Agron 511- Cropping System And Sustainable Agriculture (2+0)

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Plant ideotype for dryland, plant growth regulators and their role in sustainability

PLANT IDEOTYPES

The term ideotype was introduced by Donald (1968).

Ideotype “a biological model, which is expected to perform or behave in a predictable manner within a defined environment.

A crop ideotype is a plant model, which is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar. This term has the following synonyms:

Plan of the phenotype of a cultivar that will perform optimally in a specific set of climatic, soil, biotic and socio-cultural conditions (Hall 2001).

Types of ideotypes

1) Isolation ideotype

2) Competition ideotype

3) Crop ideotype

Isolation ideotype : It is the model plant type that perform best when the plants are space-planted.

Competition ideotype: This ideotype perform well in genetically heterogeneous population. In case of cereals, this ideotype is tall, leafy, free-tillering plant that is able to shade its less aggressive neighbors. 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.

Crop ideotype:

This ideotype perform best at commercial crop densities because it is a poor competitor. In case of cereals, a crop ideotype is erect, sparsely-tillered plant, with small erect leaves.

Ideotype for Dryland Farming:

- Short growth duration
- Effective root system
- Drought tolerance
- High yield potentiality with altered morphology viz.

- Plant with few leaves just sufficient to maintain photosynthetic output and growth (to minimize the use of water).

  • Leaves horizontally disposed for better light interception contrary to vertically disposed most effective under irrigated conditions.

Several other ideotype are:

Market ideotype: Includes traits like seed colour, seed size, cooking and baking quality, etc.

Climatic ideotype: Includes traits important in climatic adaptation such as heat and cold resistance, maturity duration, drought resistance etc.

Edaphic ideotype: Includes salinity tolerance, mineral toxicity/ deficiency tolerance etc.

Stress ideotype: Shows resistance to both biotic and abiotic stress.

Disease/pest resistance ideotype :

Wheat ideotype

Features of wheat ideotype

- A short strong stem
- Erect leaves
- Few small leaves
- Larger and an erect ear
- Presence of awns

The improved wheat lines developed at CIMMYT, Mexico have some features in common such as

- Reduced height
- Photoperiod insensitivity due to *Ppd1 or Ppd2*
- Durable rust resistance

Rice ideotype

Erect, short and thick leaves

- Semi- dwarf stature
- High tillering capacity
- More panicles
- High harvest index

Maize ideotype : In 1975, Mock and Pearce proposed Ideal plant type of maize

- Small tassel size
- Low tillers
- Large cobs
- Angled leaves for
- good light interception

Ideotype of cotton for rainfed conditions

- Short stature
- Medium to big boll size (3.5 to 4 g)
- High degree of resistance to insects and diseases
- Few smaller and thick leaves with sparse hairiness

Ideotype for irrigated cultivation

- Short stature (90-120cm)
- Short duration (150-165days
- Responsive to high fertilizer dose
- High degree of resistance to insect pests and diseases
- Boll size (3.5 to 4g)

Plant growth regulator

- Plant growth regulators may be defined as any organic compounds, which are active at low concentrations in promoting, inhibiting or modifying growth and development.
- The naturally occurring (endogenous) growth substances are commonly known as plant hormones, while the synthetic ones are called growth regulator
- Plant hormone is an organic compound synthesised in one part of the plant and translocated to another part, where in very low concentrations it causes a physiological response.
- The plant hormones are identified as promoters (auxins, gibberellin and cytokinin), inhibitors (abscissic acid and ethylene) and other hypothetical growth substance (florigen, Flowering hormone, *etc*

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

- ✓ Hormones are vital to plant growth and lacking them, plants would be mostly a mass of undifferentiated cells Plant growth regulators (also known as growth regulators or plant Hormones) are chemicals used to alter the growth of a plant or plant part.
- ✓ Hormones are substances naturally produced by plants, substances that control normal plant functions, such as root growth, fruit set and drop, growth and other development processes.

- ✓ Plant growth regulators are regulated as pesticides by the Florida Department of Agriculture and Consumer Services (FDACS) and must be registered with the FDACS for lawful use in Florida like any pesticide lawfully used in Florida

FDACS Definition of “Plant Regulator

Any substance or mixture of substances intended, through physiological action, for accelerating or retarding the rate of growth or maturation or for otherwise altering the behavior of ornamental or crop plants or the produce thereof, but not including substances intended as plant nutrients, trace elements, nutritional chemicals, plant inoculants, or soil amendments. 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 .

Type of plant growth regulator

I. Growth Promoter –
Auxin, Gibberellins, Cytokinin
II. Growth Inhibitors –
Abscisic acid & Ethylene

Five major plant hormones or plant growth regulators are below

1) Auxins (cell elongation)

2) Gibberellins (cell elongation + cell division - translated into growth)

3) Cytokinin (cell division + inhibits senescence)

4) Abscisic acid (abscission of leaves and fruits + dormancy induction of buds and seeds)

5) Ethylene (promotes senescence, epinasty, and fruit ripening

Auxins:

Auxins: Dr. Kogl and his co-workers in 1933 isolated auxins – ‘a’ from human urine and auxin ‘b’ from corm germ oil. Auxin: is a Greek word which means to *increase*

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.

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 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 indoleacetic acid or IAA. The correlation of auxins and cytokinins in the plants is a constant (A/C = const.).

Auxin increases the plasticity of plant cell walls and is involved in stem elongation.

Frits Went (1926) determined auxin enhanced cell elongation. It is discovered as substance associated with phototropic response. It occurs in very low concentrations.

It is a generic term for chemicals that typically stimulate cell elongation, but auxins also influence a wide range of growth and development response. The chemical isolations and

characterization was done by Kogi*et al. (1934).*

Auxins are the first identified hormones of which IAA seems to be the major naturally occurring, endogenous auxin in crops.

Besides IAA, plants contain three other compounds which are structurally similar and elicit many of the same response as that of IAA, 4, chloroindole acetic acid (CIAA),phenylacetic acid

(PAA), indole butyric acid (IBA).

Synthetic compounds are classified into five major categories; indole acids, naphthalene acids, chlorophenoxy acids, benzoic acid and picolinic acid derivatives.

Functions of auxins

Auxin transport – pola- basi- apex to base.

2. Cell elongation.

3. Promote root initiation.

4. Inhibits root elongation.

5. Delay leaf abscission.

6. Induce callus formation.

7. Restore apical dominance.

Examples

1. IAA (Indole Acetic Acid).
2. IBA (IndoleButyricAcid).
3. NAA (Naphthalene Acetic Acid).
4. 2, 4-D (2, 4 – Dichlorophenxy Acetic Acid).
5. 4-CPA (4-Chloropenoxy Acetic Acid).

Gibberellins

It is the active substance isolated from the soil borne fungus *Gibberellafujikuroi*the concentration of GA3 is usually highest in mature seeds.

Reaching up to 18 mg / kg fresh weight in *Phaseolus species,* but it decreases rapidly as the seed mature.

In general, roots contain higher amounts of GA3 than shoots.

Gibberellins have also been found effective in overcoming both kinds of dormancy, buds as wells as seeds.

Treatments with Gibberellins have been observed and it substitute effectively for long day, low temperature or red light exposure requirements.

Gibberellin: In 1929 scientist 'Yabata and Hayashi' first isolated gibberellins from fungal culture.

Gibberellins are named after the fungus *Gibberellafujikuroi* which causes rice plants to grow abnormally tall. It is synthesized in apical portions of stems and roots, important effects on stem elongation and hastens seed germination.

Gibberellins areimportant in seed germination, affecting enzyme production that mobilizes food production used for growth of new cells.

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 produce 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.

Effects of Gibberellins

GA induces cellular division and cellular elongation; auxin induces cellular elongation alone.

GA-stimulated elongation does not involve the cell wall acidification characteristic of auxin-induced elongation.

Breaking of dormancy in buds and seeds.

Seed Germination - Especially in cereal grasses, like barley. Not necessarily as critical in dicot seeds. Promotion of flowering.

Transport is non-polar, bidirectional producing general responses.

Thompson Seedless" grapes grown in California are treated with GA to increase size and decrease packing.

Functions of Gibberellins:

1. Promote growth
2. Promote bolting and flowering.
3. Replace chilling requirements of plants and light requirements.
4. Promote seed germination and break dormancy.
5. Increase pollinations.
6. Increase cell elongation.
7. Induce maleness.

Role of gibberellic acid

1. Gibberellic acid Synthesis in leaf and induce shoot elongation (IAA + GA3).
2. Enhance metabolic activity Mobilisation of reserve food material promotes growth and height, increase root actively and Kinetin production in root- translocate to growing Bud (GA3).
3. Shoot elongation GA3 spray increase height of nursery seedlings.
4. Delay senescence Increase photosynthesis and proteins synthesis and thereby decrease abscission.
5. Increase cambial growth and differentiation. Induce flower and fruit set (IAA + GA3).
6. Dwarf plant (genetically) to normal height GA3.
7. Promote flowering in long day plants. Substitute for long day conditions and cold treatment (verbalizations).
8. Induction of parthenocarpyeg. Grapes

Cytokinins:

The first Cyotkinins hormone in plant was identified by ‘Lethan and his coworkers’ from corn seeds which can stimulate cell division.

Gottlieb Haberland in 1913 reported an unknown compound that stimulated cellular division.

In the 1940s, Johannes van Overbeek, noted that plant embryos grew faster when they were supplied with coconut milk (liquid endosperm), which is rich in nucleic acids.

Miller, Skoog and their coworkers isolated the growth factor responsible for cellular division from a DNA preparation calling it kinetin which belongs to a class of compounds called cytokinins

In 1964, the first naturally occurring cytokinin was isolated from corn calledZeatin and zeatinriboside are found in coconut milk.

First endogenous cytokinin was isolated from maize kernels named as zeatin.

Germinating seeds, roots, sap streams, developing fruits and tumor tissue are rich in cytokinins.

Cytokinins imbibed seeds germinate better in dark than unimbibed lettuce seeds.

Similarly cytokinin together with gibberllin effectively breaks the photodormancy of celery (*Apiumgraveolens) seeds.*

Synthetic cytokinins are kinetin, benzyladenine and ethoxy ethladenine.

All cytokinins (artificial or natural) are chemically similar to adenine.

Cytokinins move nonpolarly in xylem, phloem, and parenchyma cells.

Cytokinins are found in angiosperms, gymnosperms, mosses, and ferns. In angiosperms, cytokinins are produced in the roots, seeds, fruits, and young leaves.

Cytokinins and auxin affect organogenesis. High cytokinin/auxin ratios favor the formation of shoots.

Low cytokinin/auxin ratios favor the formation of roots. Most cytokinin produced in root apical meristems and transported throughout plant.

Cytokinins or CKs are a group of chemicals that influence cell division and shoot formation.

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.

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 (A/C = const.).

Functions of Cytokinine

1. Cell division.

2. Shoot initiation.

3. Breaking dormancy: promote seed germination.

4. Retard senescence: freeness's of plants.

5. Promote hermaphrodite flower. e.g Grape.

6. Induce parthenocarpic and increase fruit size

Abscisic Acid (ABA)

To stop elongation

• Induce dormancy

• Delay germination

• Inhibit growth process

Role of inhibitors

• Accumulation leads to induce dormancy

• Regulation of flowering, senescence and tuber formation

• Induction of cold hardiness and cause abscission and dehiscence of fruits

• ABA application increase GA (Gibberellic acid) levels and may cause increase in growth

• Suppress the formation of a amylase in the barley endosperm

• Interfere with DNA and RNA synthesis

• Modify the nucleic acid and protein synthesis systems.

• Phenolic compounds inhibit stem and root growth and affect almost all the metabolic system

The name "abscisic acid" was given because it was found in high concentrations in newly abscissed or freshly fallen leaves.

Abscisin is made from carotenoids and moves nonpolarly through plant tissue. 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.

It acts as an inhibitory chemical compound that affects bud growth, 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.

Ethylene

1. Ethylene is a gas that forms through the Yang Cycle from the breakdown of methionine, which is in all cells.
2. 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.
3. Ethylene is produced at a faster rate in rapidly growing and dividing cells, especially in darkness. Newly germinated seedlings produce more ethylene than escape the plant, which leads to elevated amounts of ethylene, inhibiting leaf expansion.
4. 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.

Functions of Ethylene

1. Apical dominance arrested.
2. Stimulate of lateral growth.
3. Promote abscission of leaves, flowers, and fruit.
4. Induction of flowering.
5. Helps in fruit ripening.
6. Promote rooting.
7. Helps in chlorophyll formation.
8. Promote seed germination.
9. Increase female flowers.
10. Breaks dormancy.
11. Gaseous in form and rapidly diffusing.
12. Gas produced by one plant will affect nearby plants.

13. Fruit ripening.

14. Epinasty – downward curvature of leaves.

15. Encourages senescence and abscission.

16. Initiation of stem elongation and bud development.

17. Flowering - Ethylene inhibits flowering in most species, but promotes it in a few plants such as pineapple, bromeliads, and mango.

18. Sex Expression - Cucumber buds treated with ethylene become carpellate (female) flowers, whereas those treated with gibberellins become staminate (male) flowers.

Neljubow (1901) is credited with having identified the active growth-regulating component of the illuminating gas as ethylene. Ethylene is formed naturally in plants in amounts sufficient to bring about regulatorly effects and it might be considered as plant hormone.

Ethylene may be active in alleviation of secondary dormancy also (Ross,1984).Synthetic chemical known as Etherel, Ethephon, Chloroethyl phosphonic acid (CEPA) has been reported to release ethylene when applied on plants.

Role of ethylene

- Breaking dormancy
- Induce ripening of fruits
- Induce abscission of leaves
- Inhibit elongation and lateral bud growth

Others hormone

- Jasmonic acid: Inhibits growth and promote senescence
- Brassinosteroids: Same function of auxins and Gibberellins
- Oligosaccharins: Stimulated elongation of cell, regenerated tobbacco tissue, inhibite roots and stimulate flowers