Original Research Article

Effect of irrigation scheduling and sowing windows on yield and yield attributes of wheat

ABSTRACT

Present experiment was conducted during *Rabi* season 2016-17 and 2017-18 at Research farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Durgapura, Jobner, Rajasthan to find out the response of wheat cultivars to irrigation scheduling under different sowing dates. Thirty six treatment combinations were investigated. Treatments comprises four irrigation levels: I_1 (0.6 ETc), I_2 (0.8 ETc), I_3 (1.0 ETc) and I_4 (1.2 ETc), three cultivars: C_1 (Raj-4120), C_2 (Raj-4079) and C_3 (Raj-4238) and three dates of sowing: D_1 (15^{th} Nov.), D_2 (30^{th} Nov.) and D_3 (15^{th} Dec.) in split plot design. A critical examination of results showed that irrigation applied at 1.2 ETc (I_4) recorded the maximum values of yield parameters (effective tiller per metre row length, number of grains per spike, length of spike per spike, spikes per metre square area and test weight) and yields. Further results on cultivar indicated that the Raj 4079 proved significantly superior over Raj 4120 and Raj 4238 with respect to all yield attributes. However, results showed that sowing of wheat on 15^{th} November gave higher values for yield attributes and yield.

Key words: Wheat, yield attributes and yield

1. INTRODUCTION

Wheat [*Triticum aestivum* (L.) emend. Fiori & Paol)] is grown all over the world for its wider adaptability and high nutritive value than any other food crop. Global demand of wheat is increasing due to the unique viscoelastic and adhesive properties of gluten proteins, which facilitate the production of processed foods, whose consumption is increasing as a result of the worldwide industrialization process and the westernization of the diet. Agricultural production being an integrated effect of weather, climate, soil, water and cultivars an effective scientific management of the complex system it is crucial for enhancing crop productivity on sustained basis without detriment to the environmental ecology. Among the various production inputs, improved cultivars and water are considered as the two key inputs, contributing maximum to crop productivity. Variability in climate is one of the major environmental threat to agriculture particularly wheat crop (Levitt, 1980, Anonymous, 2010). According to world estimates, about 50% losses in crop yield are due to different abiotic stresses under changing climatic conditions (Trnka *et al*., 2004). The growth and yield of wheat crop is adversely affected by environmental stresses such as soil moisture deficit, high temperature, low light intensity *etc*. Among these stresses irrigation water is a scare resource, it's optimization is fundamental to water resources use. It permits better utilization of all other production factors and thus leads to increased yields per unit area and time. The objective of irrigation is to maintain the soil moisture at optimum level in the plant root zone, so that root will have a constant supply of moisture with adequate aeration. Efficient water management requires thorough study of plant water relationship, climate, agronomic practices and economic assessment. The goal of effective scheduling programmes is to supply the plants with sufficient water while minimizing losses to deep percolation or runoff (Mandal and Roy, 2012). On the other hand wheat is a thermo-sensitive long-day crop. Temperature is a major determinant of its growth and productivity. Sowing time of wheat is one of the most important factors that governs the crop phenological development and efficient conversion of biomass into economic yield. Normal sowing has optimum growth duration, which consequently provides an opportunity to accumulate more biomass as compared to late sowing and hence, forth manifested in higher grain and biological yield (Singh and Pal, 2003). Whereas in case of delayed sowing, the wheat crop is exposed to sub-optimal temperatures at established and supra-optimal temperature at reproductive phases that leads to forced maturity and reduction in grain yield (Sardana *et al*., 1999). Growing of suitable cultivar at an appropriate time is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable cultivar for different seeding time further gets prime importance. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. Keeping in view the above facts, a field investigation entitled planned during winter (*Rabi*) seasons 2016 -17 and 2017-18 at research farm of Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan.

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2. MATERIALS AND METHODS

The field experiment was conducted during *Rabi* season 2016-17 and 2017-18 at Research farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Durgapura, Jobner, Rajasthan (75^o 47' East longitudes, 26^o 51' North latitude and at altitude of 390 m above mean sea level). The soil of experimental field was loamy sand in texture, slightly alkaline in reaction containing 0.25% organic C, with *p*H 8.2, EC 0.15ds m^{-1}, available nitrogen 136.5 kg ha^{-1}, phosphorous 33.30 kg ha^{-1} and potassium 195.45 kg ha^{-1}. The meteorological data was recorded daily from sowing to harvest from meteorological observatory situated near the experimental farm. The experimental site characterized by aridity of the atmosphere and extremity of temperature both in summer (45.5ºC) and winter (4ºC). Under semi-arid climatic conditions, the area receives 500-700 mm per annum rainfall which is mostly occurring during July to September. Rainfall received during the wheat growing season (Nov. to April) was 22.9 mm. The mean monthly maximum and minimum temperatures during the wheat growing season (Nov. to April) varied from 21.55 to 38.32 and 6.05 to 23.25^oC, respectively. The cumulative bright sunshine hours during the growing season varied between 6.70 to 10.05 hrs. The experiment was laid out in Split plot design with three replications. Thirty six treatment combinations were investigated. Treatments comprises four irrigation levels: I_1 (0.6 ETc), I_2 (0.8 ETc), I_3 (1.0 ETc) and I_4 (1.2 ETc), three cultivars: C_1 (Raj-4120), C_2 (Raj-4079) and C_3 (Raj-4238) and three dates of sowing: D_1 (15^{th} Nov.), D_2 (30^{th} Nov.) and D_3 (15^{th} Dec.). In the recommended irrigation treatments applied at different irrigation intervals according to ET_C level with the help of water meter. Standard crop production practice and methods were followed for weeding, fertilizer application and crop protection management to grow the crop. Observations of different yield attributes including spike length was counted separately which were obtained randomly from five tagged plants and their averages were recorded. For determining number of spikelet per spike and number of grains per spike, five spikes were selected at random from each plot and the number of grains in each spike was counted and their mean was recorded. The data were analyzed statistically using standard tools. To determined different growth indices of wheat at various phases during whole crop duration using the equation

3. RESULTS AND DISCUSSION

Effect of irrigation scheduling

Yield of crop is a complex function of metabolic and bio-chemical processes taking place in a plant system which may be modified by the environment and the suitable cultural practices adopted in the cultivation of the crop. Generally, economic yield depends on the fruiting organs produced by plant. In wheat, yield depends mostly on yield attributes *viz.,* effective tillers, number of grains spike^{-1}, spike length, number of spikelets spike^{-1}, number of spikes per unit area and test weight. In present study, effective tillers, number of grains spike^{-1}, spike length, number of spikelets spike^{-1}, number of spikes per unit area and test weight was taken as components related with the grain yield of wheat. Number of effective tillers per metre row length and number of spikes per metre square (Table 1.) had significant variation due to different irrigation schedules, wherein, the maximum number of effective tillers and number of spikes per metre square was recorded under the treatment I_4 (Irrigation at 1.2 ETc), followed by I_3 (Irrigation at 1.0 ETc), while minimum effective tillers and number of spikes per metre square was registered under the treatment I_1 (Irrigation at 0.6 ETc). Maximum number of effective tillers and number of spikes per metre square was possibly due to the fact that during vegetative period, crop received optimum moisture. This is because of optimum availability of water at crop growth that provides all available nutrients from the soil. Besides this, it maintained chlorophyll content in leaves of wheat and plant remain stay-green for longer period of time that helped higher photosynthesis of crop through better assimilation of carbon from atmosphere that favours the growth and more number of ear bearing tillers. Chaplot and Sumeriyan (2013) also reported similar results in wheat. Least number of effective tillers and number of spikes per metre square in I_1 (Irrigation at 0.6 ETc) was possibly due to water stress experienced by the crop during the growth period. The results are in conformity with those of (Jayanthi *et al*., 2002, Ghosh *et al*., 2003 and Yadav *et al*., 2009). Data further indicated that spike length, Number of spikelets spike^{-1} and number of grains spike^{-1} was remarkably influenced by different irrigation schedules (Table 1.). Treatment I_4 (Irrigations at 1.2 ETc) produced the maximum spike length, Number of spikelets spike^{-1} and number of grains spike^{-1} which being statistically at par with I_3 (Irrigation at 1.0 ETc) proved superiority over I_2 and I_1. The minimum spike length, number of spikelets spike^{-1} and number of grains spike^{-1} was observed under the treatment I_1 (Irrigation at 0.6 ETc). As already mentioned, the treatment receiving irrigation without any stress during reproductive phase *i.e.*, I_4 and I_3 the higher reproductive efficiency was the main reason responsible for more spike length, number of spikelets spike^{-1} and number of grains spike^{-1}. When the spike length increased, number of spikelet spike^{-1} the number of grains spike^{-1} also increased as all the three parameters are closely associated with each other. The results obtained by (Singh *et al*., 2003, Sharma *et al*., 2007, Kumar *et al*., 2015 and Nayak *et al*., 2015) also confirm the findings of present investigation. An appraisal of results in respect of test weight indicated that the treatment I_4 (Irrigations at 1.2 ETc) and I_3 (Irrigation at 1.0 ETc) recorded higher test weight over rest of the irrigation scheduling treatments (Table 1.). The increase in test weight under irrigation schedules I_4 (Irrigations at 1.2 ETc) and I_3 (Irrigation at 1.0 ETc) was due to ample supply of irrigation water to crop during reproductive phase and thereby the better growth of crop which helped the supply of sufficient photosynthates at the grain filling stage. Moreover, higher soil and plant water status under irrigation schedule at 1.2 ETc and 1.0 ETc throughout the growth during reproductive phase might have facilitated easy translocation of food material from source to sink and better nourishment provided to the plant might have resulted in better yield attributing characters like effective tillers, number of grains spike^{-1}, spike length, number of spikelets spike^{-1}, number of spikes per unit area and test weight. The reduction in above yield attributes under treatment I_1 (Irrigation at 0.6 ETc) was probably due to reduced growth and yield attributes of wheat. These results are also in accordance with those reported by (Singh and Pal, 2003, Bikrmaditya *et al*., 2011 and Nayak *et al*., 2015) who reported that increasing levels of irrigation helped in enhancing yield attributes of wheat. Data on grain yield (Table 1.) indicated that it was markedly influenced due to different irrigation schedules. The treatment I_4 (Irrigations at 1.2 ETc) recorded significantly higher grain yield of wheat (5136 kg ha^{-1}) in two years pooled analysis, respectively over I_1 and I_2 and at par with I_3 (Irrigations at 1.0 ETc). While significantly lowest grain yield (3442 kg ha^{-1}) was recorded under the treatment I_1 (Irrigations at 0.6 ETc). Higher grain yield under the treatment I_4 and I_3 might be the result of cumulative effect of improvement in growth and yield attributes such as effective tillers, number of grains spike^{-1} test weight, spike length, number of spikes per unit area, number of spikelets spike^{-1}. It was also found that with sufficient moisture in the soil profile under I_4 irrigation schedule, plant nutrients particularly nitrogen, phosphorus and potassium were more available and might have translocated to produce more dry matter. Secondly, higher yield with higher levels of irrigation might be due to its key role in root development by reducing mechanical

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resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis due to metabolic activities in plant (Bhunia *et al.,* 2006). The other reason of yield increase might be that irrigation scheduling at 1.2 ETc and 1.0 ETc throughout growth and reproductive phase created longer reproductive period with larger photosynthetic surface and reproductive storage capacity to attain higher allocation of net photosynthates to grain yield. The results obtained by (Sharma and Pannu, 2008, Sarwar *et al.*, 2010, Kumar *et al.*, 2015 and Mishra and Kushwaha, 2016) also confirm the findings of present investigation. On the other hand, significantly lowest grain yield (3442 kg ha^{-1}) in both the years pooled analysis was recorded under treatment I_1 (Irrigation at 0.6 ETc). The reasons for lowest grain yield may be ascribed due to unsaturated soil moisture environment, a vapour gap would be formed around the roots by their turgour pressure under water stress. Such a gap, if ever present, would reduce the availability of nutrients to the roots probably due to lesser contact between roots and water particles causing drastic reduction in dry matter production and uptake of nutrients. The second reason was probably due to maintaining lower soil plant water status, unfavourable condition for cell division, cell expansion which resulted into less absorption of photosynthetically active radiation and lower rates of net photosynthesis. The third reason might be due to lower values of yield attributes reported in I_1. A remarkable reduction in grain yield under limited water supply (I_1) was explained on the basis of internal water status in relation to different physiological processes taking place in plant. Saren and Jana (2001) concluded that moisture status and cycle within the plant was related to water supply in the soil as well as the facility for absorption, placing the plants under stress would reduce yield or quality of the harvested crop. Thus, all growth and yield attributes were adversely affected which might have lowered the grain yield. It is further mentioned that the yield obtained under I_4 (Irrigation at 1.2 ETc) was also comparable to that obtained under either I_3. But the yield difference occurred between the treatments. This might be due to the fact that in I_4 and I_3 water was applied in a proper amount at both vegetative and reproductive phases to satisfy the evaporative demand of atmosphere, irrespective of the stage of crop. Similar results were also reported by (Parihar and Tiwari, 2003, Sharma and Pannu, 2008). Like grain yield, significantly higher straw yield (6115 kg ha^{-1}) was recorded under the treatment I_4 (Irrigation at 1.2 ETc) (Table 1.) which being at par with I_3 (Irrigation at 1.0 ETc) proved superiority over rest of the treatments. Significantly lowest straw yield of (4003 kg ha^{-1}) was found under treatment I_1 (Irrigation at 0.6 ETc) during pooled analysis of both the years of study. Higher straw yield under optimum level of irrigation schedules might be due to better healthy vegetative growth in terms of dry matter (Table 1.), obviously resulted into more straw yield. Other reason for higher straw yield under optimum scheduling of irrigation was obvious as the crop flourished vigorously under optimum or higher water availability, especially in vegetative phase which enhanced growth attributes as already discussed. These findings are in cognizance with the results of (Bandyopadhyay and Malick, 2003, Dhaka *et al.*, 2006, Sarwar *et al.*, 2010, Bikrmaditya *et al.*, 2011, Narolia *et al.*, 2016 and Rojh *et al.*, 2021). The data pertaining to harvest index showed that various irrigation schedules not influenced the harvest index. Harvest index of all of the treatments was more or less same. These results are in close conformity with those of (Mehta *et al.*, 2010).

Effect of Cultivars

It was observed that yield components *i.e.,* effective tillers, length of spike, number of grains spike^{-1}, number of spikes per unit area, number of spikelets spike^{-1} and test weight were significantly higher in cultivar Raj 4079 as compared to other cultivars (Table 1.). However, it was at par with cultivar Raj 4238. Further, cultivar Raj 4079 produced significantly higher grain, straw and biological yield as compared to other cultivars (Table 1). However, it was at par with cultivar Raj 4238 due to its genetic potential when grown under late conditions and improved growth of plants at successive stages as reflected by higher production of biomass per metre row length at harvest. This subscribe to the view that there was adequate supply of metabolites under Raj 4079, compared to other cultivars for growth and development of reproductive structures. In wheat crop, besides environmental factors, development of tillers depends on supply of growth inputs (both metabolites and nutrients). The inadequate supply of these growth inputs resulted in poor initiation of tillers due to depressed growth of lateral buds at an early stage and later on competition between vegetative and generative parts, restricting development of individual tiller and its transformation to spike bearing shoot (effective tiller). It is well established that in wheat crop, the potentials of various yield components are decided during vegetative phase, while reproductive phase affects their realizable number. Thus, least competition between reproductive and vegetative growth structures for metabolites due to higher production of dry matter in cultivar Raj 4079 led to higher grain, straw and biological yield as compared to other cultivars *i.e*., Raj 4238 and Raj 4120. Since, wheat yield is a complex process and governed by interaction between source (photosynthesis and availability of assimilates) and sink component (storage organs). Thus, as a consequence of marked improvement in both these regulative process as evidenced from higher accumulation of biomass and nutrients as well as yield components under cultivar Raj 4079 led to significant increase in grain yield. Further, the grain yield of wheat is dependent on two most important components namely spikes per unit area and weight of grains (test weight). Thus, due to more number of grains by virtue of increased number of spikes and more test weight under Raj 4079, increased the grain yield over Raj 4238 and Raj 4120, and remained at par with cultivar Raj 4238. Since, biological yield is a sum of grain and straw yield produced by the crop, the increased grain yield under Raj 4079 might have resulted in higher biological yield in this cultivar. The marked variation in various yield components and yield between cultivars was observed by (Pandey *et al*., 1999, Sardana, 2001 and Singh *et al.*, 2007).

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Effect of varying sowing dates

In the present investigation, yield attributing characters *viz.,* effective tillers per metre row length, spike length, number of grains spike^{-1}, spikes per metre square area, spikelets spike^{-1} and seed, straw and biological yield were affected due to sowing time of wheat (Table 1.). Distinct positive effect of dates of sowing was noticed on these yield attributes and yield. All these parameters attained higher values with timely sown crop and reduced by delay in sowing. The potentiality of these characters was restricted to a considerable extent when the crop was sown late. The 15th November sown crop produced spike of maximum length, spikelets spike^{-1} and that of minimum length by 15th December sown crop. It might be attributed due to the fact that when the crop was sown late, there would have been low temperature in beginning but after (February on ward) the temperature started rising very fast and the plant do not get sufficient favourable environment to express their full potentiality. Such observations were also reported by (Kumar and Sharma, 2003, Shahzad *et al*., 2007). Number of grains spike^{-1} and spikes per metre square area significantly influenced by sowing time and it gradually decreased as sowing was delayed. It is influenced by environment particularly that of temperature prevailed during the time of sowing and vegetative and reproductive stages. In 15th November sown crop the number of grains spike^{-1} and spikes per metre square area was more, which positively contributed to high yield. High temperature during the later part of the reproductive stage of 15th December sowing caused forced maturity of the crop resulting in development of less number of grains spike^{-1} which were small, shrivelled and of low weight as evident from its low test weight. Such observations were also reported by (Shirpukar *et al*., 2008, Kumar *et al*., 2013, Tomar *et al*., 2014,) Test weight influenced by environment particularly that of temperature prevailed during the time of reproductive stages. Test weight was significantly influenced by dates of sowing, it was highest in the crop sown on 15th November and decreased as sowing was delayed. This might be due to the fact that under later sown conditions the grains were forced to mature and dry because of sudden rise in temperature coupled with hot wind. Thus, the grains obtained from 15th December sown crop were small and shrivelled and ultimately resulted in lower test weight. Nainwal and Singh (2000) stated that immature and shrivelled grains are produced in late sown crop, which remain in the milky stage during the period of high temperature. On the other hand, the timely sown crop gets an advantage because after having completed its vegetative growth satisfactory it comes in the ear stage when the temperature is quite favourable. Deshmukh *et al.* (2015) and Bashir *et al.* (2016) also reported similar findings and stated that timely sowing gave higher test weight as compared to delayed sowing. Yields of wheat increased significantly when sowing of wheat on 15th November which was statistically at par with sowing on 30th November (Table 1.). Yield decreased significantly as sowing was delayed from 15th November. This might be due to cumulative effect of poor expression of vegetative growth and yield contributing characters *i.e*., number of spikes, ear length, grains spike^{-1} and test weight under late sown conditions accompanied with high temperature and hot winds which leads toward forced maturity of the crop and ultimately resulted in lower grain , straw and biological yield. The early sown crop, on the other hand, having favourable cool weather conditions for longer duration recorded better growth and yield attributes resulted in greater productivity (Mumtaz *et al*., 2015 and Marasini *et al*., 2016).

Table: 1 Effect of irrigation scheduling, cultivars and varying sowing dates on yield attributes and yield of wheat

Treatment	Total tillers metre^{-1} row length	Number of spikes m^{-2}	Spike length (cm)	Number of spikelets spike^{-1}	Effective tillers metre^{-1} row length	Grains spike^{-1}	Weight of 1000 grains (g)	Grain yield	Straw yield	Biological yield	Harvest index
Irrigation scheduling											
I_1 (Etc 0.6)	122.16	298.64	6.33	10.49	89.97	28.91	35.80	3442	4003	7445	46.42
I_2 (Etc 0.8)	136.59	325.28	9.34	14.62	100.35	38.53	39.02	4600	5531	10130	45.53
I_3 (Etc 1.0)	148.56	351.71	11.17	16.59	111.99	43.88	39.98	4986	5981	10967	45.65
I_4 (Etc 1.2)	151.06	353.72	11.44	17.00	116.41	44.96	40.34	5136	6115	11250	45.86
SEm±	1.67	5.24	0.12	0.17	1.46	0.51	0.51	49	65	102	0.86
CD(P= 0.05)	5.13	16.15	0.36	0.53	4.49	1.57	1.57	151	199	315	NS
Cultivars											
V_1 (Raj 4120)	131.90	319.06	7.51	11.45	83.38	29.93	37.17	3788	4169	7957	47.58
V_2 (Raj 4079)	144.82	343.13	10.68	16.43	116.22	44.01	40.02	4974	6078	11051	44.95
V_3 (Raj 4238)	142.05	334.83	10.51	16.14	114.44	43.26	39.17	4861	5975	10835	45.06
SEm±	1.17	3.13	0.09	0.12	0.89	0.30	0.30	39	40	80	0.62
CD(P= 0.05)	3.36	9.03	0.27	0.34	2.57	0.86	0.86	113	116	229	NS
Date of sowing											
D_1 (15th NOV.)	147.25	345.79	10.92	16.49	119.22	43.62	40.36	5201	6210	11411	45.79
D_2 (30th NOV.)	142.93	334.90	10.10	15.70	110.64	41.38	39.19	4780	5741	10520	45.73
D_3 (15th DEC.)	128.59	316.33	7.68	11.83	84.18	32.20	36.81	3641	4271	7912	46.08
SEm±	0.83	2.63	0.06	0.09	0.85	0.24	0.24	31	27	58	0.51
CD(P= 0.05)	2.34	7.38	0.18	0.24	2.38	0.67	0.67	86	76	164	NS

CONCLUSION

Based on the findings of the present study, it may be concluded that the sowing of wheat cultivar Raj 4079 on 15th November with irrigation scheduling at 1.2 ETc was found better with respect to yield attributes and yield in relation to economics as compared to other cultivars. This remained at par with irrigation scheduling at 1.0 ETc under 15th November sown crop. However, under late sowing (15th December) the cultivar Raj 4238 produced higher grain yield as compared to all other cultivars. This study helps to the farmers in gaining an accurate knowledge of the optimum sowing window and efficient irrigation scheduling approach to achieve crops productive potential and higher yield.

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Comment [D6]: Not mention in MS

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