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Interaction Effect of Different Sowing Dates and Irrigation Schedule on Yield Attributes of Wheat Cultivars under Rajasthan Conditions

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A B S T R A C T

A field experiment was conducted under loamy sand soil during two consecutive *Rabi* seasons of 2016-17 and 2017-18 at Research Farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Durgapura, Jobner. The experiment comprises four irrigation scheduling treatments (Irrigation at 0.6 ETc, 0.8 ETc, 1.0 ETc and 1.2 ETc), three cultivars (Raj 4120, Raj 4079 and Raj 4238) and three dates of sowing (15th November, 30th November and 15th December) assigned, respectively to main plot, sub plot and sub-sub plots were replicated three times in split plot design. The results revealed that spike length and grains per spike of wheat crop were significantly influenced by different dates of sowing, varieties and irrigation schedules. Among different varieties, sowing dates and irrigation schedules, the maximum spike length, number of spikelet per spike, grains per spike and grain yield was recorded with variety Raj 4079 sowing of wheat on 15th Nov. and irrigation scheduling at 1.2 Etc, respectively. Sowing of wheat variety Raj 4079 on 15th Nov along with 1.2 ETc irrigation scheduling resulted in maximum spike length (12.77 cm), grains per spike (50.64), spikelets per spikes (19.04) and grain yield (5968 kg ha^{-1}).

Introduction

Wheat is the world's largest grown cereal crop, belonging to family 'Graminae' and genus *Triticum*. It is the 3rd most produced cereal after maize and rice in world. Currently it is grown on an area of about 224.82 million hectares and production of about 732.98 million tonnes with productivity of 3.26 tonnes per hectare (Anonymous, 2015a). India ranks second in terms of area, production & productivity next to China. Wheat is an important food crop of the world as it provides food to 36 % of the global population. Wheat contains about 10-14% protein, 1-2% total fat, 0.3-0.5%

carbohydrates (DWR, annual report 2015). Wheat is an important *Rabi* crop, which is grown in between September & December & harvested between February & May.

It is grown in diverse agro-climatic conditions from 11 ^{0}N -35 ^{0}N latitude and 72 ^{0}E-92 ^{0}E longitudes. It is mainly cultivated in Indo - Gangetic plains which accounts for roughly 20 million hectares covering states like Punjab, Uttar Pradesh, Madhya Pradesh, Haryana, Bihar and West Bengal.

India has the largest area under wheat cultivation (30.4 million hectares), but ranks second in production (99.70 million tonnes) after China with the average productivity of 3279 kg ha^{-1} (ICAR-IIWBR, 2018). India is blessed with both the rich land and extremely suitable weather climate for crops production.

Therefore, the rate of wheat production is second highest in the world. There are still many factors, which are responsible for low average yield of wheat in this country. One of such environmental factors is untimely planting which affects the yield of wheat crop considerably (Saini *et al.,* 1988). Another important aspect is lack of improved cultivars which are having short maturity and suitable under late sown condition due to relatively shorter growing period available to the crop.

Moreover, varieties also vary both in yield and nutrient uptake under late sown condition (Singh *et al.,* 1997). Earlier it was reported that wheat crop, apart from being governed by genetic characters depend largely on a number of environmental factors, which vary under different sowing dates (Saini *et al.,* 1988).

The sowing of wheat is delayed either to fit it in multiple or relay crop sequence, where wheat is sown after very short duration winter (*Rabi*) crop or after long duration rice crop or Sugarcane ratoon. Thus, the yield of wheat decreases with delayed sowing though the magnitude of reduction varies with the varieties. The sowing time is the most important factor determining the yield of wheat.

There are many factors responsible for low yield of wheat but poor irrigation and use of varieties with low yield potential are most important (Mehta and Mathur, 1979). Earlier researchers showed that irrigation consistently increased wheat yields in Pakistan (Hussain *et al.,* 2015). Moreover, Wajid *et al.,* (2002) reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages.

Because irrigation is an expensive input, so farmer, agronomist and economist need to know the response of yield to irrigation. Keeping in view of the aforesaid facts, the present study was undertaken to evaluate the performance and adaptability of newly developed varieties of wheat to a wider range of sowing dates in irrigated conditions.

Materials and Methods

The field experiment was conducted during *Rabi* season 2016 and 2017 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^{o}C, 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 (15th Nov.), D_2 (30th Nov.) and D_3 (15th 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.

Results and Discussion

Spike length (cm)

Results revealed (Table: 1.) that spike length of wheat was significantly influenced by interaction of cultivar and sowing date. Results showed that the highest spike length was obtained from D_1V_2 (12.01, 12.37 and 12.19 cm) which were statistically similar with D_1V_3 (11.83, 12.15 and 11.99 cm).

On the other hand the lowest spike length was observed at D_3V_1 (5.99, 6.07 and 6.03 cm) in both the year of study and pooled analysis, respectively. Interaction effect of improved wheat cultivar and irrigation showed significant differences on spike length.

Results showed (Table: 1.) that the highest spike length was obtained from I_4V_2 (12.66, 12.87 and 12.77 cm) which was statistically at par with I_4V_3 (12.47, 12.65 and 12.56 cm), I_3V_2 (12.25, 12.68 and 12.47 cm) and I_3V_3 (12.07, 12.47 and 12.27 cm) in both the year of study and pooled analysis, respectively.

On the other hand the lowest spike length was observed at I_1V_1 (4.91, 5.03 and 4.97cm). Further data on Interaction effect of different levels of irrigation and sowing date showed significant differences on spike length of these three types of modern wheat Cultivar.

Results showed that the maximum spike length was recorded in I_4D_1 (12.96, 13.14 and 13.05 cm) which was recorded at par with I_3D_1 (12.53, 12.95 and 12.74 cm) and the lowest was at I_1D_3 (5.05, 5.11 and 5.08 cm) in both the year of study and pooled analysis, respectively. These results are in closed conformity of (Suhail *et al.*, 2002; Shah *et al.*, 2006).

Table.1 Interaction effects of irrigation scheduling, cultivars and varying sowing dates on spike length of wheat

I Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	8.46	7.78	5.99	**V_1**	4.91	7.19	8.62	8.91	**D_1**	7.13	10.44	12.53	12.96
V_2	12.01	11.05	8.51	**V_2**	6.97	10.21	12.25	12.66	**D_2**	6.56	9.60	11.53	11.91
V_3	11.83	10.88	8.38	**V_3**	6.87	10.06	12.07	12.47	**D_3**	5.05	7.40	8.88	9.18
SEm±	0.16			**SEm±**	0.26				**SEm±**	0.18			
CD	0.44			**CD**	0.78				**CD**	0.51			
II Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	8.68	8.08	6.07	**V_1**	5.03	7.47	8.90	9.03	**D_1**	7.31	10.86	12.95	13.14
V_2	12.37	11.51	8.64	**V_2**	7.16	10.64	12.68	12.87	**D_2**	6.81	10.11	12.05	12.23
V_3	12.15	11.31	8.49	**V_3**	7.04	10.46	12.47	12.65	**D_3**	5.11	7.59	9.05	9.19
SEm±	0.16			**SEm±**	0.26				**SEm±**	0.18			
CD	0.44			**CD**	0.78				**CD**	0.51			
Pooled													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	8.57	7.93	6.03	**V_1**	4.97	7.33	8.76	8.97	**D_1**	7.22	10.65	12.74	13.05
V_2	12.19	11.28	8.58	**V_2**	7.07	10.42	12.47	12.77	**D_2**	6.68	9.86	11.79	12.07
V_3	11.99	11.10	8.44	**V_3**	6.95	10.26	12.27	12.56	**D_3**	5.08	7.50	8.97	9.18
SEm±	0.11			**SEm±**	0.19				**SEm±**	0.12			
CD	0.31			**CD**	0.53				**CD**	0.39			

Spikelets per spike

Spikelets spike^{-1} of wheat was significantly influenced by the interaction of cultivar and sowing date at all samples. Results showed (Table: 2.) that the highest spikelets spike^{-1} was obtained from D_1V_2 (18.16, 18.77 and 18.47) which was statistically similar with D_1V_3 (17.89, 18.38 and 18.14). On the other hand the lowest spikelets spike^{-1} was observed at D_3V_1 (9.16, 9.30 and 9.23) which was followed by D_2V_1 (12.12, 12.38 and 12.25) in both the year of study and pooled analysis, respectively. These results are in accordance with those of (Mesbah, 2009; Dixit *et al.*, 2014).

Interaction effect of improved wheat cultivar and irrigation showed significant differences on spikelets spike $^{-1}$ at all sampling dates. Results revealed (Table: 2.) that the highest spikelets spike^{-1} were obtained from I_4V_2

(18.87, 19.21 and 19.04) which was statistically similar with I_4V_3 (18.59, 18.81 and 18.70), I_3V_2 (18.31, 18.85 and 18.58) and I_3V_3 (18.04, 18.45 and 18.25).

On the other hand the lowest spikelets spike^{-1} was observed at I_1V_1 (8.07, 8.29 and 8.18) in both the year of study and pooled analysis, respectively. Interaction effect of different levels of irrigation and sowing date showed significant differences on spikelets spike^{-1} of these three types of modern wheat cultivar. A critical examination of data (Table: 2.) indicated that the maximum spikelets spike^{-1} found in I_4D_1 (18.95, 19.25 and 19.10) which was observed similar at I_3D_1 (18.39, 18.89 and 18.64) and the lowest spikelets spike^{-1} was observed at I_1D_3 (8.35, 8.57 and 8.46) in both the year of study and pooled analysis, respectively.

Table.2 Interaction effect of irrigation scheduling, cultivars and varying sowing dates on number of spikletes per spike of wheat

I Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	12.72	12.12	9.16	**V_1**	8.07	11.22	12.82	13.21	**D_1**	11.58	16.10	18.39	18.95
V_2	18.16	17.30	13.09	**V_2**	11.53	16.03	18.31	18.87	**D_2**	11.03	15.34	17.52	18.06
V_3	17.89	17.05	12.89	**V_3**	11.36	15.79	18.04	18.59	**D_3**	8.35	11.60	13.25	13.66
SEm±	0.21			**SEm±**	0.32				**SEm±**	0.24			
CD	0.59			**CD**	0.97				**CD**	0.68			
II Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	13.01	12.38	9.30	**V_1**	8.29	11.59	13.07	13.32	**D_1**	11.98	16.76	18.89	19.25
V_2	18.77	17.86	13.42	**V_2**	11.96	16.72	18.85	19.21	**D_2**	11.40	15.94	17.97	18.31
V_3	18.38	17.48	13.14	**V_3**	11.71	16.37	18.45	18.81	**D_3**	8.57	11.98	13.51	13.76
SEm±	0.21			**SEm±**	0.34				**SEm±**	0.25			
CD	0.61			**CD**	1.02				**CD**	0.71			
Pooled													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	12.86	12.25	9.23	**V_1**	8.18	11.41	12.94	13.26	**D_1**	11.78	16.43	18.64	19.10
V_2	18.47	17.58	13.25	**V_2**	11.74	16.37	18.58	19.04	**D_2**	11.22	15.64	17.75	18.19
V_3	18.14	17.26	13.02	**V_3**	11.53	16.08	18.25	18.70	**D_3**	8.46	11.79	13.38	13.71
SEm±	0.15			**SEm±**	0.27				**SEm±**	0.23			
CD	0.42			**CD**	0.89				**CD**	0.68			

Table.3 Interaction effects of irrigation scheduling, cultivars and varying sowing dates on number of grains per spike of wheat

I Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	32.40	30.46	23.89	**V_1**	21.53	28.52	32.40	33.23	**D_1**	32.10	42.52	48.31	49.55
V_2	48.85	45.93	36.02	**V_2**	32.46	42.99	48.85	50.10	**D_2**	30.18	39.98	45.42	46.58
V_3	48.11	45.23	35.47	**V_3**	31.96	42.34	48.11	49.33	**D_3**	23.67	31.35	35.62	36.53
SEm±	0.57			**SEm±**	0.83				**SEm±**	0.66			
CD	1.63			**CD**	2.49				**CD**	1.88			
II Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	34.44	32.95	25.45	**V_1**	22.76	30.53	34.84	35.66	**D_1**	32.45	43.53	49.67	50.85
V_2	49.43	47.29	36.52	**V_2**	32.66	43.81	49.99	51.18	**D_2**	31.05	41.64	47.52	48.65
V_3	48.51	46.41	35.84	**V_3**	32.05	42.99	49.06	50.23	**D_3**	23.98	32.16	36.70	37.57
SEm±	0.59			**SEm±**	0.86				**SEm±**	0.68			
CD	1.67			**CD**	2.57				**CD**	1.93			
Pooled													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	33.42	31.71	24.67	**V_1**	22.14	29.52	33.62	34.45	**D_1**	32.28	43.02	48.99	50.20
V_2	49.14	46.61	36.27	**V_2**	32.56	43.40	49.42	50.64	**D_2**	30.62	40.81	46.47	47.62
V_3	48.31	45.82	35.65	**V_3**	32.01	42.67	48.58	49.78	**D_3**	23.82	31.76	36.16	37.05
SEm±	0.41			**SEm±**	0.60				**SEm±**	0.60			
CD	1.15			**CD**	2.09				**CD**	1.72			

Number of grains per spike

Number of grains spike^{-1} of wheat was significantly influenced by the interaction of cultivar and sowing date. Results revealed (Table: 3.) that the highest number of grains spike^{-1} was obtained from D_1V_2 (48.85, 49.43 and 49.14) which was statistically similar with D_1V_3 (48.11, 48.51 and 48.31).

On the other hand the lowest grain spike^{-1} was observed at D_3V_1 (23.89, 25.45 and 24.67) according to study years and pooled analysis, respectively. Similar results were also reported by (Shahzad *et al.*, 2002; Spink *et al.*, 2000).

Interaction effect of improved wheat cultivar and irrigation showed significant differences on grain spike^{-1} at all sampling dates. Results showed (Table: 3.) that the highest grain spike^{-1} was obtained from I_4V_2 (50.10, 51.18 and 50.64) which were statistically similar with I_4V_3 (49.33, 50.23 and 49.78), I_3V_2

(48.85, 49.99 and 49.42) and I_3V_3 (48.11, 49.06 and 48.58). On the other hand the lowest grain spike^{-1} was observed at I_1V_1 (21.53, 22.76 and 22.14) according to study years and pooled analysis, respectively.

Interaction effect of different levels of irrigation and sowing date showed significant differences on grain spike^{-1} of these three types of modern wheat cultivar. A critical examination of data in table.3 indicated that the maximum number of grains spike^{-1} was given at I_4D_1 (49.55, 50.85 and 50.20) which were statistically similar with I_3D_1 (48.31, 49.67 and 48.99) and the lowest grain spike^{-1} was observed at I_1D_3 (23.67, 23.98 and 23.82) in 2016-17, 2017-18 and pooled analysis, respectively.

Grain yield

A critical examination of data (Table: 4.) indicated that the interaction effect of sowing dates and cultivars treatments on grain yield of wheat was found to be significant in both the years of study and pooled analysis.

Table.4 Interaction effects of irrigation scheduling, cultivars and varying sowing dates on grain yield of wheat

I Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	4374	4012	2890	**V_1**	2908	3663	4046	4418	**D_1**	3900	5227	5625	5928
V_2	5777	5074	3953	**V_2**	3612	5028	5541	5556	**D_2**	3684	4822	5106	5374
V_3	5359	5154	3969	**V_3**	3732	5017	5256	5303	**D_3**	2668	3660	4112	3976
SEm±	70			**SEm±**	101				**SEm±**	81			
CD	199			**CD**	304				**CD**	229			
II Year													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**	**I_2**	**I_3**	**I_4**
V_1	4429	4065	2956	**V_1**	2941	3718	4109	4498	**D_1**	3941	5289	5689	6008
V_2	5848	5153	4036	**V_2**	3653	5090	5653	5654	**D_2**	3739	4874	5181	5457
V_3	5419	5221	4042	**V_3**	3803	5082	5310	5381	**D_3**	2717	3726	4201	4068
SEm±	72			**SEm±**	120				**SEm±**	83			
CD	203			**CD**	360				**CD**	235			
Pooled													
V x D	**D_1**	**D_2**	**D_3**	**I X V**	**I_1**	**I_2**	**I_3**	**I_4**	**I X D**	**I_1**		**I_3**	**I_4**
V_1	4401	4039	2923	**V_1**	2924	3690	4077	4458	**D_1**	3921	5258	5657	5968
V_2	5813	5113	3994	**V_2**	3633	5059	5597	5605	**D_2**	3712	4848	5144	5416
V_3	5389	5188	4006	**V_3**	3768	5049	5283	5342	**D_3**	2692	3693	4157	4022
SEm±	50			**SEm±**	79				**SEm±**	79			
CD	140			**CD**	227				**CD**	227			

The treatment combination D_1V_2 recorded the significantly higher grain yield (5777, 5848 and 5813 kgha^{-1}) over rest of the treatment combinations and the minimum grain yield was recorded under D_3V_1 (2890, 2956 and 2923 kgha^{-1}) in 2016-17, 2017-18 and pooled analysis, respectively.

Interaction effect of improved wheat cultivar and irrigation showed significant differences on grain yield. Results showed (Table: 4.) that the highest grain yield was obtained from I_4V_2 (5556 and 5654 kgha^{-1}) which were statistically similar with I_4V_3 (5303 and 5381 kgha^{-1}), I_3V_2 (5541 and 5653 kgha^{-1}) and I_3V_3 (5256 and 5310 kgha^{-1}) in 2016-17 and 2017-18. Further data revealed that in pooled analysis highest grain yield was obtained from I_4V_2 (5605 kg/ha) except I_3V_2 (5597 kgha^{-1}).

On the other hand the lowest grain yield was observed at I_1V_1 (2908, 2941 and 2924 kgha^{-1}) according to study years and pooled analysis, respectively.

Interaction effect of different levels of irrigation and sowing date showed significant differences on grain yield of these three types of modern wheat Cultivar. Results (Table: 4.) showed that the maximum grain yield was recorded at I_4D_1 (5928, 6008 and 5968 kg/ha) and the lowest grain yield was observed at I_1D_3 (2668, 2717 and 2692 kg/ha) in 2016-17, 2017-18 and pooled analysis, respectively. These results are in accordance with those of (Spink *et al.,* 2000; Aslam *et al.,* 2003; Joshi *et al.,* 2016).

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