REVIEW ARTICLE Agricultural Reviews, Volume 42 Issue 2 : 225-229 (June 2021)

Water Management for Improving Pearl Millet Production under Irrigated Environment: A Review

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ABSTRACT

Pearl millet also called "poor man food" is known for its drought resistance, well adaptation to harsh conditions like soils with poor water holding capacity, low nutrient status, problematic soils, *etc.* Irrigation has been recognized as a basic necessity for sustaining high productivity of various crops. Moreover, it affects the crop yield directly as well as indirectly by increasing their response to other inputs including fertilizers and various management practices. It is well known that water deficit is one of the major abiotic factors limiting crop productivity in the semi-arid tropics. Out of the various production constraints; low productivity of pearl millet is mainly attributed to its cultivation under dry land conditions and improper water management under irrigated conditions. So application of irrigation water offers the scope for improving the quality as well as productivity of pearl millet. Therefore, to augment the productivity of the poor's man crop, review of the research work related to irrigation scheduling and moisture conservation practices of pearl millet has been presented here for directing the future research.

Key words: Crop production, IW/CPE, Environment, Pearl millet, Water management.

Pearl millet is the sixth most important cereal crop in the world after wheat, rice, maize, barley and sorghum (Singh *et al.,* 2003). It is a major forage crop of high nutritional quality in the semi-arid regions Henry and Kettlewell, 1996; Dakheel *et al.,* 2009; Maiti and Rodriguez, 2010. It is getting more attention in the present time due to increasing evidences of less seasonal rainfall, increase in temperature, frequent occurrence of extreme weather events coupled with scanty water resources. The crop is hardy, require less water and has a short-growing period (Jakhar *et al*., 2006, Om Prakash *et al*., 2008, Singh *et al*., 2010). Though adapted to resource-poor situation, pearl millet also suffers badly due to low soil fertility and scarce water availability, thereby reducing the yield potential. However, the growth rate of this crop has been as high as wheat and much higher than other coarse cereals, like maize and sorghum in the last few decades, mostly due to introduction of high yielding disease-resistant varieties (Khairwal and Yadav, 2005). In India, it is mostly grown in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana as its cultivation is mostly rainfed as a mono cropping and to some extent it is also sown under high intensity cultivation involving double cropping to enhance the productivity per unit area per unit time, if the water is available. Irrigation plays a major role in increasing the pearl millet yield. The water constraint may be bestowed with irrigating the crop at critical crop growth stages alone which could increase the yield rather than loosing yield due to irrigating the crop at unwanted stages. Agricultural land area is inelastic and hence enhancement of productivity is the only alternative. Hence special attention is needed to achieve the goal of increasing and stabilizing agricultural production in moisture deficit areas. Soil moisture is the most important factor for successful crop production in dry lands. Use of organic manure as well as mid-season corrections through mulches, anti-transpirants and planting methods are effective in increasing the productivity and water use efficiency of pearl millet. Agricultural production in arid and semi-arid conditions will improve, if investments are made on soil and water conservation measures to improve soil fertility, enhance soil moisture and use the stored water as supplemental irrigation at critical crop growth stages. Pearl millet production in summer season is greatly influenced by irrigation. Better results, both in terms of growth attributes and yield of pearl millet can be achieved with proper scheduling of irrigation (Patel *et al*., 1994). Parihar *et al.* (1975) have advocated the use of IW: CPE ratio for different crops.

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How to cite this article: Kumar, P. and Kumar, A. (2021). Water Management for Improving Pearl Millet Production under Irrigated Environment: A Review. Agricultural Reviews. 42(2): 225-229. DOI: 10.18805/ag.R-1990.

Submitted: 17-03-2020 **Accepted:** 24-12-2020 **Online:** 09-03-2021

Water requirement

Water is indispensable for human, animal and plant life. When plants are green, water constitute over 90 percent of plant body weight. Water availability influences various biochemical and physiological processes in plants. Water is one of the most important inputs essential for the production of crops and plants need it continuously during their life and that too in huge quantities. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients and cell division besides some other metabolic processes. Both its shortage and excess affect the growth and development of a plant directly and consequently, its yield and quality. In India, however, rainfall is notoriously capricious, causing floods and droughts alternately. Frequency, distribution and amount of rainfall are not in accordance with the needs of the crops. Artificial water supply through irrigation on one occasion and the removal of excess water through drainage on another occasion, therefore, become imperative, if the crops are to be raised successfully. Water management in India, thus, comprises irrigation or drainage or both, depending considerably on the environmental conditions, soil, crops and climate. It is a situation oriented entity. Water affects the performance of crops not only directly but also indirectly by influencing the availability of other nutrients, the timing of cultural operations, *etc*. Water and other production inputs interact with one another. In proper combinations, the crop yields can be boosted manifold under irrigated conditions.

Water is essential to crops in the following ways

i Water serves as solvent. Plants can absorb nutrients when these are present in solution form. Water itself acts as a nutrient also.

ii Water is necessary for photosynthesis process and its end product is translocated to different parts of the plants in water solution.

iii It helps in maintaining cell wall turgidity, cell enlargement and cell division which ultimately affects plant growth, when it is available in plenty. Conversely, plants die when water supply is curtailed down.

iv It is essential for seed germination, root growth and multiplication of microorganisms present in soil.

v Due to its essentiality in the hydrolytic process, water helps in conversion of starch into sugar in the plants.

vi Water is necessary in chemical, physical and biological reactions in soil.

vii It protects the plant from adverse conditions such as high temperature, low temperature injury, drought and frost, *etc.* Leaves get heated up with solar radiation. Plants dissipate heat by increased transpiration. Water acts as a buffer against high or low temperature injury as it has high heat of vaporization and high specific heat.

viii The process of weathering and soil formation depends on water.

ix Good tilth can be secured at right stage of moisture content. Physical, chemical and biological activities in the soil are regulated by availability of water to a great extent.

x Transpiration is a vital process in plants and it occurs at a potential rate as long as water is available in adequate amount. If there is soil water deficit, transpiration process is curtailed down seriously affecting plant growth and yield.

Water in crop production is largely associated with irrigation. Pearl millet is a rainfed crop and there is hardly any need for irrigation. In pearl millet only about 4 percent of the total area is under irrigation in Gujarat, Punjab, Maharashtra, Tamil Nadu and Andhra Pradesh. Irrigate the crop if there are no rains. Generally, two irrigations during the growing period of the crop is enough. Most critical crop stages for irrigation are after germination, tillering, ear head emergence (heading) and grain filling. Since pearl millet does not withstand water logging so care should be taken that there should be proper drainage facility. The irrigation requirement of pearl millet when grown in the *Kharif* season varied from 150 to 200 mm in most parts of the country. Pearl millet tolerated 75 per cent depletion of available water from 0-30cm depth of soil on the heavy black clay soils (Patil *et al.,* 1969) and on sandy loam soils (D.A.R.E, 1975).

Irrigation scheduling approach

In view of the high investment costs of developing irrigation facilities and limited availability of irrigation water, it should be used most efficiently. It has to be transported to the site of use and applied to the fields efficiently at appropriate timing and in adequate amounts. Irrigation scheduling is a systematic method of deciding when and how much water to apply for maximizing crop yields and water use efficiency. The basic objective of irrigation scheduling is to replenish the soil moisture to the desired level. Scheduling irrigation based on data of pan evaporation is likely to increase agricultural production at least by 15 to 20 per cent (Dastane, 1972). Various approaches have been used to schedule irrigation *viz*.

Soil Water Status Approach

Soil water is considered equally available over the entire range between upper and lower limits. Soil water availability gradually decreases from upper to the lower limit of available water and based on the existence of critical soil moisture level within the available soil moisture range below which yield reduction is significant. Irrigation is therefore, needed when this lowest limit of optimum water regime is reached and it is considered as the most opportune time for irrigation.

Soil water depletion technique

Irrigations are scheduled based on depletion of available water from effective root zone of the crops. In this approach periodical determination of soil water content in the root zone is made to know the time, when the available soil water depletion reached the critical level irrigation is scheduled.

Soil moisture tension

Plant response to soil moisture is better correlated with water tension than the water content in the soil. The use of the soil-water tension or potential to schedule irrigation overcomes much of the difficulty in applying results from one area to another. Soil water potential can be determined by tensiometers or electrical resistance units. Soil moisture tension may vary from soil surface to the bottom of root zone. It has been observed that, soil moisture tension measured at a depth of 15 to 30 cm is used as an indicator for scheduling irrigation.

Plant water contents and leaf water potential

The leaf water content (ΦL) and leaf water potential (ΨL) in most of the plants changes with variation in soil water availability. As the ΦL or ΨL drops below a certain criterion limit, specific to plant species and its growth stage, the physiological and growth phenomenon are adversely affected. Consequently these threshold values can serve as reliable indications for irrigating crops. For many plant species, stresses are mild when mid afternoon ΨL depressions are not more than -12 bars; moderate if in the range of -12 to -16 bars and extreme if below -16 bars.

Critical crop growth stage

Some physiological stages of crop growth are found to be more sensitive to water stress than other stages. The stages of the crop at which moisture stress affects the yield significantly are called critical growth stages.

Infrared thermometry

It simultaneously measures canopy temperature (Tc) and air temperature (Ta) and displays Tc -Ta values, which can be used for scheduling irrigation. The negative value indicates that plants have sufficient amount of water, whereas, zero or positive value indicates stress. Hence, irrigation is scheduled.

Irrigation water (IW)/cumulative pan evaporation (CPE) ratio

Considering the strong relationship between the pan evaporation and crop ET, particularly in semi-arid tropics, the IW/CPE ratio has been suggested as a practical approach for irrigation scheduling. IW represents the fixed amount of irrigation water and CPE is cumulative pan evaporation (USWB pan evaporation) minus effective rainfall, since previous irrigation. The first step in this approach is to find out the irrigation depth on the basis of permissible soil water depletion from the root zone for potential yield. The next step is to find a factor (known as IW/CPE ratio) which is to be multiplied with CPE to compute the depth of water depleted from the soil storage. Irrigation is applied as soon as CPE multiplied with IW/CPE ratio becomes equal to the irrigation depth. This criterion can easily be adopted by Indian farmers but the lacunae of this criterion is that it is region and soil specific. Irrigation to pearl millet is being scheduled at IW/ CPE ratio on the basis of open pan evaporation values which helps in working out permissible intervals between successive irrigations.

Criteria most suitable for scheduling irrigations vary from one situation to another. Although several approaches are available, best method of scheduling of irrigation and the choice of method is to be chosen based on experience. Scheduling irrigation based on climatologically approach is more precise and appropriate (Ramu *et al.,* 1991). Germination, seedling, flowering and grain formation stages were critical for irrigation and getting higher yield. Among different approaches to schedule irrigation, climatologically approach based on the ratio between irrigation water (IW) and cumulative pan evaporation (CPE) was found the most appropriate, as it integrates all the weather parameters giving their natural weightage in a given soil-water plant continuum (Parihar *et al.,* 1974).

Effect of moisture conservation practices and irrigation based on the ratio between irrigation water (IW) and cumulative pan evaporation (CPE) on pearl millet

Patel *et al*. (2010) recorded significantly higher values for growth, yield attributes, grain and fodder yield of pearl millet when irrigation scheduled at 1.1 IW: CPE ratio. The increase in grain yield under 1.1 IW: CPE ratio was to the tune of 18.2 per cent and 4.6 per cent over 0.7 and 0.9 IW: CPE ratios, respectively. Sonawane *et al.* (2010) found that the application of irrigation at 40 mm depth produced significantly higher grain yield, fodder yield and water use efficiency as compared to 60 mm irrigation depth. Irrigation scheduled at 1.00 IW/CPE ratio produced maximum grain yield but the water use efficiency was found to be significant at 0.50 IW/CPE ratio which was at par with irrigation given at critical growth stages. For obtaining the higher yield and water use efficiency of summer pearl millet, the application of 40 mm depth of irrigation water at critical growth stages was best Keshavarz *et al*. (2013) obtained the highest value for FFY and FDY in irrigation at 100% of filed capacity. Irrigated condition recorded significantly higher plant height, dry matter accumulation, root dry weight, ear head girth, test weight and yield of pearl millet than rainfed condition (Yadav *et al*., 2014). Tiwana *et al*. (2012) observed significantly higher fodder yield under irrigated condition as compared to un-irrigated and the magnitude of increase was 15.9 per cent. The high crude protein content (8.50%) was obtained in un-irrigated as compared to irrigated (8.01%) crop. The application of irrigation at IW/CPE ratio of 0.7 recorded significantly higher yields *viz*. grain and stover yield and soil moisture parameters *viz*. consumptive use of water, water use efficiency was at par with application of IW/CPE ratios of 0.9 (Bhuva and Sharma, 2016). Kachhadiya *et al*., (2010) registered significantly highest values of grain and dry fodder yields as well as protein content with 1.0 IW: CPE ratio, but it remained statistically at par with the 0.8 IW: CPE ratio in case of grain and dry fodder yields. Khafi *et al*. (2011) observed that grain and fodder yields of pearl millet were significantly affected due to different depths of irrigation and different irrigation intervals. Application of irrigation at 40 mm depth gave higher grain and fodder yield over 60 mm by 25 and 21 per cent, respectively. An increase in IW: CPE ratio from 0.50 to 1.00 favorably influenced almost all the growth attributes. Scheduling irrigation at 1.00 IW: CPE ratio out yielded the rest of the treatments by recording significantly higher grain and fodder yield and fodder yield was at par with irrigating the crop at 0.75 IW: CPE ratio. Net return of different treatments clearly indicated that IW: CPE ratio of 0.75 with 11 irrigations at 7-8 days interval gave the highest profit as compared to other ratios and also higher benefit : cost ratio of 1.32. Raval *et al*. (2014) reported that irrigation at 1.2 IW: CPE ratio produced significantly higher green fodder yield, dry matter yield, crude protein content and yield, available nitrogen and phosphorus over 0.6, 0.8 and 1.0 ratios. However, water use efficiency was higher with 0.8 IW/CPE ratios. Singh *et al.* (2008) found that increase in biomass accumulation was faster in irrigated plots than rainfed and it increased with N treatment. Drip irrigation at 150 per cent pan evaporation and 125 per cent N fertigation levels recorded higher crude protein content and crude protein yield as compared to control (Alagudurai and Muthukrishnan, 2014). Hence, new planting patterns *viz*. ridge, bed and seed drill system that act as the *in-situ* soil moisture conservation may be very beneficial.

Application of moisture conservation through modification in surface configuration as ridge and furrow, plastic mulch and seed hardening with 0.02% KNO_3 significantly enhanced grain yield of pearl millet by 22.21, 48.82 and 10.50 per cent, respectively and gave net returns of Rs. 23985, 28189 and 22765 ha^{-1}, with B: C ratio of 2.92, 3.29 and 2.86, respectively (Kanwar *et al*., 2015).

CONCLUSION

The low productivity of pearl millet is mainly attributed to its cultivation under dry land areas and improper irrigation management. So, judicious use of irrigation water offers a scope for improving the quality as well the productivity of this wonderful hardy crop. Generally two irrigations are sufficient. Most critical crop stages are after germination, tillering, ear head emergence (heading) and grain filling. The irrigation requirement when grown in the *Kharif* season varied from 150 to 200 mm in most parts of the country. It can tolerate 75 per cent depletion of available soil water from 0-30 cm depth. Criteria most suitable for scheduling irrigations vary from one situation to another. Although several approaches are available, best method of scheduling of irrigation and the choice of method is to be chosen based on experience. Among different approaches to schedule irrigation, climatologically approach based on the ratio between irrigation water (IW) and cumulative pan evaporation (CPE) was found the most appropriate, as it integrates all the weather parameters giving their natural weightage a given soil-water plant continuum.

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