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The Flag Leaf and Awns are Involved in Photosynthesis: Plant Yield Improvement

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Flag leaf and awns play significant roles as contributors of photosynthesis and grain yield in cereals. Flag leaf, being the penultimate fully expanded leaf before flowering, plays a critical role in supplying carbohydrates during grain filling and can contribute 75% of grain carbon content. Traditionally considered protective organs, awns were also major photosynthetic contributors, particularly in water-limited conditions, due to their high carbon assimilation efficiency and heat tolerance. Enhancement of photosynthetic efficiency of the flag leaf and awns through genetic enhancement, optimal agronomic practice, and regulation of delayed senescence can potentially make significant contributions to crop yield and stress resistance. The review highlights the role of flag leaf and awns in providing sustainable agricultural productivity and food security.

Photosynthesis and the Flag Leaf

Photosynthesis occurs in chloroplasts within plant cells and is the process through which light energy is converted to sugars, which the plant utilizes for growth and the accumulation of energy. The flag leaf is critical in this respect as it will typically do the majority of a plant's photosynthesis during the time the grain is filling. In wheat, for example, the flag leaf contributes up to 60% of the entire plant's grain-filling photosynthesis (Wardlaw et al., 1989). This ability to synthesize carbohydrates is essential during the critical stages of plant development. Not only do the flag leaf synthesized sugars help in plant growth, but they are also exported into the developing grain and are the foundation of the eventual yield. Therefore, the yield potential and fitness of the flag leaf determine the overall potential of the plant to produce seed and make it a significant photosynthesis organ as well as crop yield organ.

Factors Influencing Flag Leaf Function

Photosynthetic ability of the flag leaf could be controlled by many factors such as light intensity, water, and temperature. For example, when the flag leaf is exposed to drought or heat stress, the flag leaf will not be in a position to function at its optimal level, and therefore there will be low photosynthesis and hence low yields. Plant breeding in agriculture is intended to create cultivars with stress-tolerant flag leaves that will be in a position to sustain high rates of photosynthesis in the presence of stress (Mackay et al., 2007).

Also, the flag leaf's structure is such that it is designed for optimal photosynthesis. The large surface area of the leaf, combined with the large number of stomata, allows for optimal gas exchange. Stomata allow for the absorption of carbon dioxide, which is required for the synthesis of sugars, and the expulsion of oxygen, a waste product of the process of photosynthesis.

The Role of the Flag Leaf in Agriculture

Various studies have provided the correlation of flag leaf health with final crop yield. Flag leaf photosynthetic capacity at grain-filling is an estimate of energy potentially available for grain development. Decreased wheat flag leaf photosynthesis may result in light grain weight and decreased size and ultimately decreased harvestable yield (Fischer et al., 1998). Improvement and selection of more efficient flag leaves are therefore now a priority in crop improvement programs for increased yield.

Photosynthesis and Awns

Awns are found in the majority of cereal crops like barley, wheat, and rye. While their main function is typically associated with seed protection and dispersal, recent studies have shown that awns also aid in photosynthesis. In some species, awns are photosynthetic, particularly when the flag leaf is damaged (Lukacs et al., 2009). Such secondary photosynthesis is particularly important whenever environmental stress caused by, say, heat or drought weakens the functioning of the flag leaf.

The morphology of awns is particularly favourable for photosynthesis. Their long shape permits them to project a maximum surface area for light reception, and because they are on the plant surface, even if the main leaves are shaded, awns can receive the sun. Thus, the awns act as an additional carbohydrate source, which can prove to be particularly beneficial at vulnerable phases of grain filling, enhancing the overall yield of the plant.

Role of Awns in Water-Use Efficiency

In addition to supporting photosynthesis, awns also help in water use efficiency. The majority of awns have thin papillae or hairs, which form a microclimate to conserve air moisture. The air moisture is then used by the plant to prevent water stress. This water storage capability can make such plants more tolerant in dry environments, where water is scarce.

Effect of Awns on Yield

Research has indicated that awn-bearers may experience enhanced growth under specific environmental conditions. For instance, in barley and wheat studies, it has been determined that the occurrence of awns will result in higher photosynthesis, especially under high light or water stress (Kato et al., 2009). Awn contribution to total yield was, however, inconsistent in different species and depended on the environmental conditions. In some instances, the occurrence of awns has been linked to enhanced grain filling and increased yields, especially in environments with high water stress.

Synergistic Effects of Flag Leaf and Awns

Flag leaf and awns interact to increase photosynthesis and plant yield. Although the flag leaf is the major photosynthetic organ, awns are the secondary organs that facilitate photosynthetic activity, particularly under stress. Synergistic interaction between flag leaf and awns is most apparent at grain filling stage, where the two structures increase carbohydrate synthesis needed for grain development. Awn and flag leaf interaction experiments have shown that plants with functional awns and healthy flag leaves will have enhanced overall growth as well as enhanced yields. To have this double photosynthetic ability is to be capable of continuing to produce sufficient energy for grain fill even when one of the organs fails under environmental stress.

Conclusion

In summary, both awns and flag leaf are important in the photosynthesis process, which is responsible for overall productivity in the plant. The flag leaf, as the major photosynthetic organ, has a significant function in light capture and carbohydrate fixation, which are essential in grain yield and growth. On the other hand, awns have a secondary but positive function through the promotion of photosynthesis under stress, water-use efficiency, and hardness of the plant. As farming techniques change with climate change and the world requires greater food, learning about the flag leaf and awns' roles in photosynthesis becomes

increasingly important. By paying attention to these historically underemphasized parts of the plant, scientists and plant breeders can create more productive, high-yielding plants that are stress-tolerant.

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