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Growth, phenology and yield of summer Pearl millet (*Pennisetum glaucum* L.) as affected by varied application of water, nutrients and hydrogel

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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, yield and economics 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: P_2O_5: K_2O/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: P_2O_5: K_2O/ha (125% RDF) significantly improved growth parameters, seed yield, stover yield and harvest index over 100 % RDF (120: 60: 00 kg N: P_2O_5: K_2O/ha). Higher grain yield was a reflection of higher plant height, effective tillers/m, total dry-matter production, grain yield and stover yield of pearl millet under application of 5.0 kg hydrogel/ha. Significantly the highest net returns was obtained under higher levels of inputs *viz.*, irrigation, nutrients and hydrogel.

Keywords: pearl millet yield, growth, phenology, water, nutrients, hydrogel

Introduction

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Pearl millet (*Pennisetum glaucum* L.) is an important drought hardy millet crop and satiates the nutritional security for poor people in a short period. Pearl millet is cultivated during both *kharif* and summer seasons basically on light textured sandy soils of arid and semi-arid regions of the world. 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) [7]. 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) [3]. The water absorbing products like hydrogel may be used as soil amendment to enhance water use efficiency (Huttermann, 2006) [6]. 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). 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 (24º19' N, 72º19' 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. 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 32ºC to 44ºC. During crop season of the year 2015, the minimum temperature ranged from 14.8ºC to 27.1ºC, maximum temperature ranged from 30.1ºC to 41.2ºC and daily pan evaporation ranged from 3.2 to 13.5 mm/day, while in the year 2016, the minimum temperature ranged from 17.6ºC to 27.7ºC, maximum temperature ranged from 34.1ºC to 45.2ºC 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 *p*H 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). 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: P_2O_5: K_2O/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 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. 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 required cultural practices were followed as per recommended package. 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 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. For dry-matter accumulation, plant material first air dried, then chopped and oven dried at 70ºC for 72 hrs to a constant weight. The sun dried bundles were threshed and winnowed and seed so obtained were weighed and data on seed and stover yields were recorded. The economics of the treatments was carried out on the basis of prevailing market prices of inputs and outputs. 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

Growth parameters

Significantly higher plant height at 30, 60 days after sowing (DAS) and at harvest was recorded at an IW: CPE of 1.2 over IW: CPE of 0.8 and 1.0. The increase in the plant height might be due to optimum supply of soil moisture surrounding the root zone, which cause favourable improvement in the uptake and translocation of the nutrients and ultimately linked with the plant growth and development in terms of plant height. Increased plant height with increasing level of irrigation was also reported by Patel *et al.* (2013). Application of irrigation at an IW: CPE of 1.2 recorded significantly higher number of effective tillers and lowest number of non-effective tillers over rest of irrigation levels IW: CPE of 0.4 and 0.6 but remained at par with 0.8 IW: CPE.

Among the treatments during all the growth stages the performance of pearl millet crop.

Dry matter was significantly different and it was in the decreasing order of 1.2 IW: CPE > 1.0 IW: CPE > 0.8 IW: CPE treatments during all the stages of growth in pooled analysis. Improved growth in terms of dry-matter accumulation at 30, 60 DAS and harvest was attained with higher IW: CPE of 1.0 and 0.8. As water is not a limiting factor, plant can absorb more nutrients from soil, which encourages physiological processes such as cell division and cell expansion. Hence leaves/plant increased and ultimately it reflected in higher dry matter accumulation. The dry-matter is a cumulative effect of all growth parameters like plant height, number of tillers etc. which were significantly more in 1.2 IW: CPE, the resultant dry matter also more. Similar increase in dry matter accumulation with higher level of irrigation was also reported by Pareek *et al*. (2015) [9]. Higher level of irrigation also recorded significantly more crop growth rate and better relative growth rate than lower level of irrigation, could be owing to maintaining its progeny with the available resources.

Fertility levels had also significant effect on plant height at 30, 60 days after sowing (DAS) and at harvest. The higher plant height and effective tillers were recorded under 150:75 kg N: P_2O_5/ha over 120: 60 kg N: P_2O_5/ha, while the lowest non effective tillers was registered under higher fertility level (Table 1). The increase in these components seems to have been brought about by increase in amount of growth substances and naturally occurring phyto hormones with increased fertility supply. Probably the increase in auxin supply with higher levels of fertility brought about increase in the tillers/plant. Application of fertilizer at 150:75 kg N: P_2O_5/ha recorded significantly higher dry matter/plant at 30, 60 DAS and at harvest. Improved dry matter production at higher levels of fertility (125% RDF) may be attributed to the fact that nutrients being important constituent of nucleotides, proteins, chlorophyll and enzymes, involves in various metabolic processes which have a direct impact on vegetative and reproductive phase of pearl millet plants. Beneficial effects of higher levels of fertility on dry matter production in pearl millet were also reported by Tetarwal and Rana (2007), Kumar *et al*. (2014). Higher level of fertilizer recorded the maximum crop growth rate at better relative growth rate whereas; the poor growth rates were registered under lower fertility treatment (F_1).

A perusal of pooled data (presented in Table 1 & 2) revealed that plant height, number of effective tillers and dry matter accumulation was highest with application of 5.0 kg hydrogel/ha while minimum under no hydrogel application treatment during all the stages of observations. This increase in these growth parameters was due to more retention of moisture and indirectly the availability of nutrients provided by hydrophilic polymer, where it might have helped to increase the activity of cell division, expansion and elongation, ultimately leading to increased growth. Similar results were also observed by

Anupama *et al.* (2005) in chrysanthemum. Application of hydrogel @ 5.0 kg/ha also registered highest CGR and RGR on pooled basis. Significantly higher dry matter production value was recorded in polymer treated soil at all stages of crop. This suggested that super absorbent polymer resulted in increased dry matter production, CGR and RGR. Polymers improve water holding capacity and nutrient supplying capacity of soil which ultimately improve growth and dry matter production of plants (El-Hady *et al*., 1981).

Phenology

Days to five leaf stage, flag leaf stage and days to physiological maturity was significantly influenced by irrigation, fertility and hydrogel levels. (Table 3). Each higher level of irrigation from 0.8 to 1.2 IW: CPE significantly reduced the number of days taken for five leaf stage, flag leaf stage and days to physiological maturity. On the pooled data basis, five leaf stages was attained earlier when the crop was irrigated at 1.2 IW: CPE while the stage was significantly delayed when there was moisture deficit condition (irrigation at 0.8 IW: CPE). This might be due to very favourable conditions for nutrients flow under higher levels of irrigation. Higher level of fertility (treatment $F_{2:}$ 125 % RDF) significantly reduced the number of days taken to five leaf stage of pearl millet. The treatment F_2 (125 % RDF) had taken significantly lesser number of days (19.35 days) to attend the five leaf stage in pooled data as compared to days taken under treatment F_1 (100 % RDF). Such type of changes might be taken place due to enhanced metabolic activities under higher fertility levels. Rani (2007) also observed the similar effects of fertilizer application on the phenophasic development of pearl millet genotypes. Application of 5.0 kg hydrogel/ha (treatment H_2) showed its significant superiority by attending five leaf stage in 19.70 days. This duration was earlier than days taken under no hydrogel and 2.5 kg hydrogel/ha application treatments.

In similar fashion, flag leaf stage was attained earlier (44.14 days) when the crop was irrigated at 1.2 IW: CPE while the stage was significantly delayed when there was moisture deficit condition (irrigation at 0.8 IW: CPE). The earliness in emergence of flag leaf is due to rapid translocation of photosynthates towards active growing parts of plant under ample nutrient flow under higher moisture levels. Higher level of fertility treatment F_2 (125 % RDF) significantly reduced the number of days taken to flag leaf stage in pearl millet. The treatment F_2 (125 % RDF) taken significantly lesser number of days 44.34 days to attain the flag leaf stage as compared to days taken under treatment F_1 (100 % RDF). Application of hydrogel @ 5.0 kg/ha (treatment H_2) showed its significant superiority by attending flag leaf stage in 45.14 days which was earlier than days taken under no hydrogel and 2.5 kg hydrogel application treatments.

Barihi *et al.* (2013) reported that the enhancement in soil moisture retention and improvement in seed germination and seedling growth due to superabsorbent hydrogel amendments resulted in early emergence of flag leaf.

Pearl millet crop physiologically matured statistically in similar days whether it was irrigated at 0.8, 1.0 and 1.2 IW: CPE. However, the crop attended physiological maturity earlier (79.87 days) when, it was irrigated at 0.8 IW: CPE over rest of irrigation levels. Crop remains in green stage for longer period (82.36 days) it was irrigated frequently (treatment $I_{3:}$ 1.2 IW: CPE). Crop grown under higher level of fertility (treatment $F_{2:}$ 125 % RDF) physiologically matured in minimum days 80.52 days. There were no significant differences in pearl millet genotype GHB 732 among various treatments of irrigation, fertility and hydrogel in terms of number of days taken to physiological maturity. This might be due to the basic nature of the crop that phenology of a crop (genotype trait) might not be influenced markedly by some factors of crop growth and development. Rani (2007) also observed the similar effects of fertilizer application on the phenophasic development of pearl millet genotypes. Pearl millet crop physiologically matured statistically in similar number of days whether, it got higher level of hydrogel treatment 5.0 kg/ha or no hydrogel treatment. Physiological maturity of crop might be delayed under hydrogel treated plots due to availability of moisture for longer period.

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. The fertility level 150:75 kg $N:P_2O_5$/ha (125% RDF) produced significantly the highest seed and stover yield as compared to 120:60 kg $N:P_2O_5$/ha. The extent of increase in seed and stover yields under 150:75 kg $N:P_2O_5$/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 Kumar *et al*. (2014).

Maximum grain yield (4488 kg/ha) and stover yield (7480 kg/ha) was registered under treatment H_2 (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) 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) [9]. 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 H_2 (5.0 kg hydrogel/ha) while different levels of hydrogel failed to exert any significant effect on benefit: cost ratio.

Table 1: Plant height and tillers/plant of summer pearl millet as influenced by irrigation, fertility and hydrogel levels (pooled of 2 years)

Treatments	Plant height (cm)			Tillers/plant	
	30 DAS	60 DAS	At harvest	Effective	Non effective
Main Plot A. Irrigation levels					
I_1: 0.8 IW: CPE	42.5	112.3	145.8	2.21	1.43
I_2: 1.0 IW: CPE	55.9	140.8	181.8	2.32	1.00
I_3: 1.2 IW: CPE	68.4	152.9	191.7	2.37	0.88
S.Em. ±	0.8	1.9	2.4	0.027	0.029
C.D. at 5 %	2.3	5.4	7.0	0.077	0.083
Main Plot B. Fertility levels					
F_1: 100 % RDF	50.4	129.6	167.3	2.10	1.24
F_2: 125 % RDF	60.8	141.1	179.0	2.51	0.97
S.Em. ±	0.7	1.5	2.0	0.022	0.023
C.D. at 5 %	1.9	4.4	5.7	0.063	0.068
Sub Plot C. Hydrogel levels					
H_0: No Hydrogel	49.3	128.9	166.4	2.23	1.14
H_1: 2.5 kg/ha	54.7	134.3	172.3	2.32	1.12
H_2: 5.0 kg/ha	62.8	142.9	180.6	2.36	1.06
S.Em. ±	0.3	0.9	1.1	0.016	0.012
C.D. at 5 %	0.9	2.4	3.2	0.045	0.033

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

Treatments	Dry matter accumulation/plant (g)			CGR (g m^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
	30 DAS	60 DAS	At harvest	At 30-60 DAS	At 30-60 DAS
Main Plot A. Irrigation levels					
I_1: 0.8 IW: CPE	2.22	34.30	66.65	26.73	0.0913
I_2: 1.0 IW: CPE	4.83	39.87	76.12	29.20	0.0703
I_3: 1.2 IW: CPE	5.60	43.30	83.86	31.42	0.0681
S.Em. ±	0.030	0.639	0.623	0.511	0.0004
C.D. at 5 %	0.086	1.839	1.794	1.471	0.0010
Main Plot B. Fertility levels					
F_1: 100 % RDF	3.97	36.75	72.66	27.31	0.0767
F_2: 125 % RDF	4.46	41.56	78.42	30.92	0.0764
S.Em. ±	0.024	0.521	0.508	0.417	0.0003
C.D. at 5 %	0.071	1.502	1.465	1.201	NS
Sub Plot C. Hydrogel levels					
H_0: No Hydrogel	4.14	38.34	70.03	28.49	0.0765
H_1: 2.5 kg/ha	4.23	39.11	75.31	29.07	0.0764
H_2: 5.0 kg/ha	4.27	40.02	81.29	29.79	0.0768
S.Em. ±	0.021	0.302	0.403	0.245	0.0003
C.D. at 5 %	0.058	0.852	1.137	0.691	NS

Table 3: Phenological stages, yield and economics of pearl millet as influenced by irrigation, fertility and hydrogel levels (pooled of 2 years)

Treatments	Phenological stages (days)			Grain yield (kg/ha)	Stover yield (kg/ha)	Net return (`/ha)	Benefit: Cost Ratio
	Five leaf	Five leaf	Physiological maturity				
Main Plot A. Irrigation levels							
I_1: 0.8 IW: CPE	21.16	48.75	79.87	3526	5810	47691	1.26
I_2: 1.0 IW: CPE	20.06	46.21	81.26	4209	7152	63132	1.58
I_3: 1.2 IW: CPE	19.48	44.14	82.36	4511	8113	70571	1.67
S.Em. ±	0.302	0.655	0.677	76.9	160.3	1640	0.040
C.D. at 5 %	0.870	1.887	NS	322	981	4725	0.116
Main Plot B. Fertility levels							
F_1: 100 % RDF	21.12	48.40	81.81	3789	6628	54364	1.38
F_2: 125 % RDF	19.35	44.34	80.52	4375	7422	66564	1.64
S.Em. ±	0.247	0.535	0.552	62.8	130.3	1339	0.033
C.D. at 5 %	0.710	1.541	NS	181	376	3858	0.095
Sub Plot C. Hydrogel levels							

H_0: No Hydrogel	20.80	47.68	80.70	3683	6577	55085	1.50
H_1: 2.5 kg/ha	20.20	46.29	81.01	4076	7017	60298	1.51
H_2: 5.0 kg/ha	19.70	45.14	81.78	4488	7480	66011	1.53
S.Em. ±	0.169	0.381	0.408	68.6	111.3	1270	0.032
C.D. at 5 %	0.477	1.074	NS	194	314	3581	NS

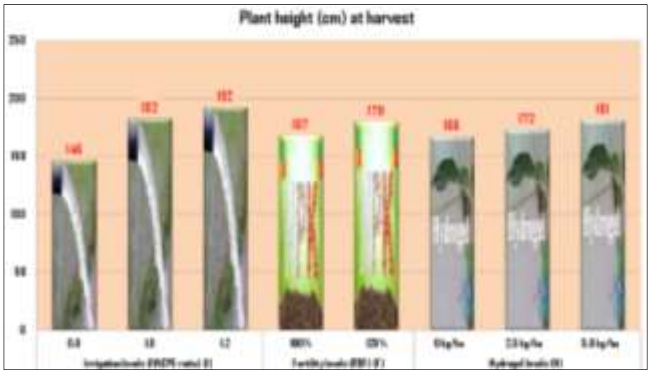

Fig 1: Plant height (cm) at harvest of summer pearl millet as influenced by irrigation, fertility and hydrogel levels (Mean of pooled)

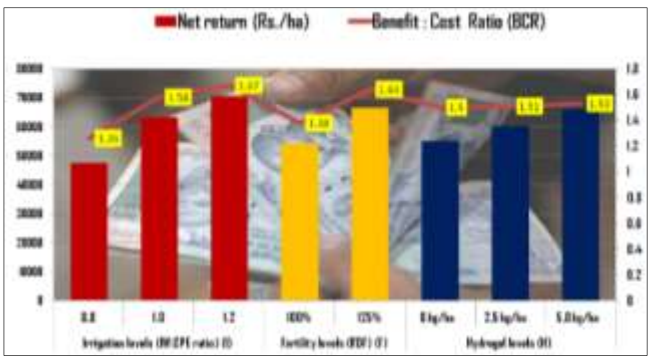

Fig 2: Economics of summer pearl millet as influenced by irrigation, fertility and hydrogel levels (Mean of pooled)

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