Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 1199-1203
Received: 26-05-2018
Accepted: 28-06-2018

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Development parameters, yield and agro-meteorological indices of wheat as affected by different dates of sowing, compaction levels and irrigation schedules

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Abstract
Field experiments were conducted at N. E. Borloug Crop Research Center of the G. B. Pant University of Agriculture and Technology, Pantnagar during two *rabi* seasons of 2014-15 and 2015-16 in sandy loam soil with wheat cv. UP-2565 under three compaction levels (C) *viz.* no compaction (C_1), two passes of 500 kg RCC (reinforced cement concrete) roller (C_2) and four passes of roller (C_3); three irrigation schedules (I) *viz.* irrigation at 30% depletion from available soil moisture (ASM)- I_1, irrigation at 40% depletion from ASM- I_2 and irrigation at 50% depletion from ASM- I_3 at three dates of sowing (D) *viz.* 5 November (D_1), 20 November (D_2) and 5 December (D_3) with three replications. Maximum days to seedling emergence was recorded with D_3 (8.11) and C_3 (7.69) during 2015-16 while maximum days to anthesis and physiological maturity was recorded with D_1 (91.49 and 135.39, respectively), C_3 (90.12 and 131.85) and I_1 (87.96 and 129.37, respectively) during 2014-15. Accumulated GDD at maturity (ºC days) was recorded higher in D_1 (1500.31), C_3 (1514.83) and I_2 (1472.16) during 2014-15. Accumulated PTU at maturity (ºC days-hour) was also recorded higher with D_1 (8942.46), C_2 (9009.28) and I_2 (8646.85) during 2014-15. Highest value of HUE was recorded with D_3 (3.63), C_2 (3.32) and I_2 (3.27) during 2015-16. Grain yield (q ha^{-1}) was found higher during 2014-15 with D_3 (48.30), C_2 (47.07) and I_1 (45.88)

Keywords: Wheat, sowing dates, compaction levels, irrigation schedules, agro-meteorological indices

Introduction
Wheat is one of the oldest and widely consumed cereals by human being. China, India, France, U.S.A. and Canada are the major wheat growing countries in the world. India has the largest area under wheat (30.6 million hectares) which is the second most important food crop after rice in India. Wheat (*Triticum aestivum* L.) is very important food grain crop food grain in *Tarai* region of Uttarakhand, which is sown from November-December and harvested from March-April. It is a *rabi* season crop and amount of rainfall during this period is very less. Hence, the water requirement of the crop is fulfilled by irrigation. In the past decade a general slowdown in increase in the productivity of wheat has been noticed, particularly under environments relatively unfavourable for growth and development of wheat (Jat *et al*. 2011) [1]. The productivity of crop is greatly affected by number of factors. One of the most important reasons of low productivity of wheat in India is late sowing with reduced crop duration. During past few years, more than 50 per cent sowing of wheat often gets delayed till December or early January causing substantial loss in grain yield. With the advent of mechanization of the agricultural operations throughout the world, there has been increase in the number of reports in the literature on soil compaction, which eventually has effects on soil physical conditions and plant growth. The soil physical properties, which are mainly affected by compaction are, infiltration rate of water, bulk density, soil strength, or soil resistance, aeration, moisture availability to plants, heat flux etc. These soil properties are considered to have marked influence on plant growth particularly root development, penetration and proliferation. Soil compaction affects soil physical properties and, eventually, the crop production. In case of soils having excessive permeability mainly because of their coarse texture, looseness and poor organic matter content, compaction has desirable effects on soil physical conditions. Moisture retention capacity of sandy to sandy loam soils is also very low and more than one third of applied or rain water gets lost by deep percolation (Mann and Singh, 1975) [2]. The possibility of increasing micro-pores at the expense of macro-pores by compacting soil at optimum moisture creates a barrier of relatively high bulk density was suggested by Ghildyal and Satyanarayana (1965) [3]. Somani (1988) [4] advocated compaction of sandy soil is convenient and economic method of decreasing permeability and nutrient

losses. Yadav (1984) [5] and Majumdar (1994) [6] suggested compaction of sandy soils for minimizing percolation losses of nutrients and it improves moisture storage capacity in the soils. Hence, soil compaction can play role in savings the number of irrigations. Since water is a precious commodity, therefore, studies on scheduling of irrigation, water use efficiency (WUE) and moisture depletion pattern in the soil are of direct interest for maximizing crop yields. Keeping in view the above said facts the present study was conducted to find out an effective way to save water in the wheat growing season without markedly reducing wheat yield and to evaluate the performance and adaptability of wheat cv. UP-2565 to a range of sowing dates, compaction levels and irrigation schedules in a sandy loam soil of *tarai* region of Uttarakhand at Pantnagar.

Material & Methods

The field experiments were conducted during *rabi* seasons of 2014-15 and 2015-16 in sandy loam soil with wheat cv. UP-2565 in C_5 plot situated at N. E. Borloug Crop Research Center of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The center is located at 29^o N latitude, 79 30^o E longitude and at an altitude of 243.84 m above the mean sea level. The area lies in the *tarai* belt of Uttarakhand which is 15-18 km wide strip lying immediately south of the *Bhabar* zone, at the foot hills of Shivalik range of the Himalayas. During 2014-15, excessive rainfall was recorded (187.4 mm) while, only 2.5 mm was recorded during 2015-16. Experiments were conducted under three compaction levels (C) *viz.* no compaction (C_1), two passes of 500 kg RCC (reinforced cement concrete) roller (C_2) and four passes of roller (C_3); three irrigation schedules (I) *viz*. irrigation at 30% depletion from available soil moisture (I_1), irrigation at 40% depletion from available soil moisture (I_2) and irrigation at 50% depletion from available soil moisture (I_3) at three dates of sowing (D) *viz*. 5 November (D_1), 20 November (D_2) and 5 December (D_3) with three replications during two consecutive *rabi* seasons, in 81 plots each of 4m x 3m size laid out in split-split plot design with dates of sowing as main plots factor, compaction levels as sub plot factor and irrigation schedules as sub-sub plot factor.

The counting of the spikes was done on every day starting from the day when pollens were seen on few spikes till the number of the anthesised spikes became constant. At the end of the dough stage the moisture content of the kernels was determined regularly. The date on which the seeds had 30-35% moisture content was considered the date of physiological maturity and the days from sowing were calculated and recorded as days to physiological maturity. The Agro-meteorological indices growing degree days (GDD), photothermal units (PTU) and heat use efficiency (HUE) were calculated using following formula:

$$\textbf{GDD}=\frac{\text{Maximum Temperature + Minimum Temperature}}{2} - \text{Threshold Temperature of wheat}*$$

PTU = GDD × maximum sunshine hours (Rajput, 1980 [7]; Pandey *et al*. 2010) [8].

$$\textbf{HUE [(kg ha)/}^o\textbf{C day)]} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Accumulated GDD (}^0\text{C day)}}$$

*Threshold temperature of 5 °C was considered for wheat crop (Nuttonson, 1955) [9].

Result and Discussion

Grain yield

Data pertaining to grain yield of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 1. It is apparent from the data that among the dates of sowing and compaction levels, grain yield was significantly higher with D_3 (48.30 q ha^{-1} and 46.02 q ha^{-1} during 2014-15 and 2015-16, respectively) and C_2 (47.07 q ha^{-1} and 45.16 q ha^{-1} during 2014-15 and 2015-16, respectively), respectively. Grain yield with treatment I_1 (45.88 q ha^{-1} and 44.66 q ha^{-1} during 2014-15 and 2015-16, respectively) was found higher over the grain yield with other irrigation schedules during both the years but reached up to the level of significance only during 2015-16. All treatment interactions were found non-significant during both the years.

Results obtained with the significant effect of dates of sowing in increasing grain yield were found to be in line with Negi *et al*. (2003) [10] and Haj *et al*. (2012) [11]. They also reported higher values of grain yield with delay in sowing. Efficient use of resources particularly rainfall and sun shine by early sown than late sown crop might be the reason for better grain yield under D_3 than other dates of sowing. Significant effect of compaction levels on grain yield was also observed by Majumdar and Das (1997) [12]. They also reported that compaction at proctor moisture increased the yield of wheat by 10-30%. Prihar (1984) [13] advocated that soil compaction increases crop yield in coarse textured soils by decreasing the percolation losses of nutrients and improving moisture storage in the soil. Similar trend of irrigation schedules on grain yield was also reported by Idnani and Kumar (2012) [14]. They also reported about the significant effect of irrigations on grain yield of wheat.

Days to seedling emergence

Data pertaining to days to seedling emergence of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 1. Among the dates of sowing, days to seedling emergence was significantly higher with D_3 (7.92 and 8.11 during 2014-15 and 2015-16, respectively). During 2014-15, days to seedling emergence was more with C_3 (7.60 and 7.69 during 2014-15 and 2015-16, respectively) over the days to seedling with other compaction levels but reached up to level of significance during 2015-16 only. Days to seedling emergence during 2014-15 and 2015-16 was non-significantly more with treatment I_2 (6.53) and I_1 (6.72), respectively over the days to seedling emergence with other irrigation schedules. All treatment interactions were found non-significant during both the years.

Number of days to seedling emergence with delay in sowing increased significantly, which is in conformity with the findings of Ejaz *et al.* (2003) [15]. They also reported that with delay in sowing of wheat crop, number of days to seedling emergence increased significantly. Increased bulk density and penetration resistance in compacted soil, attributed to increase in days to seedling emergence. Ramzan *et al.* (2014) [16] also reported that days to seedling emergence of wheat with four tractor passes (11.18 days) is more than the days to seedling emergence with zero tractor passes (10.98 days).

Days to anthesis

Data pertaining to days to anthesis of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 1. It is apparent from the data that among the dates of sowing, days to anthesis was significantly higher with D_1 (91.49 and 81.94 during 2014-15 and 2015-16, respectively). Days to anthesis was found more with C_3 (90.12 and 76.16 during 2014-15 and 2015-16, respectively) over the days to anthesis with other compaction levels but reached up to level of significance only during 2014-15. Days to anthesis during both the years was found more with I_1 (87.96 and 79.17 during 2014-15 and 2015-16, respectively) over the days to anthesis with other irrigation schedules but found significant only during 2015-16. All treatment interactions were found non-significant during both the years.

Mumtaz *et al.* (2015) [17] also reported that late sowing of crop affect the development of plant organs and cause the reduction in numbers of days taken to anthesis which is in conformity the results observed with dates of sowing during both the years. More number of irrigations might be the reason for delay in anthesis with I_1. Ngwako and Mashiqa (2013) [18] also reported delay in anthesis with increased number of irrigations.

Days to physiological maturity

Data pertaining to days to physiological maturity of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 1. It is evident from the data that among the dates of sowing and compaction levels, days to physiological maturity was found significantly higher with D_1 (135.39 and 125.45 during 2014-15 and 2015-16, respectively) and C_3 (131.85 and 120.19 during 2014-15 and 2015-16, respectively), respectively. Days taken to physiological maturity was found higher with I_1 (129.37 and 119.00 during 2014-15 and 2015-16, respectively) over the days to physiological maturity with other irrigation schedules but reached up to the level of significance during 2015-16 only. All treatment interactions were found non-significant during both the years.

Mumtaz *et al.* (2015) [17] also reported that late sowing of crop affect the development of plant organs and cause the reduction in numbers of days taken to physiological maturity which is in conformity the results observed during both the years. More number of irrigations might be the reason for delay in physiological maturity with I_1. Ngwako and Mashiqa (2013) [18] also reported delay in physiological maturity with increased number of irrigations.

Table 1: days to seedling emergence, days to anthesis, days to physiological maturity and grain yield wheat crop as influenced by dates of sowing, compaction levels and irrigation schedules during *Rabi* seasons of 2014-15 and 2015-16.

Treatments	Days to seedling emergence		Days to anthesis		Days to physiological maturity		Grain yield (q ha^{-1})	
Dates of sowing	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**
D_1	5.21	5.23	91.49	81.94	135.39	125.45	42.29	41.68
D_2	6.25	6.42	89.02	75.37	129.95	116.58	46.50	44.83
D_3	7.92	8.11	82.35	70.02	122.39	109.46	48.30	46.02
SEm±	0.06	0.15	0.58	1.77	1.62	1.89	0.64	0.79
CD (P=0.05)	0.23	0.58	2.26	5.35	4.95	5.69	2.52	3.09
Compaction levels								
C_1	5.30	5.35	84.82	75.65	126.50	114.20	44.47	43.13
C_2	6.48	6.72	87.92	75.93	129.39	117.11	47.07	45.16
C_3	7.60	7.69	90.12	76.16	131.85	120.19	45.54	44.24
SEm±	0.32	0.33	0.48	0.46	0.68	0.42	0.39	0.42
CD (P=0.05)	0.98	1.03	1.49	NS	2.12	1.29	1.21	1.31
Irrigation Schedules								
I_1	6.41	6.72	87.96	79.17	129.37	119.00	45.88	44.66
I_2	6.53	6.48	87.53	75.71	129.28	117.02	45.85	44.50
I_3	6.44	6.55	87.37	72.47	129.06	115.48	45.50	43.50
SEm±	0.06	0.06	0.20	0.80	0.23	0.39	0.20	0.22
CD (P=0.05)	NS	NS	NS	2.48	NS	1.20	NS	0.63
Interactions								
D*C	NS	NS	NS	NS	NS	NS	NS	NS
C*I	NS	NS	NS	NS	NS	NS	NS	NS
D*I	NS	NS	NS	NS	NS	NS	NS	NS
D*C*I	NS	NS	NS	NS	NS	NS	NS	NS

Accumulated growing degree days

Data pertaining to accumulated growing degree days of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 2. Among the dates of sowing and compaction levels, highest accumulated growing degree day at anthesis was found with D_1 (924.46 ^{0}C days and 909.98 ^{0}C days during 2014-15 and 2015-16, respectively) and C_3 (878.10 ^{0}C days and 769.89 ^{0}C days during 2014-15 and 2015-16, respectively), respectively. During 2014-15, higher values for accumulated growing degree days at anthesis was observed with I_2 (851.45 ^{0}C days) while during 2015-16, higher accumulated growing degree days was observed with I_1 (801.97 ^{0}C days) over the accumulated growing degree days with other irrigation schedules.

Among the dates of sowing and compaction levels, highest accumulated growing degree day at physiological maturity was found with D_1 (1500.31 ^{0}C days and 1470.72 ^{0}C days during 2014-15 and 2015-16, respectively) and C_3 (1514.83

^{0}C days and 1412.27 ^{0}C days during 2014-15 and 2015-16, respectively), respectively. During 2014-15, higher values for accumulated growing degree days at physiological maturity was observed with I_2 (1472.16 ^{0}C days) while during 2015-16, higher accumulated growing degree days were observed with I_1 (1392.94 ^{0}C days) over the accumulated growing degree days with other irrigation schedules.

Accumulated photo thermal units

Data pertaining to accumulated photo thermal units of wheat crop as influenced by different dates of sowing, compaction levels and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 2. Among the dates of sowing, highest accumulated photo thermal units (PTU) at anthesis were found with treatment D_1 (5312.96 ^{0}C days-hour and 4546.70 ^{0}C days-hour during 2014-15 and 2015-16, respectively). During 2014-15, higher values for accumulated PTU at anthesis was observed with treatment C_3 (4543.34 ^{0}C days-hour) while during 2015-16, with C_2 (3529.26 ^{0}C days-hour) higher accumulated PTU was observed over the accumulated PTU with other compaction levels. Among irrigation schedules, highest values for accumulated PTU at anthesis was observed with I_2 (4410.25 ^{0}C days-hour) during 2014-15 while during 2015-16, higher accumulated photo thermal units were observed with I_1 (3681.38 ^{0}C days-hour). Among the dates of sowing and compaction levels, highest accumulated PTU at physiological maturity was found under D_1 (8942.46 ^{0}C days-hour and 8072.49 ^{0}C days-hour during 2014-15 and 2015-16, respectively) and C_3 (9009.28 ^{0}C days-hour and 7884.04 ^{0}C days-hour during 2014-15 and 2015-16, respectively), respectively. During 2014-15, highest values for accumulated PTU at physiological maturity was observed with I_2 (8646.85 ^{0}C days-hour) while during 2015-16, higher accumulated photo thermal units were observed with I_1 (7733.89 ^{0}C days-hour) over the accumulated PTU with other irrigation schedules.

Heat use efficiency

Data pertaining to Heat use efficiency (HUE) of wheat crop as influenced by different date of sowing, compaction and irrigation schedules during *rabi* seasons 2014-15 and 2015-16 has been depicted in Table 2. It is apparent from the data that among the dates of sowing, HUE was found to higher with D_1 (3.43 kg ha^{-1}/ ^{0}C day and 3.63 kg ha^{-1}/ ^{0}C day during 2014-15 and 2015-16, respectively). HUE was found higher with C_2 (3.21 kg ha^{-1}/ ^{0}C day and 3.32 kg ha^{-1}/ ^{0}C day during 2014-15 and 2015-16, respectively) over the HUE with other compaction levels during both the years. Among the irrigation schedules, HUE was found higher with treatment I_1 (3.14) during 2014-15 while during 2015-16, HUE was recorded higher with I_2 and I_3 (3.27).

Table 2: Accumulated growing degree days (GDD) at anthesis and physiological maturity, accumulated photo thermal units (PTU) at anthesis and physiological maturity and heat use efficiency (HUE) on grain yield basis of wheat as influenced by dates of sowing, compaction levels and irrigation schedules during *rabi* seasons of 2014-15 and 2015-16

Treatments	Accumulated GDD at anthesis (ºC days)		Accumulated GDD at physiological maturity (ºC days)		Accumulated PTU at anthesis (ºC days- hour)		Accumulated PTU at physiological maturity (ºC days- hour)		HUE on grain yield basis (kg ha^{-1}/^{0}C day)	
Dates of sowing	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**
D_1	924.46	909.98	1500.31	1470.72	5312.96	4546.70	8942.46	8072.49	2.82	2.83
D_2	837.78	754.09	1480.00	1344.27	4327.04	3176.92	8356.18	7128.55	3.14	3.33
D_3	777.11	610.92	1408.45	1268.89	3532.98	2834.67	8577.45	7015.95	3.43	3.63
Compaction levels										
C_1	811.89	769.04	1408.58	1311.29	4237.98	3510.56	8247.05	7099.61	3.16	3.29
C_2	849.35	736.05	1465.35	1360.32	4391.65	3529.26	8606.38	7496.64	3.21	3.32
C_3	878.10	769.89	1514.83	1412.27	4543.34	3518.47	9009.28	7884.04	3.01	3.13
Irrigation schedules										
I_1	842.96	801.97	1461.22	1392.94	4374.28	3681.38	8604.91	7733.89	3.14	3.21
I_2	851.45	742.98	1472.16	1359.16	4410.25	3519.10	8646.85	7483.54	3.11	3.27
I_3	844.94	730.04	1455.39	1331.78	4388.45	3357.81	8610.95	7262.86	3.13	3.27

Conclusion

On the basis of agro-meteorological indices and results obtained for grain yield, sowing on 5th December, two passes of RCC roller on sandy loam soil and Irrigation scheduling at 30% depletion from available soil moisture found best for wheat cv. UP-2565 in *tarai* region of Uttarakhand.

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