Lecture No: 1

CROP PHYSIOLOGY

AN INTRODUCTION AND ITS IMPORTANCE IN AGRICULTURE

Introduction:

Plants play a vital role in the existence and survival of most of the organisms. They provide food and also supply the much required oxygen for breathing. In addition plants also provide fibers for diverse purposes and wood for housing and shelter. They also provide medicines, rubber, spices, condiments, beverages etc. It is difficult to imagine the existence of human beings without the availability of plants. The science which deals with the knowledge about plants is called Botany. In fact the science that deals with the study of living objects is called Biology. Since plants and animals are living, biology includes study of both. Biology is therefore divided into two branches Botany and Zoology. **Branches of Botany:** Botany may be studied from two aspects: a) Pure / basic botany and b) Applied / economic botany. Pure botany deals with study of plants as a part of nature while applied botany is applied to the well being of mankind.

Branches of Botany:

1) **Morphology:** Morpho means form and logus – science.

2) **Histology:** Histos – tissue. Study of detailed structure of tissue making up different organs of plant as revealed by the microscope is called Histology.

3) **Anatomy:** The study of gross internal structure of plant organs by the technique of section cutting is called Anatomy.

4) **Cytology:** Cytology deals with study of cell structure with special reference to behavior of nucleus.

5) **Ecology:** Environmental science and Agro - ecology deals with relationship between individual plant, plant communities and surrounding conditions in which they are living.

6) **Taxonomy:** or systemic botany. Taxis – arrangement. Mainly deals with identification and classification of plants.

7) **Genetics:** Fact and laws of inheritance, variation and heredity from generation to generation.

8) **Economic Botany:** deals with the various uses of plant and their products. Also includes methods for their improvement for better utilization by mankind.

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9) Plant Physiology: Physios- nature of life. Plant physiology deals with various vital processes and functions that plant perform.

Genetic potential of a plant and its interaction with environmental factors decides its growth and development by influencing or modifying certain internal processes. Plant physiology studies about these internal processes and their functional aspects. It helps to understand various biological processes of the plants like photosynthesis, respiration, transpiration, translocation, nutrient uptake, plant growth regulation through hormones and such other processes which have profound impact on crop yield. In plant physiology natural phenomenon operating in living plants and plant parts are studied. It is a discipline of botany where the structure of the cell, tissues and organs is associated with processes and functions. The different responses of organisms to environmental alterations and the resultant growth and development which are the outcome of such responses are also studied. In plant physiology an attempt is also made to study the factors which modify growth and development. For the said purpose a sound knowledge of chemistry, biochemistry, physics and statistics is required. These sciences have contributed immensely in elucidating the functional and structural aspects of plants. Several of the plant processes could only be revealed by the usage of sophisticated instruments and techniques provided by chemical and physical sciences e.g. techniques of radioisotopes, chromatography, scanning and transmission electron microscopy, spectrometry etc.

The meaning of Plant Physiology refers to "the science of properties and functions in normal conditions". The aim of the Plant Physiology has been described as early as the early20th Century by the **Russian Plant Physiologist, V.I. Palladin** as: "Which is to gain a complete and thorough knowledge of all the Phenomena occurring in plants, to analyze complex life processes. So as to interpret them in terms of simpler one and reduce them finally to the principles of physics and chemistry". Nevertheless, **Noggle and Fritz (1983)** described the Plant Physiology as "the science concerned with processes and functions, the response of plants to changes in environment and the growth and development that results from responses.

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Crop: Crop is a group of plants grown as a community in a specific locality and for a specific purpose. So when plant processes are studied in a unit area of land, it is called Crop physiology.

Crop Physiology – Definition:

1) Crop physiology is the study of the ways in which plant physiological processes are integrated to cause whole plant responses in communities.

2) Crop physiology can be defined as systematic application of knowledge of natural processes occurring in crop plants and fundamental principles for efficient crop production.

3) Crop physiology is concerned with the processes and functions of the crops at cellular, sub-cellular and whole plant levels in response to environmental variables and growth. In short, Crop physiology is the study of functional aspects of crop plants.

BRIEF HISTORY OF CROP PHYSIOLOGY:

1771 – Joseph Priestly: Plants could regenerate oxygen in the atmosphere

1779 – Ingenhouz: Studied the role of light in photosynthesis

1804 – De Saussure: Plant uptake of mineral nutrients and nitrates from soil

1837 – Boussingault: Nitrogen uptake by plants both from soil and atmosphere

1865 – Julius Sachs: Published a book *'Experimentelle Pflanzenphysiologi'*. By this time all branches of plant physiology were completely established, but their development in the next fifty years showed little concern with crop productivity and yield, except in the area of mineral nutrition. In this period essentiality and role of many mineral nutrients was established. Towards the end of that period herbicide physiology also became prominent.

1915 – W.L.Balls: Along with Holton he analysed the effect of plant spacing and sowing date on the development and yield of Egyptian cotton plants within crop stand, **not in isolated plants.** It was from his work the term 'Crop Physiology' came in to existence.

1924 – In England – a rapid development of the methods of growth and yield analysis by different investigators (V.H.Blackman, F.G.Gregory, G.E.Briggs etc.) was started. With the development of various methods of growth analysis, they started explaining 'the physiology of crop yield'.

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1947 – The concept of LAI (Leaf Area Index) was developed by **D.J.Watson.** This index has provided a more meaningful way of analyzing growth in crops, and stimulated renewed interest in crop physiology.

1950's – Studies on photosynthetic rate of the leaf and the loss of photosynthates by respiration was studied by the development of 'Infra Red Gas Analysis (**IRGA**)' method. This method has facilitated the estimation of short term rates of photosynthesis and respiration by crops in the field.

1953 – Monsi and Saeki: Explained about the manner of light interception by the crop canopy with their concept of light interception coefficient.

1963 – Hesketh and Moss: showed that photosynthesis by leaves of Maize, Sugarcane, and related tropical grasses could reach much higher rates, with less marked light saturation, than leaves of other plants (This was the starting point for research to find other photosynthetic CO_2 fixation pathways like C_4 and CAM mechanisms).

Later on several research works were carried out to understand the processes like translocation of food materials, their partitioning towards economic yield, storage mechanisms, physiology of flowering, effect of stressful environmental factors on crop growth and development, role of plant growth regulators in increasing the crop productivity etc All these areas have enriched the knowledge of physiological processes and their role in deciding the crop yield.

The role of crop physiology in different aspects of agriculture: OR

IMPORTANCE OF CROP PHYSIOLOGY IN AGRICULTURE:

1. Seed Physiology:

Seed is the most important input in agriculture. Germination of seed and proper establishment of seedling depends upon various internal and external factors. Knowledge of **seed physiology** helps in understanding of different physiological and morphological changes that occur during germination. Any deviation in these processes causes seed dormancy. The dormant condition of the seed bars immediate use of harvested seed for next crop which is important in intensive agriculture. By understanding the causes and effects of this problem, Crop Physiologists have come up with different methods of breaking the seed dormancy. For example, when ever paddy is used as a seed material in the very next season it is recommended to treat the seed either with HNO_3 or with GA.

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2. Mineral Nutrition:

The detection of deficiencies and toxicities of particular mineral nutrient elements have enabled us to make adequate soil amendments for better plant growth. Several physiological disorders of crop plants such as wheat, rice, pulses and oil seeds have been successfully corrected with the help of knowledge on physiology. For example, Zinc deficiency leads to *khaira* disease in rice. This can be corrected either by soil or by foliar application of zinc sulphate. Similarly, knowledge of water relations and mineral utilization has led to improved crop management and now it is possible to grow plants at places where they never grew, by providing proper physiological conditions. Studies on *chelates* and chelating agents have gone a long way in making unavailable elements available at functional sites and controlling toxicities of heavy metals.

3. Photoperiodism and Vernalization:

Response of plant to the relative length of day and night is called as photoperiodism. This concept was used to choose photo insensitive varieties. The semi dwarf rice varieties that have revolutionized Indian agriculture, are lodging resistant, fertilizer responsive, high yielding and **photo insensitive**. Photo insensitivity has allowed rice cultivation in non-traditional areas like Punjab. Even in traditional areas rice-wheat rotation has become possible only due to these varieties. Researches on photoperiodism and vernalization have made it possible to grow certain plants and make them flower even in *off* seasons by suitably altering the photoperiods and providing low temperature treatments.

4. Production Physiology:

Carbohydrates are major produce of plants and highly valued to human beings. Hence, for increasing its yield capacity, three aspects may be considered: i) production (Photosynthesis) ii) storage (sink potential), and iii) control of distribution in plants, i.e. directing the food material efficiently towards storage organ (translocation of solute). Higher translocation capacity towards storage organs like seeds helps to produce higher yields. In case of rice, the sink capacity of panicles, as well as, the size and longevity of the photosynthetic system after anthesis (flowering) can influence grain yield appreciably.

Total amount of dry matter produced less the photosynthates used in respiration is the net product of photosynthesis. Economic yield depends on how the dry matter is distributed among different organs of the plant. Partition of total dry matter amongst the major plant organs is of interest to the farmers as they are more interested in its partition towards economic yield. For example, excessive vegetative growth period in groundnut produces less number of pods as the reproductive period gets constricted. Thus, groundnut varieties with relatively extended period of reproductive growth are desirable.

5. Photosynthesis:

Green plants utilize less than one per cent of solar energy for the production of food, and there are two types of plants, C_3 and C_4 based on CO_2 assimilation. C_3 plants are less efficient photosynthesisers than C_4 plants, though these plants are more precious

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to human beings. C_3 plants include pulses, oilseed crops, fiber crops, important cereals such as wheat, rice, barley etc. Their lower efficiency is due to occurrence of photorespiration which deviate *Rubisco* enzyme from photosynthesis. Therefore, there is a great need to reduce wasteful process of photorespiration or to find out newer crop varieties with low rate of photorespiration.

6. Plant Growth Physiology:

Synthetic auxins and related compounds are being used for thinning of crops, prevention of premature fruit drop, promotion of plant growth and yield, induction of seedless or parthenocarpic fruits, promotion of root formation in cuttings for vegetative propagation, budding or sprouting, induction of flowering, control of fruit set and quality, hastening maturity, inducing dormancy in potato, controlling weeds etc. For example, commercial preparations of rooting compounds are available (Indole Buteric Acid @ 250 ppm) that promote callus and root formation which can improve establishment from stem cuttings.

Gibberellins have found great use in breaking dormancy, inducing uniform crop emergence, producing staminate flowers in cucurbits, loosening fruit clusters, increasing fruit size, hastening maturity, improving fruit quality, production of seedlessness, increasing sugar content in sugarcane, inducing flowering etc.

Cytokinins have been widely used for increasing shelf life of fruits, quickening root induction and producing efficient root system, increasing yield and oil contents of groundnut, breaking dormancy, delaying senescence of living organisms, causing cell division etc.

Ethylene has shown great potentials in making chemical harvesting possible, thinning by causing abscission, inducing bulbing in onion and tillering in other crops, causing dwarfness of plants, preventing lodging and inducing femaleness.

A number of other chemicals are also being used for causing male sterility, overcoming incompatibility, environmental engineering and land maintenance. In well-developed countries, some growth regulators are frequently used in agriculture. For example, chlormequat (CCC) chlorocholine chloride (2-chloroethyl tri-methyl ammonium chloride) is used as dwarfing agent in wheat. Ethephon is used to induce flowering in pineapple and as sugarcane ripener. Maleic hydrazide is used as growth retardant, for sucker control on tobacco, and as turf grass growth inhibitor. Daminozide is used to enhance size and colour of various fruits. Glyphosine is used as sugarcane ripener. Mepiquat chloride is a recent addition in the group of growth retardants, having potential use in cotton, ground nut, banana and many vegetable crops.

Role of various hormones like, auxins, gibberellins, cytokinins and ethrel in inducing and promoting flowering is now well documented. Ethrel is widely used to increase the number of female flowers followed by higher yield in cucumber.

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In several plants such as mango, apple, cotton *etc.*, the fruits abscise and fall before attaining maturity. Auxins have been found successful in preventing immature fall of fruits and thus saving the enormous loss. Planofix (a formulation of NAA) is commonly used in cotton, mango and coconut.

Tissue culture is the technique used to make successful *in vitro* growing of plant parts under controlled aseptic conditions. Tissue culture practices are now widely used and found immensely valuable in crop improvement programmes and hybridization programmes. This technique is commonly used in:

* Micro propagation in orchids, bananas, potatoes etc.
* Production of disease free plants in potato, cassava, sugarcane, sweet potato etc.
* Androgenic haploid and their use in breeding
* Embryo rescue for successful hybridization, as in case of interspecific hybridization between *Phaseolus vulgaris* and *P. angustissimus*.
* Induction and selection of mutants
* Somoclonal variations, as in case of wheat, potato and tomato
* Protoplast technology, as in production of pomato (a hybrid of potato and tomato produced by protoplasmic fusion)

7. Herbicide Physiology:

The use of **herbicides** to kill unwanted plants is widespread in modern agriculture. Majority of herbicides – about half of the commercially important compounds act by interrupting photosynthetic electron flow. [Ex. Paraquat, diuron (DCMU: Di chloro phenyl di- methyl urea)]. When the electron transport is blocked it virtually stops light reaction of photosynthesis. When light reaction is stopped the dark reaction does not happen and thus CO_2 is not fixed as carbohydrate. Therefore the weed is killed by starvation.

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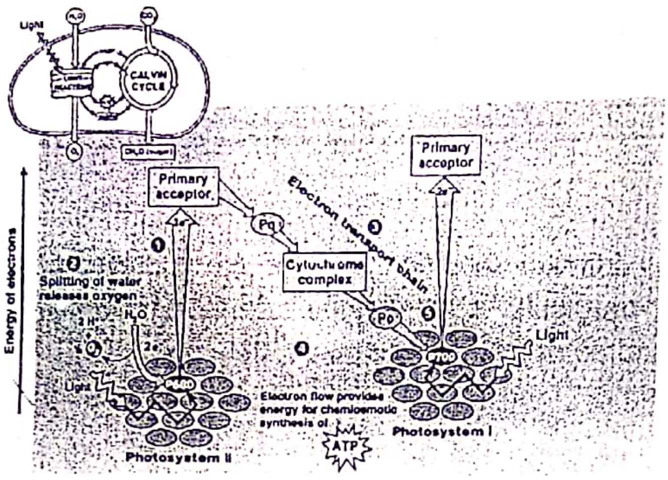

8. Environment Physiology:

The environmental factors influencing growth and yield of crops include temperature, solar radiation (light), atmospheric carbon dioxide, water supply, air humidity, wind velocity etc.

i) Temperature:

Extreme temperatures are destructive to plant growth. The critically low and high temperatures normally vary from one stage to another. The critical temperature will be below 20°C and above 30°C for many of the crops. These temperatures also differ according to variety, duration of critical temperature, diurnal changes and physiological status of the plant. Temperature greatly influences the growth rate just after germination. Within a temperature range of 22-31°C, the growth rate increases almost linearly with increasing temperatures.

Depending on the growth stages, injury to crop due to low temperature occurs when the daily mean temperature drops below 20°C. Common cool injuries are failure to germinate, delayed seedling emergence, stunting, leaf discolouration, panicle tip degeneration, incomplete panicle exertion, delayed flowering, high spikelet sterility and irregular maturity. On the other hand, high temperatures cause high percentages of spikelet sterility, when the temperatures exceed 35°C at anthesis for more than 1 hour.

***Vernalization*:** This is a method of inducing early flowering in plants by pre-treatment of their seeds at very low temperatures. Practical utility of vernalization are i) crops can be produced earlier ii) crops can be grown in the regions where they do not naturally reproduce and iii) plant breeding work can be accelerated.

ii) Solar Radiation (Light):

Most of radiant energy from the sun has a wavelength between 300 and 3000nm, often referred as short wave radiation. Photosynthesis in green leaves uses solar energy in wave lengths from 0.4 to 0.7 µm (400-700 nm), often refer as Photosynthetically Active Radiation (PAR). The solar radiation requirements of a crop differ from one growth stage to another. For example, in rice, shading during the vegetative stage only, slightly affects

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yield and yield components. Shading during the reproductive stage, however, has a pronounced effect on spikelet number. During ripening, it reduces grain yield considerably because of a decrease in the percentage of filled spikelet.

Flowering:

The physiological mechanism responsible for flowering is found to be controlled by duration of light (photoperiodism) and temperature (vernalization).

Photoperiodism: On the basis of length of photoperiod requirement the plants are classified into: short-day plants, long-day plants and day-neutral plants.

Short-day plants: For flowering of short-day plants, the day length must not exceed a certain critical value; the day length required is less than the critical length. Short-day plants will not flower even if a flash of light is provided during the continuous dark period. *e.g.* Rice, onion, upland cotton and strawberry.

Long-day plants: Long-day plants require a photoperiod of more than a critical length, which may vary from 14 to 18 hours. The best flowering of long day plants usually occurs in continuous light. *e.g.* Lettuce, radish, alfalfa, sugar beet, spinach etc.

Day-neutral plants: Their flowering is not affected by the length of the day. They can flower even if the light provided is from few hours to continuous illumination. *e.g.* Tomato, cucumber, cotton, pea, maize, sun-flower etc.

iii) CO_2 concentration:

Being one of the raw materials for photosynthesis, CO_2 concentration affects the rate of photosynthesis markedly. Because of its very low concentration in the atmosphere (360 ppm), it acts as a limiting factor for natural photosynthesis. The rate of photosynthesis increases markedly with increase in the CO_2 level up to a certain extent. Under full sunlight, photosynthesis increases up to 1000 ppm CO_2.

iv) Water Supply:

Water stress at any growth stage may reduce yield. The most common symptoms of water deficit are leaf rolling, leaf scorching, and impaired tillering, stunting and delayed flowering, spikelet sterility and incomplete grain filling. Depending on topography and rainfall patterns, low-lying areas may be subjected to different water depths and to different duration. When a crop is submerged for a long time during critical growth stages, the grain yield is reduced.

9) Stress Physiology:

Indian agriculture being predominantly rain fed in nature, development of drought resistant varieties is very important. Root zone depth, density of roots, plant water potential, relative water content, water use efficiency, xerophytic characters of leaves etc. are some of the characters helped to bred drought tolerant varieties and to develop

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efficient irrigation management practices (sprinkler and drip irrigation).

10) Post harvest physiology:

Post harvest losses of agriculture and horticulture are causing a great distress to farming community. Moisture and temperature are the two important factors causing physiological changes that reduce the post harvest quality of grains. Control of moisture content and maintenance of low temperatures have proved effective in storage of grains.

Shelf life of cut flowers can be increased by application of kinetin (cytokinin). This will reduce the burst of ethylene and thus reduces the rate of senescence.

Thus, physiological understanding of crop plants provides the fundamental scientific base about various aspects of metabolism, growth and development. This is immensely important for crop improvement or technology improvement in agriculture.

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