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Effect of hydrogel and irrigation scheduling on growth, yield and quality of summer pearl millet (*Pennisetum glaucum* L.)

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Abstract
Field experiment was conducted on "Effect of hydrogel and irrigation scheduling on growth, yield and quality of summer pearl millet (*Pennisetum glaucum* L.)" was carried out during summer season of 2020 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh. There were nine treatment combination consisting of three irrigation scheduling based on IW/CPE ratio (I_1= 0.6, I_2= 0.8 and I_3= 1.0) and three hydrogels (H_1= 0.0 kg/ha, H_2= 2.5 kg/ha and H_3= 5.0 kg/ha) were tested in a split plot design with three replications. Results indicated that scheduling irrigation at an IW/CPE ratio of 1.0 recorded significantly higher values of plant height (30, 60 DAS and at harvest), number of tillers per plant. Similarly, irrigation scheduling at 1.0 recorded significantly higher value of yield and quality components *viz.*, effective tillers per plant, length and girth of earhead as well as grain weight per earhead, grain yield (4563 kg/ha), stalk yield (7718 kg/ha) and protein yield. Almost all the growth characters, yield attributes, grain and stalk yields as well as net return and B : C ratio of pearl millet was found significantly higher when crop was sown at H_2 (hydrogel at 5.0 kg/ha) over H_1 (hydrogel at 2.5 kg/ha) and H_0 (hydrogel at 0.0 kg/ha). Interaction between irrigation scheduling and hydrogel levels was also observed significant for number of effective tillers per plants, grain weight per earhead, grain and stalk yield ha^{-1} under treatment combination I_3H_2 followed by I_2H_2.In correlation study indicated that grain yield had highly significant positive correlation with almost all the growth and yield attributes and quality traits. Higher gross and net realization with B:C ratio were obtained when crop was irrigated with IW/CPE ratio of 1.0 and hydrogel at 5.0 kg/ha followed by 0.8 IW/CPE ratio on medium black soil of South Saurashtra Agro climatic conditions.

Keywords: Pearl millet, irrigation, hydrogel, IW/CPE ratio, water use efficiency

Introduction
Pearl millet is the most widely grown type of millet. Because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature. It also provides good quality fodder to cattle in the arid and semi-arid tropical regions, and recognized as valuable forage crop because of its robust and quick growth habit. 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) [6]. 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) [1]. The water absorbing products like hydrogel may be used as soil amendment to enhance water use efficiency (Huttermann, 2006) [4]. 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) [5]. 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 hydrogel and irrigation scheduling on growth, yield and quality of summer pearl millet.

Materials and Methods

The experiment was conducted during the *Zaid* season of 2020 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat). The Instructional Farm is situated at 21.5^0 N latitude and 70.5^0 E longitudes with an altitude of 60 meters above the mean sea level and 80 kilometers away from Arabian Sea coast on Western side at the foothill of the mount Girnar. The experiment was laid out in split plot design, replicated thrice. The treatment comprised of 3 Irrigation scheduling, noted as I_1 (0.6 IW/CPE), I_2 (0.8 IW/CPE) and I_3 (1.0 IW/CPE) assigned as main plot. Each main plot was further divided into 3 sub plots, i.e. Hydrogel levels H_0 (0 kg/ha Hydrogel), H_1 (2.5 kg/ha Hydrogel), H_2 (5.0 kg/ha Hydrogel) through surface application and the possible combination is presented in Table 1 with details of pearl millet crop. During the growing season, the mean maximum and minimum temperature during the crop growth and development period ranged between 29.8 to 43.5 °C and 14.2 to 28.5 °C, respectively. The summer season remained very hot particularly during second week of April to first week of June (15^{th} to 23^{rd} standard week) with maximum temperature below 43.2 °C and minimum temperature above 28.5 °C. The range of average relative humidity, bright sun shine, wind speed and daily evaporation was 27.0-86.0 %, 7.3-10.3 h, 4.5-7.5 km/h and 5.5-12.1 mm, respectively. Pearl millet was sown at a spacing of 60 × 10 cm using seed rate of 3-4 kg/ha. The field was uniformly irrigated before one day of sowing and further irrigated based on treatment. The RDF (80-40-0 NPK kg/ha) i.e Nitrogen (80 kg/ha) was applied through urea and DAP in two equal splits, first as basal and remaining dose at 30 DAS (days after sowing), whereas full dose of P_2O_5 (40 kg/ha) were applied as basal through DAP. Hydrogels were applied in each plots according to the treatments before sowing of seed along with fertilizers during first split as basal. Observations on growth parameters, yield attributes and yield of pearl millet, was recorded and their significance was tested by the variance ratio (F value) at 5% level (Gomez and Gomez, 1984). Relative economics was calculated as per the prevailing market prices of the inputs and produced during summer season.

Results and discussion

A. Growth parameter

Growth parameters of pearl millet, *viz.* plant height (cm), days to full stigmatic stage, Days to maturity, total tillers, effective tillers, earhead length (cm), earhead girth (cm) and test weight (g) varied due to different irrigation scheduling and hydrogel level are presented in Table 1. The treatment receiving 1.0 IW/CPE (I_3) resulted in higher plant height (187 cm), total tillers (5.46), effective tillers (3.72), earhead length (22.66 cm) and earhead girth (10.83 cm). In the above treatment, I_3 was recorded significantly higher plant height (cm), total tillers, effective tillers, earhead length and earhead girth was found statistically similar followed by 0.8 IW/CPE (I_2). While increasing dose of hydrogel level 5.0 kg/ha (H_2) also contributed significantly higher plant height (181 cm), total tillers (5.12), effective tillers (3.47), earhead length (21.72 cm) and earhead girth (10.67 cm) and it was statistically at par with hydrogel level 2.5 kg/ha (H_2). Optimum crop resulted from higher nutrient availability due to the effect of irrigation at important phases, adding hydrogel improves water holding capacity of soil which ultimately improves growth and Dry matter production of plants (Saini *et al.*, 2018) [10]. Growth attributing characters such as days to full stigmatic stage, days to maturity and test weight showed non-significant result for irrigation scheduling and hydrogel level. Higher earhead length (cm) was recorded significantly superior under 1.0 IW/CPE (I_3), which help to maximum yield. In case of hydrogel level (H_2) increased the effective tillers/plant and earhead length significantly over no hydrogel application. Irrigation scheduling and hydrogel application resulted in higher yield attributes over less irrigation (I_1) and no hydrogel application (H_0). Due to sufficient moisture surrounding root zone promotes vegetative growth and hence length and girth of earhead increased and also increased test weight with increase in hydrogel level and frequency of irrigation, similar results reported by Sayyari and Ghanbari, (2012) [8] and Saini *et al.*, (2018) [10].

B. Yield

Grain weight per earhead, grain and stalk yield significantly higher for irrigation scheduling for 1.0 IW/CPE (I_3) and hydrogel level 5.0 kg/ha (H_2) are showed in Table 2. Grain and stalk yield varied considerably significant due to various irrigation scheduling and application of 1.0 IW/CPE (I_3) recorded up to 30.2 % and 15.2 % higher grain yield than that of 0.6 IW/CPE (I_1) and 0.8 IW/CPE (I_2) respectively. Stalk yield significantly higher under 1.0 IW/CPE (I_3) (7718 kg/ha). In case of hydrogel, 5.0 kg/ha hydrogel application recorded significantly higher grain yield which fetched 16.5 % more over no hydrogel application. Similar findings recorded in stalk yield due to application of hydrogel 5.0 kg/ha (7152 kg/ha) produced more biomass significantly over other hydrogel application. Biological yield increase for more irrigation scheduling and higher level of hydrogel. Harvest index and quality parameter like as protein content found non-significant result. Increase in irrigation frequency and hydrogel levels tended in increase consumptive use of water, which provided congenial condition throughout the growth period of the crop more over less moisture stress experienced by crop during their vegetative and reproductive growth period, that too later stages of crop growth resulting in an improvement of growth and yield attributing characters, thereby produced higher grain and dry folder yield was confirmed with the result of Singh, (2012) [9] and Saini *et al*., (2020) [7].

C. Water use efficiency

Water use efficiency refers largely to the production of economic produce of crop per unit of water used by it throughout the life of crop. Unlike consumptive use of water, the water use efficiency decrease with each successive increase in IW/CPE ratio (Table 3). The highest mean water use efficiency (11.11 kg/ha/mm) was observed under irrigation scheduled at 0.6 IW/CPE ratio (I_1). The lowest mean water use efficiency (9.18 kg/ha/mm) was recorded under treatment I_3 (1.0 IW/CPE ratio). When more quantity of water was applied the reduction in water use efficiency could be because, in higher moisture regimes, more moisture is used for evaporation rather than for production, thereby reducing the water use efficiency. It might be also proportional to quantity of water used. The WUE

decreased with higher IW/CPE ratios and frequent irrigation applied under these treatments increased the moisture loss due to evapotranspiration in summer season. The higher WUE with lower irrigation *i.e.* 0.6 IW/CPE ratio was stemmed from less water loss due to evaporation under limited water supply. Similar results were observed by Thakor *et al*. (2018) [11]. The data indicated that the highest mean water use efficiency (10.99 kg/ha/mm) was observed under H_2 (5.0 kg/ha hydrogel). While, the lowest mean water use efficiency (9.01 kg/ha/mm) was recorded under treatment H_0 (no hydrogel). The increase in water use efficiency might be due to higher grain yield which was obtained in an application of 5.0 kg/ha hydrogel, followed by 2.5 kg/ha hydrogel as compared to control (no hydrogel application) treatment. This result confirms the results of Dabhi *et al.* (2013) [2].

Economics

Economics play an important role in deciding the adoption of a particular treatment by the farmers. The gross and net return and B:C ratio were calculated for irrigation scheduling as well as for hydrogel levels are presented in Table 4. The economic evaluation of different treatments revealed that the gross and net return increased with increase in irrigation scheduling and hydrogel levels. The maximum net return of ₹ 60,383 per ha and B:C ratio of 2.45 were obtained under 1_3 (1.0 IW/CPE ratio) followed by 1_2 (0.8 IW/CPE ratio) with ₹ 46,198 per ha and 2.14, respectively. Data further showed H_2 (5.0 kg hydrogel/ha) recorded maximum net realization and B:C ratio of ₹ 51,590 per ha and 2.19, respectively. Therefore, irrigation at 1.0 IW: CPE along with application of 80:40 kg $N:P_2O_5$/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: Growth parameters of pearl millet as influenced by level of irrigation and hydrogel

Treatment	Plant height (cm)	Days to full stigmatic stage	Days to maturity	Total tillers	Effective tillers	Ear head Length (cm)	Ear head Girth (cm)	Test weight (g)
(A) Main plot treatment								
Irrigation scheduling: (I)								
I_1 : 0.6 IW/CPE	163	48.44	78.33	4.24	2.51	18.56	8.76	11.85
I_2 : 0.8 IW/CPE	172	49.89	79.44	4.66	3.13	20.74	10.02	12.37
I_3 : 1.0 IW/CPE	187	50.67	81.20	5.46	3.72	22.66	10.83	13.16
S.Em.±	5.48	1.44	2.21	0.15	0.09	0.62	0.33	0.37
C.D. at 5 %	16.21	NS	NS	0.59	0.34	2.44	1.30	NS
C.V. %	9.47	8.67	8.30	9.35	8.28	9.01	10.03	9.02
(B) Sub plot treatment								
Hydrogel level: (H)								
H_0 : 0.0 kg ha^{-1}	165	48.89	79.22	4.42	2.76	19.34	9.00	12.19
H_1 : 2.5 kg ha^{-1}	175	49.78	79.56	4.83	3.12	20.91	9.93	12.30
H_2 : 5.0 kg ha^{-1}	181	50.33	80.20	5.12	3.47	21.72	10.67	12.88
S.Em.±	3.78	1.06	1.69	0.13	0.06	0.53	0.30	0.36
C.D. at 5 %	10.65	NS	NS	0.40	0.17	1.63	0.92	NS
C.V. %	6.53	6.37	6.36	8.04	7.41	7.66	9.11	8.62
Interaction Effect (I x H)								
S.Em.±	6.55	1.83	2.93	0.22	0.10	0.91	0.52	0.62
C.D. at 5 %	NS	NS	NS	NS	0.30	NS	NS	NS

Table 2: Yield & yield attributes and quality parameters of pearl millet as influenced by level of irrigation and hydrogel

Treatment	Grain wt./ear head (g)	Grain yield (kg/ha)	Stalk yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)	Protein content (%)
(A) Main plot treatment						
Irrigation scheduling: (I)						
I_1 : 0.6 IW/CPE	25.44	3184	5344	8528	36.87	8.98
I_2 : 0.8 IW/CPE	29.26	3869	6535	10404	37.18	9.63
I_3 : 1.0 IW/CPE	32.75	4563	7718	12281	37.26	10.43
S.Em.±	0.95	109.51	221	318	1.15	0.34
C.D. at 5 %	3.74	430	869	1250	NS	NS
C.V. %	9.81	10.64	10.17	9.17	9.29	10.58
(B) Sub plot treatment						
Hydrogel level: (H)						
H_0 : 0.0 kg ha^{-1}	26.65	3529	5927	9456	36.89	9.26
H_1 : 2.5 kg ha^{-1}	29.51	3859	6518	10377	37.26	9.75
H_2 : 5.0 kg ha^{-1}	31.29	4227	7152	11379	37.64	10.03
S.Em.±	0.82	86.55	154	245	0.92	0.28
C.D. at 5 %	2.54	267	477	753	NS	NS
C.V. %	8.49	8.71	7.11	7.05	7.41	8.59
Interaction Effect (I x H)						
S.Em.±	1.43	149	268	424	1.59	0.48
C.D. at 5 %	4.87	461	826	NS	NS	NS

Table 3: CUW and WUE as influenced by level of irrigation and hydrogel

Treatment	Consumptive use of water (mm)			Water use efficiency (kg/ha/mm)
	0-15 cm	15-30 cm	Total	
(A) Main plot treatment				
Irrigation scheduling: (I)				
I_1: 0.6 IW/CPE	141.97	144.53	286.50	11.11
I_2 : 0.8 IW/CPE	198.03	200.40	398.43	9.71
I_3 : 1.0 IW/CPE	247.34	249.65	496.99	9.18
(B) Sub plot treatment				
Hydrogel level: (H)				
H_0 : 0.0 kg ha^{-1}	195.51	197.62	393.13	9.01
H_1 : 2.5 kg ha^{-1}	195.83	198.20	394.03	10.03
H_2 : 5.0 kg ha^{-1}	196.00	198.77	394.77	10.99

Table 4: Economics of summer pearl millet as influenced by level of irrigation and hydrogel

Treatment	Gross Return (₹/ha)	Cost of cultivation (₹/ha)	Net Return (₹/ha)	B:C ratio
(A) Main plot treatment				
Irrigation scheduling: (I)				
I_1 : 0.6 IW/CPE	71186	38351	32835	1.85
I_2 : 0.8 IW/CPE	86589	40391	46198	2.14
I_3 : 1.0 IW/CPE	102133	41750	60383	2.45
(B) Sub plot treatment				
Hydrogel level: (H)				
H_0 : 0.0 kg ha^{-1}	78906	37096	41810	2.11
H_1 : 2.5 kg ha^{-1}	86369	40353	46016	2.13
H_2 : 5.0 kg ha^{-1}	94633	43044	51590	2.19

Conclusion

On the basis of field study, pearl millet needs a less amount of water as compared to rice or wheat. Application of hydrogel along with irrigation during critical stage of crop in pearl millets provides a better results as compared to only irrigated conditions. Hence for better growth and yield of pearl millet, application of 1.0 IW/CPE ratio at different growth stages along with hydrogel 5.0 kg/ha considerable increased and found economically beneficial. Hydrogel breaks down to CO_2 and ammonia when comes in contact with sunlight leaving behind zero residue. Application of hydrogel with limited amount of irrigation available with farmers in different part of arid and semi-arid region of India can be helpful by increase yield of crop without any detrimental effect to soil.

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