WATER MANAGEMENT TO SORGHUM - A REVIEW

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ABSTRACT

Sorghum also called "Crop Camel" is known for its drought resistance, but there is a scope for improving the quality as well as grain yield when it is grown under irrigated conditions. India ranks first in area under sorghum, second in production and 51st position in terms of productivity. This pathetic situation is mainly because of its cultivation in dryland conditions and improper irrigation management under irrigated conditions. So, to augment the productivity of sorghum, review of the research work related to irrigation scheduling of sorghum has been presented here for directing the future research.

Sorghum is the third major food crop next to rice and wheat. It is widely cultivated in the semi-arid tropics of the world. In India, it is mostly grown as a rainfed crop and also as irrigated crop. The area, production, productivity and coverage under irrigation of sorghum in India is 11.57 million ha, 11.09 million tonnes, 958 kg ha$^{-1}$ and 6.7% respectively (Anonymous, 1998). Irrigation plays a major role in increasing the sorghum yield. The water constraint may be bestowed with irrigating the crop at critical stages alone which could increase the yield rather than loosening yield due to irrigating the crop at unwanted stages.

Water requirement: Water requirement of sorghum vary with the season, soil, nutrition and other environmental conditions. Sorghum crop requires about 610 mm water for optimum yield (Raheja, 1961). 488 mm water was adequate under Tamil Nadu conditions (Chandramohan, 1970). Water requirement of main and ratoon sorghum was assessed at 606 and 320 mm respectively when irrigation was scheduled at 50% available soil moisture (ASM). Irrigation scheduling based on plant indicator method using sunflower as indicator crop for sorghum was found that water requirement in both main and ratoon crop of sorghum was 520 and 293 mm respectively (Subbarayalu, 1982). Higher grain yield of 4.92 t ha$^{-1}$ can be obtained by applying 45 kg N ha$^{-1}$ with a water requirement of 425 mm (Sharma and Neto, 1986). The water requirement for pure sorghum was lesser than sorghum + groundnut intercropping systems respectively (Shinde and Umrani, 1988).

Scheduling Irrigation: Various approaches have been used to schedule irrigation. Important approaches are transpiration ratio approach, soil moisture depletion approach, climatological approach and phenological stage approach. Although several approaches are available, best method of scheduling of irrigation and the choice of method is to be chosen based on experience (Kramer, 1983). Scheduling irrigation based on climatological approach was more precise and appropriate (Ramu, et al., 1991). Seedling, preflowering and grain formation stages coinciding with 2 to 4, 12 to 14 and 17 weeks after sowing respectively were critical for water demand (Balasubramanian, et al., 1966). Germination, seedling, flowering and grain formation stages were critical for irrigation and getting higher yield (Dastane, 1974).

Influence of irrigation on sorghum

Large number of evidences are available on the influence of water on growth components in sorghum under different irrigation practices.

Growth parameters: CSH I sorghum was tallest when irrigated at 60% ASM
(Gopalakrishnan, 1966). Improvement in sorghum plant height was observed with normal irrigation than irrigation given at critical stage (Thangamuthu, 1979). Sorghum grew to a taller and comparable height when irrigation was scheduled at 50% ASM or through plant indicator method than the rainfed crop (Subbarayalu, 1982). Very high positive correlation was recorded between irrigation and plant height in sorghum (Robins and Domingo, 1953; Jacob, 1963; Bielorai, et al., 1964; Kannagara, et al., 1983). Water stress at an early stage reduced the amount of leaf area at flowering (Fischer and Hagan, 1965). Stress at critical stages limited the elongation of stalk and significantly reduced LAI (Oizumi, et al., 1965). Moisture stress on sorghum had marked effect on LAI (Krishnamoorthy, et al., 1973). Drought stress can have significant effect on the growth of sorghum plants by limiting leaf area development by altering photosynthetic activity and transport of assimilates and by influencing pattern and rate of senescence (Simpson, 1981). Considerable correlation was noted between leaf area development and water stress (Kannagara, et al., 1983). Water deficit reduced dry matter production (DMP) (Colman and Lazenby, 1975; Boovendran, 1977). Increase in DMP with increase in moisture supply was reported in sorghum (Subbarayalu, 1982). Root developed under limited soil moisture were finer and had larger branches of secondary and tertiary roots (Knoch, et al., 1957). About 83% of moisture was extracted from the root zone mostly from 0 to 30 cm depth (Pharande, et al., 1973). Greater root length to be associated with moderate stress through light and frequent irrigation (Clements, 1964; Robertson, et al., 1980).

**Physiological parameters:** Restriction of leaf expansion with lower leaf area ratio is more common determinant to reduce relative growth rate (RGR) even during mild stress (Hsiao, 1973; Kanemasu and Tanner, 1969). Lower RGR in sorghum was recorded when it was experiencing moisture stress condition (Bangarusamy, 1988). Maintenance of higher crop growth rate (CGR) under moisture stress condition is a desirable attribute for high productivity of rainfed sorghum and may be possible by the maintenance of higher physiological activities (Durga Devi, et al., 1987). No reduction in sorghum grain yield when moderate stress was given in which the average leaf water potential (LWP) were between -15.8 and -20.3 bars. However, when the periods of stress was extended to a LWP of -21.7 bars beginning at early boot stage or heading stages yield was reduced by 27%. For the same length of period and level of stress beginning at early grain filling stage reduced yields by 12% while season long moisture stress with a LWP of -24 bars reduced yield significantly by 54% (Eck and Musick, 1979). At -1.5 MP a sorghum registered higher DMP (420 gm²) while there was gradual reduction with progressive increase in LWP (Bangarusamy, 1988). Inverse relationship between relative water content (RWC) and degree of moisture stress in drought susceptible sorghum genotypes and RWC decreased as soil moisture deficit increased (Blum and Sullivan, 1974; Bangarusamy, 1988). Higher transpiration rates were associated with adequate moisture availability which got steadily lowered with the reduced moisture status experienced by the sorghum (Gururajan, 1992). Transpiration rate decreased with the decrease in soil moisture (Aziz, et al., 1993). Transpiration was reduced when the soil water availability was below 20% due to reduction in leaf area through leaf senescence (Blum and Arkin, 1984). Sorghum exhausted the soil available water to 20 cm taking progressively less from each successive layer down the profile by extracting 64% of water from 0.2 m deep in podzolic profiles near Canbarra (USA) during dry period encompassing most of the
growth phase (Brener et al., 1986). Stomatal regulation in sorghum increased during leaf expansion period over a range of several bars of turgor pressure (Ackerson et al., 1980). Seasonal drought induced osmotic adjustment in sorghum exhibited significant differences in average values of leaf conductance and total soil water depletion (Shackel and Hall, 1983). Photosynthetic rates were reduced by increasing water stress prior to any measurable reduction in translocation rates of photosynthates from the source (leaf) (Sung and Krieg, 1980). Under stress conditions, the maintenance respiration component consumed increasingly greater amounts of the daily assimilation primarily due to reduced photosynthetic activities due to the mild water stress for brief periods reduced protein synthesis but severe prolonged stress resulted in total damage of the crop (Teare and Peet, 1983). Drought stress affected leaf area production and floral initiation and resulted in reduction of canopy photosynthesis (Blum and Arkin, 1984). Grain yields were reduced by 36% due to water stress while it reduced the dry matter production by 37% (Garrity et al., 1984).

Yield components: Adequate moisture during flowering and grain filling stages was essential to have larger panicles (Jacob, 1963). Onset of soil water stress during the early stages of panicle development resulted in shorter heads (Adams and Arkin, 1977). Longest panicle was obtained when sorghum was irrigated at 50% ASM (Subbarayalu, 1982). Increasing soil moisture by supplementary irrigation increased panicle weight of sorghum (Bielorai, et al., 1964). Soil moisture stress during flowering and grain filling stages in sorghum CSH1 reduced yield components (Mohiuddin and Yassen, 1973). Moisture stress at flowering and grain development stages reduced number of grains panicle\(^1\) and grain weight (Dastane, 1974). Only 50% of the spikelets opened fully and seeds set in during the soil moisture stress at spikelet opening stage of CS 3541 (Parameswarappa, et al., 1985). Water deficit caused decrease in the number of grains ear\(^1\) in sorghum (Inuyama, et al., 1976). Moisture deficit did not reduce 1000 grain weight in grain sorghum (Inuyama, et al., 1976; Boovendran, 1977). Reduction in seed weight was noticed when moisture stress was experienced at grain filling period (Mohiuddin and Yaseen, 1973).

Nutrient uptake: The availability of P increased with increasing frequency of irrigation due to dilution of soil solution (Singh, et al., 1971). Total uptake of N and K in sorghum was usually higher with irrigation (Benett, et al., 1964). The transport of the mineral nutrients in the soil, absorption by the roots, translocations within the plant and their metabolism were influenced by soil moisture availability (Singh, 1972). Response of applied fertilisers is depended upon the quantity and frequency of irrigation (Dastane, 1974). Response of sorghum to N fertilizers was more in Kharif season than in Rabi season which may be due to better stored soil moisture availability in Kharif season (Mahapatra, et al., 1973; Singh, 1977). N, P and K uptake was significantly higher under irrigation regime of 50% ASM (Panwar, et al., 1988).

Water use efficiency: WUE increased with increasing moisture regimes along with a rise in consumptive use in sorghum (Mertia and Bajpai, 1975). WUE of 9.95 kg grain/mm of water has been observed by Pharande, et al. (1975). Consumptive use of water increased with an increase in the frequency of irrigation while the WUE decreased with an increase in the frequency of irrigation. The WUE observed was 10.7 kg of grain/ha mm (Dhonde, et al., 1986). A WUE of 42-53 kg of dry matter/mm water was observed in fodder sorghum (Lal and
In Brazil, higher WUE of 10.93 kg of grain/ha mm of water used was noticed (Sharma and Neto, 1986). Maximum WUE of 9.22 and 9.10 kg/ha mm was observed for normal and paired row planting. In addition, pearl millet had greater WUE than sorghum under severe water deficit conditions (Singh and Singh, 1995).

**Yield:** Maize clearly tended to show a greater relative increase in both canopy net photosynthesis and biomass over sorghum with increase in frequency of irrigation from 2 (ID/CPE=0.15) to 7 (ID/CPE=1.0) while pearl millet exhibited less reduction in biomass than sorghum while shifting from wet (ID/CPE=1.0) to dry environment (ID/CPE=0.15) (Singh and Singh, 1995). At Siruguppa, Karnataka, one irrigation at 25% ASM in surface (30 cm layer) on heavy clay soils is adequate for *Kharif* sorghum (CSH 1), but summer sorghum at 50% ASM required 550-575 mm water in 9-10 irrigations for higher grain yield (Dastane, et al., 1970). At Coimbatore and Bhavanisagar (Tamil Nadu), irrigation at 50% ASM was found adequate in the Rabi season (Hukker, et al., 1977). At Rahuri and Hyderabad, grain yield of *Kharif* sorghum did not decrease even at 75% depletion of ASM in 0-30 cm soil layer (Pai and Hukker, 1979). At Parbhani and Bhavanisagar, the ID/CPE=0.4 and at Rahuri ID/CPE=0.6 with irrigation need of 6 cm, 3 cm and 17 cm gave high yields of Kharif sorghum (Prihar and Sandhu, 1968). *Rabi* sorghum at Dharwad and Navsari at ID/CPE=0.6 and 0.9 with 31 cm and 52 cm irrigation water respectively gave higher grain yield. However at Kota (Rajasthan), *Kharif* sorghum did not response to any irrigation (Pai and Hukker, 1979).

Sorghum irrigated at 50% ASM produced higher grain yield (Kaliappa, et al., 1974; Krishnaswamy and Rengaswamy, 1978). Irrigation scheduled at seedling, vegetative, flowering and grain formation stages of COH 2 sorghum recorded 4700 kg ha\(^{-1}\) which was comparable with irrigating at 50% ASM (Palaniappan, et al., 1977). Irrigation scheduled at vegetative, flowering and grain maturity stages with two irrigations in initial stages recorded increased grain yield in sorghum CSH 6 (Thangamuthu, 1979). Irrigation at IW/CPE ratio of 0.60 was found better than 1.00 and 0.80 IW/CPE ratio in terms of grain production (Kandasamy and Subramanian, 1980). During summer season, irrigating sorghum crop at 40% ASM up to 45 days and 60% ASM up to 90 days was sufficient for higher yield as well as for economic use of water (Premsekhar, 1980). At Madurai, Tamil Nadu, sorghum irrigated at 0.9 IW/CPE ratio gave higher grain yield (Gururanjan and Sundar Singh, 1981). Irrigating the sorghum intercropped with cowpea and blackgram at 25% ASM was found optimum to get higher yield of main as well as intercrops (Vasimalai, et al., 1981). The optimum irrigation interval for higher grain yield was determined to be in the range of 12-18 days (Done, et al., 1984). A significant increase in grain yield and stover yield of sorghum was recorded when irrigated at 0.40 IW/CPE ratio (Krishnamoorthy and Iruthyaraj, 1984). At Rahuri, Maharashtra, application of only one irrigation at pre-boot stage produced as much grain yield as that of two irrigations at pre-boot and boot stages or four irrigations at pre-boot, boot, flowering and milky stages in Rabi sorghum under black soil condition (Dhonde, et al., 1985). Higher grain yield of 3.7 t ha\(^{-1}\) was obtained when irrigation was scheduled at 0.6 or 0.9 IW/CPE ratio under Rahuri condition (Dhonde, et al., 1986). There was a significant decrease in plant height, DMP, test weight harvest index and grain yield of sorghum with irrigation scheduled from 25 to 75% available soil moisture depletion (ASDM) (Ashokarani, et al., 1987). At Rahuri, depth of water applied at each irrigation equal to 0.75 cm of pan evaporation at grand
growth, boot leaf, flowering and milky stages produced higher grain yield than a fixed depth of water applied at different critical growth stages (Dhonde, et al., 1987). Higher grain yield in CSH 1 and CSH 5 were recorded when irrigation was scheduled at 20% ASMD regime during post-rainy season (Anand Reddy, et al., 1988). Scheduling irrigation at IW/PAN-E ratio of 0.9 out yielded rest of the lower levels of IW/PAN-E (0.5, 0.6, 0.7 and 0.8) (Patel, et al., 1990). Irrigation at 0.6 IW/CPE ratio throughout the crop period gave higher grain yield (Ramu, et al., 1991).

Higher grain yield in sorghum CO 25 was associated with irrigation at 0.6 IW/CPE ratio and was comparable with irrigation scheduled at 0.9 IW/CPE ratio (Gururajan, 1992). Mean grain yield was higher with irrigation scheduled at 100 mm pan evaporation (Aflatoni and Daneshvar, 1993). Seed yield of sorghum was maximum with irrigation at 60 mm CPE (Nathu Singh and Narang, 1993). Four irrigations applied at vegetative, boot leaf, flowering and milky stages resulted higher grain and fodder yield of sorghum (Anonymous, 1997).

CONCLUSION

Water requirement of sorghum vary with the season and soil fertility. Sorghum crop requires 425-610 mm of water for getting higher yield. The water requirement for sorghum is less than main crop. Seedling, preflowering and grain formation stages are critical for water. Moisture stress at critical growth stages definitely affects growth, yield components, nutrient uptake and yield of crop. Irrigation scheduling at 0.6 IW/CPE ratio seems ideal for sorghum. Sorghum crop can also be irrigated with 40-60% ASM to get maximum economic yield.

FUTURE FOCUS

* Effect of antitranspirants and mulches on water requirement of sorghum has to be investigated.
* Effect of life saving irrigation on sorghum yield have to be assessed under different dry farming situations.
* Water requirement of sorghum based cropping systems may be studied.
* Role of antievaporants on WUE of sorghum may be studied.
* Water management strategy under shallow water table has to be studied.
* Irrigation management in canal command area may be studied.

REFERENCES


