



Productivity, profitability, quality and nutrient uptake of heat tolerant wheat (*Triticum aestivum*) cultivars as influenced by staggered sowing and nutrition levels

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ABSTRACT

In the present investigation, we investigated the effects of staggered sowing and nutrition levels on productivity, profitability, quality and nutrient uptake of heat tolerant wheat (*Triticum aestivum* L.) cultivars during *rabi* season of 2014-16 at the Breeder Seed Production Unit, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. Soil of the experimental plot was clay in texture, medium in organic carbon and available NPK with neutral pH (7.4). Experiment was laid out in split-plot design with three replications. The main plots consisted of three staggered sowing, i.e. 30th November, 20th December and 10th January and three nutrition levels, viz. RDF (120:60:40 kg NPK/ha), 20% higher RDF and 20% lesser RDF, while three heat tolerant varieties, viz. MP 1203, MP 3336 and GW 173 were allotted in sub-plot. Results revealed that among the sowing time, grain yield (4.20 t/ha), straw yield (5.04 t/ha), biological yield (9.25 t/ha) and harvest index (45.3%) had recorded significantly higher in 30th November sowing. Crop sown on 30th November had increased the grain yield by 11.7 and 37.7% over that of 20th December and 10th January sowing, respectively. Among the nutrition levels, 20% higher RDF had recorded significantly higher grain yield (4.01 t/ha), straw yield (4.84 t/ha), biological yield (7.78 t/ha) and harvest index (45.1%) compared to RDF and 20% lesser RDF. Application of 20% higher RDF increased the grain yield to the tunes of 9.8 and 19.7% compared to RDF and 20% lesser RDF, respectively. Significantly higher grain yield was recorded with MP 3336 (4.05 t/ha) compared to MP 1203 (3.59 t/ha) and GW 173 (3.36 t/ha). Crop sown on 30th November had significantly higher gross returns (₹ 79218/ha), net returns (₹ 55873/ha) and B:C ratio (3.39), respectively. Application of 20% higher RDF had maximum gross returns (₹ 75684/ha), net returns (₹ 51360/ha) and B: C ratio (3.11), respectively. MP 3336 had higher gross returns (₹ 76634/ha), net returns (₹ 53289/ha) and B: C ratio (3.28). Sowing on 30th November had significant superiority in nutrient content (NPK) in grain and straw as well as their uptake by crop. These attributes had significantly higher with application of 20% higher RDF. MP 3336 had higher NPK contents in grain and straw than that to MP 1203 and GW-173. Protein content had higher in 30th November sowing (16.01%). Application of 20% higher RDF had better protein content (15.43%). MP 3336 had markedly higher protein content (15.63%). Carbohydrate equivalent and carbon output had higher when crop sown on 30th November (3.0 and 4.1 /ha) along with 20% higher RDF (2.9 and 3.7 t/ha) in MP 3336 (2.9 and 4.0 t/ha), respectively. Therefore, sowing of heat tolerant wheat cv. MP 3336 on 30th November along with application of 20% higher RDF were proved the most ideal approach to achieve the higher productivity, profitability and nutrient uptake under the irrigated ecosystem of Madhya Pradesh.

Key words: Carbon output, Grain yield, Heat tolerant cultivars, Nutrient uptake, Protein content, Wheat

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of ~35 per cent of world population (Prasad *et al.* 2017). About 20 percent of protein supply of the world comes from wheat alone (Singh *et al.* 2017). In India, it is cultivated in ~31.19 million ha with production and productivity of 95.91 MT and 2445 kg/ha, respectively (Paswan *et al.* 2017). Area, production and

productivity of wheat in Madhya Pradesh is 5792 thousand ha, 13928 thousand tonnes and 2405 kg/ha, respectively (DES 2014). Crop is grown in India exclusively in winter as *rabi* crop. Crop is extremely susceptible to high temperature and delayed wheat sowing exposes its grain filling stages (Pandey *et al.* 2015). Heat stress imposed to crop due to delayed sowing is considered as one of the most significant abiotic stress affecting crop production (Joshi *et al.* 2007). Optimum temperature required at wheat anthesis and grain filling ranges between 12–22°C and exposures to temperature > 30°C at pre or post-anthesis stage reduces grain filling in wheat, thereby decreases yields and quality (Barnabas *et al.* 2008). Thus, lengthening of vegetative phase had one of the foremost facts in timely

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sowing, which utilize the abundant time for enhancing their height and thus sugar reservoirs (Kumar and Kumawat, 2014). Photosynthesis exhibits the maximum sensitivity towards elevated temperature with significant decrease in net photosynthetic rate, thereby reduces growth (Mathur *et al.* 2014). High temperatures induced impairment of chlorophyll biosynthesis held responsible for reduced accumulation of chief photosynthetic pigment (Prasad *et al.* 2017). Moreover, it disturbs activation of rubisco enzymes in wheat that inturn decreases photosynthesis (Almeselmani *et al.* 2012) and decreased stomatal conductance and transpiration rate (Gupta *et al.* 2015). Pollen development, viability and fertilization in wheat had severely impaired by high temperature, which often leads to pseudo-seed setting of the crop. Pollen maturation requires starch as an energy reserves, thus starch accumulated in stem tissue as transitory sink during reproductive phase (Zhang *et al.* 2010). Genotypic variation for thermal susceptibility had noted at reproductive stage. Crop yield is critically dependent on successful reproductive development and evaluating pollen viability may be considered as important criterion in selecting the heat tolerant genotype.

North India covers major wheat growing areas in the country and sowing of wheat begins as fields get vacated by previous *kharif* crops, viz. rice, maize, and soybean. Thus, planting time ranges from 1st week of October to end of December in Madhya Pradesh. Lack of suitable option after late harvest of *kharif* crop compelled for very late planting of wheat even after 10th January (Yadav *et al.* 2013). As a result, crop exposed to low temperature at early growth stages and higher ambient temperatures at anthesis and grain filling, which cause significant reduction in yields (Singh *et al.* 2011a). India needs to produce ~101.7 MT by 2025 to feed ever growing population (Prasad *et al.* 2017). It is a major challenge under climate change scenario, especially high temperature stress, which is one of immense environmental threat to agriculture particularly in wheat. Temperature is one of the major determinants of wheat growth, which cannot be modified in field condition (Jeet *et al.* 2010a). However, impact of high temperature on crop yields can be minimized by adoption of agronomic management practices. Adjustment in planting time is one of the most important agronomic strategies to counteract the adverse effect of temperature stress (Jeet *et al.* 2010b). In addition selection of heat tolerant varieties can help to mitigate the temperature stress effect (Kajla *et al.* 2015). Some of the high yielding varieties (HYVs) suitable for cultivation in varying environmental conditions had also developed, which had high input use efficiency (IUE) and withstand to climatic aberration (Jeet *et al.* 2010c). Intensive cropping systems with HYVs had resulted in marked depletion of nutrient reserve in the soils. Along with imbalanced fertilization results into yield stagnation, low nutrient use efficiency (NUE) as well as high environmental risk in wheat (Singh *et al.* 2011b). Further, the information regarding on nutrition demand of newly developed heat tolerant wheat cultivars is meager. Therefore, the present study was commenced to

find out the optimum sowing time and nutrition levels for suitable heat tolerant wheat cultivars for achieving higher productivity, profitability and nutrient uptake in irrigated ecosystem of Jabalpur, Madhya Pradesh.

MATERIALS AND METHODS

Field experiment was conducted for two consecutive years during *rabi* seasons of 2014–16 at the Breeder Seed Production Unit, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (23° 09' N latitude and 79° 58'E longitude and at an altitude of 411 m above mean sea level). Experimental soil was clay (sand: 25.18%, silt: 19.18% and clay: 55.64%), having pH 7.4. It was moderately fertile being medium in organic carbon (0.56%). Available N, P and K was 264.2, 13.4 and 295.2 kg/ha in soil, respectively. Experimental area occupied was quite uniform in respect of topography and fertility. Meteorological data of cropping period were presented in Fig 1. Total rainfall received during 1st year was 183.3 mm, which was distributed in 18 rainy days. During 2nd year, only 64.3 mm rainfall was received, which was distributed in 8 rainy days. Crop was exposed to the total sunshine hours of 160.8 and 165.4 hours in 1st and 2nd year, respectively. Experimental field was prepared by ploughing with tractor drawn mould board plough followed by cross harrowing with disc harrow. Levelling of field was done by using tractor drawn leveler. Thereafter layout of the experimental field was done as per treatment. After that furrows for sowing of seeds were opened manually with help the of *kudal* at a spacing of 22.5 cm. Required quantity of healthy and clean seeds were calculated using @ 100 kg/ha and treated with thiram @ 2.5 g/kg of seeds. Basal dose of fertilizers in required quantity were applied as per treatment in the furrow. Seeding was done manually and thereafter furrows were covered. The crop sowing was done in three dates on 30th November, 20th December and 10th January during both the years of study. Urea (46% N), single super phosphate (16% P₂O₅) and muriate of potash (60% K₂O) were used as sources of NPK, respectively. Recommended dose of fertilizer (RDF) was 120:60:40 kg NPK/ha. Half dose of nitrogen was applied at sowing time as basal dose along with full quantities of phosphorus and potash. Remaining half doses on N was applied in two splits as top dressing, first at 30 DAS and second at 60 DAS. Weeding was done on 30 DAS with help of *khurpi* to avoid the crop weed competition. Five irrigation were given during cropping period i.e. at crown root initiation (CRI), tiller completion, late jointing, anthesis and milking stage, respectively. Crop harvesting was done with help of sickle at maturity by removing boarder rows. After this, harvesting of net plot area was done separately for each plot and kept for sun drying and weighed. Straw yield per net plot was worked out by subtracting total harvested grain weight from total biomass. Cost of cultivation and gross returns were calculated based on the prevailing market price of inputs and produce. Crop productivity and economic efficiency were computed as suggested by Kumar *et al.* (2015). Economic yields of the

respective crops were converted into equivalent value of carbohydrate by using conversion as given by Gopalan *et al.* (2004). Carbon output was calculated based on plant biomass contains ~44% carbon content as suggested by Lal (2004). Crop samples collected after harvest was chemically analyzed for NPK contents. Samples were oven dried at 80°C for 48 hr and ground to pass a 20-mesh sieve. Total nitrogen content was determined using Kjeldahl method. Dried powder of plant material was digested in sulfuric acid added with salicylic acid and sodium thiosulfate, so as to estimate both organic and nitrate nitrogen in plant samples. Ammonia was distilled into boric acid solution using 40% NaOH solution and mixed with indicator. Ammonia absorbed in boric acid was titrated against standard solution of sulfuric acid to determine total N in sample. In order to determine P and K, finely ground plant samples digested in diacid. Total P content in plant tissue was determined by vanadate-molybdate method given by Olsen and Sommers (1982), recording absorbance at 420 nm wavelength of yellow colour complex formed due to reaction of extracted plant orthophosphates with molybdate and vanadate, using spectrophotometer fitted with blue filter. Phosphorus content in aliquot was estimated with help of standard curve prepared by using KH_2PO_4 . Potassium content in the nitric-perchloric acid digest of sample was estimated using a flame photometer with K filter and determined by standard curve prepared by using graded concentration of KCl. Nutrient uptake was estimated by multiplying N, P and K concentration of grain and straw with their respective yield. The field data obtained for 2 years were pooled and statistically analyzed using F-test (Gomez and Gomez 1984). The significant difference between treatment

means were compared with critical differences at 5% levels of probability.

RESULTS AND DISCUSSION

Crop productivity

Pooled data revealed that grain yield, straw yield and biological yield had significantly influenced by sowing times (Table 1). Among the sowing time, crop planted on 30th November had significantly superior in grain yield (4.20 t/ha), straw yield (5.04 t/ha), biological yield (9.25 t/ha) compared 20th December and 10th January sowing. Crop planted on 30th November had increased in grain yield to the tunes of 11.7 and 37.7% than that to 20th December and 10th January sowing, respectively. Higher grain yield in 30th November sown crop may be attributed to better plant growth leading to significantly more yield attributes and better partitioning of photosynthates (Kumar *et al.* 2009). Reduction in yields in late sown crop might be due to detrimental effect of higher temperature at heading to milking and milking to dough phases of crop causing poor grain filling (Jat *et al.* 2013). Similar trends were followed in case of HI, where early sown crop, i.e. 30th November had significantly higher HI (45.3%). Significantly higher crop productivity had noted under 30th November (37 kg/ha/day) than that to 20th December (36 kg/ha/day) and 10th January sowing (33 kg/ha/day). This might be due to higher grain yields (Kumar *et al.* 2017).

Varying nutrition levels had marked influence on yield attributes of wheat i.e. grain yield, straw yield and biological yield (Table 1). Among nutrition levels, application of 20% higher RDF had increased significantly grain yield (4.01

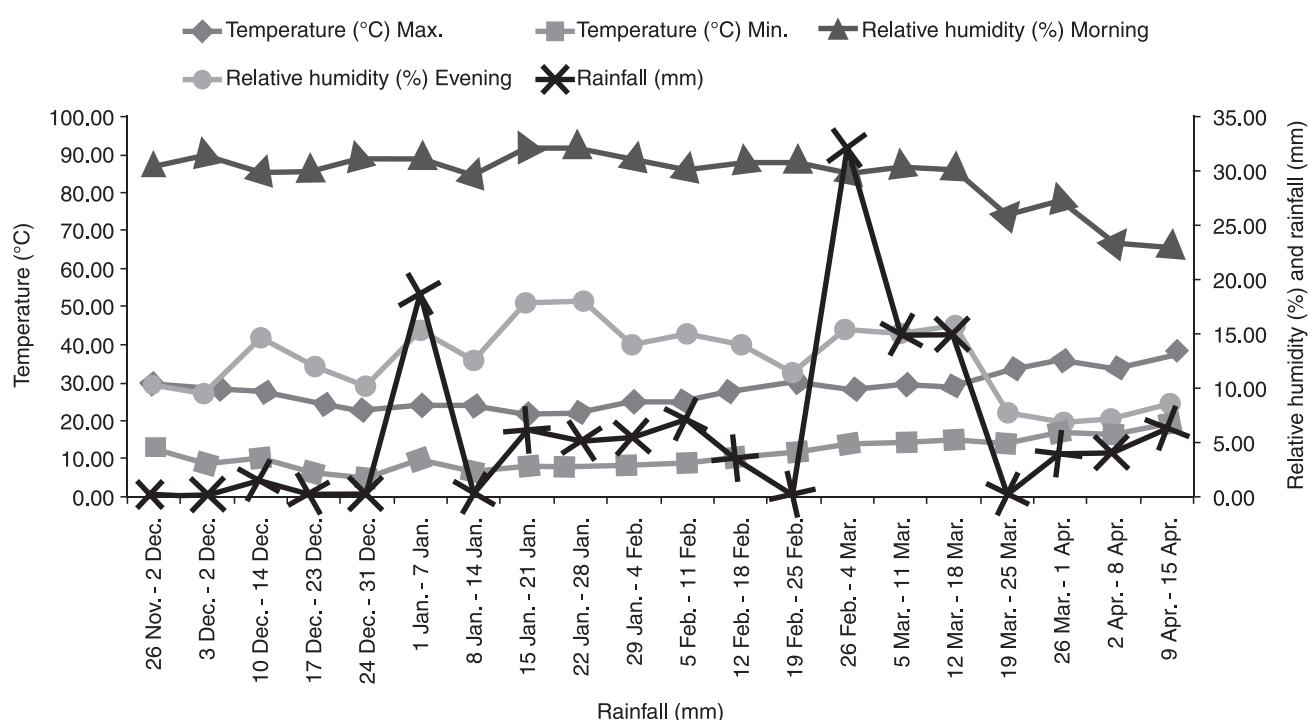


Fig 1 Mean weather data during the experimentation (2014-2016).

Table 1 Yields and economics of wheat cultivars as influenced by staggered sowing and nutrition levels (Pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Production efficiency (kg/ha/day)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)
<i>Staggered sowing</i>									
30 th November	4.20	5.04	9.25	45.3	37	79218	55873	3.39	490
20 th December	3.76	4.78	8.54	43.9	37	71700	48355	3.07	469
10 th January	3.05	4.07	7.12	42.8	33	58739	35394	2.52	383
Staggered sowing	0.03	0.03	0.05	0.02		578	578	0.03	
30 th November	0.11	0.09	0.15	0.06		1734	1734	0.07	
<i>Nutrition levels</i>									
RDF	3.65	4.64	8.29	43.9	35	69548	46203	2.98	449
20% higher RDF	4.01	4.84	8.85	45.1	39	75684	51360	3.11	499
20% lesser RDF	3.35	4.42	7.78	43.0	33	64426	42060	2.88	408
SEm ±	0.03	0.03	0.05	0.02		578	578	0.03	
LSD (P=0.05)	0.09	0.09	0.15	0.06		1734	1734	0.07	
<i>Heat tolerant cultivars</i>									
MP 1203	3.59	4.54	8.13	43.9	34	68459	45114	2.93	422
MP 3336	4.05	4.93	8.98	44.9	40	76634	53289	3.28	525
GW 173	3.36	4.43	7.79	43.1	33	64564	41219	2.77	408
SEm ±	0.03	0.02	0.04	0.02		531	531	0.02	
LSD (P=0.05)	0.07	0.06	0.11	0.06		1524	1524	0.07	

*RDF:120:60:40 kg/ha N-P₂O₅-K₂O

t/ha), straw yield (4.84 t/ha) and biological yield (8.85 t/ha), respectively compared to RDF and 20% lesser dose of RDF. Magnitude of increase in grain yield by 20% higher RDF over RDF and 20% lesser RDF were 9.9 and 19.7%, respectively. However, RDF had also registered superiority in grain yields over 20% lesser RDF. Similar trends were noted in case HI, where higher nutrition i.e. 20% higher RDF had significantly higher HI (45.3%). This might be due to adequate supply of NPK under 20% higher RDF. Adequate supply of NPK leads to high photosynthetic activity, vigorous vegetative growth and finally influences better utilization of carbohydrates. Adequate supply of P increases tiller emergence, especially secondary tillers, survival and help to increase yields through proper regulation of carbohydrates translocation, proper supply of potassium facilitates better photosynthesis, protein and chlorophyll formation/translocation of assimilate sugar from leaves to stem (Maurya *et al.* 2014). Significantly higher crop productivity had noted with 20% higher RDF (39 kg/ha/day) compared to RDF (36 kg/ha/day) and 20% lower RDF (33 kg/ha/day), respectively. This might be due to higher grain yield were associated with respective treatments (Kumar *et al.* 2017).

Wheat cultivars had marked influence on yields (Table 1). MP 3336 exhibited significantly higher grain yield (4.05 t/ha), straw yield (3.59 t/ha) and biological yield (3.36 t/ha) as compared to other cultivars. Grain yield of heat tolerant cultivars followed the trend of MP 3336>MP 1203>GW 173. Similar trends were followed in case of HI. This might be due to their genetic makeup of the particular cultivars (Tripathi *et al.* 2013). Markedly higher crop productivity

was noted in MP 3336 (40 kg/ha/day) compared to MP1203 (34 kg/ha/day) and GW 173 (33 kg/ha/day), respectively. This might be owing to higher grain yields of respective cultivars (Kumar *et al.* 2018).

Interaction effects

Pooled data showed that interaction between sowing times and varieties and nutrition and varieties had significant impact on grain yields (Table 2 and 3). Cultivar sown on 30th November had higher grain yield (4.81 t/ha). MP 3336 sown with 20% higher RDF had markedly higher grain yield (4.37 t/ha). These results are in close conformity with Malghani *et al.* (2010).

Profitability

Pooled data revealed that economic attributes, i.e.

Table 2 Interaction effect of staggered sowing and varieties on grain yield of wheat (Pooled data 2 years)

Treatment	MP 1203	MP 3336	GW 173	Mean
30 th November	4.66	4.81	3.72	4.36
20 th December	3.52	4.36	3.88	3.92
10 th January	3.19	3.54	2.83	3.19
Mean	3.79	4.24	3.47	3.83
		SE m±	CD	
			(P=0.05)	
Cultivars at same levels of planting time		0.06	0.18	
Planting time at same/ diff. levels of cultivars		0.07	0.19	

Table 3 Interaction effect of nutrition levels and cultivars on grain yield of wheat (Pooled data 2 years)

Treatment	MP 1203	MP 3336	GW 173	Mean
RDF	3.90	4.28	3.46	3.91
20% higher RDF	3.75	4.37	3.63	3.91
20% lower RDF	3.07	3.53	3.00	3.19
Mean	3.60	4.06	3.36	3.67
		SEm±	LSD	
			(P=0.05)	
Cultivars at same levels of nutrition levels		0.06	0.18	
Nutrition levels at same/diff. levels of cultivars		0.07	0.19	

*RDF: 120:60:40 kg/ha N-P₂O₅-K₂O

gross returns, net returns and B: C ratio had influenced markedly by staggered sowing (Table 1). Crop planted on 30th November fetched significantly higher gross returns (₹ 79218/ha), net returns (₹ 55873/ha) and B: C ratio (3.39) compared to 20 December and 10th January sowing. Increase in net returns by 30th November sowing than that to 20th December and 10th January sowing was 15.5 and 58.1%, respectively. This might be due to higher yields with respective treatment (Kumar *et al.* 2017). Significantly higher economic efficiency had noted with 30th November (₹ 490/ha/day) over 20th December (₹ 469/ha/day) and 10th January (₹ 383/ha/day), respectively. This might be due to higher yields and net returns (Kumar *et al.* 2018).

Increasing in nutrition levels had significant increase in gross returns, net returns and B: C ratio (Table 1). Application of 20% higher RDF had higher gross returns (₹ 75684/ha), net returns (₹ 51360/ha) and B: C ratio (3.11) compared to RDF and 20% lesser RDF, respectively. Increase in net returns by 20% higher RDF over RDF and 20% lesser RDF was 11.1 and 22%, respectively. Economic

efficiency had notably higher with 20% higher RDF (₹ 499/ha/day) as compared to RDF (₹ 449/ha/day) and 20% lower RDF (₹ 408/ha/day), respectively. This might be due to higher yields and net returns associated with the respective treatment (Kumar *et al.* 2017).

Cultivar MP 3336 had significantly higher gross returns (₹ 76634/ha), net returns (₹ 52289/ha) and B: C ratio (3.28), respectively than that to MP 1203 and GW 173 ((Table 1). Increase in net returns by MP 3336 over MP 1203 and GW 173 were 18.2 and 29.2% respectively. This might be due to higher production and coupled with higher monetary returns (Prasad *et al.* 2017).

Quality and nutrient uptake

NPK content and their uptake by grain and straw had marked influence by staggered sowing (Table 4). Crop sown on 30th November had significantly higher NPK content and their uptake by grain and straw than that of 20th December and 10th January sowing. This might be due to higher biomass production in 30th November sowing favoured by suitable climatic condition for a longer period. These results are similar to that of Mukherjee (2012). Similar trend were followed in total uptake of nutrient, where crop sown on 30th November had higher total uptake of N (140.7 kg/ha), P (32.9 kg/ha) and K (66.8 kg/ha) (Fig 2). This might be due to higher content on nutrient contents and dry matter production (Kumar and Kumawat 2014).

Varying nutrition influenced significantly NPK contents and their uptake by grain and straw (Table 4). Application of 20% higher RDF had higher NPK contents and their uptake by grain and straw. This might be due to fact that at higher levels of fertility (NPK) indeed assured the availability of these nutrients to crops in adequately. Nutrition levels in wheat applied @ 20% higher RDF had healthy and more vigorous plant, it witnessed by taller plant, and higher leaf area index with higher concentration of NPK ascertained greater uptake nutrient (Sheoran *et al.* 2015). Similarly crop

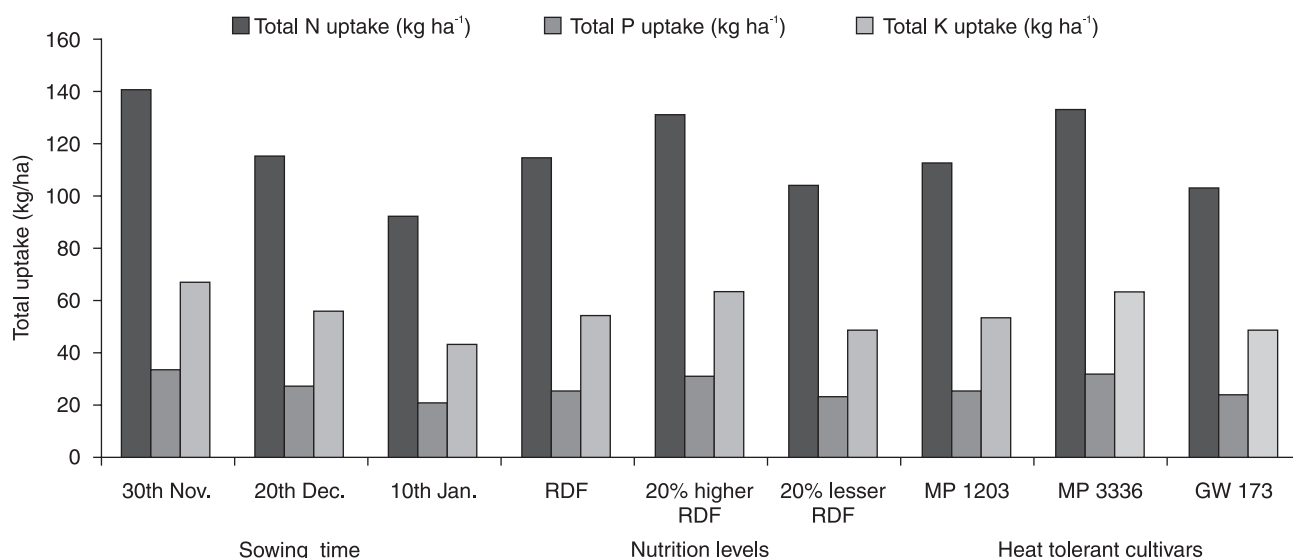


Fig 2 Total nutrient uptake of wheat cultivars as affected by staggered sowing and nutrition levels.

Table 4 Nutrient content and uptake of wheat cultivars as influenced by staggered sowing and nutrition levels (Pooled data of 2 years)

Treatment	Nutrient content (%)						Nutrient uptake (kg/ha)						Protein content (%)	Protein harvest (kg/ha)
	N		P		K		N		P		K			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw		
<i>Staggered sowing</i>														
30 th November	2.56	0.59	0.53	0.26	0.59	0.99	107.75	32.96	22.17	10.80	24.99	41.79	16.01	672
20 th December	2.32	0.64	0.48	0.23	0.55	0.93	87.64	27.99	17.97	8.42	20.85	34.96	14.45	543
10 th January	2.24	0.58	0.46	0.22	0.49	0.91	69.07	23.29	13.96	6.68	15.06	27.78	14.01	428
SEm ±	0.03	0.01	0.01	0.00	0.01	0.01	1.72	0.65	0.45	0.15	0.43	0.74	0.18	-
LSD (P=0.05)	0.09	0.04	0.03	0.01	0.02	0.04	5.17	1.94	1.34	0.43	1.29	2.21	0.52	-
<i>Nutrition levels</i>														
RDF	2.35	0.59	0.47	0.23	0.54	0.93	86.63	27.30	16.99	8.45	19.55	34.12	14.69	535
20% higher RDF	2.47	0.64	0.53	0.25	0.59	0.97	99.64	31.26	21.39	9.92	23.72	39.59	15.43	618
20% lesser RDF	2.30	0.58	0.47	0.23	0.52	0.92	78.19	25.67	15.72	7.53	17.63	30.82	14.36	481
SEm ±	0.03	0.01	0.01	0.00	0.01	0.01	1.72	0.65	0.45	0.15	0.43	0.74	0.18	-
LSD (P=0.05)	0.09	0.03	0.03	0.01	0.02	0.04	5.17	1.94	1.34	0.43	1.29	2.21	0.52	-
<i>Heat tolerant cultivars</i>														
MP 1203	2.34	0.59	0.48	0.23	0.54	0.94	85.55	26.73	17.14	8.18	19.49	33.85	14.62	526
MP 3336	2.50	0.64	0.51	0.25	0.57	0.97	101.55	31.97	21.15	10.24	23.66	39.65	15.63	634
GW 173	2.28	0.58	0.47	0.23	0.53	0.92	77.36	25.54	15.81	7.48	17.75	31.02	14.23	478
SEm ±	0.03	0.01	0.01	0.00	0.01	0.01	1.57	0.46	0.37	0.16	0.39	0.56	0.16	-
LSD (P=0.05)	0.07	0.03	0.02	0.01	0.02	0.03	4.50	1.31	1.06	0.46	1.10	1.61	0.45	-

*RDF:120:60:40 kg/ha N-P₂O₅-K₂O

fertilized with 20% higher RDF had significantly superior total uptake of N (130.9 kg/ha), P (31.3 kg/ha) and K (63.3 kg/ha), respectively (Fig 2). This might be due to higher NPK content and more biomass (Maurya *et al.* 2014).

Wheat cultivars had significant influence on NPK content and their uptake by grain and straw (Table 4). Significantly higher NPK content and their uptake by grain and straw associated with MP 3336 compared to MP 1203 and GW 173. This might be due to genetic traits of

the respective genotypes. Among cultivars, MP 3336 had higher total uptake of N (133.5 kg/ha), P (31.4 kg/ha) and K (63.3 kg/ha) (Fig 2). This might be due to higher NPK concentration and biomass (Kumar and Kumawat 2014)

Protein content and its harvest

Protein content and their harvest had marked influence by staggered sowing (Table 4). Crop planted on 30th November had higher protein content (16 %) and their

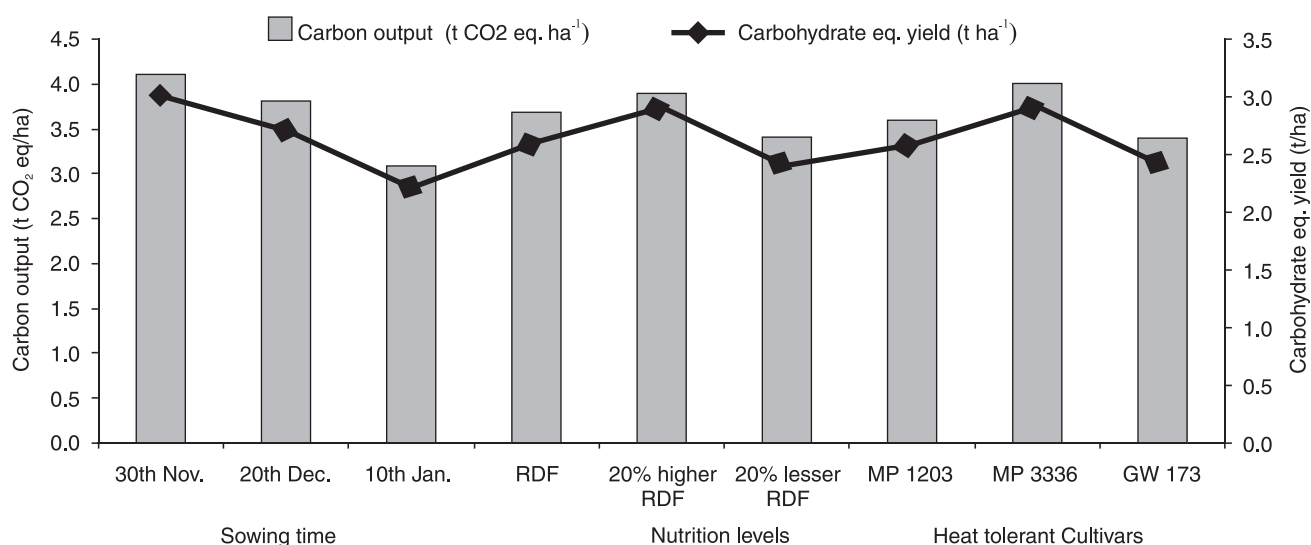


Fig 3 Carbon output and carbohydrate equivalent yield as affected by staggered sowing and nutrition levels.

harvest (672 kg/ha) compared to 20th December and 10th January sowing. Among nutrition levels, application of 20% higher RDF gave significantly higher protein content (15.4%) and its harvest (618 kg/ha) than that to RDF and 20% lesser RDF. This might be due to fact that timely sowing had favourable environment in which availability and mobility of most of nutrients increased significantly, which helped in greater absorption or translocation of nutrition to different plant part resulting into higher content of NPK. Availability of adequate quantity of nitrogen with 20% higher RDF might be helpful in giving both higher production as well as grain protein content. These findings are in close agreement with Orloff *et al.* (2012). Among cultivars, MP 3336 had higher protein content (15.6%) and their harvest (634 kg/ha) over MP 1203 and GW 173. This might be due to higher protein content and yields, which is an inherent characteristic of cultivars (Mishra *et al.* 2017).

Carbohydrate equivalent and carbon output

Crop planted on 30th November had higher carbohydrate equivalent (3.0 t/ha) and carbon output (4.1 t/CO₂ eq./ha) compared to 20th December and 10th January planting, respectively (Fig. 3). This might be due to higher yields and total harvested biomass (Kumar *et al.* 2018). Application of 20% higher RDF had the maximum carbohydrate equivalent (2.9 t/ha) and carbon output (3.9 t/CO₂ eq./ha), respectively than RDF and 20% lesser RDF. This might be due to fact that higher grain yields and total biomass were produced with increased levels of nutrition (Kumar *et al.* 2017). Among cultivars, MP 3336 had higher carbohydrate equivalent (2.9 t/ha) and carbon output (4.0 t/CO₂ eq./ha) compared to MP 1203 and GW 173. This might be attributed to inherent characteristics of cultivars to produce more yields and biomass (Kumar *et al.* 2018).

Hence, it may be concluded that to achieve the optimum productivity, profitability, quality and nutrient uptake, sowing of wheat cv. MP 3336 on 30th November along with 20% higher RDF proved to be the most ideal approach in irrigated ecosystem of Jabalpur, Madhya Pradesh.

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