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Impact of Elevated CO_2 on Physiological Parameters and Its Effect on Pigment Composition

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SUMMARY

CO_2 levels in the atmosphere are rising at an alarming rate. The planetary concentration of CO_2 has reached 400 ppm for the first time in recorded history, according to NOAA (National Oceanographic and Atmospheric Administration) 2014. This growth, along with the presence of other trace gases in the atmosphere, is commonly regarded as a major driver of global climate change. Nevertheless, the IPCC's 2012 report confirmed the growing evidence of global climate change, predicting that the worldwide averaged air temperature would rise by 1.8-6.4°C by the end of the century. Under mist conditions, there was a significant improvement in plant performance and production due to an increase in yield parameters such as number of pods, number of seeds per pod, and single pod weight.

INTRODUCTION

Whenever plants were exposed to mist under increased CO^2 conditions, they produced more leaves, root weight, shoot weight, total dry matter, and root nodules than plants that were not exposed to mist. There was also an increase in stomatal frequency, chlorophyll, starch, and sugar content in these plants.In terms of the physiological consequences of cellular water shortage, relative water content is the most relevant metric of plant water status. Several leaf physiological factors, including as leaf turgor, growth, stomatal conductance, transpiration, photosynthesis, and respiration, are all linked to leaf water status (Kramer and Boyer, 1995).

The relative water content of a plant is a reliable marker among its water balance (Yamasaki and Dilenberg, 1999). Relative water content is utilised as a most significant indicator for dehydration tolerance because it is a measure of plant water status that reflects metabolic activity in tissues. Athibha (2016) found that when CO_2 levels were raised, relative water content was higher than in the ambient chamber and open control. In terms of water levels, relative water content was found to be higher for field capacity, and it was much higher than 50% field capacity.When *Brassica juncea* plants were subjected to elevated CO_2 concentrations of about 600mol mol^{-1}, they showed increased water potential and relative water content (Rabha and Uperty, 1998). Reduced water use (Rogers *et al.,* 1984) and greater water use efficiency (Huber *et al.*, 1984) in soybean cultivated under elevated CO_2 and subjected to water stress during early reproductive growth prevented the onset of severe water stress, allowing them to maintain higher leaf water potentials. When alfalfa plants were grown under CO_2 enrichment (700 mol mol^{-1}) and at varied conditions, there was no significant difference in relative water content (Aranjuelo*et al.*, 2005).

Pigment composition

Chlorophyll is one of the most abundant organic substances on the planet, and it is needed for photosynthetic organisms to trap light and transmit energy. In the amaranthus variation Arun, elevated CO_2 was observed to increase chlorophyll a content when compared to an open control under water stress conditions (Dheeraj and Manju, 2017).In rice, there has been an increase in leaf chlorophyll content (De costa *et al.*, 2003). When exposed to increased CO2, the leaf chlorophyll concentration decreased or remained unchanged (Rao and Tower, 1970). In soybean, Reeves *et al.,* 1994 found that enhanced CO2 had no effect on total chlorophyll on an area basis.

However, increased CO_2 has been demonstrated to reduce the concentration of extractable chlorophyll in tree species (Wullschleger*et al.*, 2002).Plant productivity is a one-of-a-kind mechanism that is highly dependent on the amount of chlorophyll in the chloroplast. Chlorophyll is the pigment that gives plants their distinctive green colour, and it plays an important role in the physiology, productivity, and economics of green plants. Nutrient availability and environmental factors alter the amount of chlorophyll in leaf tissues. In thin leaf plantain seedlings, Hodge and Millard (1998) discovered that elevated CO_2 concentration encouraged belowground development more than aboveground components.The largest portion of chlorophyll's job is to collect light and transport it to a specific chlorophyll pair in the photosystem's response centre via resonance (Karacan, 2006). The amount of chlorophyll in a plant's leaves is an excellent indicator of photosynthetic activity, mutations, stress, and nutritional health.

Advancement in reducing sugar under elevated CO_2

Under high CO_2, there was a significant increase in the concentration of reducing sugars and total starch in Black gram (Sathish*et al.*, 2014). Considerable increase in foliar carbohydrate content when CO_2 levels were raised in 2004. Increased foliar carbohydrate content has been observed in plants grown in raised CO_2, including soybean, where growth at elevated CO_2 resulted in a 45 percent significant increase in total non-structural carbohydrate, despite the large increases in starch (Ainsworth *et al.*, 2002).The reducing sugar content of cowpea was found to be positively influenced by exposure to elevated CO_2 concentrations. Field capacity had the highest mean value for lowering sugars among the water levels, followed by 75 percent field capacity and 50 percent field capacity (Athibha, 2016).

A high quantity of starch has been discovered in ripe tomato leaves exposed to high CO_2 (Yelle*et al.*, 1989). When Arabidopsis shoots were exposed to high $CO_{2,}$ the starch content of the shoots grew significantly, while the soluble sugar content remained same. Carbohydrate accumulation has been shown in numerous studies during plant growth under CO_2 enrichment. Non-structural carbohydrate concentrations in leaves grown at high CO_2 levels inevitably rise. Because of CO_2 induced stomatal closure, increased CO_2 concentrations in the atmosphere result in lower transpiration (Pozo*et al.*, 2007).Koricheva*et al.* (1998) found that when temperate species were cultivated under increasing CO_2, overall phenolic concentrations increased, however responses varied by species and environmental conditions (Kinney and Lindroth, 1997). Under elevated CO_2 and water stress, the increasing trend in phenol concentration was likewise maintained. The highest phenol content was found in the presence of increased CO_2, followed by ambient and open field conditions. The bush cowpea variety Bhagyalakshmy has the highest field capacity among the water levels (Athibha, 2016).

During the last year of a three-year open top chamber experiment with increasing CO_2, greater levels of phenol were found in silver birch leaves (Peltonen*et al.*, 2005). A drop in phenolic concentration was recorded during seedling stage in a two-year study using open-top chambers using the japonica rice variety, but an increase in maturity stage was reported under elevated CO_2 concentrations of 550 mol mol1 (Goufo, 2014). Plant development in CO_2-rich environments is thought to boost the accumulation of both leaf starch and soluble carbohydrates (De Souza *et al.*, 2008).Among the water levels, significantly higher free amino acid content was recorded at 100% field capacity compared to 75% capacity and 50% field capacity (Athibha, 2016). Increasing amino acid content can be related to degradation of proteins under elevated CO_2 conditions and hydrolysis to free amino acids. Since the metabolism of carbohydrates is essential for the synthesis of amino acids, it is reasonable to assume that the effects of CO_2 enrichment should be similar for these classes of compounds. Ample carbon was available to support amino acid synthesis and the increase in soluble amino acids under CO_2 enrichment. Unlike older leaves, soluble amino acids were increased in young soybean and tobacco leaves exposed to atmospheric CO_2 enrichment (Geiger *et al*., 1998; Ainsworth *et al*., 2007).

Some analyses have found that increased CO_2 has a favourable influence on the water stress tolerance of various bread wheat cultivars (Robredo*et al.*, 2011; Bencze*et al.*, 2014). Increased CO_2 and water stress have been shown to have a favourable synergistic effect on gs, resulting in improved water usage efficiency at the stomatal and whole plant level (Bencze*et al.*, 2014; Pazzagli*et al.*, 2016).

Membrane integrity is measured as percentage leakage. After stress, a decreasing trend was found in the high CO2 chamber compared to the ambient chamber and open control. Under enhanced CO2 conditions, percent leakage was lower than under ambient conditions, and it was much lower than in open field conditions. The lowest percent leakage among the water levels was measured at 50 percent field capacity, which was much lower than field capacity (Athibha, 2016).In amaranthus, percent leakage was much reduced under high CO_2 compared to an open control. Under water stress, the variety Anagha had the lowest percent leakage, which was much lower than the variety Renusree (Dheeraj and Manju, 2017).

The level of vitamin C (ascorbic acid) was likewise shown to be higher with increasing CO_2 during the initial phase of exposure, but a large rise was observed under water stress in the latter stages (Karacan, 2006). In water stress conditions, increased ascorbic acid concentration was observed in the enhanced CO_2 chamber compared to the open control, which was considerably higher than the control chamber. In comparison to the CO^{-1} genotype, the variety Arun had the greatest ascorbic acid level among the variations (Dheeraj and Manju, 2018).

Drought with high CO_2 levels stimulated the antioxidant enzyme system in bread wheat, according to Bencze*et al.* (2014), indicating a high level of oxidative stress. The effect of increasing CO_2 on SOD activity was found to have the greatest mean value, followed by the ambient chamber and the open control. Among the water levels, the maximum SOD activity was found at 50 percent field capacity, which was substantially greater than field capacity (Athibha, 2016).

CONCLUSION

Possibility of augmenting antioxidant production by combining the impacts of diverse cultivars, CO_2 enrichment, and other abiotic variables, many of which are economically significant secondary metabolites. The combination of high CO_2 with elements like as cultivars, growth stages, light, nutrient, and abiotic stress factors brings up opportunities for improving the quality of agricultural products using new technologies in agriculture development. Because many economically important crops have been documented to have negative quality consequences when grown under field circumstances at elevated atmospheric CO_2, intensification of cultivation and quality enhancement are equally critical to solve the current concerns of global health.

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