Physiological Aspects of Crop Production under Limited Water Supply

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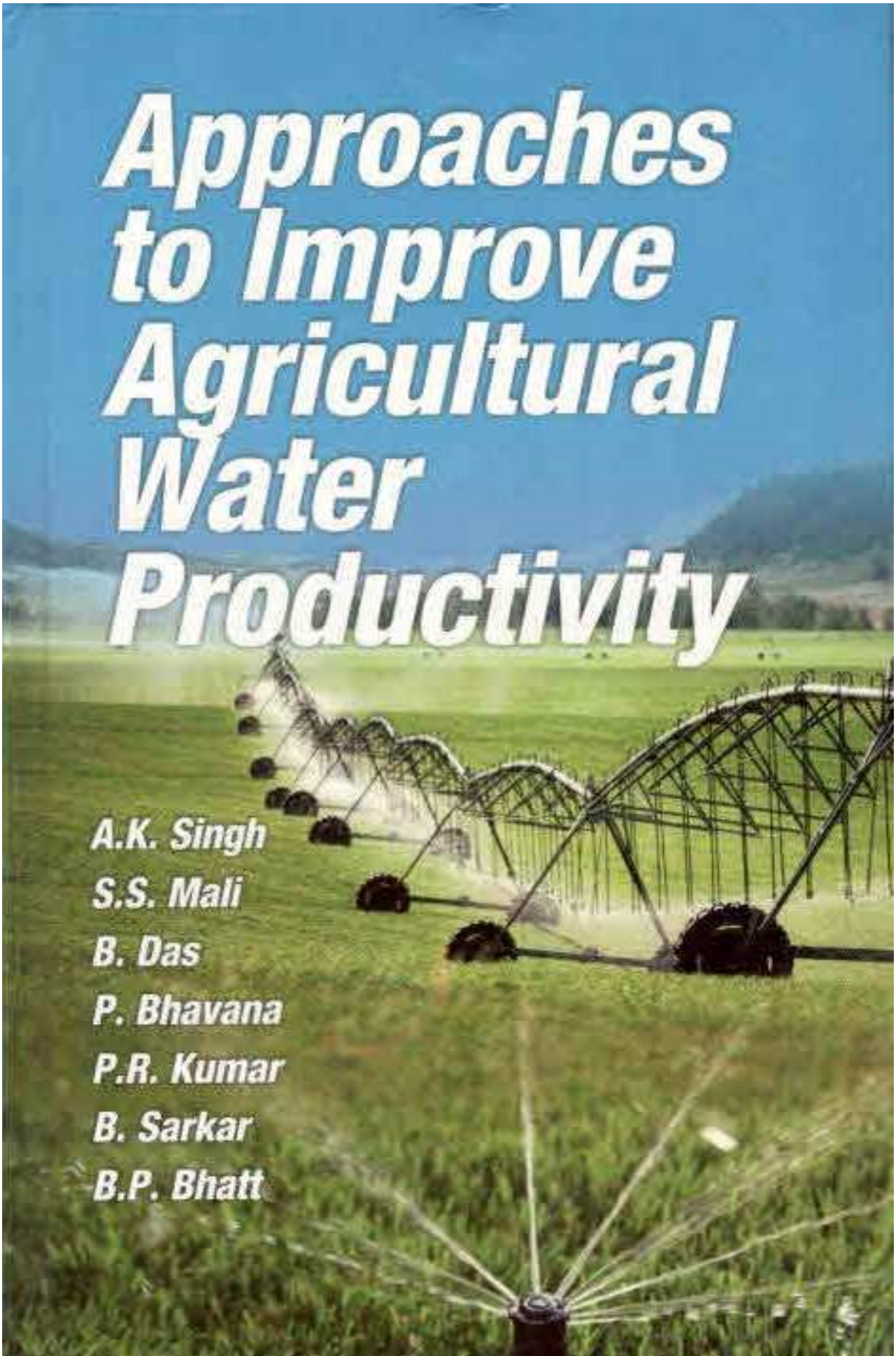
Approaches to Improve Agricultural Water Productivity
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It is estimated that in Africa and Asia, 85-90% of all the fresh water is used for agriculture and by 2025, agriculture is expected to increase its water requirements by 1.3 times (Shiklomanov, 1999). To meet the water requirements of the burgeoning population and for the industrial consumption, water has to be diverted leaving less water available for agriculture. When water becomes limited, naturally, the crop production gets hampered as there would be uncertainty in the availability of water at the critical stages of growth affecting the survival and yield prospects of the crops. Thus, there is a great need to explore the possibilities for saving available water for meeting the requirements of critical growth stages of the crop production. This article attempt to summarize the work carried out by various researchers on the physiological aspects of crop production under limited water supply. The lack of water at critical stages of plant growth is called drought stress, and researchers are working to screen the drought tolerant germplasm having the drought tolerant traits to be used in the breeding programs.

Crops under limited water expresses changes in their plant physiology and the drought tolerance can be observed with the traits related to the osmotic adjustment, cell membrane stability, epicuticular wax on the plant parts, ability for partitioning the stem reserves to the economic parts of the yield, manipulation and stability of flowering processes etc. It is reported that in Amaranth (*Amaranthus caudatus* L.), all the physiological traits such as leaf area index, leaf area ratio, specific leaf area and the leaf weight ratio decreased with decreasing water availability (Farshbaf-Jafari et al. 2014). Similarly, in Soybean (*Glycine max* L. Merr.), plant stem elongation, stomatal conductance, relative water content, water potential, osmotic potential and turgor pressure of stress plants declined in all genotypes when studied under water stress (Hossain et al. 2015). Pinheiro et al. (2005) and Kobata et al. (1996) had reported that the high dry matter production of the rice cultivars in their experiments which are drought resistant under field conditions is not due to high water use efficiency, but due to their high ability to maintain transpiration, which is supported by deep root systems.

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Price et al. (2002) concluded that the plants respond to water deficit using mechanisms of avoidance by improving root traits.

Blum (2009) who had worked extensively on drought stress and he reported that the trait one has to target in plant production under limited water supply is the effective use of water (EUW). He also reported earlier that the major plant adaptive response to drought at the cellular level is an osmotic adjustment (Blum, 2005). In an experiment with supply of nitrogen to maize under water limited conditions by Hernández et al. (2015), it was revealed that the supply of nitrogen did not influence the water use efficiency through evapotranspiration was increased. Dahanayake et. al. (2014) reported that in black gram, that the least plant height (46.76cm) and root length (15.98 cm) were observed at vegetative stage under water stress when compared to control (88.89cm plant height and 21.85 cm root length). Further, they reported that the there were a less number of pods produced per plant under soil moisture stress at the flowering stage than at fruiting stage. Serraj and Sinclair (2002) in their review of ‘Osmolyte Accumulation’ said that though osmolyte accumulation (OA) is generally considered as a mechanism for increasing crop yields under drought conditions, the field studies examining the association between OA and crop yield had not shown any benefit. However, they report in the review that the mechanism identified for beneficial yield responses to OA is the maintenance of root development in order to reach water that may be available deeper in the soil profile.

Passioura (1983) had postulated yield is a function of water used, water-use efficiency and harvest index and during the water stress, the crops have access to a substantial amount of water, but they have to exploit with the root system to mine to residual water to improve the yields. He further stated that because the roots are difficult to harvest, water-use efficiency (WUE) is usually defined as above-ground-biomass/water-used. Blum (2009) argues that in breeding programs, selection for higher WUE for water-limited conditions would lead to a reduction in yield and also drought resistance. This he substantiates with the statement that till the time biochemistry of photosynthesis is improved genetically, transpiration efficiency and WUE would lead to a reduction in transpiration and crop water-use which are very crucial for plant production. Therefore, breeding for efficient soil moisture capture traits should be the important target for yield improvement under drought stress.

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In an experiment in coffee by Meinzer et al. (1990), the variation in inherent water use efficiency exhibited by some of the genotypes was due to the reduction in stomatal conductance (g) rather than increased photosynthetic capacity at a given 'g'. In their experiment they found that by withholding the irrigation for a month caused stable carbon isotope discrimination (Δ) to decline substantially in expanding leaf tissue of all genotypes and a strong correlation (r = 0.92) between Δ and plant hydraulic efficiency (ratio of 'g' to the diurnal range in leaf water potential (ΨL)). With this experiment, they indicated that Δ might be used to evaluate several aspects of plant performance and response to specific environmental conditions.

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