Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(3): 169-172
Received: 08-03-2017
Accepted: 10-04-2017

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Effect of sowing methods, scheduling of irrigation based on IW/CPE ratio and chemical weed control on plant height, dry matter accumulation and yield of wheat

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Abstract
An experiment was conducted during two consecutive *rabi* seasons of 2013-14 and 2014-15 at Udaipur (Raj.). The experiment consisted of three IW/CPE ratios (0.8, 1.0 and 1.2), three sowing methods (line sowing, crisscross sowing and FIRB) and three weed control (weedy check, sulfosulfuron + metsulfuron (RM) and isoproturon + 2, 4-D (TM) at 35 DAS) measures, making twenty seven treatment combinations. These treatments were replicated thrice in split-plot design having IW/CPE ratios in main plots and sowing methods and weed control in sub-plots. IW/CPE ratio at 1.0 recorded significant increase in plant height, dry mater accumulation at 60, 90 and harvest and yield of wheat. Both these treatments increase grain yield by 10.60 and 12.68, straw yield by 8.23 and 11.34 and biological yield by 9.19 and 11.88 per cent, respectively over IW/CPE ratio at 08. Under the different sowing methods maximum plant height and dry matter accumulation at successive growth stages was recorded with criss cross method which ultimately increase the yield of wheat over line sowing but remained at par with FIRB system. Combination of herbicide [sulfosulfuron + metsulfuron (RM) and isoproturon + 2, 4-D (TM)] significantly increased plant height, dry matter accumulation and yield over weedy check. The magnitude of increase was 24.06 and 21.81 in grain, 22.73 and 21.76 in straw and 23.28 and 21.78 per cent in biological yield over weed chek.

Keywords: Sowing methods, IW/CPE ratio, Chemical weed control, Wheat

Introduction
Wheat is the second most important cereal in India after rice contributing substantially to the national food security by providing more than 50 per cent of the calories to the people who mainly depend on it. In chronological perspective, India has made spectacular advancement in productivity and sustainability of wheat over the years. The production of wheat grain in the year 2013-14 was estimated to be 95.91 m t from acreage of 31.19 m ha at a yield level of 3075 kg ha^{-1}. During this period, Rajasthan accounted for about 9.01 per cent of the national area and 9.3 per cent of production with average productivity of 3175 kg ha^{-1} (Govt. of India, 2014a) [1]. The estimated national production for 2014-15 however, has shown a decline and is anticipated to be about 88.94 m t (Govt. of India, 2015) [3]. Though wheat yield in India is close to the world average, yet it lags behind to many of the other wheat producing countries like France, U.K., Germany, Egypt and Poland (Govt. of India, 2014b) [3].
Among the various agronomic factors, sowing of wheat is considered to be of prime importance for proper distribution of plants over cultivated area, thereby better utilization of available soil and atmospheric resources. Wheat is generally sown in straight unidirectional row i.e., line sowing (22.5 cm apart) wherein plants are usually over-crowded. It has been reported that even distribution of plants over cropped area through bi-directional sowing at appropriate geometry facilitates greater availability of growth inputs, particularly light and nutrients, with least competition which results in realization of higher productivity over conventional/unidirectional sowing in row at 22.5 cm apart. Water is a precious and scare input plays a vital role in assured crop production since it is essential for the maintenance to turgidity, absorption of nutrients and the metabolic process of the plants.
Therefore, it becomes imperative to develop an optimum irrigation schedule to maintain the sufficient available soil moisture throughout the crop period for best exploitation of crop yield potential. Among the several recognized criteria of irrigation scheduling, climatological approach is very scientific and widely accepted among the scientists and research workers throughout the world as it is well known that evapo-transpiration by a full crop cover is closely

associated with the evaporation from an open pan (Dastane, 1972) [4]. Weed is one of the major biotic constraints in wheat production as they compete with crop for nutrients, moisture, light and space (Chhokar *et al*., 2012) [5]. Wheat is infested with majority of grassy as well as broad-leaved weeds, control of which requires a variety of herbicides (Sharma *et al.*, 2015) [11]. According to control mixed population of weeds and also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures can be employed to widen the spectrum of weed control.

Materials and methods

The experiment was conducted during two consecutive *rabi* seasons of 2013-14 and 2014-15 at the Instructional Farm (Agronomy) Rajasthan College of Agriculture, MPUAT, Udaipur. The soil was clay-loam, low in available nitrogen (284.25 kg ha^{-1}), medium in phosphorus (28.90 kg ha^{-1}) and high in potassium (320.40 kg ha^{-1}). The experiment was laid out in split-plot design, comprising three IW/CPE ratios (0.8, 1.0 and 1.2), in the main plots, three sowing methods (line sowing, crisscross sowing and FIRB) and three weed control methods [weedy check, sulfosulfuron + metsulfuron (RM) 32g+2g and isoproturon + 2, 4-D (TM) 750g+500g] at 35 DAS assigned in subplots, replicated thrice. Wheat variety 'Raj-4037' was used as test crop. The recommended dose of fertilizer nutrients, *i.e.* 80 kg N + 35 kg P_2O_5 ha^{-1} through DAP and urea were applied to the crop. Full P and half dose of N were applied at the time of sowing and the remaining N was applied in two equal splits at first irrigation and second irrigation. Plant height and dry matter accumulation were recorded at 60, 90 DAS and at harvest from five randomly selected plants in each plot and expressed as number m^{-2} and g m^{-2}, respectively. Yields were harvested from net plot.

Results and discussion

Effect on plant height

Irrigation schedule at IW/CPE ratio 1.0 significantly increased plant height at 60, 90 DAS and harvest over irrigation at IW/CPE ratio 0.8. However, it was found at par with IW/CPE ratio at 1.2 levels in this respect. In pooled data, IW/CPE ratio at 1.2 and 1.0 gave significantly higher plant height by 8.79 and 5.96, 5.93 and 5.45and 7.92 and 6.05 per cent over IW/CPE ratio 0.8 level, respectively. It is well established that any situation of water stress to plants is normally associated with reduced plant height performance (Mukharjee and Ghosh, 2006) [10]. Crisscross and FIRB system of sowing recorded significantly higher plant height at 60, 90 DAS and harvest as compared to line sowing. However, crisscross and FIRB system of sowing were observed at par in this respect. Pooled data indicate that crisscross sowing and FIRB system recorded 8.79 and 5.96, 5.93 and 5.45 and 5.01 and 3.64 per cent higher plant height over line sowing, respectively. Application of sulfosulfuron + metsulfuron (RM) recorded significantly higher plant height as compared to weedy check at 60, 90 DAS and harvest of wheat crop but remained at par with the application of isoproturon + 2, 4-D (TM) during course of investigation (Table 1). In pooled data, application of sulfosulfuron + metsulfuron (RM) and isoproturon + 2, 4-D (TM) recorded higher plant height by 5.75 and 3.68, 4.79 and 4.08 and 5.01 and 3.64 per cent over weedy check, respectively. It is an established fact that availability of metabolites and capacity of storage organs exerts an important regulatory function on the complex process of yield formation.

Effect on dry matter accumulation

Irrigation in the crop at IW/CPE ratio 1.0 recorded significantly higher dry matter accumulation at 60, 90 DAS and harvest over IW/ CPE ratio at 0.8 but was found at par with IW/CPE ratio1.2 level during both the years. Further, pooled data show that IW/ CPE ratio at 1.2 and 1.0 gave significantly higher dry matter accumulation by 13.86 and 10.39, 11.67 and 9.75 and 9.21 and 6.68 per cent over IW/ CPE ratio at 0.8, respectively. Results of the present investigation are well in conformity with the findings of Singh and Sheoran (2006) [12]. Crisscross and FIRB system of sowing gave significantly higher dry matter accumulation at 60, 90 DAS and harvest by 9.49 and 7.62, 11.67 and 9.75 and 9.21 and 6.68 per cent over line sowing, respectively. However, Crisscross and FIRB system of sowing were found at par with each other during both the years.

Weed control treatments significantly increased the dry matter accumulation over weedy check during both the years. Based on pooled data highest dry matter accumulation at 60, 90 DAS and harvest was recorded with the application of sulfosulfuron + metsulfuron (RM) but found at par with isoproturon + 2, 4-D (TM) and both these treatments increase dry matter accumulation at harvest by 13.83 and 11.43, 12.68 and 10.14 and 9.16 and 8.45 per cent over weedy check, respectively.

Effect on yield

Different IW/CPE ratio brought about significant variations in grain, straw and biological yield of wheat during both the years and on pooled basis. IW/CPE ratio at 1.0 registered significantly higher biological yield over the IW/CPE ratio at 0.8 but statistically at par with IW/CPE ratio at 1.2. Pooled data show that IW/CPE ratio at 1.2 and 1.0 significantly increased grain, straw and biological yield by 12.68 and 10.60, 11.34 and 8.23 and 11.8 and 9.19 per cent over IW/CPE ratio at 0.8, respectively. Cell enlargement is particularly dependent on at least a minimum degree of cell turgor and stem and leaf elongation are quickly checked or stopped under water deficit (Miller, 1956) [8]. Crisscross sowing and FIRB system gave significantly higher grain, straw and biological yield over line sowing. On pooled basis data, both these sowing methods resulted in 12.55 and 10.16, 12.59 and 10.74 and 12.58 and 10.51 per cent higher biological yield over line sowing, respectively. Coming on the coefficient of effectiveness or harvest index between different IW/CPE ratios from 0.8 to 1.2, it is well revealed that variations were not significant. In fact, higher yield often relates to higher DMA while co-efficient of effectiveness is usually a varietal character that is not easily changed under normal conditions (Nichiporovich, 1967) [9]. Both weed control treatments significantly increased the straw yield of wheat over weedy check during both the years of investigations and on pooled basis. Among weed control treatments, maximum straw yield was registered under sulfosulfuron + metsulfuron (RM) but it was found at par with isoproturon + 2, 4-D (TM). The pooled data reveal that sulfosulfuron + metsulfuron (RM) and Isoproturon 750 g ha^{-1} +2,4-D 500 g ha^{-1} significantly increased straw yield by 24.06, 21.81, 22.73 and 21.76 and 23.28 and 21.78 per cent over weedy check, respectively. The similar results were also reported by Idanani and Kumar (2012) [6].

Table 1: Effect of irrigation schedules, sowing methods and weed control on plant height

Treatments	Plant height (cm)								
	At 60DAS			At 90DAS			At harvest		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Irrigation schedules (IW/CPE)									
0.8	35.19	36.95	36.07	80.35	83.61	81.98	81.54	84.73	83.13
1.0	37.18	39.26	38.22	84.46	88.44	86.45	86.67	89.65	88.16
1.2	38.34	40.14	39.24	84.80	88.88	86.84	88.56	90.87	89.71
S.Em.±	0.51	0.64	0.41	0.92	1.11	0.72	1.20	1.33	0.90
CD (P=0.05)	1.76	2.21	1.33	3.18	3.85	2.35	4.16	4.59	2.92
Sowing methods									
Line sowing	34.90	35.96	35.43	80.48	84.82	82.65	82.57	85.76	84.16
Crisscross sowing	38.04	40.56	39.30	85.02	88.20	86.61	87.53	91.19	89.36
FIRB system	37.76	39.84	38.80	84.12	87.91	86.02	86.67	88.29	87.48
S.Em.±	0.36	0.38	0.30	0.79	0.85	0.67	0.85	0.86	0.70
CD (P=0.05)	1.03	1.08	0.86	2.23	2.40	1.88	2.41	2.43	1.97
Weed control									
Weedy check	35.50	37.87	36.69	81.30	84.96	83.13	83.15	85.97	84.56
Isoproturon +2,4-D (TM)	37.21	38.87	38.04	83.62	87.47	85.54	86.31	88.97	87.64
Sulfosulfuron + metsulfuron (RM)	37.99	39.61	38.80	84.69	88.51	86.60	87.31	90.30	88.80
S.Em.±	0.36	0.38	0.30	0.79	0.85	0.67	0.85	0.86	0.70
CD (P=0.05)	1.03	1.08	0.86	2.23	2.40	1.88	2.41	2.43	1.97

Table 2: Effect of irrigation schedules, sowing methods and weed control on crop dry matter accumulation

Treatments	Crop dry matter accumulation (gm^{-2})								
	At 60DAS			At 90DAS			At harvest		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Irrigation schedules (IW/CPE)									
0.8	295.35	317.12	306.23	579.42	603.99	591.71	1008.90	1065.51	1037.20
1.0	328.10	348.02	338.06	634.26	664.59	649.42	1107.01	1160.86	1133.94
1.2	335.17	362.16	348.67	646.14	675.39	660.76	1139.61	1163.75	1151.68
S.Em.±	5.32	8.83	5.15	10.39	9.93	7.19	16.80	24.29	14.77
CD (P=0.05)	18.41	30.55	16.81	35.94	34.37	23.43	58.13	84.04	48.15
Sowing methods									
Line sowing	298.27	327.98	313.12	595.61	600.02	597.81	1018.77	1084.97	1051.87
Crisscross sowing	331.67	354.03	342.85	641.82	678.33	660.07	1135.51	1162.08	1148.80
FIRB system	328.69	345.29	336.99	622.39	665.63	644.01	1101.23	1143.08	1122.15
S.Em.±	3.88	4.74	3.54	8.54	7.57	6.59	12.35	12.74	10.24
CD (P=0.05)	10.96	13.39	9.93	24.14	21.38	18.50	34.88	35.99	28.75
Weed control									
Weedy check	285.52	325.06	305.29	577.85	600.43	589.14	1008.16	1084.23	1046.20
Isoproturon+2,4-D(TM)	333.03	347.32	340.17	630.23	667.56	648.89	1121.16	1147.95	1134.55
Sulfosulfuron + metsulfuron (RM)	340.07	354.92	347.50	651.74	675.98	663.86	1126.20	1157.95	1142.07
S.Em.±	3.88	4.74	3.54	8.54	7.57	6.59	12.35	12.74	10.24
CD (P=0.05)	10.96	13.39	9.93	24.14	21.38	18.50	34.88	35.99	28.75

Table 3: Effect of irrigation schedules, sowing methods and weed control on yield and harvest index

Treatments	Grain yield ($kg\ ha^{-1}$)			Straw yield ($kg\ ha^{-1}$)			Biological yield ($kg\ ha^{-1}$)			Harvest index (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Irrigation schedules (IW/CPE)												
0.8	4297	4836	4567	6572	6765	6668	10869	11601	11235	39.79	41.91	40.85
1.0	4731	5372	5051	7137	7296	7217	11868	12668	12268	39.90	42.39	41.15
1.2	4834	5459	5146	7324	7523	7424	12158	12982	12570	39.90	42.22	41.06
S.Em.±	110.5	95.2	72.9	141.9	144.0	101.1	222.7	211.5	153.6	0.447	0.453	0.318
CD (P=0.05)	382.3	329.5	237.8	491.1	498.3	329.7	770.6	731.9	500.8	NS	NS	NS
Sowing methods												
Line sowing	4248	4902	4575	6532	6648	6590	10780	11550	11165	39.55	42.40	40.97
Crisscross sowing	4860	5439	5149	7316	7525	7420	12176	12963	12570	40.03	42.09	41.06
FIRB system	4754	5327	5040	7185	7411	7298	11939	12738	12338	40.01	42.02	41.02
S.Em.±	65.6	75.3	57.7	59.6	89.1	61.9	94.4	121.0	88.6	0.327	0.452	0.322
CD (P=0.05)	185.4	212.7	161.9	168.2	251.7	173.7	266.7	341.8	248.7	NS	NS	NS
Weed control												
Weedy check	3919	4618	4269	5973	6398	6185	9893	11015	10454	39.76	42.01	40.88
Isoproturon+2,4-D(TM)	4904	5495	5200	7496	7567	7531	12400	13062	12731	39.60	42.26	40.93
Sulfosulfuron+ metsulfuron (RM)	5038	5554	5296	7563	7620	7591	12602	13174	12888	40.23	42.25	41.24
S.Em.±	65.6	75.3	57.7	59.6	89.1	61.9	94.4	121.0	88.6	0.327	0.452	0.322
CD (P=0.05)	185.4	212.7	161.9	168.2	251.7	173.7	266.7	341.8	248.7	NS	NS	NS

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