AGRON 604 ADVANCES IN CROP GROWTH AND DEVELOPMENT (2+1)

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Concept of plant ideotypes crop physiological and new ideotypes , characteristics of ideoype for wheat, rce, maize etc, cocept and types of growth harmones their role in field crop production efficient use of resourses

1. CONCEPT OF PLANT IDEOTYPES CROP PHYSIOLOGICAL AND NEW IDEOTYPES:-

In recent years due to all round efforts of agricultural scientists it has been possible to cultivate HYVs of cereal crops which are often been termed as **"NEW PLANT TYPES".**

IDEOTYPE: refers to plant type in which morphological and physiological characteristics are ideally suited to achieve high production potential and yield reliability. The concept of ideotype was given by Donald in 1968. He illustrated that there should be minimum competition between the crops and crop must be competent to compete with weeds. The single plant would give the better result in a group when the crop has at least competition with the same type of the crop. Ideotype is the model type which may also be defined as "a biological model which is expected to perform or behave in a predictable manner within a defined environment". On the basis of environment Donald and Hamblin (1976) identified two forms of ideotypes i.e. isolation ideotypes and competition ideotypes. Competition ideotypes are suitable for mixed cultivation.

Plant breeders have developed an impressive range of techniques in their search for increased yield and better quality in crops. Mutation breeding, polyploidy, the exploitation of hybrid vigour, embryo culture and advanced statistical design and analysis are among the many procedures which have enabled more effective breeding programmes. Yet if we examine the philosophies behind these programmes, we see that they are of but two kinds. In the first group, the purpose is to remedy some known defect in the crop, and this we may call "**defect elimination**". In the second group, the basic procedure is "**selection for yield**".

"Defect elimination" is adopted when disease resistance is bred into a susceptible genotype or when earliness is incorporated into a variety prone to water stress late in the season. It may involve the correction of physical imperfections such as weak straw in cereals, or deficiencies within man-made circumstances, such as a fragile skin in tomatoes which are to be mechanically harvested. In yet other projects attention is given to defects in quality, such as weak malting performance in barley or poor flavor in potatoes. These programmes of "defect elimination" have given substantially increased crop yield and quality in a great array of circumstances.

Definition:-

In broad sense an Ideotype model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, crop Ideotype is a plant model which is expected to yield greater quantity of grains, fibre, oil or other useful product when developed as a cultivar. The term Ideotype was first proposed by Donald in 1968 working on wheat. The main points about Ideotype are given below:

1. Crop Ideotype refers to model plants or ideas plant type for a specific environment.
2. Ideotype differs from Ideotype. The former refers to a combination of various plant characters which enhance the yield of economic produce, whereas the latter refers to the morphological features of the chromosomes of a particular plant species.
3. Donald included only morphological characters to define an Ideotype of wheat, subsequently, physiological and biochemical traits were also included for broadening the concept of crop Ideotype.
4. Ideal plants or model plants are expected to give higher yield than old cultivars in a defined environment.
5. Ideotype is a moving goal which changes according to climatic situation, type of cultivation, national polley, market requirement etc. In other words, Ideotype have to be redesigned depending upon above factors. Thus, development of crop Ideotype is a continuous process.
6. Ideal plant type or model plant type also varies from species. Moreover, this is a difficult and slow method of cultivar development because various morphological, physiological and biochemical characters have to be combined a single genotype from different sources.

THE DEVELOPMENT OF MODELS

The bases of crop breeding programmes can be usefully extended by a third philosophy, namely "**the breeding of model plants or ideotypes**". Man has long used models in his approach to a great range of problems; indeed the process of invention comprises the development of theoretical models based on knowledge, experience and imagination, the construction of the models, their testing and their use. It is the familiar approach in aircraft production, building construction and instrument design, and its validity for these physical purposes is generally accepted. Can this principle be applied to biological needs? We must pose a further question: Is it possible in any defined environmental situation to design a plant which is (i) theoretically capable of greater production than the genotype it is to replace and (ii) of such design as to offer reasonable prospect that it can be bred from the material available? The satisfaction of these criteria lies in the availability of three resources, namely sufficient knowledge, adequate genetic diversity and suitable techniques.

We may not yet have enough understanding of the anatomy and physiology of some crop species to permit the design of new cultivars, but in others, notably the cereals, we may now be able to conceive models of superior productivity. Admittedly, there can be no immediate certainty of success; all agree that models must be tested for performance.

But if we can sensibly postulate a model, albeit but a crude attempt at perfection, then we have the opportunity to devise and examine a combination of characters which otherwise may not occur in breeders' plots for centuries. Further, even though the early models produce no immediately useful commercial material, they will provide new bases for the understanding of crop ecology and for the design of progressively more effective models. In contrast, "selection for yield" is unlikely ever to approach the asymptote of yield, since the appropriate combination of plant characters, never being sought, can be attained only by attrition or chance. Selection for yield has all the immediate advantages and all the longer term limitations of a wholly pragmatic procedure.

Those who question the usefulness of designing or breeding model plants do so on a number of grounds. Firstly, they affirm that we do not have sufficient physiological knowledge to devise a model with confidence. In any breeder's plots, high yielding material of diverse growth form may be seen. How, they ask, can one nominate a particular plant form when there seems to be such a wide array of compensating mechanisms or routes towards high yield. Secondly, the definition of a model is potentially hazardous, in that it will narrow the spectrum of a breeding programme, rather than permit the emergence of the highest yielding segregates without prejudice by the breeder as to the most desirable plant form. And thirdly, they add, even if the model plant were to prove high yielding, the unique character of the model would not be established. Any other model could perhaps lead to equally high yields. Only if we breed and test many different models, or a series of models with varying degrees of model-character input, can we determine the advantage, if any, of the preferred model.

LANGER (1967) questions whether the plant breeder can be expected to react to the multiplicity of suggestions currently offered by the physiologist, but he envisages considerable impact on plant breeding objectives as the physiology of yield is further elucidated. MAC KEY (1966) while contributing to the design of models, believes that they cannot be directly applied in practical plant breeding; he considers that their value will lie in providing concepts which permit appropriate decisions within breeding programmes. While the weight of these arguments and reservations is recognized, they are believed not to invalidate the proposition that cereal models of likely value can be designed and bred at the present time. The very diversity of form among currently successful cultivars may indeed suggest that each variety is deficient in one or several characteristics. The narrower array of material to be used in the breeding of models is implicit in the concepts behind such a programme, just as the aircraft designer chooses materials appropriate to his model.

THORNE (1966) and TANAKA et al. (1966) contribute to thought on models by discussing and evaluating a number of attributes which are believed to influence the grain yield of wheat, barley and rice. Others have taken a further step and have advocated cereal breeding programmes incorporating individual model characters or have actively undertaken such projects (DONALD, 1962; ASANA, 1965; BEACHELL and JENNINGS, 1965; MAC KEY, 1966; TANNER et al., 1966).

Several examples can be given of the use of model characters. Cereal breeders have long laid emphasis on **resistance to lodging**, based both on the maintenance of grain yield and on the difficulty of harvesting lodged crops. The crop physiologist has established the influence of lodging in terms of its interference with light relationships and photosynthesis. Here then, in a stout stem, is a "model character", a character currently receiving increased recognition because of the extreme resistance to lodging at high fertility of the semi-dwarf wheat of Japan, used so successfully in breeding programmes in Washington State and Mexico.

A second model character of proven value, defined both from physiological studies and through breeders' observations, is the **awn on the floret of wheat and barley**. But though this character makes a positive contribution to photosynthesis and yield, and is easily incorporated into breeding programmes, there are still many new varieties which do not have this valuable attribute.

A third model character, now gaining recognition by a few cereal breeders, **is erect foliage**. There is theoretical advantage to be gained in the photosynthesis of various cereals if they have upright leaves (e.g. MONSI and SAEKI, 1953; DUNCAN et al., 1967); it is significant that the modern high yielding rice varieties of Japan and Taiwan, both japonica and indica types, which yield so much more than do the rice varieties of the tropics, all have this feature in common, together with relatively dwarf stature.

CONCEPT OF PLANT IDEOTYPES

Donald (1968) proposed the ideotype approach to plant breeding in contrast to the empirical breeding approach of defect elimination and selection for yield per se. He defined ‘‘crop ideotype’’ as an idealized plant type with a specific combination of characteristics favorable for photosynthesis, growth, and grain production based on knowledge of plant and crop physiology and morphology.

He argued that it would be more efficient to define a plant type that was theoretically efficient and then breed for this (Hamblin, 1993). In rice, Tsunoda (1962) compared yield potential and yield response to nitrogen (N) fertilizer in relation to the plant type of rice genotypes. Varieties with high yield potential and greater responsiveness to applied N had short sturdy stems and leaves that were erect, short, narrow, thick, and dark green. The close association between certain morphological traits and yielding ability in response to N led to the ‘‘plant type concept’’ as a guide for breeding improved varieties (Yoshida, 1972).

Simulation models predicted that a 25% increase in yield potential was possible by modification of the following traits of the current plant type (Dingkuhn et al., 1991):

1. Enhanced leaf growth combined with reduced tillering during early vegetative growth,
2. Reduced leaf growth and greater foliar n concentration during late vegetative and reproductive growth,
3. A steeper slope of the vertical n concentration gradient in the leaf canopy with a greater proportion of total leaf n in the upper leaves,

4. Increased carbohydrate storage capacity in stems.
5. A greater reproductive sink capacity and an extended grain-filling period.

These traits are both physiological and morphological. To break the yield potential barrier, IRRI scientists proposed modifications to the high-yielding indica plant type in the late 1980s and early 1990s (Khush, 1995). The newly designed plant type was mainly based on the results of simulation modelling and new traits were mostly morphological since they are relatively easy to select for compared with physiological traits in a breeding program. The proposed new plant type (NPT) has low tillering capacity (3–4 tillers when direct seeded); few unproductive tillers; 200–250 grains per panicle; a plant height of 90–100 cm; thick and sturdy stems; leaves that are thick, dark green, and erect; a vigorous root system; 100–130 days' growth duration; and increased harvest index (Peng et al., 1994).

PRINCIPLES OF DESIGN OF CEREAL IDEOTYPES

Concepts of cereal plants with high yield based on more culms, more ears, spikelets or grains are derived from considerations of the isolated plant. Here such criteria are valid. But the performance of a plant growing in isolation may have little relationship to its potential for yield as a community. The principles of plant design here enunciated are based on experimental findings and theoretical concepts related specifically to capacity for high grain yield when grown as a crop. In a field crop each plant suffers intense competition from its neighbours, with its yield reduced to 20% or 10% or less of the yield of an isolated plant, and it is in this crowded community that any ideotype has to succeed. This capacity of a genotype to yield well in a community can be analysed in terms of two parameters, namely

(a) the yield per plant in the absence of competition from neighbours, and

(b) its response to crowding among other plants of like genotype.

The response by wheat cultivars to crowding is almost unexplored. In no wheat environment do we know how much of the success of leading cultivars is due to their capacity to yield well at wide spacing and to maintain that margin over other cultivars when sown as a dense crop, or alternatively the degree to which a successful cultivar may be a low producer under very wide spacing, but with a capacity to maintain its yield per plant relatively well within a crop. In rice it is the latter attribute which gives success under crop conditions (TANAKA et al., 1964), and a similar situation may be indicated for wheat (WIEBE et al., 1963). It is because of these relationships that much of the work on the physiology and yield of the isolated plant may have but limited relevance to the crop situation.

Clearly the individual plant within the community will express its potential for yield most fully if it suffers minimum interference from its neighbours. Thus its neighbours should be weak competitors. And since, for the purpose of this discussion, all plants in the crop are of like genotype, then the ideotype itself must be of low competitive ability.

This may seem a paradox - that a successful crop plant should be other than an aggressive competitor for those factors needed for growth. But this seems to be so. While strong competitive ability is advantageous against other species such as weeds, it will lead in a monoculture to intensified competition and heavy mutual depression among the crowded plants. For example, a genotype which shows effective interception of light through expansive leaf display by the isolated plant, may show less efficient utilization of light within a community of that genotype, because of mutual shading by neighbours.

The efficient production of dry matter by a monotypic community will depend on the ability of the individual plant to make maximum use of the resources of the limited environment in which it grows, and to encroach to a minimum degree on the environment of its like neighbours. For example, if an erect leaf can photosynthesize effectively within a less horizontal area than a drooping leaf of like size, it is operating with a less demand on the light resources. Similarly a genotype of high net assimilation rate or with a particular pattern of deployment of photosynthates may be efficient in terms of its demand on resources within the community. But some of these same attributes may be disadvantageous among widely spaced plants.

Though the individual plant in a crop should have a low demand on resources relative to its production, the community as a whole must press on total resources to a maximum degree, for only then can full production be envisaged. The means towards this end does not lie in the aggressiveness of the individual plant but in a high density of plants resistant to crowding (i.e. of low competitive ability against each other), each making efficient use of its limited environment, yet each ultimately in intense competition with its neighbours because of dense planting. It is submitted that the successful crop plant will be of low competitive ability relative to its mass and of high efficiency relative to its environmental resources.

This low competitive ability of the successful crop plant means that as well as the negative relationship already indicated (performance at low and high density respectively), there may be a second negative relationship; this is the relationship of (a) the competitive ability of a particular cultivar within a mixture of different cultivars with (b) the yield of that same cultivar in pure culture. This has been demonstrated with barley (SUNESON, 1949), and dramatically for rice (JENNINGS and DE JESUS, 1968), where it has been shown that high yielding cultivars are suppressed and even totally eliminated in mixtures.

In some species the ‘economic part’ clearly forms a sink for photosynthates during the later part of the plant’s growth. The cereal grain and the potato tuber are such organs; thus ear production and ear characteristics in cereals will have high relevance to grain yields. Here lies further opportunity to define characteristics of an effective ideotype.

The **design of a cereal ideotype** will thus depend heavily on theoretical knowledge and experimental evidence in three areas, namely **photosynthesis in cereal communities, the role of the cereal ear as an available or limiting sink for photosynthates and the operation of plant competition in crop communities**.

The question arises whether any of these principles of design can have substantial constancy of expression over a wide range of environments. Though the principles be valid, their application may conceivably lead to such a range of models as to make plant design both difficult and profitless.

It is suggested that two considerations should influence the approach to plant ideotypes in relation to environments. Firstly, it seems reasonable that the designer should initially seek to cater for the simplest environmental situation, and, further, one which can readily be defined. In general this will be the situation in which the factors needed for growth and development approach maximal needs. In particular, water and nutrients should be in non-limiting supply, with emphasis centred on the efficiency of the crop community as a photosynthesizing system. Here then will be a basic ideotype designed to give maximum production in a highly favourable or idealized environment. If such an ideotype is developed, then the effect of any curtailment of resources, as by a decrease in nutrient or water supply, can be examined in terms of the progressive modification of the basic ideotype. This approach promises a more rational array of variants than could be achieved by a series of ideotypes independently conceived for each major environmental situation.

The second point pertaining to environment is that the production of a crop ideotype may call for the concurrent creation of a new environment. HUTCHINSON et al. (1947) wrote, “Successful evolutionary change depends on a fortunate coincidence of the emergence of a new character with the occurrence of an environmental change which makes it advantageous.” Similarly the conscious development of an ideotype may need to be accompanied by conscious change of the environment. Though we are concerned in this instance with a potential to yield well as a pure culture rather than with a potential to compete successfully with other genotypes, the concept of the relationship to the environment is basically the same. Model building need not, therefore, be exclusively associated with existing environments, but may involve the concurrent design of new environments, including such man made components of the plant environment as the crop density, planting arrangement and nutrient level.

TYPES OF IDEOTYPE

1. **Isolation ideotype: -** It is the model plant types that perform best when the plants are space-planted.
2. **Competition ideotype: -** This ideotype perform genetically well in heterogeneous population. In case of cereals, this ideotype is tall, leafy, free-tillering plant that is able to shade its aggressive neighbours. In case of annual seed crops, such an ideotype will include the following features: annual habit, tallness, leafy Canopy, tillering or branching,seed size,speed of germination and root characters
3. **Crop ideotype; -** This ideotype perform best at commercial crop densities because it is poor competitor. In case of cereals, a crop ideotype is erect, sparsely-tillered plan, with small erect leaves.th

Several other ideotypes are:

1. **Market ideotype: -** includes traits like seed colour, seed size, cooking and baking quality, etc.
2. **Climatic ideotype: -** includes trait heat and colds important in climate adaptation such as heat and cold resistance, maturity duration, drought resistance etc.
3. **Edaphic ideotype: -** includes salinity tolerance, mineral toxicity/deficiency tolerance etc.
4. **Stess ideotype: -** shows resistance to both biotic and abiotic stress.

FEATURES OF CROP IDEOTYPE

The crop Ideotype consists of several morphological and physiological traits which contribute for enhanced yield or higher yield than currently prevalent crop cultivars. The morphological and physiological features of crop Ideotype is required for irrigated cultivation or rainfed cultivation. Ideal plant whether the Ideotype is required for irrigated cultivation or rainfed cultivation.

CHARACTERISTICS OF IDEOYPE FOR WHEAT, RICE, MAIZE ETC.:-

Ideal plant types or model plants have been discussed in several crops like wheat, rice, maize, barley, cotton, and bean. The important features of Ideotype for some crops are briefly described below:

WHEAT IDEOTYPE

The term Ideotype was coined by **Donald in 1968** working on wheat. The feasibility of designing a examined by attempting such a with the foregoing discussion, the ideotype here presented is conceived as potentially capable of high grain yield when grown as a crop community environment favourably endowe supply, though most of the characters are believed also to be of ubiquitous value. This basic ideotype is submitted therefore as suited to well-fertilized, well All the attributes of the ideotype are morphological characters, but all are based on considerations. It is believed that the model may offer levels of yield appreciably greater than those available from genotypes of currently prevalent plant features of the model are:

1. A **short, strong stem-** As already discussed, the advantage of a short stout stem of lodging, is well established. The need for a strong stem increases as fertility is raised, since the modulus due to wind becomes greater as the A secondary effect of height will be to change leaf disposition, in particular the successive leaves on the stem. If the leaves are very closely stem, there may be serious shading of arrangement of grass leaves. This seems cultivars with all four of the dwarfness. (This relates also to the 'leaf area density' (KASANAGA and MONSI, 1954), discussed under leaf size). It is possible that shortness of stem may make a small contribution by reducing the investment of photosynthates into stem production, but this proposition is doubtfull in wheat because the stem is itself covered with photosynthesizing tissues. If we weigh these points it seems that a relatively short stout stem, though not excessively so, is essential as a safeguard against lodging, while still providing a sufficient dispersal of leaves in the canopy.

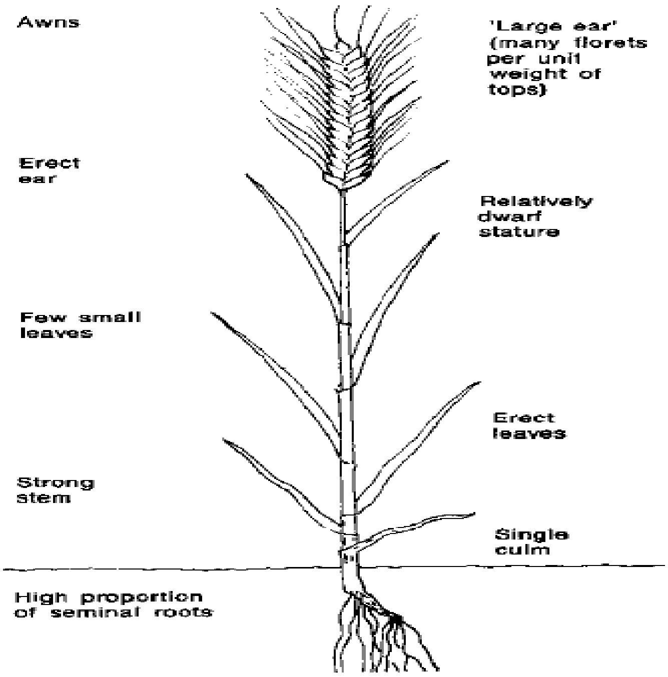


Fig-1. A basic wheat ideotype, designated to give a high grain yield as a crop community two-ranked proposition is doubtful

2. **Erect leaves**- Reference has been made to this aspect of plant form in rice breeding programmes. It is based on the concept that in a dense community, near-vertical leaves will permit adequate illumination of a greater area of leaf surface than will occur in a canopy of long, horizontal or drooping leaves, in which the upper leaves will be overlit and the lower leaves harmfully shaded. This relationship will apply to any species in which the leaf is nearly saturated for photosynthesis at a light intensity substantially below that of the ambient light. Such is the case for rice (e.g. MURATA, 1961) and wheat (e.g. WARDLAW, 1967).

3. **Few small leaves**- The postulated advantage of small leaves is mainly based on theoretical considerations. KASANAGA and MONSI (1954) showed that a scattered leaf arrangement (a low leaf area within each 'leaf plane' of the canopy) is potentially advantageous in plant communities under high illumination, i.e. in crops, in contrast

to shade communities. WILSON (1960) similarly calculated that the more uniform the dispersion of leaves in each leaf layer, the greater will be the crop growth rate. Each of these theoretical considerations indicates an advantage of many small leaves over a few larger leaves. In support of this hypothesis, TSUNODA (1959b) reported that in both rice and soybean the varieties adapted to heavy fertilizer application (we may regard this as applicable also to high density situations) tend to have smaller-sized leaves. In wheat, small leaves and more especially shorter leaves, tend also to be erect leaves, while longer leaves are more likely to be floppy and downward curving.

4. **A large ear-** (Many florets per unit of dry matter). There is much circumstantial evidence that the wheat ear is normally a limiting sink for photosynthates. In brief, this evidence is of two kinds. Firstly, when various individual parts of the photosynthetic surface responsible for grain filling (flag leaf, upper stem, ear) are removed or shaded, the remaining parts can partially compensate for the loss of the part that has been removed or shaded (e.g. BUTTROSE and MAY, 1959; THORNE, 1963). Thus none of these organs normally operates at full capacity. Secondly when the grain number in a wheat ear is reduced from the full complement, the weight per grain may show no increase (BUTTROSE, 1962). This indicates that in the control ear, the number and potential size of the grains, rather than the supply of assimilates, may govern the total weight of grain produced.

5. **An erect ear-** This is adopted in the belief that the best mean illumination of all sides of all ears will be attained in a community of erect ears. This is the common ear disposition in wheat, though drooping ears are to be seen in some commercial varieties.

6. **The presence of awns-** There is evidence dating back to 1920 (HARLAN and ANTHONY, 1920) that the additional surface provided by awns will contribute significantly to photosynthesis by the cereal ear. GRUNDBACHER (1963), who has reviewed the literature on this topic, considers that as assimilating organs they may contribute more than ten percent of the total grain dry weight. The contribution seems to be greater under semi-arid conditions, supposedly because of the xeromorphic structure of awns compared to that of cereal leaves. This contribution to yield by the

awns has been recognized in many plant breeding programmes (e.g. VOGEL et al., 1963). Perhaps there is a limitation to the advantage of awns, in that very heavy awns or branched awns may shade the photosynthetic surface of the glumes to a significant degree. But of the value of simple awns there can be no doubt.

7. **A single culm-** It is important to appreciate that the number of culms per plant (main stem plus tillers) in any cereal community is not characteristic of the species, but is a consequence of the selection of a genotype to fit the local climate and more particularly the local agronomic practices. For example under crop conditions, rice in Japan has more than 20 fertile culms, while wheat in the United Kingdom has 2 or 3.

8. **Other characters-** The ideotype here formulated does not permit the nomination of particular parents solely because of their strong display of desired characters. There may be various routes towards a variety conforming to the general pattern of the model; further it has already been emphasized that the ideotype must meet local requirements for disease resistance and so on. Thus the parental material must include high yielding, locally adapted cultivars, and indeed the extent to which this is needed is an index of the limit to our knowledge of the desirable attributes of our ideotype.

9. In summary the wheat ideotype will be of such form that it is a weak competitor relative to its mass, and thus will be less affected by crowding among like neighbours. It will make a minimum demand on resources per unit of dry matter produced, but each unit of dry matter will include a sufficient number of florets. The ear is to have a capacity to accept all photosynthates either from its own green surfaces or from other parts of the plant. These criteria are to be satisfied especially at high fertility, and when the total pressure by the community on the environmental resources is intensified by high density of population.

Thus, Donald included only morphological traits in the Ideotype. However, all the traits ere based on physiological consideration. Finally (1968) doubted the utility of single clum in wheat Ideotype. Considered tillering as important features of wheat flag type a wheat plant with moderately short but broad flag leaf, long flag leaf sheath, short ear extrusion with long ear, and moderately high tillering capacity should give yield per plant (Hsu and Watson, 1917). Asana proposed wheat Ideotype for rainfed cultivation. Recent workers included both morphological and physiological characters in wheat Ideotype.

RICE IDEOTYPE

The concept of plant type was introduced in rice breeding by **Jennings in 1964**, through the term **Ideotype was coined by Donald in 1968**. World rice production must increase by approximately 1% annually to meet the growing demand for food that will result from population growth and economic development (Rosegrant et al., land. Yield potential is defined as the yield of a variety when grown in environments to which it is adapted; with nutrients and water non-limiting; and with pests, diseases, weeds, lodging, and other stresses effectively controlled (Evans, 1993). Yield potential of irrigated rice has experienced two quantum leaps (Chen et al., 2002a). The first one was brought about by the development of semi dwarf varieties in the late 1950s in China and early 1960s at the International Rice Research Institute (IRRI). Dwarf breeding began in China in 1956 using the Sd-1 gene from Ai-zi-zhan (Huang, 2001). In 1959, the first dwarf variety, Guang-chang-ai, was developed in China. In 1962, plant breeders at IRRI made crosses to introduce dwarfing genes from Taiwanese varieties such as Dee-geowoo- gen, Taichung Native 1, and I-geo-tse to tropical tall land races. In 1966, IR8, the first semi-dwarf, high-yielding modern rice variety, was released for the tropical irrigated lowlands (Khush et al., 2001). The birth of IR8 increased the yield potential of the irrigated rice crop from 6 to 10 t ha-1 in the tropics (Chandler, 1982). The second leap in yield potential was brought about by the development of hybrid rice in 1976 in China (Yuan et al., 1994). Standard heterosis of indica/indica hybrids was reported to range from 15% to 25% in China, but no information is available about the actual increase in yield potential of hybrid rice in temperate and subtropical areas. In the tropics, Peng et al. (1999) reported that indica/indica hybrid rice has increased yield potential by 9% compared with the best inbred cultivars in irrigated lowlands.

Donald (1968) proposed the ideotype approach to plant breeding in contrast to the empirical breeding approach of defect elimination and selection for yield per se. He defined ‘‘crop ideotype’’ as an idealized plant type with a specific combination of characteristics favorable for photosynthesis, growth, and grain production based on knowledge of plant and crop physiology and morphology. He argued that it would be more efficient to define a plant type that was theoretically efficient and then breed for this (Hamblin, 1993). In rice, Tsunoda (1962) compared yield potential and yield response to nitrogen (N) fertilizer in relation to the plant type of rice genotypes. Varieties with high yield potential and greater responsiveness to applied N had short sturdy stems and leaves that were erect, short, narrow, thick, and dark green. The close association between certain morphological traits and yielding ability in response to N led to the ‘‘plant type concept’’ as a guide for breeding improved varieties (Yoshida, 1972).

CHINA’S ‘‘SUPER’’ RICE BREEDING

Since the development of the first improved semi-dwarf variety in Guangdong, China, in 1959 (Huang, 2001) and three- line indica F1 hybrid rice in 1976 (Yuan et al., 1994), breeding for high-yielding rice varieties has never stopped in China. Huang (2001) developed bushy-type varieties with early vigour such as Guichao and Teqing in 1980s. These varieties are tolerant of shading and high plant density and were widely grown in southern China. Yang et al. (1996) stated that a further increase in rice yield potential has to come from a combination of improvement in plant type and use of growth vigor. They proposed an erect panicle plant type and developed Shennong265 with this trait, which was grown in Liaoning Province. Zhou (1995) developed three-line intersubspecific F1 hybrid rice between indica and japonica with a heavypanicle plant type, which is suitable for rice-growing areas such as Sichuan with high humidity, high temperature, and limited solar radiation. Although progress has been achieved in increasing rice grain yield through crop improvement, China’s rice breeding activities for increasing yield potential using an ideotype approach were not organized at the national level until 1996. Stimulated by IRRI’s NPT breeding program, China established a nationwide mega project on the development of ‘‘super’’ rice in 1996 (Cheng et al., 1998, 2007). The ‘‘super’’ rice varieties can be developed by breeding inbred and/or hybrid varieties.

A ‘‘super’’ hybrid rice breeding program was started in 1998 by Prof. Longping Yuan. In this program, the strategy was to combine an ideotype approach with the use of intersubspecific heterosis (Yuan, 2001). The ideotype was reflected in the following morphological traits:

a. Moderate tillering capacity (270–300 panicles m-2).

b. Heavy (5 g per panicle) and drooping panicles at maturity.

c. Plant height of at least 100 cm (from soil surface to unbent plant tip) and panicle height

of 60 cm (from soil surface to the top of panicles with panicles in natural position) at maturity.

d. Top three leaves: Flag-leaf length of 50 and 55 cm for the 2nd and 3rd leaves. All three leaves are above panicle height. Should remain erect until maturity. Leaf angles of the flag, 2nd, and 3rd leaf are around 5o, 10o, and 20o, respectively. Narrow and V-shape leaves (2 cm leaf width when flattened). Thick leaves (specific leaf weight of top three leaves = 55 g m-2). Leaf area index (LAI) of top three leaves is about 6.0 and Harvest index of about 0.55.

SUCCESS OF ‘‘SUPER’’ RICE BREEDING

Up to 2001, 7 inbred and 44 hybrid varieties that met the ‘‘super’’ rice criteria were released by provincial or national seed boards (Min et al., 2002). In 1998– 2005, 34 commercially released ‘‘super’’ hybrid rice varieties were grown on a total area of 13.5 million ha and produced an additional 6.7 million tonnes of rough rice in China (Cheng et al., 2007). These ‘‘super’’ rice varieties such as Xieyou9308 and Liangyoupeijiu became popular because they produce high yield and have good grain quality.

Jennings suggested that the rice an ideal or model plant type consists of

1) Semi dwarf stature,

2) High tillering capacity,

3) Short, erect, thick and highly angled leaves (Jennings, 1964, Beachell and Jennings, 1965).

Jennings also included morphological traits in his model. Now emphasis is also given to physiological traits in the development of rice Ideotype.

MAIZE IDEOTYPE

Mock and Pearce proposed ideal plant type of maize in **1975**.

Ideotype root architecture for efficient nitrogen acquisition

The use of nitrogen (N) fertilizers has contributed to the production of a food supply sufficient for both animals and humans despite some negative environmental impact.

Sustaining food production by increasing N use efficiency in intensive cropping systems has become a major concern for scientists, environmental groups, and agricultural policymakers worldwide. In highyielding maize systems the major method of N loss is nitrate leaching. In this review paper, the characteristic of nitrate movement in the soil, N uptake by maize as well as the regulation of root growth by soil N availability are discussed. We suggest that an ideotype root architecture for efficient N acquisition in maize should include (i) deeper roots with high activity that are able to uptake nitrate before it moves downward into deep soil; (ii) vigorous lateral root growth under high N input conditions so as to increase spatial N availability in the soil; and (iii) strong response of lateral root growth to localized nitrogen supply so as to utilize unevenly distributed nitrate especially under limited N conditions.

Maize Seedlings Predict Drought Tolerance

Scientists have developed a new method for measuring drought tolerance in maize. By comparing the shoot-to-root ratio in seedlings stressed by low water, scientists can predict whether a plant has the right mix of genes for adapting to drought conditions.

The ideal drought-resistant maize should have a higher ratio of root surface area compared to leaves and stems. Developing enough adult plants to determine this feature is a costly investment. The research, conducted by Nathinee Ruta at the Swiss Federal Institute of Technology, tested whether the root to shoot ratio in seedlings subjected to water stress would provide the basic genetic information about the general pattern of root system architecture leading to drought avoidance.

The findings were reported in the July/August 2010 edition of Crop Science, published by the Crop Science Society of America. The study was conducted at Peter Stamp's laboratory at the Swiss Federal Institute of Technology (ETH) in Zurich, using maize populations developed by the breeding program of the International Maize and Wheat Improvement Center (CIMMYT), headquartered in Mexico.

These maize lines were developed to increase yield in drought-prone environments such as Sub- Saharan Africa. Therefore, the data on seedling roots could be compared with yield trials in drought environments that had been generated throughout several years.

The roots of these seedlings grew on filter paper in growth pouches and were measured non-destructively using digital image analysis. The system was kept simple to allow for a handling of 200 plants per day. This was a sufficient amount of data to allow researchers to locate the positions of the genes that control root growth, and link them to other genes in the maize genome.

Most genetic studies of water stress of maize tend to focus on the above ground portion of the plant, with the roots not easily accessible, particularly under drought conditions. With little known about the correlation between root structure and drought tolerance, this research offers promising prospects for using root traits in predicting maize yield under water stress.

"There is probably an optimal maize ideotype for each combination of soil type and climate condition," stated Andreas Hund, the senior scientist leading the project. "We aim to define these ideotypes for contrasting environments and identify key loci allowing us to select for more efficient root systems."

Research is ongoing at ETH to improve techniques to measure genetic relationships between leaf and root surface area as they respond to environmental conditions. A strong focus will be on how these factors change over time or with respect to environmental stresses, such as extreme temperatures or drought.

In Maize, higher yields were obtained from the plants consisting of

1) Low tillers,

2) Large cobs, and

3) Angled leaves for good light interception. Planting of such type at closer spacings resulted in higher yields.

BARLEY IDEOTYPE

Rasmusson (1987) reviewed the work on Ideotype breeding and also suggested ideal plant type of six rowed barley. He proposed that in barley, higher yield can be obtained from a combination of

1) Short stature,

2) Long awns

3) High harvest index, and

4) High biomass. Kernel weight and kernel number were found rewarding in increasing yield.

COTTON IDEOTYPE

In cotton, genotypes with zero branch, short stature, compact plant, small leaves and fewer sympodia were considered to enhance yield levels. **Singh et al. (1974)** proposed and ideal plant type of uplant cotton growing belt. The proposed Ideotype includes

1. Short stature (90-120 cm),
2. Compact and sympodial plant habit making pyramidal shape,
3. Determinate the fruiting habit with unimodal distribution of bolling,
4. Short duration (150-165 days),
5. Responsive to high fertilizer dose,
6. High degree of inter plant competitive ability,
7. High degree of resistance to insect pests and diseases, and
8. High physiological efficiency,

Singh and Narayana (1993) proposed an Ideotype of above two species for **rainfed conditions**. The main features of proposed Ideotype include, earliness (150-165 days), fewer small and thick leaves, compact and short stature , interminate habit, spares hairness, medium to big boll size, synchronous bolling , high response to nutrients, and resistance to insect and diseases

GRAM IDEOTYPE

Pande and Saxena (1973) proposed the ideotype for gram having following features-

1. The vegetative growth must be stopped before the starting of reproductive stage.

2. The plant should have erect branching. (In the prevalent varieties of gram, the spreading and branching of its canopy is just like umbrella which interfere to penetrate the sunshine into its canopy causing humid conditions favourable for insect-pest and diseases).

3. To harness the long photoperiod and favourable temperature at the time of flowering, there should be 2-3 longer pods in the leaf axis and 2-3 seeds in each pod.

ARHAR IDEOTYPE

The growth of arhar varieties in the beginning is too less i.e. in the first two months only one or two branches are come out. Therefore, arhar is unable to harness the solar energy properly in the first two months. The flower’s drop is also a major problem. the filling of pods according to Hydro-dynamic model sets up the competition between vegetative and reproductive phases. considering all the views Pande and Saxena suggested ideotypes having following features-

1. The fast growth of plant’s canopy at least in the beginning.

2. The reproductive phase starts after the closure of vegetative growth.

3. Long floral axis having 2-3 flowers in each trifoliate axis.

4. Synchronized flowering.

5. Active root nodules for the long time.

6. Resistance to insect-pest and diseases.

A Ideotype for Dryland Farming

1. Short growth duration.

2. Effective root system.

3. Drought tolerance.

4. High yield potential with altered morphology viz.

a. Plant with few leaves just sufficient to maintain photosynthetic output and growth (to

minimize the use of water).

b. Leaves horizontally disposed for better disposed under irrigated conditions.

2. CONCEPT AND TYPES OF GROWTH HARMONES THEIR ROLE IN FIELD CROP PRODUCTION EFFICIENT USE OF RESOURCES:-

Plant hormones (also known as **phytohormones**) are chemicals that regulate plant growth, which, in the UK, are termed 'plant growth substances'.

Plant growth and development involves the integration of many environmental and endogenous signals that, together with the intrinsic genetic program, determine plant form. Fundamental to this process are several growth regulators collectively called the plant hormones or phytohormones. This group includes auxin, the gibberellins (GAs), cytokinin, abscisic acid (ABA), ethylene, the brassinosteroids (BRs), and jasmonic acid (JA), each of which acts at low concentrations to regulate many aspects of plant growth and development.

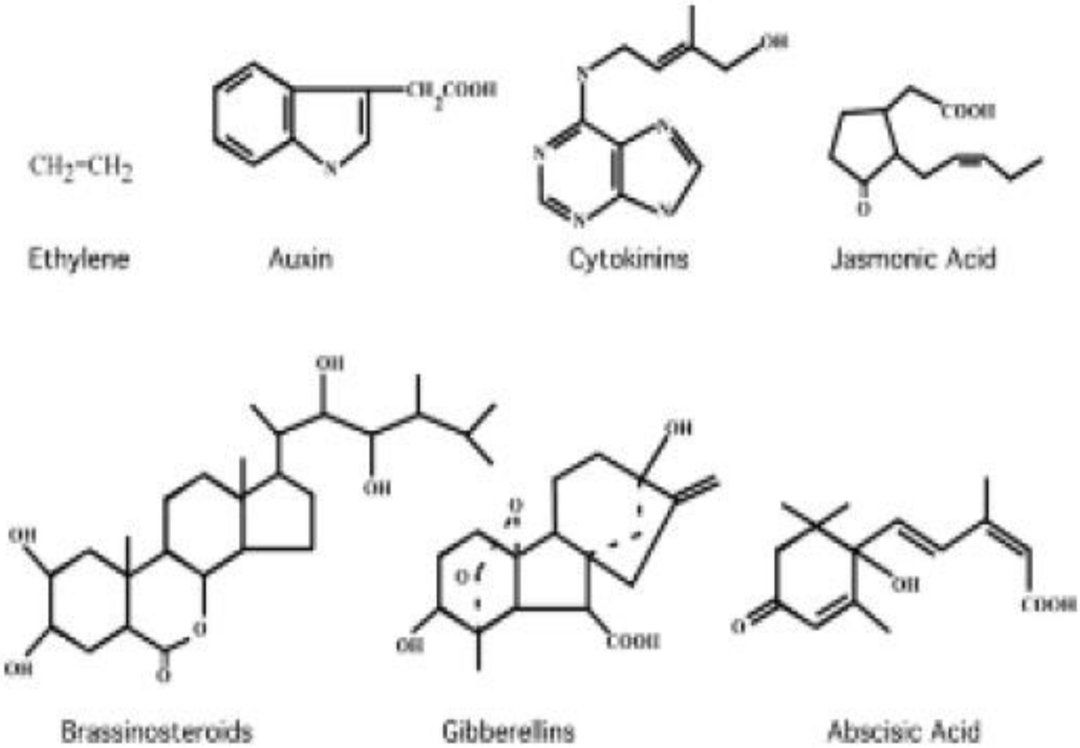


Fig 2. Chemical Structures of the Plant Hormones

Plant hormones are signal molecules produced within the plant, and occur in extremely low concentrations. Hormones regulate cellular processes in targeted cells locally and, when moved to other locations, in other locations of the plant. Hormones also determine the formation of flowers, stems, leaves, the shedding of leaves, and the development and ripening of fruit. Plants, unlike animals, lack glands that produce and secrete hormones. Instead, each cell is capable of producing hormones. Plant hormones shape the plant, affecting seed growth, time of flowering, the sex of flowers, senescence of leaves, and fruits. They affect which tissues grow upward and which grow downward, leaf formation and stem growth, fruit development and ripening, plant longevity, and even plant death. Hormones are vital to plant growth, and, lacking them, plants would be mostly a mass of undifferentiated cells. So they are also called as growth factors or growth hormones. The term **'Phytohormone'** was coined by **Thimann** in 1948.

A partial list of the responses elicited by each hormone is provided below. Ethylene gas promotes fruit ripening, senescence, and responses to pathogens and abiotic stresses. IAA (an auxin) regulates cell division and expansion, vascular differentiation, lateral root development, and apical dominance. Cytokinins are adenine derivatives first identified by their ability to promote cytokinesis. JA is a volatile signal that modulates pollen development and responses to pathogen infection. The BRs regulate cell expansion and photomorphogenesis (light-regulated development). GAs are diterpenoid compounds that promote germination, stem elongation, and the induction of flowering. ABA promotes seed dormancy and is involved in several stress signaling pathways. is involved in several stress signaling pathways.

With the notable exception of the steroidal hormones of the BR group, plant hormones bear little resemblance to their animal counterparts (fig 2). Rather, they are relatively simple, small molecules such as ethylene gas and indole-3-acetic acid (IAA), the primary auxin in the majority of plant species. The concept of plant hormones originates from a classical experiment on phototropism, the bending of plants toward light, carried out by Charles Darwin and his son Francis in 1880. The Darwins were able to demonstrate that when oat seedlings were exposed to a lateral light source, a transported signal originating from the plant apex promoted differential cell elongation in the lower parts of the seedling that resulted in it bending toward the light source. This signal was subsequently shown to be IAA, the first known plant hormone.

What Do They Do?

Virtually every aspect of plant growth and development is under hormonal control to some degree. A single hormone can regulate an amazingly diverse array of cellular and developmental processes, while at the same time multiple hormones often influence a single process. Wellstudied examples include the promotion of fruit ripening by ethylene, regulation of the cell cycle by auxin and cytokinin, induction of seed germination and stem elongation by GA, and the maintenance of seed dormancy by ABA. Historically, the effects of each hormone have been defined largely by the application of exogenous hormone. More recently, the isolation of hormone biosynthetic and response mutants has provided powerful new tools for painting a clearer picture of the roles of the various phytohormones in plant growth and development.

How Do They Work?

Plant biologists have been fascinated by the regulatory capacity of phytohormones since the time of their discovery, and the notion that hormone levels or responses could be manipulated to improve desired plant traits has long been an area of intense interest. Perhaps the best-known example of this is the isolation of dwarf varieties of wheat and rice that led to the “green revolution” in the second half of the 20th century, which is credited with saving millions of people around the globe from starvation. These dwarf varieties have shorter stems than wildtype, making these plants less susceptible to damage by wind and rain. The molecular isolation of these “dwarfing genes” has revealed that they encode components of the GA biosynthesis and response pathways (Peng et al. 1999; Sasaki et al. 2002).

To elucidate the molecular mechanisms underlying phytohormone action, several researchers have utilized the genetically facile model plant *Arabidopsis thaliana* to isolate mutations that confer altered response to applied hormone. Molecular and biochemical analysis of the gene products defined by these mutations, coupled with expression studies aimed at identifying the downstream target genes that mediate hormonal changes in growth and development, has begun to unlock some of the mysteries behind phytohormone action. While no hormone transduction pathway is completely understood, we now have a rudimentary understanding of many of the molecular events underlying hormone action.

CHARACTERISTICS

The word hormone is derived from Greek, meaning *set in motion*. Plant hormones affect gene expression and transcription levels, cellular division, and growth. They are naturally produced within plants, though very similar chemicals are produced by fungi and bacteria that can also affect plant growth. A large number of related chemical compounds are synthesized by humans. They are used to regulate the growth of cultivated plants, weeds, and in vitro-grown plants and plant cells; these manmade compounds are called **Plant Growth Regulators** or **PGRs** for short. Early in the study of plant hormones, "phytohormone" was the commonly used term, but its use is less widely applied now.

Plant hormones are not nutrients, but chemicals that in small amounts promote and influence the growth, development, and differentiation of cells and tissues. The biosynthesis of plant hormones within plant tissues is often diffuse and not always localized. Plants lack glands to produce and store hormones, because, unlike animals which have two circulatory systems (lymphatic and cardiovascular) powered by a heart that moves fluids around the body plants use more passive means to move chemicals around the plant. Plants utilize simple chemicals as hormones, which move more easily through the plant's tissues. They are often produced and used on a local basis within the plant body. Plant cells produce hormones that affect even different regions of the cell producing the hormone.

Hormones are transported within the plant by utilizing four types of movements. For localized movement, cytoplasmic streaming within cells and slow diffusion of ions and molecules between cells are utilized. Vascular tissues are used to move hormones from one part of the plant to another; these include sieve tubes or phloem that move sugars from the leaves to the roots and flowers, and xylem that moves water and mineral solutes from the roots to the foliage.

Not all plant cells respond to hormones, but those cells that do are programmed to respond at specific points in their growth cycle. The greatest effects occur at specific stages during the cell's life, with diminished effects occurring before or after this period. Plants need hormones at very specific times during plant growth and at specific locations. They also need to disengage the effects that hormones have when they are no longer needed. The production of hormones occurs very often at sites of active growth within the meristems, before cells have fully differentiated. After production, they are sometimes moved to other parts of the plant, where they cause an immediate effect; or they can be stored in cells to be released later. Plants use different pathways to regulate internal hormone quantities and moderate their effects; they can regulate the amount of chemicals used to biosynthesize hormones. They can store them in cells, inactivate them, or cannibalise already-formed hormones by conjugating them with carbohydrates, amino acids, or peptides. Plants can also break down hormones chemically, effectively destroying them. Plant hormones frequently regulate the concentrations of other plant hormones. Plants also move hormones around the plant diluting their concentrations.

The concentration of hormones required for plant responses are very low (10−6 to 10−5 mol/L). Because of these low concentrations, it has been very difficult to study plant hormones, and only since the late 1970s have scientists been able to start piecing together their effects and relationships to plant physiology. Much of the early work on plant hormones involved studying plants that were genetically deficient in one or involved the use of tissue-cultured plants grown *in vitro* that were subjected to differing ratios of hormones, and the resultant growth compared. The earliest scientific observation and study dates to the 1880s; the determination and observation of plant hormones and their identification were spread-out over the next 70 years.

CLASSES OF PLANT HORMONES

In general, it is accepted that there are five major classes of plant hormones, some of which are made up of many different chemicals that can vary in structure from one plant to the next. The chemicals are each grouped together into one of these classes based on their structural similarities and on their effects on plant physiology. Other plant hormones and growth regulators are not easily grouped into these classes; they exist naturally or are synthesized by humans or other organisms, including chemicals that inhibit plant growth or interrupt the physiological processes within plants. Each class has positive as well as inhibitory functions, and most often work in tandem with each other, with varying ratios of one or more interplaying to affect growth regulation.

The five major classes are:

1. ABSCISIC ACID: - Abscisic acid (also called ABA), was discovered and researched under two different names before its chemical properties were fully known, it was called *dormin* and *abscicin II*. Once it was determined that the two compounds are the same, it was named abscisic acid. The name "abscisic acid" was given because it was found in high concentrations in newly abscissed or freshly fallen leaves.

This class of PGR is composed of one chemical compound normally produced in the leaves of plants, originating from chloroplasts, especially when plants are under stress. In general, it acts as an inhibitory chemical compound that affects bud growth, and seed and bud dormancy. It mediates changes within the apical meristem, causing bud dormancy and the alteration of the last set of leaves into protective bud covers. Since it was found in freshly abscissed leaves, it was thought to play a role in the processes of natural leaf drop, but further research has disproven this. In plant species from temperate parts of the world, it plays a role in leaf and seed dormancy by inhibiting growth, but, as it is dissipated from seeds or buds, growth begins. In other plants, as ABA levels decrease, growth then commences as gibberellin levels increase. Without ABA, buds and seeds would start to grow during warm periods in winter and be killed when it froze again. Since ABA dissipates slowly from the tissues and its effects take time to be offset by other plant hormones, there is a delay in physiological pathways that provide some protection from premature growth. It accumulates within seeds during fruit maturation, preventing seed germination within the fruit, or seed germination before winter. Abscisic acid's effects are degraded within plant tissues during cold temperatures or by its removal by water washing in out of the tissues, releasing the seeds and buds from dormancy.

In plants under water stress, ABA plays a role in closing the stomata. Soon after plants are water-stressed and the roots are deficient in water, a signal moves up to the leaves, causing the formation of ABA precursors there, which then move to the roots. The roots then release ABA, which is translocated to the foliage through the vascular system and modulates the potassium and sodium uptake within the guard cells, which then lose turgidity, closing the stomata.

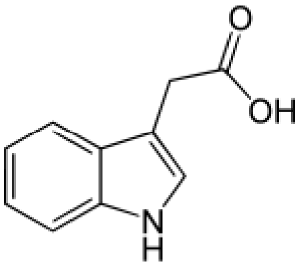
ABA exists in all parts of the plant and its concentration within any tissue seems to mediate its effects and function as a hormone; its degradation, or more properly catabolism, within the plant affects metabolic reactions and cellular growth and production of other hormones. Plants start life as a seed with high ABA levels. Just before the seed germinates, ABA levels decrease; during germination and early growth of the seedling, ABA levels decrease even more. As plants begin to produce shoots with fully functional leaves, ABA levels begin to increase, slowing down cellular growth in more "mature" areas of the plant. Stress from water or predation affects ABA production and catabolism rates, mediating another cascade of effects that trigger specific responses from targeted cells. Scientists are still piecing together the complex interactions and effects of this and other phytohormones.

Abscisic Acid: - Absicisic acid is found mostly near leaves, stems, unripe fruit.

Function of Abscisic Acid:

- Stimulation of closing of stomata
- Inhibition of shoot growth
- Inducing seeds for synthesizing storage of proteins

2. AUXINS:-



The auxin indole-3-acetic acid

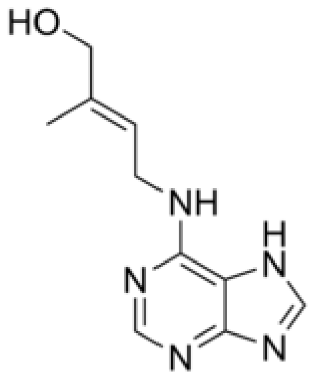
Auxins are compounds that positively influence cell enlargement, bud formation and root initiation. They also promote the production of other hormones and in conjunction with cytokinins, they control the growth of stems, roots, and fruits, and convert stems into flowers. Auxins were the first class of growth regulators discovered. They affect cell elongation by altering cell wall plasticity. They stimulate cambium, a subtype of meristem cells, to divide and in stems cause secondary xylem to differentiate.

Auxins act to inhibit the growth of buds lower down the stems (apical dominance), and also to promote lateral and adventitious root development and growth. Leaf abscission is initiated by the growing point of a plant ceasing to produce auxins. Auxins in seeds regulate specific protein synthesis, as they develop within the flower after pollination, causing the flower to develop a fruit to contain the developing seeds. Auxins are toxic to plants in large concentrations; they are most toxic to dicots and less so to monocots. Because of this property, synthetic auxin herbicides including 2, 4-D and 2, 4, 5-T have been developed and used for weed control. Auxins, especially 1-Naphthaleneacetic acid (NAA) and Indole-3-butyric acid (IBA), are also commonly applied to stimulate root growth when taking cuttings of plants. The most common auxin found in plants is indole-3-acetic acid or IAA. The correlation of auxins and cytokinins in the plants is a constant.

Function of Auxins:

1. This hormone is present in the seed embryo, young leaves and apical buds meristem.
2. Stimulation of cell elongation; cell division in cambium, differentiation of phloem and xylem, root initiation on stem cuttings, lateral root development in tissue culture
3. Delaying leaf senescence
4. Suppression of lateral bud growth when supplied from apical buds
5. Inhibition or promotion of fruit and leaf abscission through ethylene stimulation
6. Fruit setting and growth is induced through auxin in some plants
7. Auxin can delay fruit ripening
8. In Bromeliads, the auxin hormone promotes flowering
9. Stimulation of flower parts, femaleness of dioecious flowers and production of high concentration of ethylene in flowering plants

3. CYTOKININS:-



The cytokinin zeatin, the name is derived from *Zea*, in which it was first discovered in immature kernels.

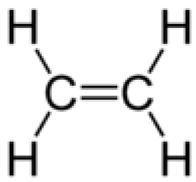
Cytokinins or CKs are a group of chemicals that influence cell division and shoot formation. They were called kinins in the past when the first cytokinins were isolated from yeast cells. They also help delay senescence or the aging of tissues, are responsible for mediating auxin transport throughout the plant, and affect internodal length and leaf growth. They have a highly synergistic effect in concert with auxins, and the ratios of these two groups of plant hormones affect most major growth periods during a plant's lifetime. Cytokinins counter the apical dominance induced by auxins; they in conjunction with ethylene promote abscission of leaves, flower parts, and fruits. The correlation of auxins and cytokinins in the plants is a constant.

Cytokinin:- Cytokinins are synthesized in roots and then transported to other plant parts.

Function of Cytokinins:

1. Stimulation of cell division, growth of lateral buds and apical dominance
2. Stimulation of shoot initiation and bud formation in tissue culture
3. Leaf cell enlargement that stimulation of leaf expansion
4. In some plant species, enhancement of stomatal opening
5. Etioplasts are converted into chloroplasts through stimulation of chlorophyll synthesis.

4. ETHYLENE:-



Ethylene is a gas that forms through the Yang Cycle from the breakdown of methionine, which is in all cells. Ethylene has very limited solubility in water and does not accumulate within the cell but diffuses out of the cell and escapes out of the plant. Its effectiveness as a plant hormone is dependent on its rate of production versus its rate of escaping into the atmosphere. Ethylene is produced at a faster rate in rapidly growing and dividing cells, especially in darkness. New growth and newly germinated seedlings produce more ethylene than can escape the plant, which leads to elevated amounts of ethylene, inhibiting leaf expansion (see Hyponastic response). As the new shoot is exposed to light, reactions by phytochrome in the plant's cells produce a signal for ethylene production to decrease, allowing leaf expansion.

Ethylene affects cell growth and cell shape; when a growing shoot hits an obstacle while underground, ethylene production greatly increases, preventing cell elongation and causing the stem to swell. The resulting thicker stem can exert more pressure against the object impeding its path to the surface. If the shoot does not reach the surface and the ethylene stimulus becomes prolonged, it affects the stem's natural geotropic response, which is to grow upright, allowing it to grow around an object. Studies seem to indicate that ethylene affects stem diameter and height: When stems of trees are subjected to wind, causing lateral stress, greater ethylene production occurs, resulting in thicker, more sturdy tree trunks and branches.

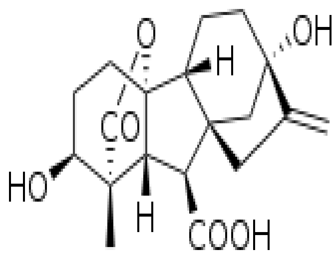
Ethylene affects fruit-ripening: Normally, when the seeds are mature, ethylene production increases and builds-up within the fruit, resulting in a climacteric event just before seed dispersal. The nuclear protein Ethylene Insensitive2 (EIN2) is regulated by ethylene production, and, in turn, regulates other hormones including ABA and stress hormones.

Ethylene: - Ethylene is present in the tissues of ripening fruits, nodes of stems, senescent Leaves and flowers.

Function of Ethylene:

1. Ethylene leads to release of dormancy state
2. It stimulates shoot and root growth along with differentiation
3. Leaf and fruit abscission
4. Flower induction in Bromiliad
5. The femaleness of dioecious flowers is stimulated
6. Flower opening is stimulated
7. Flower and leaf senescence stimulation
8. Fruit ripening is stimulated by ethylene

5. GIBBERELLINS:-



Gibberellins, or GAs, include a large range of chemicals that are produced naturally within plants and by fungi. They were first discovered when Japanese researchers, including Eiichi Kurosawa, noticed a chemical produced by a fungus called *Gibberella fujikuroi* that produced abnormal growth in rice plants. Gibberellins are important in seed germination, affecting enzyme production that mobilizes food production used for growth of new cells.

This is done by modulating chromosomal transcription. In grain (rice, wheat, corn, etc.) seeds, a layer of cells called the aleurone layer wraps around the endosperm tissue. Absoption of water by the seed causes production of GA. The GA is transported to the aleurone layer, which responds by producing enzymes that break down stored food reserves within the endosperm, which are utilized by the growing seedling. GAs produces bolting of rosette-forming plants, increasing internodal length. They promote flowering, cellular division, and in seeds growth after germination. Gibberellins also reverse the inhibition of shoot growth and dormancy induced by ABA.

Gibberellin: - The gibberellins are present in the meristems of apical buds and roots, young leaves, embryo.

Function of Gibberellins:

1. Stimulates stem elongation
2. Gibberellin can lead to development of seedless fruits
3. It can delay senescence in leaves and citrus fruits
4. It can end seed dormancy in plants that require light for induction of germination

OTHER KNOWN HORMONES: -

Other identified plant growth regulators include:

1. **Brassinosteroids** are a class of polyhydroxysteroids, a group of plant growth regulators. Brassinosteroids have been recognized as a sixth class of plant hormones, which stimulate cell elongation and division, gravitropism, resistance to stress, and xylem differentiation. They inhibit root growth and leaf abscission. Brassinolide was the first identified brassinosteroid and was isolated from extracts of rapeseed (*Brassica napus*) pollen in 1979.
2. **Salicylic acid** activates genes in some plants that produce chemicals that aid in the defense against pathogenic invaders.
3. **Jasmonates** are produced from fatty acids and seem to promote the production of defense proteins that are used to fend off invading organisms. They are believed to also have a role in seed germination, and affect the storage of protein in seeds, and seem to affect root growth.

4. **Plant peptide hormones** encompasses all small secreted peptides that are involved in cell-to-cell signaling. These small peptide hormones play crucial roles in plant growth and development, including defense mechanisms, the control of cell division and expansion, and pollen self-incompatibility.
5. **Polyamines** are strongly basic molecules with low molecular weight that have been found in all organisms studied thus far. They are essential for plant growth and development and affect the process of mitosis and meiosis.
6. **Nitric oxide (NO**) serves as signal in hormonal and defense responses (e.g. stomatal closure, root development, germination, nitrogen fixation, cell death, stress response).[20] NO can be produced by a yet undefined NO synthase, a special type of nitrite reductase, nitrate reductase, mitochondrial cytochrome c oxidase or non enzymatic processes and regulate plant cell organelle functions (e.g. ATP synthesis in chloroplasts and mitochondria).
7. **Strigolactones,** implicated in the inhibition of shoot branching.
8. **Karrikins,** a group of plant growth regulators found in the smoke of burning plant materials that have the ability to stimulate the germination of seeds.
9. AMO 1618 (a quaternary ammonium salt) is used in the cultivation of ornamental plants and causes a bushy shape and a study growth of the treated plants.
10. Paclobutrazol: Reduces the problem of biennial bearing in mango.
11. Mapiquat chloride, chlormequat chloride (cycocel): used in ornamental plants for shorter internodes and thicker stems (used in poinsettias). It also prevents lodging and increases tillering in cereals.
12. Malichydrazide (MH) prevents premature sprouting of onion and potato.
13. 2,3,5-T or Triiodo benzoic acid (TIBA): Increases flowering in chrysanthemum.

Signal Integration and Combinatorial Control

Long ago, plant physiologists noted the apparent antagonistic interactions between some of the phytohormones, such as between auxin and cytokinin in the regulation of root–shoot differentiation and between GA and ABA in germination. Other processes are synergistically regulated by multiple hormones. While it has long been obvious that hormones do not function in discrete pathways, but rather exhibit extensive cross-talk and signal integration with each other and with environmental and developmental signaling pathways, the molecular basis for such coordinated regulation has been unclear.

ROLE OF GROWTH HORMONES IN FIELD CROP PRODUCTION AND EFFICIENT USE OF RESOURCES

Plant hormones have been extensively studied for their importance in innate immunity particularly in the dicotyledonous model plant Arabidopsis thaliana. However, only in the last decade, plant hormones were demonstrated to play conserved and divergent roles in fine-tuning immune in rice (Oryza sativa L.), a monocotyledonous model crop plant. Emerging evidence showed that salicylic acid (SA) plays a role in rice basal defense but is differentially required by rice pattern recognition receptor (PRR) and resistance (R) protein-mediated immunity, and its function is likely dependent on the signaling pathway rather than the change of endogenous levels. Jasmonate (JA) plays an important role in rice basal defense against bacterial and fungal infection and may be involved in the SA-mediated resistance. Ethylene (ET) can act as a positive or negative modulator of disease resistance, depending on the pathogen type and environmental conditions. Brassinosteroid (BR) signaling and abscisic acid (ABA) either promote or defend against infection of pathogens with distinct infection/colonization strategies. Auxin and gibberellin (GA) are generally thought of as negative regulators of innate immunity in rice. Moreover, GA interacts antagonistically with JA signaling in rice development and immunity through the DELLA protein as a master regulator of the two hormone pathways. Plant growth and response to environmental cues are largely governed by phytohormones. The plant hormones ethylene, jasmonic acid, and salicylic acid (SA) play a central role in the regulation of plant immune responses. In addition, other plant hormones, such as auxins, abscisic acid (ABA), cytokinins, gibberellins, and brassinosteroids, that have been thoroughly described to regulate plant development and growth, have recently emerged as key regulators of plant immunity. Plant hormones interact in complex networks to balance the response to developmental and environmental cues and thus limiting defense-associated fitness costs. The molecular mechanisms that govern these hormonal networks are largely unknown. Moreover, hormone signaling pathways are targeted by pathogens to disturb and evade plant defense responses.

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Synthetic as well as natural hormones are extensively used in the propagation of various horticultural, silvicultural plants through tissue culture techniques.

Potential medical applications: - Plant stress hormones activate cellular responses, including cell death, to diverse stress situations in plants. Researchers have found that some plant stress hormones share the ability to adversely affect human cancer cells. For example, sodium salicylate has been found to suppress proliferation of lymphoblastic leukemia, prostate, breast, and melanoma human cancer cells. Jasmonic acid, a plant stress hormone that belongs to the jasmonate family, induced death in lymphoblastic leukemia cells. Methyl jasmonate has been found to induce cell death in a number of cancer cell lines.

Hormones and plant propagation:- Synthetic plant hormones or PGRs are commonly used in a number of different techniques involving plant propagation from cuttings, grafting, micropropagation, and tissue culture.

The propagation of plants by cuttings of fully developed leaves, stems, or roots is performed by gardeners utilizing auxin as a rooting compound applied to the cut surface; the auxins are taken into the plant and promote root initiation. In grafting, auxin promotes callus tissue formation, which joins the surfaces of the graft together. In micropropagation, different PGRs are used to promote multiplication and then rooting of new plantlets. In the tissue-culturing of plant cells, PGRs are used to produce callus growth, multiplication, and rooting.

Seed dormancy:- Plant hormones affect seed germination and dormancy by acting on different parts of the seed.

Embryo dormancy is characterized by a high ABA: GA ratio, whereas the seed has a high ABA sensitivity and low GA sensitivity. In order to release the seed from this type of dormancy and initiate seed germination, an alteration in hormone biosynthesis and degradation toward a low ABA/GA ratio, along with a decrease in ABA sensitivity and an increase in GA sensitivity, must occur.

ABA controls embryo dormancy, and GA embryo germination. Seed coat dormancy involves the mechanical restriction of the seed coat. This, along with a low embryo growth potential, effectively produces seed dormancy. GA releases this dormancy by increasing the embryo growth potential, and/or weakening the seed coat so the radical of the seedling can break through the seed coat. Different types of seed coats can be made up of living or dead cells, and both types can be influenced by hormones; those composed of living cells are acted upon after seed formation, whereas the seed coats composed of dead cells can be influenced by hormones during the formation of the seed coat. ABA affects testa or seed coat growth characteristics, including thickness, and effects the GA-mediated embryo growth potential. These conditions and effects occur during the formation of the seed, often in response to environmental conditions. Hormones also mediate endosperm dormancy: Endosperm in most seeds is composed of living tissue that can actively respond to hormones generated by the embryo. The endosperm often acts as a barrier to seed germination, playing a part in seed coat dormancy or in the germination process. Living cells respond to and also affect the ABA/GA ratio, and mediate cellular sensitivity; GA thus increases the embryo growth potential and can promote endosperm weakening. GA also affects both ABA-independent and ABA-inhibiting processes within the endosperm.

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