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Research Paper

Maximizing wheat (*Triticum aestivum*) productivity through variable nutrient management practices

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ABSTRACT

Field experiment was conducted during the winter (*rabi*) seasons of 2017–18 and 2018–19 at Indira Gandhi Krishi Vishwavidyalaya, Raipur to evaluate the effect of foliar NPK application and nutrient management practices on wheat (*Triticum aestivum* L.) productivity. Selected twelve treatments combinations of three nutrient levels, four timings of N application and 2 foliar sprays were tested in RBD with 3 replications. The soil of experimental field was *Vertisol,* being neutral (*p*H 7.04) in reaction, medium (0.45 %) in soil organic carbon, low in N (182 kg/ha), medium in P (16.2 kg/ha) and high in K (312 kg/ha) content. Results revealed that number of effective tillers, dry matter accumulation and yield attributing characters, viz. length of ear (cm), number of grains/ear, ear weight (g), grain yield (3.99 and 4.07 t/ha), harvest index, highest net return (₹ 50,350 and ₹ 56,694/ha) and B:C ratio (2.72 and 2.94) were significantly higher under the treatments 150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage) + foliar spray of NPK (19:19:19) @ 5 g/l of water at 5 days after (DA) tillering and 5 DA late jointing stage as compared to others. It was at par with same fertilizer dose with or without one foliar spray at 5 days after late jointing stage during 2017–18 and 2018–19, respectively. Plots receiving 150% of recommended doses of fertilizers and two foliar sprays adjunct with 4 splits of N have accounted for higher available NPK status in the soil and elevated NPK built-up.

Key words**:** Apparent gain, Grain yield, Net return, Nutrient use efficiency

Wheat cultivation has been a symbol of green revolution and self-sufficiency in food grain production in India and its production in 2018–19 was 104 million tonnes from 30.23 million ha acreage. In Chhattisgarh, wheat occupies an area of 1.05 lakh ha with the production of 1.53 million tonnes and productivity of 1.42 t/ha (Anonymous, 2018). The main emphasis has been on increasing the productivity of wheat by adopting the improved cultivation practices through the effective and efficient management of nutrients. Yield in wheat depends mainly on the number of spikes per unit area and average seed yield per spike. Nitrogenous fertilizers play a vital role in yield enhancement, however only 20–50% of the soil applied nitrogen is recovered by the annual crops. Nutrients applied through the fertilizers at the time of sowing are not fully utilized by the crop. In this situation, the partial and inefficient use of nitrogen results in lower crop harvests. Nitrogen insufficiency influences biomass synthesis and use of solar energy for productivity of the plant, with an extraordinary effect on grain yield and yield contributing parameters (Heinemann *et al*., 2006). Phosphorus is linked with a plant's ability to use and store energy, including the process of photosynthesis. It's also needed to help plants growth and develop normally. Potassium helps to strengthen the plants' abilities to resist disease and plays an important role in increasing crop yields and overall quality.

Among fertilizer application methods, apart from split and band placement, one of the most important methods of application is foliar nutrition through leaves. It is an efficient technique of fertilizer which enhances the availability of nutrients. Foliar nutrients facilitate easy and quick consumption of nutrients by penetrating the stomata or leaf cuticle and enter the cells. Foliar fertilizers can provide the plant nutrient at critical stages of plant growth and increases plants' mineral status when the nutrient requirement exceeds the normal uptake for certain nutrients (Fageria *et al*., 2009). Foliar feeding of mineral nutrients at crown root initiation (CRI), tillering, jointing, booting

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stages of wheat crop is much effective in utilization of nutrients to increase the yield (Zecevic *et al*., 2004). Supplemental foliar nutrition of nutrients is more advantageous than soil application due to better translocation from the leaves to the developing seeds and efficient utilization of nutrients (Manonmani and Srimathi, 2009). Foliar spray of one or more nutrients to supplement soil application of fertilizers has been gaining more attention in recent years to overcome the problem of low fertilizer nutrient supply from soil to plant (Reena *et al*., 2018, Rajesh and Paulpandi, 2013). Foliar application of water soluble fertilizers may be a very good option under this situation to promote the rate of tillering, branching, flowering, yield and ensures timely maturity of cereal crops under reduced cost of cultivation (Sharma & Singh, 2020). NPK 19:19:19 fertilizer is available as 100% water soluble containing N, P and K each 19% with low salt index. Hence, nutrient balancing is very important for achieving higher grain yield as well as to sustain the crop production, improving soil health and enhancing the nutrient-use efficiency. Keeping these points in view, the present study was undertaken on "Maximizing wheat productivity through seed rate manipulation, foliar NPK feeding and nutrient management practices" to find the effect of foliar feeding of NPK on different levels and timings on growth and yield of wheat.

MATERIALS AND METHODS

Experiment was carried out at Instructional cum Research Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur during *rabi* season of 2017–18 and 2018–19. The soil of experimental field was clayey in texture (Vertisols). The soil was neutral (*p*H 7.04) in reaction with medium in fertility having 0.45 % soil organic carbon, low nitrogen (182 kg/ha), medium phosphorus (16.2 kg/ha) and high potassium (312 kg/ha) content. Experiments were laid out in randomized block design with three replications during two consecutive winter seasons. Selected twelve treatments viz. T_1, 50% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage); T_2, 100% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage); T_3, 150% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage); T_4, 50% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage); T_5, 100% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage); T_6, 150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage); T_7, T_4 + foliar spray of NPK (19 : 19 : 19) @ 5g/l of water at 5 DA late jointing stage; T_8, T_5 + foliar spray of NPK (19 : 19 : 19) @ 5g/l of water at 5 DA late jointing stage, T_9, T_6 + foliar spray of NPK (19 : 19 : 19) @ 5g/l of water at 5 DA late jointing stage; T_{10}, T_4 + foliar spray of NPK (19 : 19 : 19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage; T_{11}, T_5 + foliar spray of NPK (19 : 19 : 19) @ 5 g/l of water at 5 DA tillering and 5 DA late jointing stage; T_{12}, T_6 + foliar spray of NPK (19 : 19 : 19) @ 5 g/l of water at 5 DA tillering and 5 DA late jointing stage. Sowing of seeds was done manually at a depth of 5 cm keeping inter row spacing of 20 cm using recommended seed rate of 100kg/ha and recommended dose of fertilizer, i.e. 100 : 60 : 40 kg N : P_2O_5 : K_2O/ha. The wheat variety 'GW-366' was sown on 28/11/2017 and 19/11/2018 and harvested on 30/03/2018 and 18/03/2019, respectively. The crop received 17.6 mm and 83.4 mm rainfall during 2017–18 and 2018–19 respectively. Observations on various growth parameter and yield attributes, grain and straw yields, economics and available NPK status in the soil were determined as per standard procedures. Variable cost of inputs viz. seed, fertilizers, pesticides, irrigation etc. applied to each treatment were calculated on the basis of prevailing market rates and cost of cultivation was worked out. The total cost of cultivation was deducted from the gross return to work out the net income (₹/ha) for each treatment while, the return per rupee investment was worked out by dividing gross return by net return.

RESULTS AND DISCUSSION

Dry matter accumulation, effective tillers and yield attributes

Foliar nutrition at variable nutrient levels and timing of nitrogen application significantly influenced the dry matter accumulation at 60 DAS and at harvest (Table 1). Highest dry matter accumulation at harvest (1.317 and 1.344 kg/m^2) was recorded under the treatment T_{12}, 150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage) + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage being at par with treatment T_9, T_6, T_3, T_{11}, T_8 and T_5 during both the years. Increased dry matter accumulation was due to the adequate and continuous supply of major nutrients through split dose of soil applied nutrients under T_5, T_8 and T_{11} and liquid foliar application of NPK fertilizers adjoined with higher dose of NPK at different timing in T_3, T_6 and T_9 might be responsible for increased dry matter production. These results are in agreement with the findings of Nehra *et al.* (2001) and Samadiyan *et al.* (2013).

The number of productive tillers per unit area is the most important yield contributing component. As the number of productive tillers/plant increases, the grain yield/ha also increases. Significantly maximum number of effective tillers (407 and 408/m^2) was obtained with 150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage) + foliar spray of NPK (19:19:19) @ 5g/ l of water at 5 DA tillering and late jointing stage

Table 1. Dry matter accumulation and number of effective tillers as influenced by nutrient management practices in wheat

Treatment		Dry matter accumulation (kg/m²)				Number of effective tillers (No./m²)	
		60 DAS		At harvest			
		2017–18	2018–19	2017–18	2018–19	2017–18	2018–19
T_1	50% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.181	0.177	0.883	0.961	326	328
T_2	100% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.244	0.235	1.066	1.155	356	365
T_3	150% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.278	0.279	1.192	1.281	385	390
T_4	50% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.182	0.181	0.972	1.030	334	339
T_5	100% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.271	0.257	1.128	1.207	365	370
T_6	150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.281	0.283	1.233	1.321	385	395
T_7	T_4 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.238	0.228	1.027	1.095	339	345
T_8	T_5 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.272	0.258	1.139	1.228	369	375
T_9	T_6 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.290	0.289	1.279	1.326	396	401
T_{10}	T_4 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.243	0.233	1.077	1.124	341	354
T_{11}	T_5 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.277	0.272	1.187	1.255	379	383
T_{12}	T_6 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.299	0.298	1.317	1.344	407	408
	SEm±	0.017	0.012	0.068	0.063	16	13
	CD (P=0.05)	0.049	0.037	0.201	0.187	48	40

(T_{12}) during 2017-18 and 2018-19 respectively (Table 1). Treatments T_9, T_6, T_3, T_{11}, T_8 and T_5 produced at par effective tillers (365, 370/m²) to that of T_{12}. The higher number of effective tillers/m² in these treatments might be due to higher and sufficient availability of nitrogen which might have increased the nutrition to active growing part of plant and therefore ultimately led to higher tillering (Kachroo and Rajdan, 2006). Nitrogen has major effect throughout the plant growth while at reproductive stage its role become more considerable and thus the split and foliar application of liquid fertilizers affected the number of effective tillers significantly. Suboptimal dose of fertilizer (50% of RDF) as in T_1 and 100% RDF as in T_2 both with three splits of N (50% of N as basal + 25% at CRI + 25% late jointing stage) without foliar spray of nutrients produced the lesser number of effective tillers compared to T_{12}. The result clearly showed the effect of foliar spray combined with split application over only one split application and two foliar sprays of NPK over single one. Shirazi, *et al*. (2014) also concluded that more absorption of nitrogen by plants produced more numbers of tillers/unit area through enhanced vegetative growth.

Significantly maximum yield attributing characters, viz. number of grains/ear, length of ear, ear weight and harvest index (43.30 and 43.20%) were registered in T_{12} during 2017-18 and 2018–19, being at par with T_9, T_6, T_3, and T_{11} to rest of the treatments during both the years. The ear head weight is governed by the grain development supported by CO_2 assimilation during the vegetative phase. Thus, better nutrition of plants associated with increased fertilization helped in maintaining better vegetative growth leading to greater interception of solar radiation by the crops and ultimately contributed towards the significant increase in earhead weight. These results are in conformity with Khan *et al*. (2000).

Grain yield

Among three fertility levels of 50%, 100% and 150% of RDF, the maximum grain yield of 3.99 and 4.09 t/ha was obtained from T_{12} during 2017–18 and 2018–19 respectively. Grain yield (3.82 and 3.95 t/ha) attained under treatment having 150% RDF and four split of N followed by one foliar spray of NPK (19:19:19) 5g/l of water at 5 DA late jointing stage (T_9) was found to be comparable to that of T_{12}. Splitting of 150% N for three times (T_3) or four times (T_6) had also produced the statically similar grain yield to that of T_{12}. Yield increment was more in four split over three splits. Higher availability and less leaching losses and effective use of applied N could be responsible for yield advantage in 150% RDF over the other 2 levels. These results are in corroboration with the findings of Mukherjee (2019). Fifty per cent increase in RDF significantly increased the grain yield over RDF. The increased grain and biological yield might be owing to the availability of N at various critical growth stages in optimal amount (Mor *et al*., 2019). Among the all essential nutrients applied to the plants, nitrogen is the major one which has key role in the process of photosynthesis. Increased rate of photosynthesis by the high dose of nitrogen gave more yield because large amount of dry matter, more assimilates were produced and transported to fill the seeds as a result of more applied nitrogen. Further, fertility level of 100 and 150% of RDF during 2017–18 provided strong nutrient base and increased the N, P and K status in the soil for the crop during second year which performed better than the previous year under conducive environment of soil fertility during 2018-19. However, no significant difference in grain yield was found between 3 and 4 split of N at same level of nutrient.

Apart from split application, foliar nutrition through leaves is an efficient technique of fertilizer management which enhances the availability of nutrients. Foliar nutrients facilitate easy and quick consumption of nutrients by penetrating the stomata or leaf cuticle and enter into the cells. It is established fact that during crop growth, supplementary foliar application of fertilizer increases plants minerals status and improve crop yields. The foliar nutrition through leaves is efficient technique which enhances the availability of nutrients and ultimately exalted the grain yield. This fact was clearly depicted from the study that the split application of N with foliar feeding of NPK liquid fertilizer at critical stages of wheat crop resulted in

Table 2. Yield attributes, grain yield and economics of wheat as influenced by nutrient management practices

Treatment	No. of grains/ ear head		Length of ear head (cm)		Ear head weight (g)		Grain yield (t/ha)		Harvest index (%)		Cost of cultivation (₹/ha)	Net return (₹/ha)		Benefit: cost ratio	
	2017–18	2017–18	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19		2017–18	2018–19	2017–18	2018–19
T_1	36	36	9.9	10.8	1.6	1.8	2.42	2.58	39.76	40.63	24,319	24,904	30,766	2.02	2.27
T_2	43	43	10.5	12.3	2.2	2.3	3.13	3.23	41.32	41.85	26,179	37,123	42,250	2.42	2.61
T_3	47	47	12.3	13.9	2.6	2.7	3.62	3.67	42.27	42.71	28,040	44,723	49,378	2.59	2.76
T_4	37	37	10.1	11.1	1.6	1.9	2.59	2.78	40.17	40.71	24,569	28,164	34,613	2.15	2.41
T_5	43	43	10.9	12.7	2.3	2.4	3.26	3.27	41.59	41.91	26,429	39,244	42,835	2.48	2.62
T_6	48	48	12.8	14.1	2.7	2.8	3.71	3.82	42.69	42.93	28,290	45,967	52,168	2.62	2.84
T_7	39	39	10.2	11.3	1.8	2.0	2.82	2.95	40.27	40.79	24,929	32,295	37,850	2.30	2.52
T_8	45	45	11.4	13.3	2.4	2.5	3.44	3.58	42.11	42.34	26,789	42,258	48,739	2.58	2.82
T_9	49	49	13.1	14.2	2.8	2.9	3.82	3.95	42.78	43.12	28,650	47,873	54,475	2.67	2.90
T_{10}	41	41	10.2	12.2	2.0	2.1	3.09	3.15	41.22	41.47	25,539	36,889	41,317	2.44	2.62
T_{11}	46	46	11.5	13.4	2.5	2.5	3.59	3.61	42.25	42.55	27,399	44,596	48,816	2.63	2.78
T_{12}	49	49	13.2	14.8	2.8	2.9	3.99	4.09	43.30	43.20	29,260	50,350	56,694	2.72	2.94
SEm±	2	2	0.7	0.7	0.2	0.2	0.19	0.21	0.53	0.38	-	-	-	-	-
CD (P=0.05)	6	6	2.0	2.1	0.5	0.5	0.55	0.62	1.55	1.11	-	-	-	-	-

increased yield components, which ultimately reflected on grain yield. It is also beneficial when roots are unable to absorb the nutrient from soil due to the interference of various edaphic factors such as low soil moisture and loss of nutrients due to leaching (Patel *et al*., 2004). Effect of 2 foliar spray @ 5 g/l of water at 5 DA tillering and 5 DA late jointing stage adjunct with 4 splits of N with 100% RDF as under T_{11} although produced 0.4 and 0.47 t/ha lesser yield to that of T_{12} but was found to be statistically at par to that of 150% RDF as under T_{12}, T_9, T_6 and T_3. Non-significant but sizable difference (8–12%) was found between two foliar sprays and no foliar spray (T_4 and T_{10}, T_5 and T_{11}, T_6 and T_{12}) at same level of nutrient (Table 2). Similar result was also reported by Gupta *et al*. (2007). Although, having same nutrient level of 150% of RDF, treatment No. 6 (4 N splits) recorded higher grain yield, but it was at par to T_3 (3 N splits) which were significantly superior to T_1 (50% RDF) and T_2 (100% RDF). In that case, those farmers who could not afford an extra wage for going fourth split of N, can adopt T_3 treatment, as it is also giving the same grain yield as T_6 in lesser cost. Similarly, with foliar application of liquid NPK 19:19:19, comparable grain yield was obtained under the treatment T_9 to that of T_{12} and one extra foliar spray at late jointing stage could be eliminated without any remarkable yield loss.

Economics

Significantly the higher gross return (₹79,610 and ₹85,954/ha), net return (₹50,350 and ₹56,694/ha) and B:C ratio (2.72 and 2.94) were received under the treatment (T_{12}) during 2017–18 and 2018–19 (Table 2). Treatment having 150% RDF and four split of N followed by one foliar spray of NPK (19:19:19)

Table 3. Organic carbon and available nutrient in soil as influenced by nutrient management practices in wheat

Treatment		OC (%)		Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)	
		2017–18	2018–19	2017–18	2018–19	2017–18	2018–19	2017–18	2018–19
T_1	50% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.41	0.41	183	184	19.7	19.8	306	307
T_2	100% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.44	0.45	200	202	20.6	20.6	318	320
T_3	150% RDF (50% of N as basal + 25% at CRI + 25% late jointing stage)	0.46	0.47	214	216	21.9	22.0	339	347
T_4	50% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.43	0.42	185	186	19.8	19.7	307	308
T_5	100% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.45	0.45	207	209	21.1	21.3	320	326
T_6	150% RDF (25% of N as basal + 25% at CRI + 25% tillering stage + 25% late jointing stage)	0.46	0.48	224	225	21.9	22.4	345	353
T_7	T_4 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.43	0.43	187	190	19.8	19.9	307	309
T_8	T_5 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.45	0.45	209	211	21.4	21.6	330	336
T_9	T_6 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA late jointing stage	0.46	0.48	231	232	22.7	22.9	347	355
T_{10}	T_4 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.44	0.44	192	197	20.4	20.4	307	313
T_{11}	T_5 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.45	0.46	211	212	21.2	21.6	333	338
T_{12}	T_6 + foliar spray of NPK (19:19:19) @ 5g/l of water at 5 DA tillering and 5 DA late jointing stage	0.47	0.49	231	233	22.7	23.0	354	357
	SEm±	0.07	0.05	10	9	0.7	0.8	12	11
	CD (P=0.05)	NS	NS	29	28	2.0	2.3	35	32

5g/l of water at 5 DA late jointing stage (T_9) was found to be second best treatment. However, spending just ₹610/- on additional foliar spray at tillering stage as in T_{12} generated more than 3 times profit (₹2,348/ha) over T_9. Similarly, one foliar spray at 5 DA late jointing stage as in T_9 costing just ₹360/ha over no foliar spray as in T_6 with same level of soil applied nutrients provided ₹2,100/ha extra over T_6. Further, having same nutrient level of 150% of RDF, treatment No. 6 (4 N splits) recorded higher grain yield (Table 3), being at par to T_3 (3 N splits) which were significantly superior to T_1 (50% RDF) and T_2 (100% RDF). In that manner, without spending extra wage for fourth split of N, T_3 also gave the same net return and B:C ratio as T_6 with lesser cost.

Soil properties

Organic carbon was not affected due to foliar nutrition on wheat at variable nutrient levels and timing of nitrogen application. The plausible explanation might be that the changes in organic carbon are generally insensitive to recent management practices including fertilizer application as these changes occur slowly and are relatively very small as compared to the initial values (Gong *et al.*, 2009). A slightly higher organic carbon (0.47 and 0.49%) was recorded under the treatment T_{12} and lowest organic carbon was noted under the treatment T_1 for both the years (Table 3).

The available N, P and K in soils was significantly higher under the treatment T_{12} and was statistically at par with the available nutrient values under treatment T_9, T_6, T_3, T_{11}, T_8 and T_5 which were significantly superior to the rest of treatments during both the years. The higher availability of NPK in plots received higher dose of fertilizers as in T_{12}, T_9, T_6 and T_3 and two foliar spray adjunct with 4 splits of N as T_{11}, T_8 and T_5 might have accounted to direct quantitative effect of fertilizers (Table 3) during both the years. This indicated that higher levels of NPK fertilization met the requirement of crops and helped to a great extent in maintaining the soil fertility. Similar finding have also been corroborated by Usadadiya *et al*. (2014).

Thus, it can be concluded that application of 150% RDF doing with foliar spray of NPK (19:19:19) is a suitable option for enhancing wheat productivity in Madhay Pradesh.

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