lowering your overall calorie intake

Prevents Cancer - Compounds restricting tumor activity are found in some mushrooms. All forms of edible mushrooms, and white button mushrooms in particular, can prevent prostate and breast cancer.

Fresh mushrooms are capable of arresting the action of 5-alpha-reductase and aromatase, chemicals responsible for growth of cancerous tumors. The drug known as Polysaccharide-K (Kresin), is isolated from *Trametes versicolor* (*Coriolus versicolor*), which is used as a leading cancer drug. Some mushroom-derived polysaccharides have ability to reduce the side effects of radiotherapy and chemotherapy too. Such effects have been clinically validated in mushrooms like *Lentinula edodes, Tramtes versicolor, Agaricus bisporous* and others.

Diabetes Control - Studies have shown that type 1 diabetics who consume high-fiber diets have lower blood glucose levels and type 2 diabetics may have improved blood sugar, lipids and insulin levels. One cup of grilled portabella mushrooms and one cup of stir-fried shiitake mushrooms both provide about 3 grams of fiber.

Heart Health - The fiber, potassium and vitamin C content in mushrooms all contribute to cardiovascular health. Potassium and sodium work together in the body to help regulate blood pressure. Consuming mushrooms, which are high in potassium and low in sodium helps to lower blood pressure and decrease the risk of high blood pressure and cardiovascular diseases.

Anti-Aging Property - The polysaccharides from mushrooms are potent scavengers of super oxide free radicals. These antioxidants prevent the action of free radicals in the body, consequently reducing the aging process. Ergothioneine is a specific antioxidant found in *Flammulina velutipes* and *Agaricus*

bisporus which is necessary for healthy eyes, kidney, bone marrow, liver and skin.

Strengthens immunity - Mushrooms are capable of strengthening the immune system. A diverse collection of polysaccharides (beta-glucans) and minerals, isolated from mushroom is responsible for up-regulating the immune system. These compounds potentiate the host's innate (non-specific) and acquired (specific) immune responses and activate all kinds of immune cells.

Conclusion

Mushrooms are known as healthy foods throughout the world with proteins, vitamins, minerals, chitin, essential amino acids as well as low fat and calories.4 The nutritional value of mushroom is comparable to foodstuffs such as corn, soybeans or beans. They are especially important foods with the basic amino acids they contain. Within the mushrooms, there are proteins at levels ranging from 5-49% of dry weight. In addition to protein, dietary fibers, minerals such as potassium, phosphorus iron, and vitamins and carbohydrates.

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5. AGRICULTURE

Effect of High Temperature on Rice Growth and Yield

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Introduction

Global mean temperature have increased by 0.74°C during last 100 years. Global circulation models predict 1.4 to 5.8°C rises in global temperature because of projected increase in the concentrations of all greenhouse gases by the end of this 21st century. Increase in average daily temperature is projected majorly due to increase in night temperature. Night temperatures are expected to increase at a faster rate than day temperatures due to less radiant heat loss because of increased cloudiness.

Rice (*Oryza sativa*) is an important cereal crop and as a primary source of food accounts for 37-75 % of calories intake of more than 3 billion humans. With the likely growth of world's population toward 10 billion by 2050, the demand for rice will grow faster than for other crops. It is more vulnerable to the potential impacts of global warming. There are already many challenges to achieving higher productivity of rice. In future, the new challenges will include climate change and its consequences. Rice requires minimum temperature of 15℃, optimum temperature of 20 - 30°C and maximum temperature of 45℃. The optimum temperature for the normal development of rice ranges from 27 to 32℃.

Effect of High Temperature on Rice Growth Parameters

Growth parameters like plat height, leaf area index and tiller umbers were affected by temperature. Plant height was reduced under high temperature than the ambient temperature. After transplanting, the aerial growth of rice plants is accelerated linearly from 18 – 33°C and growth is reported to decrease above this temperature range. In initial stages of plant growth, up to vegetative stage there is no changes in leaf area index if temperature increase. After vegetative stage, temperature increases which decrease the leaf area index because reproductive stage is sensitive to temperature than vegetative stage. Less number of tillers obtained under high temperature. High temperature may affect mobilization of assimilates. At maturity, the number of tillers was found to be lower in high temperature conditions than under ambient temperature.

On Yield Attributes

When temperature increases, number of panicles per plant was reduced. After the active tillering stage, high temperatures decrease the number of panicles, especially at maturity. If daily mean temperature increases from 25°C to 29°C, number of panicles per plant was reduced up to 50%. Maximum temperature for getting high spikelet number is 22°C. Above that, temperature increases, reduce the number of spikelet upto 60 %. Temperature at which sterility occurs varies with the cultivars. Above 35°C during anthesis can result in 90 % floral sterility in several cultivars. High temperatures cause poor anther dehiscence characterized by tight closure of the locules, which was shown to reduce pollen dispersal in rice. High temperature may leads to flower abnormality so the pollen viability is affected. Albinism of panicles and spikelets occur when temperature increase. Albinism is the absence of chlorophyll producing a white panicles or spikelet in rice. Temperature increases, reduce the spikelet fertility percentage. Spikelet fertility percentage is a key component which determines the final grain yield of rice. High temperature reduces the filled grain percentage by controlling the capacity of grains to accept carbohydrate. High night temperatures are related to decreased panicle mass and increased numbers of chalky kernels. The sink capacity under high temperature can be low due to the increase in the percentage of sterile spikelet and the reduced activity of starch synthesis can result in reduction of test weight.

On Rice Yield

The temperature at or above 40-41°C resulted decrease in grain yield. Threshold temperature for getting higher grain yield is between 32°C and 35°C. Even brief exposure to high temperatures during seed filling can accelerate senescence, diminish seed set and seed weight and reduce yield. Grain yield declined by 10 % for each 1°C increase of minimum temperature.

Mitigation Strategies to High Temperature in Rice

- Changing planting date is a powerful tool to reduce the effect of high temperature on rice growth, yield and grain quality.
- Developing tolerant rice cultivars for high temperature stress. IR 64 tolerant to high temperature up to 40°C.
- Hybrid able to adapt to elevated temperature in all growth character than variety.
- Modification of micro climate through providing shelter and shade as in agro forestry system.
- Adopting a late or early maturing cultivar and shifting the crop season. Application of chemical substances like osmoprotectants or plant growth regulator which will help to withstand the plant under high temperature. Eg: ABA, salicylic acid to increases antioxidant levels thereby protecting the membranes.
- During high temperature, transpiration will be more in plants, which will leads to reduce the water potential of the leaf. To maintain water potential of the leaf and also to reduce transpiration, leaf rolling will be occur in rice plant.
- Under high temperature crop mature early than the ambient temperature because to avoid the water loss, energy loss from the crop. Shortening the ripening period in rice due to increase in temperature caused by higher activity of enzymes involved in starch synthesis during early grain growth stage.

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6. PLANT PATHOLOGY

Salvadora Persica: An Important Tree of Saline and Drought Tolerant

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Salvadora persica L. also known as Arak (in Arabic), Peelu (in Urdu) or Miswak. It is a facultative halophyte of ethnoecological importance belonging to the family *Salvadoraceae*. It is an important medicinal plant and all parts of this plant can be utilized for different medicinal purposes. It is widely distributed in arid, semiarid, and saline regions of India. It can tolerate high salinity, high or low rainfall, high temperature and low humidity conditions. In harsh saline and desert condition, this species supports the wildlife and are important parts of the ecosystem. It is an upright evergreen that grows as a small tree or shrub with a crooked trunk. It is seldom more than one foot in diameter, reaching a maximum height of 3 meters. The leaves are small, rounded to ovate, slightly fleshy, thick and succulent, having a strong smell of cress or mustard. The fragrant flowers are small. The fruits are like fleshy berries; small and barely noticeable. They are edible in both fresh and dried form. It is widespread in arid regions, on saline lands, in coastal regions, thorn shrubs, desert flood plains, and grassy savannahs. It is native to the Arabian Peninsula, Africa, Iraq, India, Pakistan, and Sri Lanka. The plant response to salinity involves changes in the activity of genes and proteins, which invariably lead to changes in plant metabolism. Miswak is a traditional chewing stick prepared from the roots, twigs, and stem of *Salvadora persica* and has been used as a natural method for tooth cleaning in many parts of the world for thousands of years. Several scientific studies have demonstrated that the miswak (*Salvadora persica*) possesses antibacterial, anti-fungal, anti-viral, anti-cariogenic, and anti-plaque properties. Several studies have also claimed that miswak has anti-oxidant, analgesic, and anti-inflammatory effects.

The antioxidant system and several metabolites in plants play vital roles in adaptation under stress conditions. Salinity and arsenic induced oxidative damage to the plants trigger the generation of ROS, leading to the peroxidation of membrane lipid, and degradation of nucleic acids, proteins, enzymes and chloroplastic pigments. Plants have antioxidant defense mechanisms to survive against stress-induced oxidative damage, which neutralize, remove, and scavenge the stress-induced ROS. The antioxidant system includes some key

enzymes like SOD, CAT, APX, GR, DHAR, MDHAR, and GPX and non-enzymatic antioxidants such as ascorbate, glutathione, carotenoids, and α-tocopherol which also detoxify ROS. The primary cause of oxidative stress under salinity is the overproduction of reactive oxygen species (ROS) such as superoxide (O_2^- radical), hydroxyl radical (OH^- radical) and hydrogen peroxide (H_2O_2). Therefore, the production and regulation of several primary and secondary metabolites involved in various physiological processes of the plants are directly affected for management of salt-induced perturbations as well as genome manipulation.

Health Benefits and Industrial Applications of *Salvadora persica*

Salvadora persica L. is frequently used as a toothbrush (miswak) is highly recommended by Prophet Muhammad. With a long history in folk medicine for centuries, *S. persica* was used in oral hygiene, food, cosmetics, fuel, and even as a medicine. Previous phytochemical investigation of its different parts afforded different classes of secondary metabolites such as flavonoids, glycosides, sterols, terpenes, carbohydrates and alkaloids. Organic sulfur-containing compounds and elemental sulfur are also present. Many pharmacological activities were reported experimentally, including antimicrobial, antioxidant, analgesic, anthelmintic, anti-inflammatory, antiulcer, sedative, anticonvulsant, anti-osteoporosis, antidiabetic, hypo-lipidemic, in addition to wound-healing, antidepressant and antitumor activities. Recently, a possible activity against COVID-19 protease was documented by molecular docking.

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7. AGRICULTURAL STATISTICS

Testing of Hypothesis and its Applications in Agricultural Research

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Introduction

Testing a hypothesis is an essential part of the scientific method and is used to determine the validity of a proposed explanation or prediction. The process typically involves designing and conducting experiments or gathering data to support or reject the hypothesis.

Here is a general outline of how hypothesis testing is conducted:

1. Formulate the hypothesis: Start by stating a clear hypothesis that can be tested. A hypothesis is an educated guess or prediction about the relationship between variables.
2. Design the experiment or study: Determine the appropriate methodology to test the hypothesis. This involves identifying the variables, selecting the sample participants and specifying the experimental conditions or data collection procedures.
3. Collect data: Conduct the experiment or gather the necessary data according to the predetermined design. Ensure that the data collected is reliable and relevant to the hypothesis being tested.
4. Analyze the data: Use Statistical analysis techniques to examine the collected data. The choice of statistical tests will depend on the nature of the data and the specific hypothesis being tested. The analysis will provide

objective results that can be used to evaluate the hypothesis.

5. Draw conclusions: Based on the analysis of the data, determine whether the results support or reject the hypothesis. Consider the significance level, which indicates the probability of obtaining the observed results by chance. If the results are statistically significant, it suggests that the hypothesis is likely to be true. If the results are not significant, the hypothesis may be rejected or further refined.
6. Communicate the findings: Present the results, conclusions, and any limitations of the study.

Different tests of hypothesis commonly used in statistical analysis:

There are various statistical tests used to evaluate hypotheses and determine the significance of the results. The choice of test depends on the nature of the data and the specific research question. Here are some commonly used hypothesis tests:

1. Z-test: The Z-test is used when the sample size is large. It compares a sample mean to a known population mean and determines whether the difference is statistically significant.
2. t-test: The t-test is used when the population standard deviation is unknown. It is commonly employed to compare means of two independent groups (independent samples t-test) or to compare the mean of a single group to a known value (one sample t-test).
3. Chi-square test: The chi-square test is used to analyze categorical data and determine if there is a significant association between two variables. It is often used to test hypotheses about proportions or to compare observed and expected frequencies in contingency tables.
4. ANOVA (Analysis of Variance): ANOVA is used to compare means across three or more independent groups. It assesses whether there are statistically significant differences among the group means and can help identify which specific groups differ from each other.
5. Mann -Whitney U test: This non-parametric test is used to compare the medians of two independent groups when the data are not normally distributed. It is an alternative to the independent samples t-test.
6. Wilcoxon signed-rank test: This non-parametric test is used to compare the medians of two related or paired groups when the data are not normally distributed. It is an alternative to the paired samples t-test.
7. Kruskal -Wallis test: The Kruskal-Wallis test is a non-parametric alternative to ANOVA. It is used to compare three or more independent groups when the data do not meet the assumptions of normality or equal variances.
8. Spearman's rank correlation: This test assesses the strength and direction of the relationship between two ordinal variables. It is a non-parametric alternative to Pearson's correlation coefficient.
9. Pearson's correlation coefficient: This test measures the strength and direction of the linear relationship between two continuous variables.

Applications of Testing of Hypothesis in Agricultural Research:

Hypothesis testing is a valuable tool in agricultural research and can be used in various ways to address research questions and make informed decisions. Here are some examples of how hypothesis testing is applied in agriculture.

1. Variety or cultivar selection: Agricultural researchers often compare different varieties or cultivars of crops to determine which ones perform better in terms of yield, disease resistance, tolerance to environmental conditions, or other important factors. Hypothesis testing can be used to compare the means or other relevant measures of performance between different varieties to determine if there are statistically significant differences.
2. Fertilizer or nutrient management: Hypothesis testing can be used to assess the effectiveness of different fertilizer or nutrient management practices. Researchers can compare the mean yields or other relevant outcomes of plots or treatments with

different fertilizer levels or application methods to determine if there are significant differences in performance.

3. Pest and disease management: Hypothesis testing can be used to evaluate the efficacy of different pest and disease management strategies. For example, researchers may compare the mean pest or disease incidence or severity between treated and untreated plots to determine if there is a statistically significant difference in control effectiveness.
4. Soil management practices: Hypothesis testing can be applied to assess the impact of different soil management practices on soil quality, nutrient availability, erosion control, or other soil-related parameters. Researchers can compare means or other measures of interest between plots with different management practices to determine if there are statistically significant differences.
5. Crop response to environmental factors: Hypothesis testing can be used to investigate how crops respond to environmental factors such as temperature, rainfall, light conditions, or climate change. Researchers can analyze the data to determine if there are significant correlations or differences in crop performance or physiological responses under different environmental conditions.
6. Crop breeding and genetic improvement: Hypothesis testing plays a crucial role in crop breeding programs. Researchers may test hypotheses related to the inheritance of desirable traits, such as yield potential, disease resistance, or drought tolerance. They can use statistical tests to determine if the observed trait variations are statistically significant and heritable.
7. Precision agriculture and technology evaluation: Hypothesis testing can be used to assess the effectiveness and benefits of precision agriculture technologies, such as remote sensing, GPS-guided machinery, or variable rate application. Researchers can compare the performance or outcomes of fields or treatments using these technologies with conventional approaches to determine if there are significant improvements or differences.

Conclusion:

By employing hypothesis testing in agriculture, researchers can obtain objective and statistically sound results that help in making evidence-based decisions, optimizing agricultural practices, improving crop productivity, and addressing challenges in sustainable agriculture.

8. PLANT PATHOLOGY

Characterization and Mass Multiplication of Bio-Control Agents

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Morphological characteristics of *Trichoderma* sp.:

A pure *Trichoderma* culture produce profuse white fluffy mycelium of spongy consistency two to three fine defined concentric mycelium (white) and conidia (green) rings that spread throughout the plate. The culture fast growth in culture medium and development of conidia with green-yellow colour.

Microscopic characteristics of *Trichoderma* sp.:

Trichoderma sp. produce dense conidia, branched conidiophores, ampulliform phialides, slightly globose conidia with yellow-green pigmentation.

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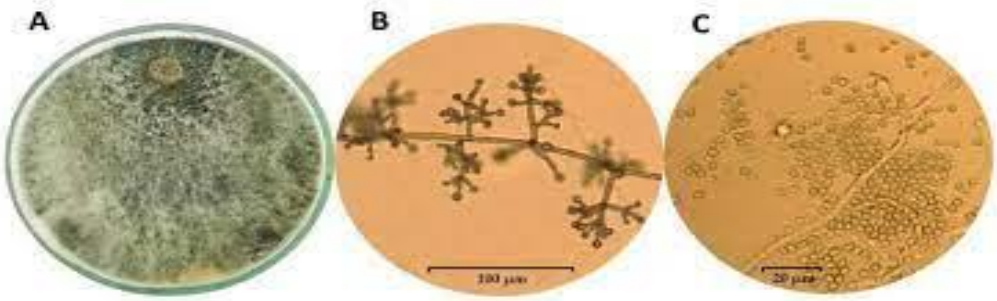
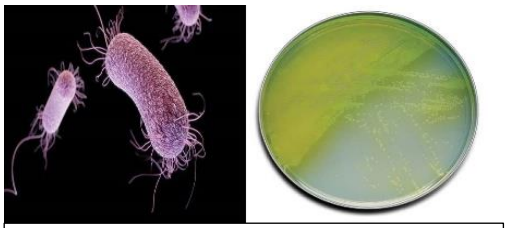


Morphological and Microscopic characteristics of *Pseudomonas fluorescens*

Rod-shaped bacteria and cells are single in arrangement, cephalotrichous flagella, showing gram negative reaction in Gram staining. Special characteristic: Fluorescent pigment *i.e.,* yellowish green fluorescent pigment observed under UV light (365 nm).

Morphological and Microscopic characteristics of *Bacillus subtilis*

Circular colony of this bacteria is rough, opaque, fuzzy white or slightly yellow with jagged edges. It is also a rod-shaped bacteria and cells are single in arrangement, monotrichous flagella, showing gram positive reaction in Gram staining.



Pseudomonas fluorescens

Bacillus subtilis

Isolation of Bio-control agents:

Bio-control agents are isolating by using the soil dilution plate method in a particular media like for isolation of *Trichoderma* sp. in Trichoderma Specific Medium (TSM), for *Pseudomonas fluorescens* in King's B Medium and for *Bacillus subtilis* in Nutrient Agar Medium.

Mass multiplication of Trichoderma sp.:

Preparation of mother culture and Mass multiplication:

Potato Dextrose Broth is prepared as: Peeled Potato: 30 g, Dextrose: 5 g , Distiller water:1000 ml. The medium is prepared and dispensed into conical flasks and sterilized at 15 lb pressure for 15 minutes in an autoclave. After the medium is cooled it is in inoculated with 10 days old fungal disc of *T. sp*. and then incubated for 10 days for fungal growth. This serves as mother culture. Molasses yeast medium is prepared in fermenter and sterilized as described earlier. Then after the medium is cooled, the mother culture is added to the fermenter @ 1.5 lit / 50 lit of the medium and incubated at room temperature for 10 days. Then the incubated broth containing the fungal culture is used for commercial formulation preparation using talc powder.

Mass production of ***Pseudomonas fluorescens and Bacillus subtilis:***

Preparation of mother culture and Mass multiplication:

For *Pseudomonas fluorescens*, mother culture is prepared by using the King's B medium: Peptone: 20.0 g, K_2HPO_4: 1.5 g, $MgSO_4$: 1.5 g, Glycerol: 10 ml, Distilled water: 1000 ml, while for the *Bacillus subtilis,* Mother culture is prepared by using the Nutrient Broth medium: Glucose: 5.0 g, Peptone: 5.0 g, Beef extract: 3.0 g, Sodium chloride: 3.0 g, Distilled water: 1000 ml. The above broths are dispersed into conical flasks

and autoclaved at 15 lb pressure for 15 minutes and cooled and inoculated with a loop of *P. fluorescens* and *B. subtilis* are incubated for 2 days. The King's B medium and Nutrient Broth are prepared and poured into the fermenter and sterilized at 15 lb pressure for 15 minutes. After the broths have cooled below the mother culture of *P. fluorescens* and *B. subtilis* are added to the King's B medium and Nutrient Broth in the fermenters at the rate of 3 lit for 40 lit of the broth. Then it is incubated in the fermenters for 2 days with frequent mixing of the broth by operating the stirrer. Then the broth containing the bacterial growth is collected in plastic buckets and used for mixing with talc powder for commercial formulation.

Quality control parameters for *Biocontrol agents*:

1. Fresh product should contain not less than 2.8 x 10^6 cfu /g for fungal and 2.5 x 10^8 cfu/g for bacterial bioagents.
2. After 4 months of storage at room temperature, the population should be 2.0 x 10^6 cfu /g for fungal and 8-9 x 10^7 cfu/g for bacterial bioagents.
3. Maximum storage period in talc is 3- 4 months.
4. The talc size should be 500 microns
5. The product should be packed in polythene bags
6. Moisture content of the final product should not be more than 20%.

9. PLANT PATHOLOGY

Understanding Rice Black Streak Dwarf Virus: A Threat to Rice Production

Saranya S[1] and Ganesuni Lakshmi Prasanna[2]

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Introduction

Rice is one of the world's most important crops and is the primary food source for more than half of the global population. However, rice production is threatened by a range of diseases, including rice black streak dwarf virus (RBSDV). Rice black streak dwarf virus (RBSDV) is a significant pathogen of rice that can cause severe damage to the crop. This article will provide an overview of RBSDV, its symptoms, transmission, and control measures.

RBSDV

RBSDV is a member of the genus Fijivirus, family Reoviridae, and is a significant pathogen of rice. The virus is transmitted by several species of planthopper, including the white-backed planthopper and the brown planthopper. Once infected, the rice plant shows typical symptoms of yellowing and stunting, and leaves may exhibit black streaks, hence the name of the virus. The disease can significantly reduce yields, with losses of up to 60% reported in some cases. RBSDV can infect both the vegetative and reproductive stages of the rice plant, making it particularly difficult to control.

Transmission

RBSDV is primarily transmitted by planthoppers, which feed on the sap of infected plants and transmit the virus to healthy plants as they move from plant to plant. Infected seeds and plant debris can also serve as a source of the virus. The virus can infect both the vegetative and reproductive stages of the rice plant, making it particularly difficult to control.

Control measures

There are several methods for controlling RBSDV, including cultural, chemical, and biological control measures. Cultural control measures include the use of resistant rice varieties, crop rotation, and removal of plant debris after harvest. Chemical control measures involve the use of insecticides to control planthopper populations. However, these methods can be costly and have adverse effects on the environment and human health. Biological control measures involve the use of natural

enemies of the planthopper, such as parasitoids and predators. These methods can be effective, but require careful management to avoid unintended effects on non-target organisms.

There are several methods for controlling RBSDV, including cultural, chemical, and biological control measures. Cultural control measures include the use of resistant rice varieties, crop rotation, and removal of plant debris after harvest. Chemical control measures involve the use of insecticides to control planthopper populations. However, these methods can be costly and have adverse effects on the environment and human health.

Biological control measures involve the use of natural enemies of the planthopper, such as parasitoids and predators. These methods can be effective, but require careful management to avoid unintended effects on non-target organisms. Integrated pest management (IPM) approaches that combine different control methods may be the most effective.

Research into RBSDV and its management is ongoing. For example, researchers have developed RNA interference-based resistance against RBSDV, which involves using small RNA molecules to interfere with the expression of viral genes and reduce viral replication in the plant.

Conclusion

RBSDV is a significant threat to rice production, causing substantial yield losses and economic damage. Understanding the transmission and symptoms of the virus is critical for developing effective control measures. While there are several control measures available, including cultural, chemical, and biological methods, integrated pest management (IPM) approaches that combine different control methods may be the most effective. Continued research into RBSDV and its management will be necessary to ensure sustainable rice production in the future.

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10. PLANT PATHOLOGY

Bacteriophages: An overview

Saranya S[1] and Ganesuni Lakshmi Prasanna[2]

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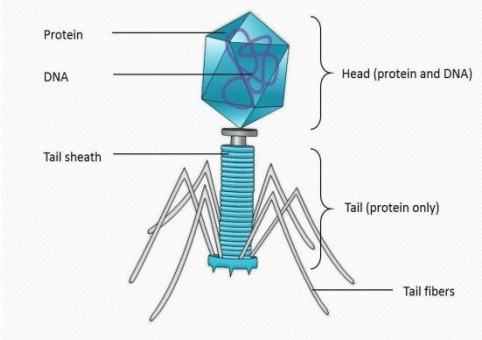
Introduction

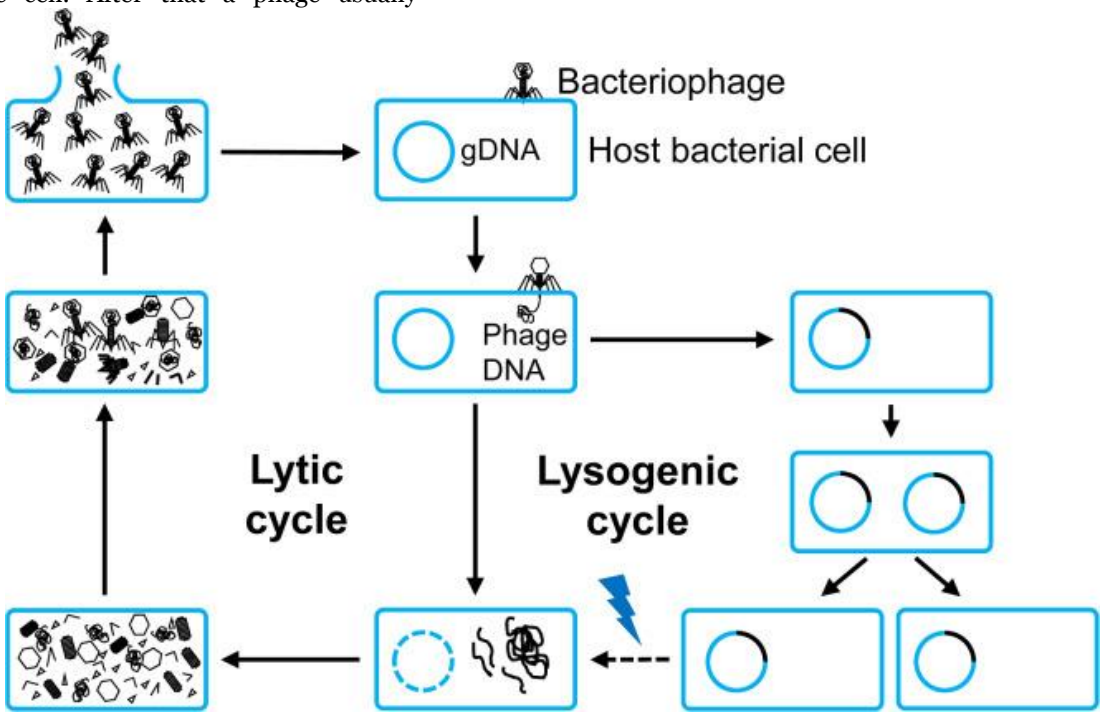
As plant diseases continue to have a serious impact on food production worldwide, new approaches for control are sought. This has seen a resurgence of studies into the use of phage for prophylaxis and treatment of phytopathogens. The word Phage is derived from a Greek word *Phagein* meaning "to devour". As the name suggests, bacteriophages are a group of viruses that can infect and replicate within bacteria. It was first discovered by William Twort in 1915 and the name bacteriophage was given by d'Herelle in 1917. Bacteriophages are the most abundant biological entity in the biosphere with an estimated number of 10^{31}, as total prokaryotic cell numbers are understood to be around 10^{30} in the biosphere and phage numbers are believed to be at least 10 times greater than this value.

Structure of bacteriophage



Life cycle of bacteriophage

During infection a phage attaches to a bacterium and inserts its genetic material into the cell. After that a phage usually follows one of two life cycles, lytic (virulent) or lysogenic (temperate). Lytic phages take over the machinery of the cell to make phage components. They then destroy, or lyse, the cell, releasing new phage particles. Lysogenic phages incorporate their nucleic acid into the chromosome of the host cell and replicate with it as a unit without destroying the cell. Under certain conditions lysogenic phages can be induced to follow a lytic cycle.



Advantages of bacteriophages

The use of phages in disease control has the following possible benefits

1. Phages proliferate only as long as the host bacterium is present in the environment, and they self-destruct soon if it is not.
2. Phages are naturally occurring elements of the biosphere; they are easily isolated from any environment containing bacteria, such as soil, water, plants, animals, and the human body.
3. Phages can be directed towards bacterial receptors that are crucial for pathogenesis, attenuating the virulence of resistant mutants.
4. Eukaryotic cells are not harmful to phages.

5. Phages are specific or highly discriminatory, removing only the target bacterium without harming other, perhaps advantageous, members of the local flora. As a result, their usage can be combined with the use of bacteria that are antagonistic to the pathogen.

Limitations in using phages

A major limiting factor in using phages for control of plant diseases was the probability of developing bacterial strains resistant to the phage. This can be overcome by application of mixture of wild type and mutant phages.

Application of bacteriophages against plant bacteria

In agriculture sector, bacteriophages have been treated in various ways in the greenhouse and field conditions, such as soil drenching, foliar spraying, infiltration, and immersion in the case of seed treatments. It can be applied either as individual or as cocktails/mixtures.

Several examples of phage treated bacterial diseases include

Target diseases and pathogens	Bacteriophages	Supplements	Hosts	Treatment methods	Test conditions	Control efficacy
Bacterial wilt: *Ralstonia solanacearum*	Single (RsPod1EGY)	None	Tomato	Soil drench	Greenhouse	100
	Cocktail (NJ-P3, NB-P21, NC-P34, NN-P42)	None	Tomato	Soil drench	Greenhouse	80
				Soil treatment	Field	80
	Cocktail (M5, M8)	None	Banana	Soil treatment	Greenhouse	100
Bacterial blight: *Xanthomonas oryzae* pv. *oryzae*	Cocktail (P4L, P43M, P23M1)	Skim milk	Rice	Spray	Field	50.8
Black rot: *X.campestris* pv. *campestris*	Single (XcpSFC211)	None	Broccoli	Spray	Greenhouse	60
		Non-pathogenic strain	Broccoli	Spray	Field	16.7-55
Soft rot: *Pectobacterium carotovorum* subsp. *carotovorum*	Single (PP1)	None	Cabbage	Spray	Greenhouse	80
	Cocktail (φMA11, φMA12, φMA13, φMA14)	None	Onion	Immersion and spray	Field	2.5-15

(Source: Vu & Oh, 2020)

Apart from this the utilization of bacteriophages extends to a large number of fields including veterinary science, food safety, environmental protection *etc.*

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11. HORTICULTURE

Mutation Studies and its Achievements in Fruit Crops

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Abstract

Fruit crops are of high nutritional value and there is a great need for improving the quality of the crops through various crop improvement methods, as the fruit crops have long juvenile phase. Genetic improvement presents formidable barrier through conventional breeding methods. Major problems in fruit breeding are long juvenile periods, unavailability of suitable germplasm, large tree size, delayed flowering and many fruit have vegetative means as the only source of propagation so, mutation is the only way to induce variability within short span of time.

Introduction

Mutation refers to the sudden heritable change in an organism which occurs in nature at a very small rate. But its potential to create unique variability as a result of useful mutation can revolutionize the agriculture sector. (Van Harten, 1998). Mutation breeding refers to the deliberate induction and development of mutant lines for crop improvement. It is also used in a wider sense to include the exploitation of natural as well as spontaneous mutants and in the development of any variety possessing a known mutation from whatever source.

History of mutation

- The history of plant mutations could be traced back to 300 BC with reports of mutant crops in China.
- Seth wright (1791) 1st identified short legged male lamb.
- Mutations as a mechanism of creating variability were first identified by Hugo de Vries (1900) in the late nineteenth century who considered this variability as heritable changes by mechanisms very distinctive from segregation and recombination and coined the term "mutation".
- T. H. Morgan (1910) did first mutation experiments with Drosophila and identified white eyed mutant.
- Radiation-induced mutations for generating novel genetic variability in plants advanced as a field after the discovery of the mutagenic action of X-rays (Stadler, 1927).
- The first commercial mutant variety was in tobacco in 1934.
- As a breeding tool, mutagenesis became very popular from the 1950s onwards

Situations where mutation breeding is required:

- Variability is not found in cultivated varieties or in germplasm.
- Breeding cycle is very long as in most fruit crops.
- The fruit growers are very reluctant to varietal changes.
- As mutations change only one or a few specific traits of an elite cultivar without upsetting neither the requirements of the fruit industry nor the consumers, they are used.

Types of mutation

- **Spontaneous mutations**: Those mutations that occur in the absence of exogenous chemical or physical agents.
- **Induced mutation**: Mutations may be artificially induced by a treatment with certain physical or chemical agents; such mutations are known as induced mutation. Used in self-pollinated and clonally propagated crops.

Characteristics of mutation

- Mutations are generally recessive.

- Most of the mutations are harmful but small proportion of them are beneficial
- Mutations may occur in any gene, however some genes how high mutation rates than other
- Mutations are recurrent, the same mutation may occur again and again
- Mutations occurs at very low frequency of about 1 in 1000000 hence large populations has to be screened.

Applications of mutation breeding

- Development of improved varieties: it is the simplest to isolate a desirable mutant, particularly a macro mutant and release it as a new variety.
- Induction of male sterility: induced mutations have been useful in induction of male sterility in some crop plants.
- Production of haploids: use of X ray irradiated pollens has helped in production of haploids.
- Creation of genetic variability: induced mutations are very effective in creating vast genetic variability for various economic characters
- Overcoming self incompatability : mutation of S gene by irradiation leads to restoration of self fertility in self incompatible species
- Improvement in adoption: induced mutations play an important role in improving adaptation of some crop species.

Crop	Original variety	Mutant cultivar	Nature of mutation and traits
Mango	Rosado de Ica Davis Haven	Rosica Haden	Bud sports Precocious, regular bearer, Large fruit size
Banana	Highgate Motta Poovan	Gross Michel Poovan	Sports, semi dwarf Sports
Grapefruit	Foster	Hudson	Bud sports, deep red flesh
Pear	Clapp's Favourite	Starkrimson	Bud sports, spotting of coloured
Mandarin	Owari Pongan	Clausellina Pongan 86-1	Bud sport

Table 1. Identified spontaneous mutants in fruit crops

Lamo *et al.*, 2017

Advantages of mutation breeding

- Induction of male sterility.
- Rapid method for developing new varieties.
- Effective for improvement of oligogenic characters.
- Simple, quick & best way when new character is to be induced.

Limitations of mutation breeding

- The frequency of desirable mutants is very low.
- Desirable mutations are commonly associated with undesirable side effects.
- There may be problems in the registrations of a mutant variety.
- Most of the mutations are recessive.
- Mutagen treatment reduces germination, growth rate, vigor and fertility.

Centres having facility for mutagenesis in India

- • Indian Agricultural Research Institute (IARI), New Delhi
- • Bhabha Atomic Research Centre (BARC), Mumbai
- • Tamil Nadu Agricultural University (TNAU), Coimbatore
- • National Botanical Research Institute (NBRI), Lucknow
- • Indian Institute of Horticulture Research (IIHR), Bengaluru

Achivements of mutation in fruit crops :

Table 2. Mutant varieties registered in FAO/IAEA database

Variety	Details				
	Year	Country	Mutagen	Improved character/s	
ALMOND (*Prunus amygdalus*)					
Supernova	1987	Italy	γ rays	Late maturity	
APPLE (*Malus pumila*)					
McIntosh 8F-2-32 (McIntosh)	1970	Canada	γ rays	Resistant to scab and Podosphera	
Courtagold	1972	France	γ rays	Very dwarf	
Belrene	1970	France	EMS	Early, bigger fruits	
BANANA (*Musa paradisiaca*)					
Novaria	1993	Malaysia	γ rays	Early maturity	
GRAPE (*Vitis vinefera*)					
Fikreti	1986	Russian Federation	Colchicine	Early, high yielding	
GRAPEFRUIT (*Citrus paradishi*)					
Rio Red	1984		USA	Thermal neutrons	Deeper red juice colour, wider adaptability
Star Ruby	1970		USA	Thermal neutrons	0-9 seeds/ fruit
LEMON (*Citrus limon*)					
Eureka 22 INTA	1987		Argentina	X- rays	Higher fruit yield
LOQUAT (*Eriobotriya japonica*)					
Shiro-mogi	1981		Japan	γ rays	Large fruit
MANDARIN (*Citrus reticulata*)					
Hongju 420	1986		China	γ rays	Resistant to low temperature
Papaya					
Pusa Nanha	1987		India	γ rays	Dwarf, higher

				yield
STRAWBERRY (*Fragaria x ananassa*)				
Dovar (John Downie)	1978	The Netherlands	γ rays	Variegated leaves

(FAO/IAEA database 2018)

Conclusion:

Mutation breeding is beneficial tool in bringing variability and also it gives quick results. Mutation breeding treatments have become more frequent and alternative to classical breeding and genetically modified plants. The main aim is to combine several features of many plants in one super plant. In vitro mutagenesis has become an efficient tool for this purpose. Plant breeders are focused to crop improvement techniques to improve genetic variations of useful traits by using next-generation molecular methods. In crops where diversity for a given trait is low or non-existent, induced mutagenesis provides an avenue of possibility. In many vegetatively propagated crops, mutation induction in combination with *in vitro* culture may be the only effective method for their improvement. With a clear objective, efficient mutagenic protocol mutagenesis can be of great benefit.

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SPECIAL ISSUES

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12. HORTICULTURE

Elimination of Cassava Mosaic Viruses from Diseased Plants by Meristem Tip Culture

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Introduction

Cassava mosaic disease (CMD), caused by whitefly-transmitted viruses is known to be a major con straint to cassava production in India. The continious use of CMD-infected stem cuttings has promoted the spread of the cassava mosaic disease (CMD) which has led to serious yield losses. Therefore, this study was undertaken to control the spread of these viruses by producing virus-free planting materials through *in vitro* meristem culture.

Materials and Methods

Plant Material and Source of Explants

Cassava mosaic resistant (CMR) lines showing recovery phenotypes viz, CMR 117,

CMR 1, CMR 123 and CMR 102 and highly susceptible variety H 226 were used in the present study to establish meristem culture.

Culture Media Composition and Preparation

Murashige and Skoog (MS) basal media are prepared. 20 g sucrose was added and pH was adjusted to 5.8 with 1N NaOH. Agar added (8 g-1) before autoclaving at 121°C for 20minutes at 15 lbs pressure. 1 µM NAA, 0.1 µM GA3 and 0.5 µM BAP was supplemented with MS basalmedia for meristem culture.

Meristem Culture

Selected cassava genotypes were maintained at ICAR CTCRI field from which explants were collected. shoot tips were collected from actively growing branches and washed under running tap water and disinfected with fungicide, bavistin (carbendazim 0.05%), followed by approximately 0.02% tween-20 [polyoxyethelene (20) sorbitan, oleate]. Further sterilization was done under running laminar air flow cabi-net. The explants were treated with 0.1% mercuric chloride solution for 3 minutes. Treated explants were washed four to five times with sterile distilled water to remove the effect of surface sterilizing agent. After that the explants were washed with 70% alcohol. After indexing only virus negative plants, were mass multiplied for field trial.

Virus indexing of Meristem Derived Plants using PCR

Fully opened leaf lobes of *in vitro* raised plants were excised using sterile forceps and blade. DNA was ex-tracted from 0.1mg tissue using CTAB method . The concentration of extracted DNA was determined with Nanodrop and quality was checked by running 3 µl sample on 1% agarose gel. The DNA extracted was subjected to PCR assay using virus specific primers CP (F) (GGA TCC ATG TCG AAG CGA CCA) and CP (R) (AAG CTT TTA ATT GCT GAC CGA) DNA of virus infected plants from field served as positive control. The amplified product was analyzed on 1% agarose gel, stained with ethidium bromide and photographed under UV-gel doc system.

Hardening and Acclimatization for Field Trial

Virus indexed plants were hardened for field study. The plants when attained 3-5 cm height with well de- veloped roots were hardened and survived plants were transferred to net house. Stem cuttings from these plants were used for open field study for yield loss assessment. No insecticide was used to control viral vectors in open field.The PCR reaction was performed in a 25 µL total reaction consisting of 2 µL DNA, 10 picomole each of virus specific primers 2.5 µL of 10X reaction buffer (50 mM Tris-HCl (pH 9.0 at 25 °C), 1.5 mM $MgCl_2$, 15 mM $(NH_4)_2SO_4$ and 0.1 % Triton® X-100), 1 µL of 10 mM dNTPs, 0.5 µL of (1U/ µL) Taq DNA polymerase. The PCR was performed in Eppendorf Mastercycler with the following thermal programme: one cycle at 94°C for 2 min, 30 cycles of 94 °C for 1 min, 55 °C for 2 min,72 °C for 3 min and final extension step of 72 °C for 5 min. supplemented with NAA, BAP and GA3. After 3-4 weeks the developed meristem was subcultured to MS basal medium including vitamins for shoot and root regeneration. The developed plantlets were further multiplied using nodal segments in MS medium. The developed plants in 3-4 leaf stages were virus indexed.

Statistical Analysis

In the field trial, meristem-derived plantlets of T0 and T1 generation were planted in field. The average number, tuber length, tuber girth, tuber weight, total biomass and harvest index from three randomly selected plants were evaluated to test their performance. Analysis of variances was performed for these yield-related characters using SAS Statistical Package.

Results

For the primary establishment of meristem culture from field grown plants, surface sterilization was optimized for different concentration and time with mercuric chloride solution. Among different concentrations and time periods tested, 0.1% mercuric chloride for 3 min was found to be effective for surface sterilization. About 90 % of the explants were found healthy and free of contamination, when treated with 0.1%

mercuric chloride for 3 min. At 0.05% mercuric chloride most of the explants were contaminated and at concentration 0.15% tissue killing was observed. Percentage of contaminated explants was decreased with increase in sterilization period in all varieties. But an increase in sterilization period also resulted a decrease in survivability of non contaminated explants. Many researchers previously reported the use of different sterilization methods for cassava nodal and meristem culture.Sterilizing cassava nodes with an initial wash using 70% ethanol for 5 min followed by 10% NaOCl for 20 min was found to be best .

Conclusion

The present study revealed a novel technique for elimination of cassava mosaic virus and production of virus free planting material. In view of all experimental results, it is robustly recommended the use of meristem culture to produce virus free planting material in cassava. The virus free planting material showed best performance in field in response to yield compared to conventional planting material. From the practical view point of our study, it is desirable to maintain the field free of insect vectors in order to reduce rapid re-infection in virus free planting material.

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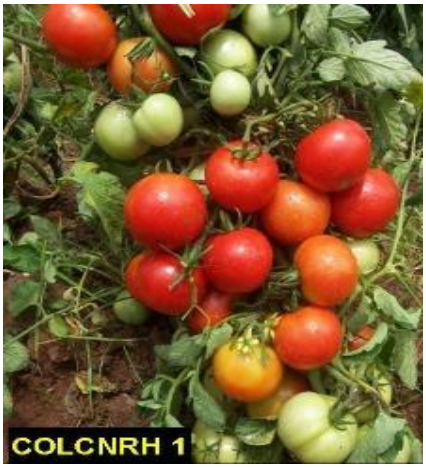
13. HORTICULTURE

Hi-Tech Cultivation of Tomato

K.Sivakumar and M.A.Vennila

Krishi Vigyan Kendra, Dharmapuri

Tomato (Lycopersicum esculentum) was considered to be poorman's apple. But tomato nowadays is costing so high that poor man could not reach it. Tomato fruit is rich in vitamin C.



Cultivation aspects of Tomato

Well drained loamy soils rich in organic matter with a pH range of 6.5-7.5 is suitable for tomato cultivation. May - June and November – December are the two suitable seasons of tomato.

Nursery bed preparation

FYM 10 kg, Neem cake 1 kg, VAM 50 g, enriched Superphosphate 100 g and Furadon 10 g per square meter has to be applied before sowing.

Seed rate Varieties : 300-350 g / ha Hybrids : 100-150 g / ha

Seed treatment The seeds are treated with Trichoderma viride 4 g or Carbendazim 2 g per kg of seeds 24 hours before sowing. Just before sowing, the seeds are treated with Azospirillum @ 40 g / 400 g of seeds. The seeds are sown in lines at 10 cm apart in raised nursery beds and covered with sand.

Protected nursery

- Prepare the nursery area of 3 cents with slanting slope of 2 % for the seedling production to cover 1 ha.
- Cover the nursery area with 50 % shade net and cover the sides using 40/50 mesh insect proof nylon net.
- Form raised beds of 1 m width and convenient length and place HDPV pipes at 2m interval for further protection with polythene sheets during rainy months.
- Mix sterilized cocopeat @ 300 kg with 5 kg neem cake along with Azospirillum and Phosphobacteria each @ 1 kg. Approximately 1.2 kg of cocopeat is required for filling one protray. 238 protrays (98 cells) are required for the production of 23,334 seedlings, which are required for one hectare adopting a spacing of 90 x 60 x 60 cm in paired row system.
- Sow the treated seed in protrays @ one seed per cell.
- Cover the seed with cocopeat and keep the trays one above the other and cover with a polythene sheet till germination starts
- After six days, place the protrays with germinated seeds individually on the raised beds inside the shade net
- Water with rosecan everyday and drench with NPK 19:19:19 @ 0.5% (5g/l) at 18 days after sowing

Field Preparation

Plough the land to fine tilth. Thoroughly prepare the field with the addition of FYM @ 25 t/ ha and form ridges and furrows at a spacing of 60 cm. Apply 2 kg/ha of Azospirillum and 2 kg/ha of Phosphobacteria by mixing with 50 kg of FYM. Irrigate the furrows and transplant 25 days old seedlings on the sides of ridges. Life irrigation to be given on 3rd day of planting.

Spacing for varieties PKM 1, Paiyur 1, COTH 2, TNAU Tomato Hybrid CO 3 : 60 x 45 cm CO 3 : 45 x 30 cm

Mulching

Mulch with black LDPE sheets of 25 micron thickness and bury both the ends into the soil to a depth of 10 cm

Weed control

Apply Pendimethalin 1.0 kg a.i./ha or Fluchloralin 1.0 kg a.i / ha as pre-emergence herbicide, followed by hand weeding once at 30 days after planting.

Irrigation

After establishment of seedlings, irrigate at weekly intervals.

Layout and planting for drip irrigation & fertigation

- Apply FYM @ 25 t / ha as basal before last ploughing.
- Apply 2 kg/ha of Azospirillum and 2 kg/ha Phosphobacteria by mixing with 50 kg of FYM.
- Apply 75 % total recommended dose of superphosphate ie 1172 kg / ha as basal.
- Install the drip irrigation with main and sub main pipes and place lateral tubes at an interval of 1.5 m.
- Place the drippers in lateral tubes at an interval of 60 cm and 50 cm spacing with 4 LPH and 3.5 LPH capacities respectively.
- Form raised beds of 120 cm width at an interval of 30 cm and place the laterals at the centre of each bed.
- Before planting, wet the beds using drip system for 8-12 hrs.
- Planting to be done at a spacing of 90 x 60 x 60 cm in the paired row system, using ropes marked at 60 cm spacing.
- Spray Pendimethalin 1.0 kg *a.i.* / ha or Fluchloralin 1.0 kg *a.i* / ha as pre-emergence herbicide at 3rd day after planting.
- Gap filling has to be done at 7th day after transplanting.

Manuring Varieties

Basal dose : FYM 25 t/ha, NPK 75:100:50 kg / ha

Borax 10 kg and Zinc sulphate 50 kg / ha
Top dressing : 75 kg N/ha on 30th day of

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planting or during earthing up.

Hybrids

Basal dose : FYM 25 t/ha, NPK 50:250:100 kg/ha

Borax 10 kg and Zinc sulphate 50 kg/ha

Top dressing : N and K each 150 kg/ha in 3 equal splits at 30, 45 and 60 days after planting.

Protected cultivation

Production practices for cultivation of tomato under shade net

During summer, the hybrid tomato can be grown in a shade level of 35 per cent under paired row planting system (80 x 40 x 60 cm - between pairs, rows and plants) with a basal application of 50 kg each of N and K and 250 kg of P / ha and fertigation of 200 kg each of N and K through straight fertilizers.

Protected cultivation of tomato in polyhouse

During rainy season, the indeterminate tomato hybrid has to be grown in the medium consisting of FYM : composted coir pith: sand (2:1:1) with irrigation regime of 20kPa and basal application of 50kg each of NPK/ha as straight fertilizers and 250 kg each of NPK as water soluble and straight fertilizers through fertigation along with black polyethylene mulch (50 microns).

Seedlings

The seeds of tomato are also grown in portrays with coco pit medium. Generally hybrid seeds germinate almost 100 per cent. So that there will be no loss to the farmers. The seedlings are raised under Green house conditions.

The seedlings grown in portrays are then transplanted to mainfield.

Artificial pollination

As under shade-net conditions there will be absence of honey bees (or) any pollinators, we have to artificially pollinate the flowers of tomato.

Training of hybrids

- Stake the plants 30 days after planting with 1 - 1.5 m tall stakes.
- Remove the side branches up to 20 cm from ground level.

Micronutrient spray

- Foliar spray of $ZnSO_4$ @ 0.5 per cent thrice at 10 days interval from 40 days after planting.
- Spray 19:19:19 + Mn @ 1 % at 60 days after planting.

Fertigation

Generally, the tomato plants are irrigated by adopting drip irrigation. The fertilizer can be provided to the crop through drip irrigation which is called as fertigation. The water soluble fertilizers (WSF) are provided to the tomato plants through drippers. The general recommendation of fertilizer to a tomato crop is 200 : 250 : 250 kg/ha of NPK. Tomato is a potassium loving crop. Potassium is generally referred as a quality parameter. Usually the nitrogenous fertilizers are provided to the crop in split doses. 75 per cent of the recommended potassic fertilizer is applied basally and remaining 25 per cent is applied at the flowering stage.

The following table gives the fertilizer schedule that is normally adopted in case of Tomato under drip fertigation.

Fertigation schedule for tomato hybrids

Recommended dose: 200:250: 250 kg / ha

Stage	Crop stage	Duration in days	Fertilizer grade	Total Fertilizer (kg/ha)	Nutrient applied			% of requirement		
					N	P	K	N	P	K
1	Transplanting to plant establishment	10	19:19:19 13:0:45 Urea (46%N)	65.78 27.77 8.44	12.50 3.61 3.88	12.50 - -	12.50 12.50 -	10.00	5.00	10.00
					19.99	12.50	25.00			

	stage									
2	Flower initiation to flowering	30	12:61:0 13:0:45 Urea (46%N)	40.98 222.22 100.27	4.92 28.89 46.12	25.00- -	- 100.00 -	40.00	10.00	40.00
					79.93	25.00	100.00			
3	Flowering to fruit set	30	19:19:19 13.0:45 Urea (46%N)	65.78 138.88 63.90	12.50 18.05 29.39	12.50- -	12.50 62.50 -	30.00	5.00	30.00
					59.94	12.50	75.00			
4	Alternate day from picking	80	12:61:0 13:0:45 Urea (46%N)	20.49 111.11 50.14	2.46 14.44 23.06	12.50- -	- 50.00 -	20.00	5.00	20.00
					39.96	12.50	50.00			
					199.82 Or 200.00	62.50	250.00	100	25	100

75% of RD of P applied as superphosphate as basal application= 1172 kg/ha

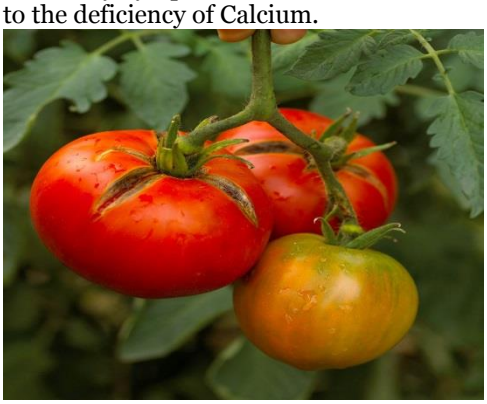
1. 19:19:19 = 132 kg / ha
2. 12:61:0 = 62 kg / ha
3. 13:0:45 = 500 kg / ha
4. Urea = 223 kg / ha

Growth regulators

Spray 1.25 ppm (625 ml in 500 litres of water) Triacontanol at 15 days after transplanting and at full bloom stage to increase the yield.

Deficiency symptoms:

Blossom End Rot (BER) is the common deficiency symptom of Tomato which is due to the deficiency of Calcium.



This can be managed by

- Growing tomatoes in well-drained soil that contains plenty of organic matter, especially well-rotted manure (but see use of chicken manure below); organic matter holds water, and also gives the plants the nutrients they need, including calcium.
- Do not allow the soil to dry out; try to make sure that the soil is moist at all times, particularly at the flowering stage.
  Mulch the plants after transplanting with dried grasses, and other dried weeds, to help prevent the soil from drying out. The mulch should be at least 10 cm thick (grass clippings are suitable as is black plastic).
- Do not cultivate too closely to plants (nor too deeply) as this may damage the roots, and stop uptake of water and minerals, including calcium.
- Do not use urea or ammonium types of fertilizers. Use of chicken manure should also be avoided.
- Shade plants, or use windbreaks, when conditions are hot, dry and windy, and when the soil moisture is low.

Blossom-end rot is characterized by a large, brown to black, dry, leathery area at the blossom end of the tomato fruit. The first

symptoms appear as small, water-soaked areas, which resemble bruises, on the blossom end of immature or green fruit.

Hybrids and varieties of Tomato:

Varieties

PKM 1,CO.1 ,CO.2 ,CO.3 , (Marutham) and Paiyur 1

Hybrids

TNAU Tomato Hybrid CO 3
COTH.1 , COTH2

Plant Protection Pests

Fruit borer

- Grow simultaneously 40 days old American tall marigold and 25 days old tomato seedlings @ 1:16 rows.
- Set up pheromone traps @ 12/ha.
- Collection and destruction of damaged fruits and grown up caterpillars.
- Release *Trichogramma pretiosum* @ 1 lakh nos. /ha/release at an interval of 7 days starting from flower initiation stage based on ETL of 10% damage.
- For *Helicoverpa armigera:* HaNPV 1.5 x 1012 POBs/ha *i.e.* NPV of *H. armigera* 0.43% AS @ 3.0 ml/lit or 2 % AS @ 1.0 ml per lit
- For *Spodoptera litura*: Sl NPV 1.5 x 1012 POBs/ha
- Provide poison bait with carbaryl 50 WP 1.25 kg, rice bran 12.5 kg, jaggery 1.25 kg and water 7.5 lit/ha
- Spray *Bacillus thuringiensis* 2g/lit or any one of the following insecticide

Insecticide	Dose
Azadirachtin 1.0 % EC (10000 ppm)	2.0 ml/ l
Indoxacarb 14.5 % SC	8 ml/10 l
Flubendiamide 20 WG	5 g/10 l
Flubendiamide 480 SC	2.5 ml/10 l
Novaluron 10 % EC	7.5 ml/10 l
Phosalone 35 % EC	13 ml/10 l
Quinalphos 20 % AF	1.5 ml/ l
Quinalphos 25 % EC	1.0 ml/ l

Helicoverpa armigera

Serpentine leaf miner

Spray Neem Seed Kernel Extract 5 %.

Whitefly

1. Install yellow sticky traps @12/ha to attract the adult.
2. Remove alternate weed host Abutilon indicum
3. Apply **carbofuran 3% G** @ 40 kg /ha or spray any one of the following insecticides

Insecticide	Dose
Dimethoate 30 % EC	1.0 ml/lit.
Malathion 50 % EC	1.5 ml/ lit.
Oxydemeton –Methyl 25 % EC	1.0 ml/ lit.
Thiamethoxam 25 % WG	4.0 ml/10 lit.

Nematode

Soil application of *Bacillus subtilis* (BbV 57) or *Pseudomonas fluorescens* as seed treatment @ 10 g/kg of seeds and soil application (SA) @ 2.5 kg / ha for the management root knot and reniform nematode infestation in soil and root. Application of liquid formulation of *Bacillus subtilis* (BbV 57) or *Pseudomonas fluorescens* @ 1000 ml/ha through drip irrigation for the management of root knot nematode in tomato.

Diseases

Damping off (nursery) Treat the seeds with *Trichoderma viride* 4 g/kg or *Pseudomonas fluorescens* 10 g /kg of seed 24 hours before sowing. Apply *Pseudomonas fluorescens* as soil application @ 2.5 kg/ha mixed with 50 kg of FYM. Water stagnation should be avoided. Drench with Copper oxychloride at 2.5 g/lit at 4 lit/sq.m.

Leaf spot

Leaf spot can be controlled by spraying Zineb or Mancozeb 2 g/lit.

Fusarial wilt and Root knot nematode

Soil solarization, before preparation of nursery bed. Seed treatment with Pseudomonas fluorescens (PF) @ 10 g /kg of seed, followed by nursery application of Pf1@ 20 g/m2 and seedling dip with Pf1 @ 5g/l along with soil application of Pf1 @ 2.5 kg mixed with 50 kg FYM /ha at 30 days of transplanting.

Leaf curl

Spray systemic insecticides like **methyl demeton or dimethoate @ 2 ml/lit. to kill** the insect vector, whitefly.

Tomato spotted wilt disease

Carbofuran 3 G @ 33 kg/ha in nursery at sowing and second application @ 40 kg /ha on 10 days after transplanting in main field and 3 sprays of phosalone 35 EC @ 1.5 ml/lit @ 25, 40, 55 days after transplanting.

Tomato spotted wilt disease

Peanut bud necrosis virus Selection of healthy seedlings and rouging of PBNV infected plants up to 45 days of planting. Apply Carbofuran 3 G 1 kg *a.i.*/ha in nursery at sowing and second application at 1.25 kg *a.i.*/ha 10 days after transplanting in mainfield and 3 sprays of Dimethoate 30 EC 1 ml/l or Methyl demeton 25 EC 1 ml/l or Phosphomidan 1.0 ml/l @ 25, 40 and 55 days after transplanting.

Duration

110- 115 days from transplanting (135 - 140 days from sowing)

Yield Varieties : 30 - 40 t / ha Hybrids : 80 - 95 t / ha Boom flower - N spray at 2ml / litre in three sprays – 30 days, 55 days and 75 days after planting increase the yield.

IPM Package for Tomato

- Seed treatment with *Pseudomonas fluorescens* @ 10g/kg of seeds
- Nursery application with *Trichoderma viride* and *Pseudomonas fluorescens*
- Application of Neem cake @ 250kg/ha
- Soil application of *Pseudomonas fluorescens* @ 2.5kg/ha
- Selection of good and virus disease free seedlings for planting
- Roguing out of virus infected plants upto 45 days of transplanting
- Grow marigold as a border crop
- Set up Helicoverpa / Spodoptera pheromone traps @ 12 numbers / ha
- Release *Trichogramma chilonis* @ 50000/ha
- Install yellow sticky traps
- Spraying Neem formulations (1%) / Neem seed kernel extract (5%)

Reference

https://agritech.tnau.ac.in/horticulture/horti_vegetables_tomato.html

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14. AGRICULTURAL METEOROLOGY

Concepts of Weather and Climate in Agriculture

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Agriculture, which is the backbone of our country, deals in the cultivation of plants, fungi, animas and other life forms for food, fodder, fiber, fuel wood, medicinal plants and other products used to sustain and enhance human life. Pre-industrial agriculture was typically subsistence agriculture in which farmers raised most of their crops for their own consumption instead of cash crops for trade. A remarkable shift in agricultural practices has occurred over the past century in response to new technologies, and the development of world markets. Agriculture is closely dependent on the endowment of natural resources and environmental conditions of soil and climate. India is a land of many climates and varieties of soils, affording scope for much diversity in agriculture. In our country, more than 50 per cent of variation of crops is determined by climate. It is climate vis-à-vis weather plays an important role, probably more so in India where aberrant weather such as drought, flood, etc., is a rule rather than an exception. India presents a range and diversity of climate, flora and fauna, with a few parallels in the world. The country presents a paradox of having highest mean annual rainfall in the world (in Meghalaya) and also dry, semi-desert area in Rajasthan. The variability of rainfall is most important in all the states, but especially where it is low. In parts of Rajasthan and the Deccan, such variability is more than 100 per cent of the mean. Years of drought account for a frequent history of crop failures, whereas the years of flood also cause very considerable loss of agricultural production.

Temperatures also vary greatly, both geographically and seasonally. In northern and central parts of India during pre-monsoon months the maximum temperatures reaches over 40 ^{o}C over a large area. Further frost may occur in winter in the plains, as far south as a line drawn through Madhya Pradesh and may be heavier in Kashmir and areas north of Punjab including various other parts of the Eastern Himalayan range.

Rainfed Agriculture

In agriculture, water is an important climatic factor that affects or determines plant growth and development. Its availability or scarcity determines total failure of a crop. Rainfall is the primary source of water for crop cultivation and allied agricultural practices.

As agriculture in India depends on the vagaries of rainfall, its amount and nature of distribution are very important, which vary with location and climate types and thereby affecting growth and yield of crop. In fact, it is an absolute requirement for all living organisms. The importance of water is essential for efficient functions in both plant and animal life. But plant responses differ with the type of plant species. Most plants are mesophytes, that is, they are adapted to conditions with moderate supply of water. But some, called hydrophytes, require watery or water-logged habitats, while other called xerophytes, are more tolerant to dry conditions.

Globally 80 per cent of the agricultural land area is rainfed which indicates that agricultural practices and crop production are performed with water received through rainfall. The rainfed agriculture generates 65 to 70 per cent staple foods but 70 per cent of the population inhabiting in these areas are poor due to low and variable productivity. India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rainfed agriculture is practiced in two-thirds of the total cropped area of 162 million hectares (66 per cent) and it supports 40 per cent of the national food basket. The importance of such agricultural practice is obvious from the fact that 55 per cent of rice, 91 per cent coarse grains, 90 per cent pulses, 85 per cent oilseeds and 65 per cent cotton are grown in rainfed areas. These areas receive an average annual rainfall

between 400 mm and 1000 mm, which is not only distributed unevenly, but also highly uncertain and erratic. In certain areas, the total annual rainfall does not exceed even 500mm. As a result of such low and erratic monsoon rainfall significant fall in food production is often noticed. Due to climate change in last couple of years the country is experiencing shift of onset of monsoon from its normal date together with its erratic distribution and reduction in amount, which largely affected our crop production system vis-à-vis agriculture as a whole.

Climate Change and Agriculture

In present day context, agriculture is most vulnerable to weather and climate changes because of its seasonality and narrow range of weather conditions influencing crop and livestock production. People across the globe witnessed above normal temperatures and more rapid warming that occurred during the last half of the 20th century. Climate change presents a profound challenge to food security *vis-a-vis* livelihood and all around development. Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have significant impact on crop growth, yields and production. Studies have shown significant effect of change in climatic factors on the average crop yield. India is likely to witness one of the highest agricultural productivity losses in the world as a consequence of climate change pattern observed and projected. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-40C with no substantial change in rainfall quantity as use of fossil fuels increased rapidly in one hand, and on the other hand, forests, the natural buffering system for climate change, are being destroyed indiscriminately for want of fuel, fodder, timbers and urbanization. For India, the area-averaged annual mean warming projected to be between 1.0°C and 1.4°C by 2020 and between 2.2°C to 2.9°C by 2050; though, the increase in temperatures would be less in *rabi* season (winter season). Further, the *kharif* (monsoon season) rainfall is expected to increase in most of the places whereas rabi rainfall may decrease in some areas.

Importance of Climatic factors

It is evident that the most important climatic factors influencing growth, development and yield of crops are solar radiation, temperature and water and not less important is the function of land and soil. Each of these factors has been found to have limiting effects on various growth processes.

1. **Solar radiation:** Three properties of this climatic factor that affect plant growth and development are light quality, light intensity, and day length or photoperiod. Light quality refers to the specific wavelengths of light; light intensity is the degree of brightness that a plant receives; and day length is the duration of the day with respect to the night period. Light is a climatic factor that is essential in the production of chlorophyll and in photosynthesis, the process by which plants manufacture food in the form of sugar (carbohydrate). Other plant processes that are enhanced or inhibited by this climatic factor include stomatal movement, phototropism, photomorphogenesis, translocation, mineral absorption, and abscission. Any impedance on reduction on the availability of light will affect plant.
2. **Water:** Water is an important climatic factor that affects or determines growth and development of plant. Its availability, or scarcity, can mean a successful harvest, or diminution in yield, or total failure. Nevertheless, water participates directly or indirectly in all metabolic processes in all living organisms. As a solvent, it also serves as a transport medium for mineral nutrients from the soil, as well as in the translocation of organic substances within the plant. It is a chemical reactant in photosynthesis and hence vital to life. It is also responsible for regulating temperature of plants through the process of transpiration. Rainfall is the most common form of precipitation and other forms of precipitation are freezing rain, sleet or ice pellets, snowfall, fog and hail.
3. **Evapotranspiration (ET):** It is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for

the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle. Potential evapotranspiration (PET) is a representation of the environmental demand for evapotranspiration and represents the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile.

4. **Temperature:** This climatic factor influences all plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis, and translocation. At high temperatures the translocation of photosynthate is faster so that plants tend to mature earlier. Moreover, due to prevalence of high temperature, plants try to complete its life-cycle by early flowering that causes yield loss. In general, plants survive within a temperature range of 0 to 50°C. Enzyme activity and the rate of most chemical reactions generally increase with rise in temperature. Up to a certain point, there is doubling of enzymatic reaction with every 10°C temperature increase. But at excessively high temperatures, denaturation of enzymes and other proteins occur. Conversely, excessive low temperatures also cause limiting effects on plant growth and development. For example, water absorption is inhibited when the soil temperature is low because water is more viscous at low temperatures and less mobile, and the protoplasm is less permeable.
5. **Air:** The air is a mixture of gases in the atmosphere; about 75% of air is found in the troposphere, the layer of the atmosphere which extends about 17 km above sea level at the equator and about 8 km over the poles. In addition, about 99% of the clean, dry air in the troposphere consists of 78% nitrogen and 21% oxygen. The remainder consists of argon (slightly less than 1%), carbon dioxide (0.036%), and traces of other gases. Oxygen (O_2) and carbon dioxide (CO_2) in the air are of particular importance to the physiology of plants. Oxygen is essential in respiration for the production of energy that is utilized in various growth and development processes. Carbon dioxide (CO_2) is a raw material in photosynthesis. The air also contains water vapour (H_2O), suspended particles of dust and chemical air pollutants such as carbon monoxide (CO), carbon dioxide (CO2), sulfur dioxide (SO_2), sulfur trioxide (SO_3), nitrogen oxides, methane (CH_4), propane, chlorofluorocarbons (CFCs), solid particles of dust, soot, asbestos and lead, ozone and many more. However, the composition of this climatic factor is susceptible of variation.
6. **Humidity:** The amount of water vapor that the air can hold depends on its temperature; warm air has the capacity to hold more water vapor than cold air. There is almost one-half reduction in the amount of water vapor that the air can hold for every 10°C drop in temperature. But, we are concerned mostly with Relative humidity (RH), which is the amount of water vapor in the air, expressed as the proportion (in percent) of the maximum amount of water vapor it can hold at certain temperature. For example, an air having a relative humidity of 60% at 27°C temperature means that every kilogram of the air contains 60% of the maximum amount of water that it can hold at that particular temperature. The amount of water vapor in the air ranges from 0.01% by volume at the frigid poles to 5% in the humid tropics. In relation to each other, high RH means that the air is moist while air with minimal content of moisture is described as dry air. Compared to dry air, moist air has a higher relative humidity with relatively large amounts of water vapor per unit volume of air. The relative humidity affects the opening and closing of the stomata which regulates loss of water from the plant through transpiration as well as photosynthesis.
7. **Wind:** Wind, the air movement, is due to

the existence of pressure gradient on a global or local scale caused by differences in heating. On a global scale it consists of the jet stream flow and movement of large air masses. On the local scale only a smaller quantity of air moves. Surface winds are lower and less turbulent at night due to the absence of solar heating. When air is close to the ground it cools, and subsequently it contracts and the pressure rises; when it warms, it expands and pressure drops. Where both cold and warm air occur in proximity, as over a lake and its adjacent shore, the cold flows to the direction of the warm air or from high to low pressure area to correct the pressure imbalance. This also happens in tropical Asia but in a larger and more complex way, as the monsoon winds. Moderate winds favor gas exchanges, but strong winds can cause excessive water loss through transpiration as well as lodging or toppling of plants. When transpiration rate exceeds that of water absorption, partial or complete closure of the stomata may ensue which will restrict the diffusion of carbon dioxide into the leaves. As a result, there will be a decrease in the rate of photosynthesis, growth and yield.

15. HORTICULTURE

Microgreen: An Exciting New Trend in the Culinary World

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Introduction

Microgreens are immature plants harvested for consumption within 10 to 20 days of seedlings emergence just after the development of cotyledon leaves or seed leaves. It is smaller than baby greens because they are consumed soon after sprouting rather than the plants have matured to produce multiple leaves. Microgreens have gained popularity as a new cooking trend over the last few years. It has immense potential for adapting leafy vegetables production to a micro- scale, and improving nutritional value in the human diet. Microgreens are an excellent source of microelements in a balanced human diet, and the consumption of microgreens could be a health-promoting strategy to meet the requirement of element dietary reference intakes, particularly for children. They are gaining popularity also due to their varying and attractive colours, textures, and flavours. At the same time, microgreens can be grown very easily even in very small spaces, making them suitable for urban agriculture and as part of life support systems in space.

Mineral Composition and Health Benefits

Adequate intake of minerals through food is necessary for human health and well-being. For human nutrition, unfortunately; mineral malnutrition remains a prevalent problem worldwide and is recognized as one of the most significant global challenges. (Xiao *et al.,* 2016). Deficiency of macro elements (such as Ca, Mg, P, K, and Na) and microelements (also Known as trace elements, such as Fe, Zn, Cu, and Mn) can lead to metabolic disturbances and organ damage, leading to acute and chronic disease and even death in humans. Microgreens generally appear to contain higher nutrient levels than mature plants. Microgreens are loaded with higher amounts of phytonutrients (ascorbic acid, β-carotene, α-tocopherol, and phylloquinone) and minerals (Ca, Mg, Fe, Mn, Zn, Se, and Mo) as compared to their mature- leaf counterparts. Microgreens represent a rich food source particularly for vegetarians and vegans, who can diversify and enrich their diet using a large variety of available microgreens. Furthermore, as the microgreens are generally consumed raw, they can also satisfy the specific needs of the so-called 'raw foodists' (Renna *et al.,* 2018).

Different Types of Microgreens

Microgreens can be grown from different types of seeds. The most popular varieties are produced using seeds from the following plant families:

- **Brassicaceae:** Cauliflower, broccoli, cabbage, watercress, radish and arugula
- **Asteraceae:** Lettuce, endive, chicory and radicchio
- **Apiaceae:** Dill, carrot, fennel and celery
- **Amaryllidaceae:** Garlic, onion, leek
- **Amaranthaceae** : Amaranth, quinoa Swiss chard, beet and spinach
- **Cucurbitaceae:** Melon, cucumber and squash

However, in some cases, cereals such as rice, oats, wheat, corn, and barley, and legumes such as chickpeas, beans, and lentils, are also grown into microgreens.

Growing Media

Microgreens can grow without soil under hydroponics system, but they typically grow best when planted in soil. However, the soil should be well sterilized before use. Coco coir, perlite, and vermiculite are the common growing medium used in hydroponics to grow microgreens. Some growers prefer perlite, while others prefer mixers (Verlinden, 2020). Composts mixed with sand and vermiculite (Anon, 2016 & Verlinden, 2020) and sand, peat, coconut coir dust, sugarcane filter cake, and vermicompost in several ratios have also been evaluated and found effective in producing microgreens (Muchjijab et al., 2015).

Growing of Microgreens

For home use, microgreens may be grown by individuals in a raised garden bed with good potting soil, or a mix of potting soil and peat moss. Scatter the seed mix on the soil so that the seeds are about 1/8 inch to 1/4 inch apart. As they are ready to harvest in a very young stage, so they don't need a lot of space. Once the seeds are scattered over the area, cover them with about 1/8 inch of soil. Water with a spray bottle or mister to evenly moisten the soil. For growing microgreens in a Container, choose a pot that is at least 2 inches deep and as large in diameter. Fill it with a good quality organic potting mix, and smooth the soil. Mist daily, keeping the soil moist but not wet. Sprouts will pop up in about three to seven days. For containers, mixing in a bit of granular fertilizer before sowing is recommended if the potting mix doesn't contain fertilizer. In most crops, the seed provides adequate nutrition for the young crops, requiring significantly less or no fertilizer. Light fertilization application to the tray bottom may benefit few longer-growing microgreens crops such as micro carrots, dill, and celery (Kalal et al., 2021) Fast-growing leafy plants such as mustard watercress and Swiss chard can also benefit from light fertilization as they sprout quickly and exhaust their self-contained nutrient supply. Light fertilization is best achieved by floating each microgreen tray for 30 seconds in a prepared nutrient solution of approximately 80 ppm nitrogen (Kalal et al., 2021).

Harvest and Postharvest

Harvesting microgreens is labour intensive. However, use of loose substrate in trays slows down the harvesting process, whereas seeding on synthetic fibre, food-grade plastic, or burlap-type mats can facilitate easier handling and faster harvesting and cooling of the product (Treadwell et al., 2010). Most microgreens are harvested at the appearance of first true leaves, with cotyledons fully expanded, still turgid, retaining their typical colour, and having a height of 5-10 cm. Harvesting is done by cutting the seedlings manually or mechanically few millimetres above the growing media surface. Care should be taken to remove any growth medium particles or seed coats that may remain attached to the cotyledons of some species (Kyriacou et al., 2016).

Microgreens require quick cooling to remove vital heat and suppress the rate of respiration, spoilage and senescence. The use of blunt blades has been shown to shorten the storage life of fresh-cut leafy vegetables, and harvesting microgreens must likewise be performed with sharp blades to avoid bruising

and damage to stem cells adjacent to the cut (Kyriacou et al., 2016).

Packaging

Modified Atmosphere Packaging (MAP) is an effective technology for preserving freshness and extending product shelf life for fresh and minimally processed products such as lettuce, broccoli, spinach and mushrooms. Many factors influence the package atmosphere of products such as product respiration rate, packaging film Oxygen Transmission Rate (OTR), product weight, packaging surface area, storage temperature and relative humidity (Sandhya, 2010).

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16. HORTICULTURE

Special Inter Cultural Operations in Vegetables

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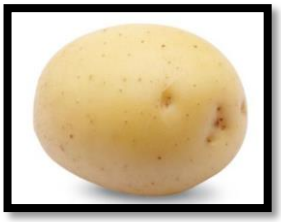
Pinching: Removal of the main stem at the tip improves the size of terminal fruits in In-determinate cultivars in Tomato. The practice of pinching back suckers allows only one or two main stems to grow. It channels the plant's energy into the existing fruit instead of growing new branches, allowing larger tomatoes.

Suberization : it is the process of wound healing. It is a vital process essential to control potato tuber dessication, development of defects and to block infection of harvest damaged tubers. A temperature of 25°c with 95% relative humidity is ideal for suberization.



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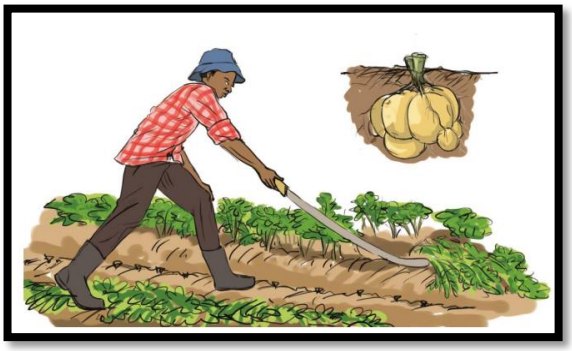
Earthing Up: It should be done in 3-4 weeks for planting. It can protect the tubers from direct contact to sunlight.

This Technique that involves mounding soil around the base of a plant to protect the plant from extreme weather conditions. In cold climates, earthing up can help insulate the roots of the plant from frost and freezing temperatures. In warm climates, earthing up can help protect the plant from scorching heat and dryness, to check the growth of weed and also to encourage the growth of roots. Eg: It can prevent the Solanin accumulation in Potato.

De-haulming: It is a practice that is done in Potato by removing the haulms (the aerial parts of the plant when the plant turns yellow) so as to stop the vegetative growth of the plant. It should be done 10-15 days before harvesting. It should be done before aphid population reaches critical level i.e. 20 Aphids / 100 compound leaves.



Blanching: it is a common practice in cauliflower to protect the curd from yellow colour after their direct exposure to sun light and to arrest the enzymatic activity in Cauliflower.

Scooping: Removal of the central portion of the curd for easy initiation of flower stalk (mainly followed in the Darjeeling hills). Cauliflower.

Speedling: In situ sowing of seeds in thermocol plates commercially followed in western countries. It is a method of raising of vegetables in a thermocol plates for the quick growth of the plant.

Thinning: The seeds of majority of the vegetables being small, it becomes difficult to sow them properly distributed. It results in the over-crowding of the seedling. The practice of removal of excess of seedlings to facilitate aeration and better development is termed as thinning.

It is largely practiced in the direct sown vegetables like palak, spinach, radish, beetroot, methi, coriander etc.

Staking: Vegetable crops having indeterminate growth habit are to be staked immediately or trained to bowers or trellis for encouraging their growth and exposure to full sunlight.

Indetermiante varieties of tomato are usually staked to poles to grow vertically. Pole type garden peas, beans and semi –trailing

cowpea are trailed to poles or tree branches. Yard long bean, pole type lablab bean, bitter gourd, snake gourd, ivy gourd, ridge gourd etc. are trained to bowers/pandals by providing support at vining stage.


Curing: it is an important process to remove the excess moisture from the outer skin and neck of the Onion. The mature bulbs are uprooted and left in the field as such for 7 days for curing. So that the neck become tight and outer scales are dried until they rustle.

Curing is done immediately after the harvest of tubers like potato, sweet potato, taro and bulb crops like onion, garlic etc. prior to storage and marketing. In onion, it is usually cured at 37.8 0 c for 3-5 days under natural conditions and 400c for 16 hours using artificial structures. Drying of outer leaves of onion and garlic protects them from infection.


Detasseling: It is an important process of removal of male flowers (tassels) to prevent pollination. Baby corn is an immature part of the female flower so that detasseling is necessary. It should be done as soon as male flowers are seen i.e. 45 DAS. Baby corn.

Pricking: The transferring of young seedlings into another bed, pan or tray is termed as pricking. The operation of pricking is practiced at the stage when the seedlings become large enough to handle. It is done with the objective of fast and vigorous development of seedlings and minimizing the transplantable time.

De-topping: It is the process of removal of growing buds after formation of sprouts in late summer or autumn. As a result, sprouts develop properly and the whole crop can be harvested in 5-6 weeks of topping. This helps in easy mechanical harvesting.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