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Research Paper

Evaluation of wheat (*Triticum* species) varieties under extra-early sown conditions in Vertisols of Central India with restricted assured irrigation

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ABSTRACT

The present study was conducted during the winter (*rabi*) seasons of 2012–13, 2013-14 and 2014-15 at Indore for three consecutive years to find out suitable and high-yielding wheat varieties for extra-early sown condition in Central India under restricted period-assured irrigation condition. Treatments consisted of 3 dates of sowing, viz. 5 October, 20 October and 5 November in main plots and ten wheat varieties, viz. 'HI 8663', 'HI 8713' and 'HI 8627' varieties of durum wheat (*Triticum turgidum* L. subsp. Durum) and 'HI 1531', 'HD 2987', 'GW 273', 'MP 3288', 'Lok 1', 'GW 366' and 'HI 1544' varieties of bread wheat (*Triticum aestivum* L.) as sub-plots, evaluated in split-plot design with 3 replications. Results show the growth and yield attributes, and grain and biological yields observed under 20 October and 5 November were at par but significantly higher than 5 October sowing. On pooled data basis, maximum values of wheat grain yield (4.48 t/ha), gross returns (GR) of ₹87.6 × 10^3/ha and production efficiency (PE) of 33.2 kg/ha/day were recorded under 20 October but the highest plant height, biological yield (12.0 t/ha), net returns (NE) of ₹40.9 × 10^3/ha, benefit: cost (B : C) ratio of 1.90, water-use efficiency (WUE) of 22.3 kg/ha-mm and net monetary use-efficiency (NMUE) of ₹303.2/ha/day were observed under 5 November sowing. Extra-early sowing (5 October) resulted in the lowest values of yields and other economical parameters but recorded the highest values of 1,000-grain weight (49.4 g) and harvest index (40.9). Durum wheat variety HI 8713 was found to be most promising and gave the highest wheat grain yield of 4.61 t/ha, GR of ₹88.8 × 10^3/ha, NR of ₹41.6 × 10^3/ha, B : C ratio of 1.88, PE 34.1 kg/ha/day and NMUE of ₹308.4/ha/day, which were closely followed by bread wheat variety 'HI 1544' (because of highest yield in 5 November sowing) and durum wheat variety 'HI 8663'. The results indicated that sowing of wheat on 5 October under extra-early condition was not beneficial despite receiving extra irrigation, and that durum varieties 'HI 8713' and 'HI 8663' under early-sown (20 October) and bread wheat variety 'HI 1544' under timely sown (5 November) conditions hold promise for realizing higher and economical wheat productivity under restricted period assured irrigated conditions in Vertisols of Central India.

Key words : Dates of sowing, Economics, Extra early sown, Net monetary-use efficiency, Production efficiency, Restricted irrigation, Water-use efficiency, Wheat varieties

Wheat (*Triticum* species) is the most widely cultivated winter (*rabi*) season cereal crop of Central India and occupies an area of around 7.5 million ha. Central Zone, consisting of Madhya Pradesh, Gujarat, Chhattisgarh, Bundelkhand region of Uttar Pradesh, and Kota and Udaipur divisions of Rajasthan. In Central Zone, Madhya Pradesh has the largest area and production of wheat and stood at the second place in area only after Uttar Pradesh across the agro-climatic wheat zones of India. Two wheat species, viz. bread wheat (*Triticum aestivum*) which is used mostly for *chapattis* and durum wheat (*Triticum turgidum* L. subsp. durum) mainly used for *suji, pasta* and other fast foods are under cultivation in Madhya Pradesh. Several varieties of durum and bread wheat have been released in the zone for different cultivation conditions like early sown rainfed or restricted irrigation, and timely or late sown irrigated conditions. Wheat is generally sown during the second fortnight of October under early-sown condition to December or even in the first fortnight of January under late-sown conditions, and harvested during February–April/May. The main cropping sequence of this zone is soybean–wheat, which occupies the largest area. Due to evolving of short-duration varieties of soybean, farmers' fields are vacated early either in the second fortnight of September or in the beginning of October. Majority of farm-holdings of the zone have limited availability of irrigation water as the monsoon rains determine the recharge of groundwater and

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harvesting of water in ponds for subsequent use for irrigating the wheat crop. Generally, most of the irrigation sources in central India dry out by December end or first fortnight of January. Hence for the maximum utilization of this limited irrigation water, the farming community is looking for wheat varieties suitable for extra-early sowing (first week of October). However, during early October temperature remains high in the zone, which is an important weather parameter that influences the growth and phonological phases of wheat, which have definite temperature requirements (Gupta *et al*., 2017). Upadhyay *et al.* (2015) also reported temperature as the deciding factor for differential effects on the developmental activities of different wheat varieties. Every wheat cultivar has its own requirements of environmental conditions for maximum growth, which could be facilitated by proper sowing date (Suleiman *et al.*, 2014). Wheat being a temperature-sensitive crop requires high attention in the optimization of sowing time, which is an important parameter to attain maximum and economic wheat productivity. Although several improved wheat varieties of both species have been released by different ICAR institutes and Agricultural Universities for Central Zone, but information on their suitability for extra-early sown condition is still lacking. Hence keeping this in view, present investigation was planned and carried out to evaluate the recently released durum and bread wheat varieties for their suitability for extra early sowing in Vertisols of Central India.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2012–13, 2013–14 and 2014–15 at Research Farm, ICAR-Indian Agricultural Research Institute, Regional Station, Indore (22.37°N', 75.50°E' and 557 m above mean sea-level), Madhya Pradesh. It has a semi-arid tropical climate with mean annual rainfall of 758 mm. The soil was a deep Vertisols (Typic Haplustert) with clayey texture (52% clay) and bulk density of 1.39 Mg/m^3, having *p*H value 7.6, electrical conductivity 0.23 dS/m (1:2 soil : water ratio), medium in organic carbon (0.53%), available N (242.5 kg/ha) and available P (16.2 kg/ha), and high in available K (452.5 kg/ha). The trial was laid out in split-plot design with 3 replications by assigning the 3 dates of sowing, viz. 5 October, 20 October and 5 November, in main plots and 10 wheat varieties, viz. 'HI 8663', 'HI 8713' and 'HI 8627' of durum wheat; and 'HI 1531', 'HD 2987', 'GW 273', 'MP 3288', 'Lok 1', 'GW 366' and 'HI 1544' in subplots. The crop, irrespective of sowing dates, was irrigated last up to 10 January during each year, to simulate the farmers' situation in regard of irrigation water availability. Mean monthly meteorological data recorded during crop season are summarized in Table 1. The crop sown on 5 October, 25 October and 5 November were harvested on 10 February, 5 March and 25 March, respectively, during all the 3 years. However, varieties like 'HD 2987', 'GW 366' and 'Lok 1' matured 8–10 days earlier, but were harvested at the same time with the other varieties. The crop was sown as per recommended normalized seed rate (1,000-grain weight (g) of variety × 2.5 = kg/ha) with a row-to-row spacing of 20 cm. In 2012–13, trial was undertaken with 2 dates of sowing, viz. 5 October and 5 November, but during 2013–14 crop sown on 5 October (extra-early sown) was totally damaged due to heavy rains just after sowing and due to that only 2 dates, viz. 20 October and 5 November sowings were considered for study. In the third year, the crop was sown under 3 dates of sowing for confirmation of the earlier 2 years' data. A total of 5, 4 and 3 irrigations were applied under 5 October, 20 October and 5 November sowings, respectively, up to 10 January. Recommended fertilizer doses, viz. 120-60-40 of N-P-K were applied to each treatment and half dose of N and full doses of P and K were applied basal and remaining N was top-dressed at the first irrigation. Rests of the package of practices were followed as recommended for growing a healthy crop. The soil samples were analysed for organic carbon, available N, P and K contents and NPK determined by modified Kjeldahl's procedure by using Kjeltec Auto Analyser, calorimetric by vanado-molybdate yellow colour method and flame photometer method (Jackson, 1973), respectively. Biological yield refers to total above ground dry-matter produced by a plant in a unit land area weighed in kg/plot and finally expressed in t/ha, and harvest index is the ratio of economic yield to total biological yield, multiplied by 100. At the time of harvesting, 5 plants from each plot were uprooted for measurements of yield-related characters like length of spike, spikelets/spike and grains/spike. Plant height and effective tillers/sq.m were counted just before harvesting of crop. The net plots were harvested at maturity and threshed with plot thresher separately, and grain yield was recorded in kg/plot and finally expressed in t/ha at optimum moisture content of 10–12%. Total number of grains from randomly selected 5 spikes were counted after threshing and averaged to single spike. The 1,000-grains were picked randomly from cleaned grains of each plot and weighed by using electronic balance for their test weight. All the data were statistically analyzed using analysis of variance (ANOVA) as applicable to split-plot design (Gomez and Gomez, 1984). The significance of the treatment effects was determined using F-test, and the difference between the means was estimated by using critical difference at 5% probability level. Water- use efficiency, production efficiency and net monetary-use efficiency were calculated as per the their standard methods and economics was worked out on the basis

of mean data over 3 years and prevalent market prices for different outputs and inputs.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth and yield attributes of wheat were significantly influenced by different dates of sowing (Table 2). The maximum plant height was observed under 5 November-(D_3) sown crop, which was significantly higher over 5 October (D_1) and 20 October (D_2) sown crop. Higher plant height in D_3 (timely sown crop) may be on account of better availability of mineral nitrogen to the plant owing to favourable soil and atmospheric temperatures which might have resulted in better utilization of carbohydrates to form more protoplasm, thereby resulted in more cell-division and increased plant height (Kumari *et al*., 2012). While maximum fertile (effective) tillers recorded with D_2 treatment were significantly higher over D_1 and D_3 treatments. In case of yield attributes, the highest length of spike (8.27 cm) recorded with D_3 was at par with D_2 but significantly higher over D_1 treatment. But, highest spikelets/spike (17.0) and grains/spike (45.6) were observed under D_2, which being at par with D_3 were significantly higher than D_1 treatments. However, maximum 1,000-grain weight (49.4 g) observed with sowing date D_1 was significantly higher over rest of the dates of sowing. The 1,000-grain weight gradually decreased with delay in the sowing dates. Higher 1,000-grain weight observed with advance sowings might be owing to higher translocation of food material for the formation of seed in advance sowing. However, termination of irrigation on 10 January might have exerted negative effect on translocation of food material in grain under delayed sowing and forced maturity resulted in lower 1,000-grain weight. Gul *et al.* (2012) also reported higher number of spikes/m^2, number of grains/spike and 1,000-grain weight in early-planted crop (24 October) over late-sown crop (13 November). Abdullah *et al*. (2007), Baloch *et al.* (2010) and Tripathi *et al.* (2013) working with wheat, also found that early sowing resulted in the maximum grain weight than late-planted wheat.

Different varieties of wheat also showed significant difference in all the growth and yield attributes. Bread wheat variety 'HI 1531' recorded significantly higher plant height over all the other varieties followed by durum wheat varieties 'HI 8627', while the lowest plant height was observed with bread wheat variety 'HD 2987' (Table 2). Highest number of tillers recorded with 'HD 2987' were at par with 'HI 1531', but significantly higher over rest of the varieties. Variation in plant height and number of tillers under different wheat varieties may be attributed to inherent potential of variety owing to their superior genetic make-up. In case of yield attributes, the maximum length of spike was observed with Lok 1, variety, being at par with varieties 'GW 273', 'MP 3288' and 'HI 1544', but significantly higher than rest of the varieties. However, the maximum spikelets/spike (17.7) recorded with 'GW 273' were at par with 'MP 3288' and 'HI 8713', but significantly higher than rest of the varieties. But numbers of grains/spike observed with durum wheat variety 'HI 8713' (49.1) were statistically at par with 'HI 8627' but significantly higher than all the other varieties. The highest 1,000-grain weight recorded with bread wheat variety 'GW 366' (50.2 g) was at par with variety 'HI 8713' (48.8 g), but significantly higher over rest of the varieties.

Grain and biological yields, and harvest index

Dates of sowing significantly affected grain and biological yields of different wheat varieties (Table 2). The maximum grain yield (4.48 t/ha) recorded with D_2 (20 October sowing) was almost similar to D_3 (lowered only by 0.11%) but significantly higher than D_1. The magnitude of increase in grain yields under delayed sowing under D_2 (20 October) and D_3 (5 November) was 19.5 and 18.1%, respectively, as compared to D_1 (5 October). The higher yield under D_2 sowing date was the function of highest number of tillers/m^2 and more number of spikelet and grains/spike. The maximum biological yield 12.0 t/ha obtained with D_3 was slightly greater (3.45%) than D_2 but significantly

Table 1. Mean monthly meteorological observations during crop seasons of 3 years

Month	Temperature (°C)						Rainfall* (mm)			Relative humidity (%)			Open PER (mm/day)		
	Maximum			Minimum											
	12–13	13–14	14–15	12–13	13–14	14–15	12–13	13–14	14–15	12–13	13–14	14–15	12–13	13–14	14–15
October	31.7	30.3	32.0	16.2	18.8	17.6	0	107.6	12.5	85.8	81.6	80.8	5.4	5.6	6.4
November	28.9	28.2	29.7	9.5	12.3	14.0	0	0	0	82.4	78.5	80.7	4.7	4.5	4.9
December	27.5	26.0	25.5	8.7	9.0	8.2	0	2.2	5.8	78.0	80.2	78.5	3.9	4.0	3.3
January	23.8	23.4	22.1	5.8	7.1	7.0	0	0	0	78.4	80.1	78.6	3.4	3.7	4.0
February	26.4	25.6	27.5	10.4	7.5	9.6	8.94	42.2	2.0	79.4	78.7	74.7	4.3	4.6	7.1
March	33.4	31.7	30.0	15.0	12.5	15.8	0	0	0	76.0	79.4	73.3	6.9	6.5	6.7
Mean	28.6	27.5	27.8	10.9	11.2	12.0	8.94	152.0	20.3	80.0	79.7	77.8	4.8	4.8	5.4

*Rainfall data are month's total

higher than D_1. The increase in biological yield under D_2 and D_3 sowing dates was higher by 26.1 and 30.4% as than D_1 sowing date. The reason of higher biological yield with D_3 sowing date was mainly ascribed to significant increase in plant height of different wheat varieties as compared to D_1 and D_2 sowing dates. Lower grain and biological yields under D_1 sowing date was mainly due to lower values of growth parameters like plant height and number of tillers/unit area, and yield attributes, viz. length of spike, spikelets/spike and grains/spike, compared with other dates of sowing. Which was mainly because of prevailing high temperatures, relative humidity and pan-evaporation values, unsuitable for growth but favourable for developmental phase of wheat crop during the entire growth period. Due to that most of the wheat varieties attains lower plant height than its genetic potential and flowered early with lower length of spike, number of spikelets/spike and grains/spike. Being a C_3 plant, it requires long cold periods for proper and normal growth, and high temperatures are not suitable for proper growth of wheat. The poor values of growth attributes under D_1 sowing date might be responsible for decreased availability of photo-assimilates for proper developmental, process of wheat spikes and grain development resulting in lower grain yields. Taller plant stature in D_3 sowing date may be owing to favourable temperature for growth just after germination, which is required for proper growth of wheat and adequate moisture availability to plant. But due to termination of irrigation by 10 January, high growth parameters could not be converted into desired developmental parameters, resulting in poor number of fertile tillers and other yield attributes, eventually leading to poor grain yield compared with D_2 sowing date. Gul *et al.* (2012) and Tripathi *et al.* (2013) also reported significantly higher wheat yields when the crop was raised in the last week of October than sowing in mid November. But its contrary, Khokhar *et al.* (2010) and Anwar *et al.* (2015) reported higher grain yield and yield attributes in November sowing than October sowing.

Data recorded on grain and biological yields of wheat varieties in different years were also significant and results revealed that, among the varieties, maximum grain yield (4.61 t/ha) recorded with durum variety 'HI 8713' was at par with 'HI 1544', 'HI 8663' and 'HD 2987' but significantly higher over all the other varieties. The highest grain yield recorded with 'HI 8713' was higher by 9.76% from most popular wheat variety Lok 1 used by farming community under extra-early sown conditions. In case of biological yield, the highest biological yield of 11.7 t/ha observed with wheat variety 'HI 8627' was statistically at par with 'HI 8713', 'HI 8663' and 'HI 1544' but significantly higher than rest of the varieties. As per practical experience, wheat varieties, viz. all durum wheat 'HI 8713', 'HI 8663' and 'HI 8627', and bread wheat 'HI 1531', 'HD 2987' and 'GW 273' have the comparatively the high potential to bear high temperature, more relative humidity and pan evaporation than the other varieties. However, above varieties are not able to express their full genetic potential of growth and productivity under extra-early sowing, i.e. first week of October, hence one of the varieties can be recommended to be sown under extra-early conditions of 5 October even

Table 2. Growth, yield attributes and yield of different wheat varieties as influenced by date of sowing (mean data of 3 years)

Treatment	Plant height (cm)	Fertile tillers/m^2	Length of spike (cm)	Spikelets/ spike	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index
Date of sowing									
D_1 (5 October)	80.8	328.5	7.76	15.3	41.6	49.4	3.75	9.2	40.9
D_2 (20 October)	88.3	382.9	8.23	17.0	45.6	44.2	4.48	11.6	38.5
D_3 (5 November)	97.2	369.3	8.27	16.5	43.8	42.1	4.43	12.0	37.1
SEm±	0.87	1.99	0.057	0.15	0.56	0.25	0.070	0.15	-
CD (P=0.05)	3.41	7.81	0.224	0.58	2.20	0.99	0.275	0.58	-
Varieties									
V_1 ('HI 8663')	84.0	355.0	6.44	16.3	45.0	47.0	4.52	11.2	40.3
V_2 ('HI 8713')	92.0	322.6	7.43	17.0	49.1	48.8	4.61	11.6	39.7
V_3 ('HI 8627')	96.7	320.4	7.35	16.8	48.8	48.2	4.25	11.7	36.4
V_4 ('HI 1531')	103.9	429.5	7.70	16.3	40.2	39.7	3.73	11.6	32.1
V_5 ('HD 2987')	74.5	436.0	7.10	13.9	32.9	42.6	4.37	10.4	42.2
V_6 ('GW 273')	92.4	363.4	9.28	17.7	43.3	45.3	4.14	10.5	39.4
V_7 ('MP 3288')	92.7	356.6	9.16	17.5	42.8	43.6	4.22	10.9	38.8
V_8 ('Lok 1')	87.6	330.8	9.33	15.8	42.2	47.6	4.20	10.5	40.2
V_9 (GW 366)	85.9	380.3	7.64	15.1	41.9	50.2	4.01	10.6	37.8
V_{10} ('HI 1544')	86.4	409.8	8.88	15.9	44.8	44.3	4.59	11.1	41.4
SEm±	1.01	9.17	0.167	0.30	1.12	0.56	0.087	0.21	-
CD (P=0.05)	2.86	26.19	0.472	0.85	3.18	1.57	0.246	0.59	-

assured availability of water for irrigation. Variation in biological yield was mainly due to inherent potential of particular variety in terms of its high stature and more tiller capacity, which resulted in varied levels of biological yields due to differences in their contribution to above ground biomass. Tomar *et al.* (2014) also tested 4 wheat verities, viz. 'HI 8498' (durum), 'HI 1544', 'GW 322' and 'Lok 1' and reported that, 'HI 1544' gave the maximum and 'Lok 1' the lowest grain yield, which was attributed to more number of tillers/m^2, ears/m^2, grains/ear and higher test weight, compared to the other varieties.

Among dates of sowing, the maximum value of harvest index (HI) was observed under D_1, which gradually decreased with delay in date of sowing, viz. D_2 and D_3 sowing dates. Higher HI under D_1 sowing date was mainly because of lower proportion of grain to biomass yield compared with D_2 and D_3 sowing dates. However, increased biomass yields under delayed sowing could not get translated in to similar gain in grain yields due to termination of irrigation by 10 January, especially under D_3, where there was possibility of forced maturity. While in case of varieties, shortest stature variety 'HD 2987' showed the highest value of HI (42.2) followed by 'HI 1544', 'HI 8663' and 'Lok 1', the high-stature varieties like 'HI 1531' and 'HI 8627' exhibited lower HI values due to higher above-ground biomass and proportionately lower grain yields. Higher value of HI is mainly attributed to high proportion of grain compared with straw in total biomass yield.

Water-use efficiency

Water-use efficiency (WUE), calculated on the basis of mean wheat yields, showed that maximum value (24.6 kg/ha-mm) was observed with D_3 owing to less frequency of irrigation and proportionately higher wheat yields, followed by D_2 (Table 3) with minimum under D_1 sowing date due to lowest wheat yields and maximum use of irrigation water. Among the varieties, wheat variety 'HI 1544' recorded the highest WUE value (20.2 kg/ha-mm), which was closely followed by 'HI 8713' and 'HI 8663'. The lowest values of WUE were observed with varieties 'HI 1531' (16.2 kg/ha-mm). Higher grain productivity of wheat with the use of similar quantity of water was the main reason for variation in WUE values of different wheat varieties.

Production efficiency

Working out of production efficiency (PE) under different dates of sowing indicated that, maximum PE (33.2 kg/ha/day) was observed in D_2 sowing date and it was closely followed by D_3 sowing date (32.9 kg/ha/day), but substantially higher over D_1 (28.0 kg/ha/day). The lowest PE value with D_1 was mainly due to comparatively lower wheat grain yields than D_2 and D_3 sowing dates but the field occupied for comparatively more number of days due extra-early sowing. This variation was mainly because of differences in wheat productivity under different dates of sowing and varied number of days of field occupation. Among the varieties, 'HI 8713' revealed the highest values of PE

Table 3. Effect of dates of sowing on warter-use efficiency, production indices and economics of different wheat varieties (mean data of 3 years)

Treatment	Water-use efficiency (kg/ha-mm)	Production efficiency (kg/ha/day)	Net monetary use-efficiency (₹/ha/day)	Economics			
				Cost of cultivation (× 10^3₹/ha)	Gross returns (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit : cost
Date of sowing							
D_1 (5 October)	12.4	28.0	167.8	49.0	71.3	22.3	1.45
D_2 (20th October)	18.8	33.2	296.6	47.2	87.6	40.3	1.85
D_3 (5th November)	24.6	32.9	303.2	45.5	86.4	40.9	1.90
Varieties							
V_1 ('HI 8663')	19.6	33.5	292.6	47.2	86.7	39.4	1.84
V_2 ('HI 8713')	20.0	34.1	308.4	47.2	88.8	41.6	1.88
V_3 ('HI 8627')	18.3	31.5	276.7	47.2	84.5	37.3	1.79
V_4 ('HI 1531')	16.2	27.9	226.5	47.2	77.7	30.5	1.64
V_5 ('HD 2987')	19.3	32.0	241.6	47.2	79.8	32.6	1.70
V_6 ('GW 273')	18.1	30.6	226.6	47.2	77.8	30.6	1.65
V_7 ('MP 3288')	18.5	31.3	255.1	47.2	81.7	34.4	1.73
V_8 ('Lok 1')	18.5	30.3	230.8	47.2	78.4	31.2	1.67
V_9 ('GW 366')	17.5	28.8	215.4	47.2	76.4	29.1	1.63
V_{10} ('HI 1544')	20.2	33.4	285.0	47.2	85.7	38.5	1.82
Mean	18.6	31.4	255.9	47.2	81.8	34.5	1.73

Labour wage @ ₹250/manday; rates of wheat grain and straw @ ₹15,500 and ₹2,500/tonne

(34.1 kg/ha/day) followed by 'HI 8663' (33.5 kg/ha/day) and 'HI 1544' (33.4 kg/ha/day) with lowest values with varieties 'HI 1531' (27.9 kg/ha/day) and 'GW 366' (28.8 kg/ha/day) due to lower wheat yields with similar days of field occupation.

Net monetary-use efficiency

Computation of net monetary-use efficiency (NMUE) showed that highest value of NMUE (303.2/ha/day) recorded with D_3 sowing date was closely followed by D_2 (296.6/ha/day), but substantially higher over D_1 (167.8/ha/day). Higher NMUE value in D_3 sowing date was mainly because of lower cost of cultivation on account of less irrigation frequency and proportionately higher wheat yield, which resulted higher net returns and NMUE values than D_1 and D_2 sowing dates. High frequency of irrigation under D_1 sowing dates and lower wheat yields substantially decreased the values of NMUE. In case of varieties, 'HI 8713' recorded the highest NMUE to the level of 308.4/ha/day followed by HI 8663 (292.6/ha/day) and 'HI 1544' (285.0/ha/day). However, wheat varieties 'GW 366', 'HI 1531', 'GW 273' and 'Lok 1' recorded considerably lower values of 215.4, 226.5, 226.6 and 230.8 292.6/ha/day, respectively' due to lower wheat grain production and similar cost of cultivation.

Economics

Economical parameters, viz. cost of cultivation, gross returns, net returns and benefit: cost ratio (Table 3) revealed that, cost of cultivation varied under different dates of sowing due to variation in levels of irrigation applied and gross returns are the multiplication values of crop yields and prevailing market price of produce. Among the dates of sowing, the maximum gross returns worked out to be ₹87.6 10^3/ha under D_2 sowing dates was closely followed by D_3 (₹86.4 × 10^3/ha) with minimum under D_1 (₹71.3 × 10^3/ha). Higher gross returns recorded with D_2 and D_3 sowing dates were higher by 22.9 and 21.2%, respectively, compared with D_1. The highest net returns and benefit: cost (B : C) ratio were observed with D_3 (₹40.9 × 10^3/ha and 1.90), which being slightly higher than D_2 (₹40.3 × 10^3/ha and 1.85) were substantially higher over D_1 (₹22.3 × 10^3/ha and 1.45). This increase under D_2 and D_3 sowing dates was to the tune of 76.2 and 83.4% in net returns and 27.6 and 31.0% in B : C ratio over D_1. Despite higher yields in D_2, the highest values of NR and B : C ratio were observed with D_3, which ascribed to higher cost of cultivation in D_2 on account of 1 more irrigation than D_2 sowing date. Among the varieties, durum wheat variety 'HI 8713' recorded highest values of gross returns (₹88.8 × 10^3/ha), net returns (₹41.6 × 10^3/ha) and B : C ratio (1.90) followed by 'HI 8663' and 'HI 1544'. The magnitude of increase with 'HI 8713', 'HI 8663' and 'HI 1544' were higher by 33.3, 26.3 and 23.4% in net returns and 12.6, 10.2 and 8.98% in B : C ratio, respectively, over most popular variety of Central Zone 'Lok 1'. Tripathi *et al.* (2013) also reported higher values of gross returns, net returns and B : C ratio under sowing of wheat in the last week of October than mid-November sowing of different wheat varieties. Tomar *et al.* (2014) recorded the highest values of net returns and B : C ratio with wheat variety 'HI 1544' under timely sown conditions, compared to varieties 'HI 8498', 'GW 366' and 'Lok 1'.

On the basis of 3 years study, it can be concluded that sowing of any wheat variety in the first week of October is not recommended even under assured availability of water for irrigation due to not beneficial in terms of yield and monetary returns. However, durum wheat varieties 'HI 8713' and 'HI 8663' under early sowing (20 October) and 'HI 1544' under timely sowing can provide higher yields and more economic returns under restricted period assured irrigation conditions in Vertisols of Central India.

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