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Influence of irrigation, fertility and hydrogel levels on yield and yield attributes of summer pearl millet (*Pennisetum glaucum* L.) in Gujarat

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Abstract

A field experiment was conducted during the summer seasons of 2015 and 2016 on loamy sand soils of Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to assess the impact of irrigation, fertility and hydrogel levels on growth attributes and yield of summer pearl millet [*Pennisetum glaucum* (L.) R. Br.]. The experiment was laid out in a split plot design with 3 replications, consisted of 3 irrigation levels [0.8, 1.0 and 1.2 irrigation water : cumulative pan evaporation ratio (IW: CPE)], 2 fertility levels (120 : 60 : 00 and 150 : 75 : 00 kg N : P₂O₅ : K₂O/ha) in main plots and 3 hydrogel levels (0.0, 2.5 and 5.0 kg/ha) in sub-plots. The pooled results indicated that irrigation at 1.2 IW/CPE being at par with 1.0 IW/CPE enhanced growth parameters viz., plant height, number of effective and non effective tillers, dry matter production, CGR and RGR and yield of pearl millet. Application of 150 : 75 : 00 kg N : P₂O₅ : K₂O/ha (125% RDF) significantly improved growth parameters, seed yield, stover yield and harvest index over 100 % RDF (120 : 60 : 00 kg N : P₂O₅ : K₂O/ha). Higher grain yield was a reflection of higher plant height, effective tillers/m, total dry-matter production, grain yield, stover yield and harvest index of pearl millet under application of 5.0 kg hydrogel/ha. Therefore, irrigation at 1.0 IW/CPE, fertilizer dose of 150 : 75 : 00 kg N : P₂O₅ : K₂O/ha and hydrogel @ 5.0 kg/ha could be applied for higher growth attributes and yields of pearl millet for appreciable saving of water and fertilizers in summer season.

Keywords: pearl millet, yield, irrigation, fertility levels, hydrogel

Introduction

India is the largest producer of pearl millet, the crop occupied an area of 8.69 million hectares, annual production of 10.05 million tonnes with an average productivity of 1156 kg/ha while in Gujarat state, pearl millet occupied an area of 9.32 lakh hectares with the production of 10.97 lakh tonnes and with the productivity of 1177 kg/ha during 2015-16 (Anonymous, 2016) [1]. Irrigation water is becoming scarce and the world is looking for water efficient agriculture. Increasing food demand and declining water resources are challenges for food security (Kreye *et al.*, 2009) [9]. The issue of water management has assumed paramount importance and occupied the centre stage of politico-economic debates in the world. Scheduling irrigation on the basis of evaporative demand results not only in efficient utilization of water but also in considerable saving of water. New method in science of soil and water is using super absorbent materials (hydrogels) as reservoirs and prevention from water wastage and increase of irrigation efficiency (Bedi *et al.*, 2004) [4]. The water absorbing products like hydrogel may be used as soil amendment to enhance water use efficiency (Huttermann, 2006) [7]. The growth of plants and their quality are mainly a function of the availability of fertilizer and water. Fertilizer use efficiency is closely related to soil moisture content. Inadequate or excess supply of any plant nutrient limits the crop production. To increase the agriculture production, there has been a tendency to apply higher level of fertilizers and irrigation water, often together (Hussain and Al-Jaloud, 1995) [6]. The optimum doses of nutrients for different crops were determined to the decades ago, but thereafter, the fertility status, crop varieties and other inputs have undergone a considerable change, so there is a need to give a fresh look to fertilizer requirement of pearl millet in the light of introduction of hybrids which has the potential yielding ability. Integration of irrigation with fertilizer management has great importance for achieving optimum and sustainable yields of pearl millet. Keeping these considerations in view, an experiment was carried out to study the effect of irrigation, fertility and hydrogel levels on growth parameters and yield of summer pearl millet.

Materials and Methods

A field experiment was conducted at the Agronomy Instructional Farm, Chimanbhai Patel

College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (24°19' N, 72°19' E, 154.52 m above the mean sea-level), banaskantha, Gujarat during summer seasons of 2015 and 2016 to study the effect of irrigation, fertility and hydrogel levels on summer pearl millet. The site of experiment is situated in the North Gujarat Agro-climatic Zone IV (AES-I) of Gujarat under Gujarat plains and hills zone of India. The climate of this region is semi-arid and sub-tropical with fairly dry and hot summer. The rainy season commences in the second fortnight of June and ends in August, with an average annual rainfall of 638 mm. July and August are the peak months of rainfall. Partial failures of monsoon once in three to four years are common occurrence in this region. Summer season commences in the second fortnight of March and ends in the middle of June. April and May are the hottest months of summer with the mean maximum temperature ranging from 32°C to 44°C. During crop season of the year 2015, the minimum temperature ranged from 14.8°C to 27.1°C, maximum temperature ranged from 30.1°C to 41.2°C and daily pan evaporation ranged from 3.2 to 13.5 mm/day, while in the year 2016, the minimum temperature ranged from 17.6°C to 27.7°C, maximum temperature ranged from 34.1°C to 45.2°C and daily pan evaporation ranged from 3.8 to 11.2 mm/day. The weather parameters, viz. mean relative humidity, wind velocity and sunshine hours were normal during both the years of experiment period. The off season rainfall was not received during the crop period. In general, the weather conditions were congenial during crop season of both the years. The experimental site had an even topography with a gentle slope and good drainage. The experimental soil was loamy sand (83.90% sand, 5.55% silt and 9.84% clay) in texture and slightly alkaline in reaction with pH 7.41 and ECe 0.13 dS/m. It was moderately fertile being low in organic carbon (2.5 g/kg) and low in available nitrogen (167.5 kg/ha), medium in available phosphorus (39.5 kg/ha) and high in available potassium (269.5 kg/ha). Besides, initial bulk densities of the soil were 1.44 and 1.45 Mg/m³ in 0–15 and 15–30 cm depth respectively. The eighteen treatment combinations consisted of three levels of irrigation [0.8, 1.0 and 1.2 irrigation water: cumulative pan evaporation ratio (IW: CPE)], 2 fertility levels (120: 60 : 00 and 150 : 75 : 00 kg N : P₂O₅ : K₂O/ha) in main plots and 3 hydrogel levels (0.0, 2.5 and 5.0 kg/ha) as sub-plots treatments were evaluated using split-plot design with 3 replications. The field plots of size 5.0 m × 4.5 m were separated from each other by using 1 m buffer rows. The measured quantity of fertilizers and hydrogel was drilled in the soils at 5 cm below the seed according to treatments. 'Gujarat Hybrid Bajara 732' was selected for the present investigation. It has attractive seed colour and bold seed size. The seeds were sown keeping 45 cm row spacing using 3.75 kg seeds/ha on 02 and 01 March during 2015 and 2016 respectively. The crop was irrigated immediately after sowing during both the years. Thereafter, irrigation was given as per treatment schedule based on irrigation water: cumulative pan evaporation ratio (IW: CPE). The excess plants were thinned out at 20 days after sowing (DAS) keeping within row distance at 15 cm for maintaining uniform plant stand. The required cultural practices were followed as per recommended package. Weeds were managed by two weeding at 25 and 45 DAS and an intercultural operation with hand hoe at 25 DAS. The quantity of irrigation water applied in each experimental plot was measured with a 7.5 cm throat size Parshall flume installed in the main water channel near the field head. The cumulative pan evaporation (CPE) values were calculated from daily pan evaporation measured with the help of USWB Class 'A' open

pan evaporimeter installed at the meteorological observatory of the farm. Irrigations were applied as per treatment on the basis of IW: CPE approach using 50 mm depth of irrigation water. Time for applying the measured quantity of irrigation water to each plot was calculated using the standard equation. The soil moisture studies were started from sowing of crop and continued up to its maturity. The soil moisture content of all the treatments was determined on same day just before irrigation and 48 hours after irrigation at 0–15, 15–30, 30–45 and 45–60 cm soil depth. The data obtained on moisture percentage in each depth were used for calculating seasonal consumptive use of water for pearl millet. The depth of water table was more than fifty meters below the surface throughout the period of experimentation. The total number of irrigations required were 9, 11 and 13 during 2015 and 11, 13 and 15 during 2016 for 0.8, 1.0, and 1.2 IW : CPE, respectively excluding the one common irrigation provided for sowing and better establishment during both the years of experiment. The evapotranspiration observed during growing seasons of 2015 and 2016 were 664.7 and 757.0 mm respectively. The crop was harvested on 30 and 29 May during 2015 and 2016, respectively. The plant height and tillers/plant were recorded from five selected plant at 30, 60 DAS and at harvest from each plot. Penultimate rows of each plot were used for recording dry matter accumulation at 30, 60 DAS and at harvest. The yield attributes, viz. number of ear heads, girth of earhead, length of earhead, grains weight/earhead and 1000-grain weight were recorded at the time of harvesting. The crop was harvested manually with the help of sickle when seed almost matured and stover had turned yellow. The sun dried bundles were threshed and winnowed and seed so obtained were weighed and data on seed and stover yields were recorded. Harvest Index (HI) was calculated by dividing the seed yield with biological yield. The economics of the treatments was carried out on the basis of prevailing market prices of inputs and outputs. Gross returns were calculated based on the seed and stover yields of the crop and their prevailing market prices during the respective crop seasons. Net returns were calculated by subtracting cost of cultivation from gross returns. The benefit: cost ratio was calculated by dividing the net returns with cost of cultivation. The statistical analysis of data was done using analysis of variance (ANOVA) technique for split plot design at 0.05 probability level.

Results and Discussion

Yield attributes

Pooled results indicated that irrigation at 1.2 IW/CPE registered highest values of yield attributing characters, viz. yield attributes viz., number of earheads (15.64/metre row), girth of earhead (12.76 cm), length of earhead (24.72 cm), grains weight/earhead (13.0 g), 1000-grain weight (12.44 g). The higher performance of these attributes over 0.8 IW: CPE of 1.0 might be due to increase in number of irrigations applied at shorter intervals. This situation avoids moisture stress and provided a favorable condition for moisture and nutrient availability to the crop. Similar findings were reported by Kachhadiya *et al.* (2010)^[8]. The availability of adequate moisture with 1.0 and 1.2 IW: CPE might be resulted in better translocation and partitioning of these photosynthates from source to sink and increased the grains weight/earhead, 1000-grain weight. Patel *et al.* (2013) also observed increased in yield attributes with higher irrigation over lower one in pearl millet.

Application of 150:75 : 00 kg N : P₂O₅ : K₂O/ha (125 % RDF) significantly improved yield attributes. Significantly higher

values of yield attributes, viz. number of earheads (16.32/metre row), girth of earhead (11.56 cm), length of earhead (23.58 cm), grains weight/earhead (12.82 g), 1000-grain weight (12.35 g) over 120 : 60 : 00 kg N : P₂O₅ : K₂O/ha (100 % RDF). Better growth under 150 : 75 : 00 kg N : P₂O₅ : K₂O/ha (125 % RDF) might have produced and converted more photosynthates into numerous metabolites needed for such yield attributes. Sharma *et al.*, (2000) found that the increase in 1,000-seed weight for higher fertility level is due to the better filling of seeds, which resulted in bold sized seeds and consequently higher 1,000-seed weight.

Application of hydrogel application @ 5.0 kg/ha (treatment H₂) showed its significant superiority in case of number of earheads (15.34/metre row), girth of earhead (11.24 cm), length of earhead (23.27 cm), grains weight/earhead (12.65 g), 1000-grain weight (13.02 g) over treatment H₁ and H₀. The results of the present investigation showed that an increase in hydrogel level significantly increased the girth of earhead. As the water content of the plant decreases, cell shrinks and turgor pressure against cell walls relaxes. This decrease in cell volume resulting from lower turgor pressure subsequently concentrates solutes in cells. SAPs increase the turgor pressure inside the cells by maintaining sufficient amount of water as per plant need and thus causing increase in yield attributes and other related parameters (Yazdani *et al.*, 2007) [18].

Yield

The result with respect to seeds and stover yields indicated that irrigation level had appreciably influenced the seed and stover yields of pearl millet. The irrigation at 1.2 IW: CPE produced significantly highest seed and stover yields as compared to 0.8 IW: CPE and remained at par with IW: CPE of 1.0. The increase in seed yield under 1.2 IW: CPE over 0.8 and 1.0 was 7.17 and 27.93%, while that of stover was 13.43 and 39.63% respectively. The higher seed and stover yields with 1.2 and 1.0 IW: CPE could be attributed to increased soil moisture coupled with accelerated nutrients uptake, which helped the plant to put optimum growth. Increase in seed and stover yields with an application of irrigation at 0.7 IW: CPE was also reported by Sonawane *et al.* (2010). The harvest index of pearl millet was not significantly influenced by irrigation, fertility and hydrogel levels in both the years of study. As a well established fact harvest index is more or less governed by genetical make up of a plant and is not influenced much more by input supply system if crop is raised under recommended practices. Our results also follow the same pattern.

The fertility level 150:75 kg N:P₂O₅/ha (125% RDF) produced significantly the highest seed and stover yield as compared to 120:60 kg N:P₂O₅/ha. The extent of increase in seed and stover yields under 150:75 kg N:P₂O₅/ha was 15.46 and 11.98% respectively over the 100% RDF. This might be due to

adequately fertilized crop benefited from higher rates of nutrition that might have resulted into a more vigorous and extensive root system of crop leading to increased vegetative growth means for more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the grains and longer and thicker earhead, ultimately reflected in higher grain and stover yield of pearl millet. These findings are corroborating with the results of Parihar *et al.* (2010) [13] and Kumar *et al.* (2014) [10].

Maximum grain yield (4488 kg/ha) and stover yield (7480 kg/ha) was registered under treatment H₂ (hydrogel application @ 5.0 kg/ha) which was significantly superior to the yields obtained under other levels of hydrogel. These results are coinciding with that obtained by Waly *et al.* (2015) [17] in rice. Hydrogel is a hydrophilic or super absorbent polymer has shown the potential to realize more yield per unit of input. Its application to the soil helped in retaining more moisture in the soil, increased water holding capacity of polymer and decreased infiltration rate of soil. Increasing the levels of hydrogel has increased water use efficiency over control.

Economics

The results pertaining to the cost: benefit analysis of the crop as influenced by irrigation levels indicated that application of irrigation at 1.2 IW: CPE recorded the highest net returns (₹ 70,571/ha) with the maximum benefit: cost ratio of 1.67, whereas irrigating at an IW: CPE of 1.0 recorded the at par value of benefit: cost ratio. The higher net returns/ha under 1.2 IW: CPE could be attributed to significantly higher seed and stover yield under this treatment as compared to other levels of irrigation. The results are in concurrence with those reported by Pareek *et al.* (2015). Fertility level The fertility level 150:75 kg N:P₂O₅/ha (125% RDF) produced significantly the highest net returns of ₹ 66564/ha with the highest benefit: cost ratio of 1.64. The higher net gain/ha under 125% RDF could be attributed to significantly higher yields as compared to 100% RDF. The highest net return (₹ 66011/ha) was recorded in the treatment H₂ (5.0 kg hydrogel/ha) while different levels of hydrogel failed to exert any significant effect on benefit: cost ratio.

Based on the study it is concluded that summer pearl millet sown in loamy sand soils of Gujarat region with 1.2 IW: CPE recorded the higher seed yield and gained the highest net returns and benefit: cost ratio over all the irrigation treatments. Fertility level 150:75 kg N: P₂O₅/ha and hydrogel level 5.0 kg/ha seems to be optimum for getting higher seed yield and monetary returns. Therefore, irrigation at 1.2 IW: CPE along with application of 150:75 kg N:P₂O₅/ha and 5.0 kg/ha hydrogel could be applied for higher yield and economical realization from pearl millet along with appreciable saving of water in summer season.

Table 1: Yield attributes of pearl millet as influenced by irrigation, fertility and hydrogel levels (pooled mean of 2 years)

Treatments	Number of earhead/ metre	Length of earhead (cm)	Girth of earhead (cm)	Grain weight/earhead(g)	1000-grain weight (g)
Main Plot A. Irrigation levels					
I ₁ : 0.8 IW : CPE	13.92	19.02	9.03	11.50	12.10
I ₂ : 1.0 IW : CPE	14.85	23.80	11.25	12.38	12.28
I ₃ : 1.2 IW : CPE	15.64	24.72	12.76	13.00	12.44
S.Em. ±	0.403	0.354	0.120	0.217	0.038
C.D. at 5 %	1.160	1.020	0.346	0.626	0.109
Main Plot B. Fertility levels					
F ₁ : 100 % RDF	13.44	21.45	10.46	11.77	12.20
F ₂ : 125 % RDF	16.32	23.58	11.56	12.82	12.35
S.Em. ±	0.329	0.289	0.098	0.177	0.031
C.D. at 5 %	0.947	0.832	0.282	0.511	0.089

Sub Plot C. Hydrogel levels					
H ₀ : No Hydrogel	14.05	21.74	10.77	11.78	11.55
H ₁ : 2.5 kg/ha	14.85	22.54	11.02	12.55	12.26
H ₂ : 5.0 kg/ha	15.34	23.27	11.24	12.65	13.02
S.Em. ±	0.200	0.174	0.073	0.136	0.032
C.D. at 5 %	NS	0.490	0.205	0.383	0.090

Table 2: Yield and Harvest index of pearl millet as influenced by irrigation, fertility and hydrogel levels (pooled mean of 2 years)

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)	Net return (₹/ha)	Benefit : Cost Ratio
Main Plot A. Irrigation levels					
I ₁ : 0.8 IW : CPE	3526	5810	38.00	47691	1.26
I ₂ : 1.0 IW : CPE	4209	7152	36.86	63132	1.58
I ₃ : 1.2 IW : CPE	4511	8113	35.71	70571	1.67
S.Em. ±	76.9	160.3	0.658	1640	0.040
C.D. at 5 %	322	981	NS	4725	0.116
Main Plot B. Fertility levels					
F ₁ : 100 % RDF	3789	6628	36.38	54364	1.38
F ₂ : 125 % RDF	4375	7422	37.33	66564	1.64
S.Em. ±	62.8	130.3	0.537	1339	0.033
C.D. at 5 %	181	376	NS	3858	0.095
Sub Plot C. Hydrogel levels					
H ₀ : No Hydrogel	3683	6577	36.01	55085	1.50
H ₁ : 2.5 kg/ha	4076	7017	37.00	60298	1.51
H ₂ : 5.0 kg/ha	4488	7480	37.56	66011	1.53
S.Em. ±	68.6	111.3	0.589	1270	0.032
C.D. at 5 %	194	314	NS	3581	NS

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