Agro- Physiological Basis for Yield Variation in Crops

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OPEN ACCESS

Keywords

Agriculture, Crop Physiology, Yield Variation

How to cite this article:

Thakur, S., Sharma, G. D., Manuja, S. and Rawat, A. 2025. Agro- Physiological Basis for Yield Variation in Crops. *Vigyan Varta* 6 (6): 55-58.

ABSTRACT

Agro-physiological basis has a significant impact on crop plant growth and development in order to achieve higher yield. Physiological aspects of photosynthesis and respiration have to be demonstrated in sorting out the regulation and function of various components. If there are inefficiencies in these systems and if causes can be identified, they would represent legitimate targets for genetic manipulation. Properties of rubisco, alternative oxidase, and photorespiration process already loom as opportunities for genetic manipulation. However, about their utilities we are yet uncertain. Serious reinvestigation of foliage canopies offers promise for important gains in photosynthetic productivity of crops. Morphological traits associated with increased yield potential include grain number and harvesting index. Increased biomass to be associated with yield increases. Various physiological processes help in maintenance of growth, yield attributes and finally increase yield of cereals.

INTRODUCTION

Climate change is one of the biggest environmental challenges facing the world today and poses serious threats to global food security. Meteorological extremities such as droughts, prolonged dry periods and declining rainfall in tropical regions are likely to reduce yield of crops while encouraging weed and pest proliferation. Total agricultural productivity has been estimated to being reduced by 21% due to climate change (Ortiz-Bobea *et al*. 2021). For obtaining high grain yield of any crop, understanding of interaction between a proper variety, environment and agronomic management practices is of utmost important. Production potential of crops is determined through their yield contributing attributes. Crop dry matter production relies on physiological processes such as photosynthesis and respiration, which are influenced by the size and activity of the photosynthetic system, as well as the length of the growth phase. Crop output depends on maximizing radiation interception, effective photosynthesis, and appropriate partitioning of nutrients across leaf, stem, root, and reproductive structures. Crop yield is merely a portion of the biomass that accumulates during the crop cycle. Establishing strong root and canopy systems, as well as stem structure for foliage display, is crucial before reproductive development begins. Yield refers to the total amount of crop biomass produced per unit area per year (Zhu *et al*. 2010). Increasing yield will depend on selecting the best traits, technologies and crops for breeding and crop management of plants, targeting sustainable increases in total productive potential.

Plant production is driven by photosynthesis. Key elements in the system are:

(i) the interception of photosynthetically active radiation (PAR, 400-700 nm spectral band),

(ii) use of that energy in the reduction of CO2 and other substrates (photosynthesis),

(iii) incorporation of assimilates into new plant structures (biosynthesis and growth), and

(iv) maintenance of plant as living unit.

Five 'P' s of yield potential:

The 'Prior events' are essential for developing a closed vegetative canopy with sufficient tillering and fruiting sites to develop a sizeable seed load and with a sufficient leaf-area index (LAD) for full radiation interception during seed setting and subsequent seed-filling stage of the crop. During the period of full canopy cover, the rate of biomass production can be maximized by management factors that optimize soil water, fertility and other genetic factors (leaf and canopy traits) that enhance photosynthesis. Partitioning is defined as the fraction of the current daily carbon assimilate that is allocated to fruits, seeds and other economic organs. Yield can be increased by extending the pod-filling period if photosynthesis and pod fill are concurrently extended. Prior accumulation of mobilizable carbohydrates and proteins and their subsequent transfer to growing seeds is of great importance. Generally, a small fraction of the carbon fixed prior to the seed filling is remobilized towards the seed as most of the photosynthates assimilated currently are utilized by the tissues that are currently growing actively.

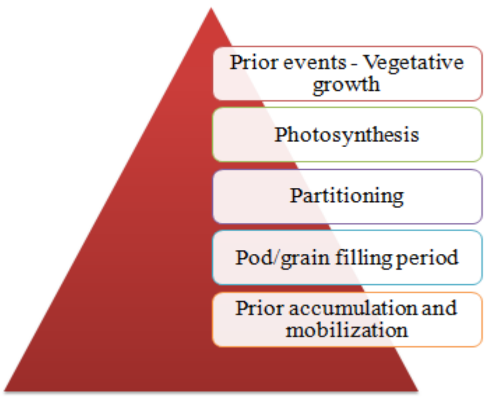

Figure 1: Five 'P' s of yield potential

Photosynthesis and Related Traits: Photosynthesis serves as the bedrock for crop growth, development, and yield formation. Enhancing the capacity for photosynthesis emerges as a critical strategy in augmenting grain yield. Application of nitrogen @225 kg/ha combined with plant growth regulators (the mixture of 3% DTA-6 and 27% ethephon) reduced the occurrence of root lodging and was conducive to photosynthate accumulation and root nutrient supply; it coordinated root regulation and morphological and physiological shoot functions and played a crucial role in reducing root lodging and improving maize yield (Sun *et al.* 2022). Todorova *et al.* (2022) observed significant reduction in net photosynthesis rate, stomatal conductance, transpiration rate and water use efficiency during drought and flooding. The disruption of photosynthesis together with reduction in the pigment content was stronger in droughted than flooded plants.

Physiological traits like relative water content (RWC %), membrane stability index (MSI %), chlorophyll content, photosynthetic rate, total soluble sugar (TSS) content and yield were improved under elevated CO_2. However, responses of these traits were negative with elevated temperature (Dwivedi *et al.* 2015). Driever *et al.* (2017) observed that transgenic lines with increased SBPase protein levels and activity showed enhanced leaf photosynthesis and increased total biomass and dry seed yield in wheat.

Source and Sink: It is commonly believed that increasing source (photosynthetic rate) and sink (partitioning to grain) strengths at the same time increases the likelihood of yield gains. Modern cultivars may have more restricted source capacity, even if the majority of trials show that growth variables prior to anthesis are the main determinants limiting production. Single grain weights were significantly lowered by removal of flag and penultimate leaves and raised by removal of spikelets on one side of each spike, indicating that while the source-sink balance was clearly altered by climatic fluctuations and N-deficient environments, wheat grain yield potential appeared to be more source-limited than sink-limited during grain filling. During grain filling, there was a strong correlation between grain yield and sink capacity (SICA), grain number, biomass, SPAD values, and leaf area index. This suggests that as sink capacity increased, there was a greater degree of source limitation. Breeders should therefore consider source limitation when increasing SICA, particularly in non-limiting settings (Xiao-li *et al*. 2022).

Respiration: Respiration is an important biochemical process that produces ATP by oxidizing organic substrates. About 30–60% of the carbon ingested during photosynthesis is lost through respiration in both annual and perennial crops (Cannell and Thornley 2000). Major staple crops experience yield penalties as a result of rising global temperatures. These losses are linked to higher maintenance respiration, which reduces non-structural carbs, and increased metabolic processes like protein turnover and ion concentration gradient maintenance. Warmer temperatures cause mitochondrial swelling and downregulation of respiration at the cellular level. This is attributed to various factors such as an increase in the ATP:ADP ratio, a reduction in ATP transfer to the cytosol mediated by abscisic acid, disruption of the concentration gradient of intermediates in the tricarboxylic acid cycle (TCA cycle), lipid peroxidation in mitochondrial membranes, and cytochrome c release, which in turn causes programmed cell death.

Green Leaf Area Duration: There are a number of additional physiological traits that have implications for yield potential and are related to increasing assimilate availability. The increase in LAD (which integrating increases in leaf area and longevity) was positively associated with an increase in dry matter at maturity and grain yield. Yield gain was achieved by reasonable increases in density and nitrogen fertilizer application to promote LAD (Li *et al*. 2022).

Adaptation to Density: Optimizing plant types for commercial sowing practices and canopy microenvironments boosts yield potential, overshadowing macroenvironmental considerations like climate. High planting density reduces resources per plant, alters light quality, increases competition for radiation, and accelerates leaf senescence, particularly lower canopy (Abeledo *et al*. 2020).

CONCLUSION

It can be concluded that crop yield variations involve the complex interactions of external environmental factors and internal plant processes shaped by genetics. Agronomic research delves into these dynamics, studying environmental impacts on growth and yield. It involves identifying factors governing environmental intensity affecting plant productivity. Genetic manipulation targets traits hindering yield, aiming to enhance productivity through improved physiological and morphological features, optimizing radiation interception, photosynthesis, assimilate partitioning, and minimizing losses.

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