BREEDING FOR ABIOTIC STRESS RESISTANCE
DROUGHT RESISTANCE

Drought: Scarcity of moisture (soil moisture) which restricts the expression of full genetic yield potential of a plant.

Drought resistance: The ability of crop plants to grow, develop and reproduce normally under moisture stress.

Mechanisms of drought resistance

There are 4 mechanisms of drought resistance.

Drought Escapes : It is due to ability of a genotype to mature early, before occurrence of drought. Drought escape is most common is plants grown is desert region.

Eg. Early maturing varieties of sorghum, maize, bajra, wheat, rice etc; give more yield than late maturing under drought.

Drought Avoidance (Dehydration avoidance) : It is due to the ability of plants to maintain favourable water balance even under stress. The plants which avoid drought retain high moisture content is their tissues and lose less water. This is possible either because of :

Increased water uptake (due to increase in root development) plants are called water spenders.(or)

Reduced water loss (due to reduction in growth of aerial parts are called water savers (i.e. to avoid transpiration)

Dehydration avoidance is interpreted as the ability of genotypes to maintain high leaf water potential when grown under soil moisture stress: Several traits contribute to dehydration avoidance Such as :

Leaf rolling, folding and reflectance narrow leaves, increased pubescence on aerial organs , presence of awns, osmatic adjustment of stomata, cuticular wax, increased water uptake ;

Reduced Transpiration : Inc rease is concentration of Abscisic Acid (ABA), closure of stomata, ABA plays role in reduction of leaf expansion, Promotion of root growth etc.

Drought Tolerance (Dehydration tolerance) : Ability of plants to produce higher yield even under 'low water potential'. In cereals drought tolerance generally occur during reproductive phase. Tolerant cultivars exhibit better germination, seedling growth and photosynthesis. Drought tolerance may be because of

i. high proline accumulation

ii. maintenance of membrane integrity

Drought Resistance : It is the sum total of avoidance and Tolerance. It refers to the genetic ability of plants to give good yield under moisture stress conditions.

Various morphological, physiological and biochemical features / parameters associated with drought resistance

Morphological

Earliness

Reduced tillering

Leaf characters :Leaf rolling , Leaf folding, Leaf shedding, Leaf reflectance

Reduced leaf area : Narrow leaf, Change in leaf angle

Hairiness (presence of hairs on leaf and other parts, lowers leaf temperature and reduce transpiration)

Colour of leaves

Wax content

Awns (eg. wheat and barley)

Root system (rooting depth and intensity)

Physiological

Photosynthesis (efficient system like C4) under stress, photosynthetic efficiency is reduced due to chloroplast damage.

Reduced Transpiration and reduced respiration losses

Stomatal behavior (closure of stomata, also change in size and number of stomata)

Osmotic adjustment

Leaf enlargement (increase in thickness)

Leaf cuticle wax (increases)

Biochemical

Accumulation of proline and betaine

Increase in Abscisic acid (barley) and Ethylene (maize & wheat)

Protein synthesis (increases under stress)

Nitrate – reductase activity

Sources of drought resistance

Cultivated varieties

Land (old or desi primitive varieties), Wild relatives (reported in several crops)

For example :

S.No.	Crop	Wild sps	Resistant to
i	Wheat	*Aegilops. variabilis*	drought
		Aegilops speltoides	"
		Aegilops umbellulata	"
		Aegilops squarrosa	"
ii	Sugarcane	*Sacharum. spontaneam*	Drought & salinity

4. Transgenes :

Eg. 'Rab' (Responsive to abscisic acid) in rice **Screening / Evaluation**

Field Env. Highly desirable

Green house Env. More precisely controlled than field

B reeding Methods and Approaches

It is important that drought resistance be incorporate in material with high genetic potential for yield.

Yield and yield components are best evaluated under non stress / optimal environments, while

Drought resistance must be evaluated under water stress.

Breeding methods : Methods are same as for yield and other economic characters. Breeding for drought resistance refers to breeding for yield under moisture stress, i.e. developing varieties which can give high yields under stress. The common methods are

Introduction

Selection

Hybridization

Mutation

Biotechnology

Limitations :

Generally resistant varieties have low yield

Do not have much wider adaptability (as abiotic resistant is location specific)

Drought resistant genes may have linkage with undesirable genes.

Transfer of resistant genes from wild types may post problem.

Drought resistance is a consequence of a combination of characters and single character can be used for selection.

Measurement of many drought resistant traits is difficult and problematic, since virtually all the useful drought resistant traits are under polygenic control. (So pedigree method most common). But if resistant genes is from agronomically inferior race then 1-2 backcrossing with cultivated type in made. If resistance gene is from wild species-go for backcrossing breeding.

Generally selection is performed on individual plant progenies instead of individual plants (i.e. similar to line breeding)

Creation of controlled moisture stress Environments

Selection require considerable resources

WATER LOGGING

As per Levitt (1980 b) flooding (i.e. water logging) is the presence of water in soil excess of field capacity. It leads to deficiency of O_2 and build up of Co_2, Ethylene and other toxic gases and this leads to reduction in aerobic respira tion.

Effects of water logging:

Once soil becomes water logged, air space in soil is displaced with water, the O_2 in the soil in dissolved in water. i.e. O_2 decreases; Co_2 ethylene and other toxic gases increases.

O_2 replacement in the soil is very inefficient. Diffusion of atmospheric O_2 into the water logged soils is very inefficient (because of the slow diffusion of atmospheric O_2 to water logged soil).

Root systems are suddenly plunged into an anaerobic condition. This switching from aerobic to anaerobic respiration disrupts root metabolism.

Carbohydrates level get depleted it is due to

- Dissipation of metabolism
- High water temperature
- Low light

Characteristics of plants in response to water logging stress :

Reduced growth / elongation.

Chlorosis, senescence and abscission of lower leaves

Wilting & leaf curling

Hypertrophy (increase in size of organ due to increase in cell size)

Epinasty (downward growth of petioles)

Mechanisms of tolerance:

Adventitious root formation on lower part of stem (close to surface so that O_2 tension is quickly restored after transient water logging) eg. Tomato

Lenticel (i.e. raised pores in the stem of plants) formation

Aerenchyma formation (soft plant tissue continues air spaces found in acquatic plants) in the cortex that provide canal paralled to the axis of the root through which gases can diffuse longitudinally (eg. rice)

Elongation capacity (In rice – best elongation response give 100% recovery from submergence and poorest elongation gives upto 49% recovery)

Scoring for elongation can be done between booting and flowering stage after flooding the crop to varying depths.

In sugarcane, *S. spontaneum* has more tolerance to flooding. Some canes gave upto 70% of their production potential when in continuous flood for 5 months (in an east at canal point Florida, USA)

Ideotype for flooded areas : The postulated ideotype for flooded areas should have the following characterstics.

Capacity to carry out functional activity at low O_2 concentration

(i.e. High cytochrome activity)

Ability for photosynthesis under low light intensity

Capacity to synthesis food rapidly

Regeneration capacity of shoots when damaged by flood

Ability to withstand drought at later growth stage

Deep root system

Narrow, medium long and dark green leaves with high sugar and protein content.

Breeding methods : Same as in other stresses.