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PRODUCTIVITY, NUTRIENT UPTAKE AND ECONOMICS OF WHEAT AS AFFECTED BY NUTRIENT OMISSIONS IN ALLUVIAL SOIL

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ABSTRACT

Field experiments were conducted with wheat (Triticum aestivum L. emend Fiorid & Paol) at four locations (Artoni, Panwari, Nanpur and Sahara) in Agra characterized by semi-arid climate in South-western plain zone of Agra region, (Uttar Pradesh) during rabi season of 2010-11 to investigate the effect of nutrient omissions on yield, uptake of nutrients and economics of the wheat crop. The results revealed that the maximum grain and straw yields of wheat were recorded with application of balanced use of fertilizers (NPKS) at all the sites. Significantly lower grain and straw yields were recorded in nitrogen omission plots as compared to other treatments. Nitrogen was the first nutrient limiting factor for yield followed by P, K and S and the reductions in grain yield due to N, P, K and S were 42, 10, 25 and 8%, respectively over balanced use of fertilizers (T_1). The N, P, K and S concentrations in grain and straw were significantly reduced in the respective nutrient in the reduction of P and K concentration in both grain and straw. The quality of produce in terms of protein content and yield improved with balanced fertilization and reduced with omission of nutrients, maximum being with N omission. The uptake of N, P, K and S significantly reduced in the respective omission treatments and reductions were higher in the N omission. The balanced use of nutrients led to maximum profit to the farmers and minimum in N omission.

Keywords: Balanced use of nutrients, uptake of nutrients, crop productivity wheat.

INTRODUCTION

Wheat is one of the most important staple food grain crops cultivated next to rice both in area and production, but it stands first in productivity amongst the cereals. Wheat accounts for 28% of the fertilizer consumption in the country and ranks second to rice. Stagnation in wheat production, lower productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application. Fertilizer constitutes one of the costliest inputs in present day agriculture. Greater economy in fertilizer can be made, if fertilizers are applied on the basis of soil test. This practice ensures balanced fertilization, higher yield and more profitability. Besides, balanced nutrition of growing crop the approach gives due consideration in soil fertility and strikes a real balance between the nutrients already available in the soil and those required by the crops to achieve a pre determined yield target. This helps to maintain soil fertility. Crop production in this area is confined primarily to the application of nitrogen and phosphorus fertilizers. Very little or no potassium is being applied by the farmers and thus most of it comes from K reserves of the soil and continuous cropping without K application has been reported to cause considerable drain of K fertilization. After N, K has been reported to be absorbed in large amount than any other element. Sulphur application is almost neglected by the farmers. Increasing S deficiency in soil as one of the major cause for declining yield seems to be true as a result of excess withdrawals than its replenishment. Farmers are experiencing declining responses to N and P due to omission of other essential nutrients in their fertilizer schedules. So adoption of balanced and judicious use of all needed nutrients can help improving the productivity of wheat crop. Efficient management of plant nutrients through fertilizer best management practices ensures that fertilizers are used in the most environmentally acceptable and sustainable way and crops are supplied with all essential plant nutrients at the appropriate time and in the required quantity. In quest to enhance food production, the plant nutrition system must operate to be socially acceptable, environmentally benign and economically viable. The yields of crop can even be increased by means of balanced nutrients to crop and

improved NPK inputs under similar conditions. Initiatives are made in recent years through nutrient omission approaches to estimate the soil and fertilizer contributions in the crop performance and finally arrive at site specific nutrient management recommendations for targeted and sustainable yield. The yield in the plot balanced fertilization with relatively good crop management can be used to estimate an attainavle yield target. Nutrient limited yields are determined from plots in which the nutrient of interest is not added. Therefore, it was desirable to assess the effect of nutrient omissions on productivity, content and uptake of nutrients and economics of wheat.

MATERIALS AND METHODS

The field experiments were conducted at four different locations viz. Artoni, Panwari, Nanpur and Sahara villages of Agra district of Uttar Pradesh during rabi season of 2010-11. The area is characterized by a semi arid climate hot summer with mean maximum temperature of 45°$\pm$ 2° C, mean minimum temperature of around 3° $\pm$ 2° C in December-January. The average annual rainfall in the study area is 650mm of which about 90% is received during kharif seasons from July to September and rest during the rabi season. The important physico-chemical characteristics of soils (0-15 cm) of four locations are presented in Table 1. The experiments were laid out in randomized block design with five treatments. Fertilizer treatments were based on soil test fertilizer recommendation of 180 kg N, 90 kg P_2O_5 and 100 kg K_2O and 30 kg S ha^{-1} and was considered as optimum treatment (OPT). Four deletion plots individually omitted N, P, K and S based on the rates in the OPT. Urea, di-ammonium phosphate, muriate of potash and elemental sulphur were used as sources for NPK and S, respectively. In OPT-N treatment, phosphorus was applied as single superphosphate. The treatments at different locations were replicated in plots of varying size with 500 m² except for nitrogen omission treatment (100 m²). Individual farmer was treated as replication for statistical analysis of the results. Wheat crop (var. PBW 343) was sown in first week of November 2010. The crop was harvested in second week of April, 2011. At harvest, yield data of the crop (grain and straw) were recorded. The nitrogen content in grain and straw of the crop was analysed by micro Kjeldahl method (Jakson, 1973). Phosphorus, potassium and sulphur in di-acid (HNO_3 and $HClO_4$) digest was determined by vanadomolybdate yellow colour method, flame photometer and turbidimetric method (Chesnin and yien 1951), respectively. Uptake of nutrients was calculated by multiplying nutrient content in grain and straw with their respective yields. The economic analysis of different nutrient management options are in terms of net returns and B:C ratio. The economic efficiency (EE) of fertilizer application was calculated from the average net returns on unit area basis and average crop duration. The crop productivity of fertilizer application was worked out by diving crop yield on unit area basis by average crop duration.

RESULTS AND DISCUSSION

Yield

The grain yield of wheat varied from 3449 to 5615, 3085 to 5358, 3227 to 5408 and 2912 to 5388 kg ha^{-1} and Artoni, Panwari, Nanpur and Sahara, respectively. The corresponding ranges for straw yield were from 5243 to 8523, 4592 to 8070, 4833 to 8159 and 4327 to 8094 ha^{-1}. Wheat productivity was influenced significantly by fertilizer management and the highest grain (5358 to 5615) and straw (8070 to 8523) yields were achieved under T_1 (NPKS) treatment. The increase in grain yield of wheat due to balanced fertilization is attributed to improvement in growth and yield attributes, which in turn resulted in higher production and translocation of photosynthates and nutrients, ultimately reflected into higher grain and straw yield. These results corporate the findings of Chandel *et al.* (2014). Omission of N, P, K and S from the fertilizer schedule resulted in a marked yield loss, indicating the significance of replenishment of these nutrients for achieving high yield targets. These data confirm that N deficiency is a general feature of wheat in Agra district. The mean yield reductions due to N, P, K and S omissions were 42, 10, 25 and 8 %, respectively. These results confirm the finding of long term experiments conducted at various locations in India, wherein application of N alone depleted the native P, K, S and micronutrients reserves of soil, thus causing significant yield loss (Sainy *et al.* 2012, Das *et al.* 2015).

Table 1: Soil characteristics of the experimental fields (mean of 5 farmer's field)

Soil characteristics	Artoni	Panwari	Nanpur	Sahara
pH (1:2.5)	7.7	7.6	8.0	8.1
EC (dSm^{-1})	0.21	0.30	0.27	0.33
Organic carbon (g kg^{-1})	3.9	3.7	3.8	3.9
Available N (kg ha^{-1})	177.5	161.0	161.2	164.0
Available P (kg ha^{-1})	12.1	10.7	12.7	11.3
Available K (kg ha^{-1})	132.2	123.7	129.7	129.2
Available S (kg ha^{-1})	16.8	12.2	15.7	14.7

Economics

Economic analysis closely followed the wheat yield with respect to the treatment used in the study. The OPT (T1) gave higher mean gross return of `. 80393.5 $ha^{-1}$ than other treatments. Wheat crop profitability responded to fertilizer treatments with highest mean net return of `.53741.2 ha^{-1} realized in the balanced fertilization plots. Highest B: C ratio of 2.02 was also realized in the optimum nutrient plots. It is obvious that realization of higher net returns and benefit: cost ratio was the result of higher productivity. Hussain *et al.* (2013) also reported higher net returns and benefit: cost ratio with higher dose of fertilizers. Cost of cultivation differed marginally on an account of nutrient omissions but resulted in large decrease in net profit. Nitrogen omission reduced the net returns drastically and P proved to be the second most limiting nutrient in wheat production. Potassium omission also reduced the net returns. The effect of S omission on net profit was only marginal at all the sites. Omission of N, P, K and S from the OPT reduced the mean profit by ` 29977.4, ` 6809.1, ` 18994.2 and ` 5658.4 ha^{-1}, respectively. Similar results reported by Dwivedi *et al.* (2011).

Table 2: Effect of nutrients on yield and economics of wheat

Treatment	Yield (kg ha^{-1})		Yield (Δ) (kg ha^{-1})	Gross return (` ha^{-1})	Net return (` ha^{-1})	B:C ratio
	Grain	Straw				
			Artoni			
T_1 NPKS	5615	8523	-	83072.5	53741.2	2.12
T_2 -N	3449	5243	2166 (39)	51046.5	23763.8	1.22
T_3 -P	5192	7849	423 (8)	76734.5	46932.1	2.03
T_4 -K	4407	6669	1208 (22)	65149.5	34797.0	1.51
T_5 -S	5142	7800	473 (9)	76062	48082.8	1.95
CD (P=0.05)	64.0	72.5	-	-	-	-
			Panwari			
T_1 NPKS	5358	8070	-	79113.0	52460.7	1.97
T_2 -N	3085	4592	2273 (43)	45415.0	22456.3	0.98
T_3 -P	4799	7200	559 (11)	70789.0	45480.4	1.79
T_4 -K	3968	5912	1390 (26)	58428.0	32515.7	1.25
T_5 -S	4913	7379	445 (9)	72490.5	46713.2	1.81
CD (P=0.05)	69.2	78.1	-	-	-	-
			Nanpur			
T_1 NPKS	5408	8159	-	79885.5	53233.2	2.00
T_2 -N	3227	4833	2181 (41)	47579.0	24620.3	1.07
T_3 -P	4788	7231	620 (12)	70745.5	45436.9	1.79
T_4 -K	4180	6290	1228 (23)	61705.0	35792.7	1.38
T_5 -S	5038	7490	370 (7)	74143.0	48365.7	1.87
CD (P=0.05)	68.5	76.7	-	-	-	-
			Sahara			
T_1 NPKS	5388	8094	-	79503.0	52850.7	1.98
T_2 -N	2912	4327	2476 (46)	42849.5	19890.8	0.87
T_3 -P	4794	7184	594 (11)	70694.0	45385.4	1.79
T_4 -K	3912	5809	1476 (28)	57554.5	31642.2	1.22
T_5 -S	4935	7384	453 (9)	72745.0	46967.7	1.82
CD (P=0.05)	62.2	71.4	-	-	-	-

- *ΔYield = Yield of OPT – Yield of omitted nutrient treatment.*
- *Data in parentheses are % yield loss*
- *n= number of farmers at each site*

Nutrient Content

Nitrogen content in wheat grain ranged from 1.95 to 2.24% and in straw from 0.56 to 0.74% irrespective to different sites, maximum values being under OPT(180 kg N + 90 kg P_2O_5 + 100 kg K_2O + 30 kg S ha^{-1}) and minimum at no nitrogen. This may be attributed to increased availability of nutrients to the crop as a result of improved soil fertility. Nitrogen content in grain and straw was significantly affected by various nutrient omission treatments. Nitrogen omission had significantly lower N content in grain and straw at all the sites. Nitrogen content in the crop was also significantly lower in the treatment where P and K were omitted. Omission of other nutrients also reduced the absorption of N because of imbalance in the nutrient supply and the role of other nutrients particularly P and K in efficient N accumulation. Similar results were reported by Hussain and Kumar (2013). Optimum fertilization treated crop had higher P content in grain and straw over P omission at all the sites. Omission of N reduced the P content but omission of K and S had a non-significant effect on P content in grain and straw. Potassium content in straw was nearly double than that of grain. The K content in wheat was significantly affected by nutrient omission treatments and significantly lower K content in grain and straw was recorded in K omission treatment. Omission of P and S had non-significant effect on K content in grain and straw. It might be due to inactivation of root system under imbalanced nutrition of the crop.

Table 3: Effect of nutrients on the content of nutrients (%) in grain and straw of wheat

Treatments	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Artoni								
T_1 NPKS	2.21	0.71	0.25	0.15	0.49	2.03	0.32	0.16
T_2 -N	1.95	0.57	0.22	0.12	0.47	1.98	0.29	0.14
T_3 -P	2.11	0.60	0.19	0.09	0.46	0.98	0.30	0.14
T_4 -K	2.13	0.62	0.22	0.12	0.40	1.84	0.30	0.11
T_5 -S	2.11	0.64	0.23	0.12	0.48	2.01	0.25	0.11
CD (P=0.05)	0.04	0.03	0.02	0.01	0.03	0.10	0.02	0.01
Panwari								
T_1 NPKS	2.24	0.74	0.24	0.14	0.49	2.07	0.32	0.16
T_2 -N	2.00	0.59	0.22	0.12	0.47	2.04	0.29	0.14
T_3 -P	2.13	0.64	0.20	0.10	0.46	2.02	0.30	0.14
T_4 -K	2.15	0.65	0.22	0.10	0.39	1.85	0.31	0.15
T_5 -S	2.17	0.66	0.27	0.13	0.46	2.04	0.26	0.10
CD (P=0.05)	0.05	0.02	0.03	0.01	0.04	0.09	0.01	0.01
Nanpur								
T_1 NPKS	2.23	0.72	0.24	0.14	0.50	2.01	0.31	0.16
T_2 -N	1.99	0.56	0.21	0.11	0.47	1.97	0.29	0.14
T_3 -P	2.12	0.60	0.18	0.09	0.48	1.97	0.30	0.14
T_4 -K	2.14	0.62	0.20	0.11	0.39	1.80	0.30	0.15
T_5 -S	2.14	0.64	0.21	0.12	0.48	1.98	0.26	0.10
CD (P=0.05)	0.04	0.02	0.03	0.02	0.03	0.08	0.01	0.01
Sahara								
T_1 NPKS	2.24	0.72	0.24	0.14	0.50	2.04	0.32	0.17
T_2 -N	2.00	0.58	0.22	0.12	0.47	2.01	0.29	0.14
T_3 -P	2.14	0.63	0.19	0.10	0.46	1.97	0.30	0.15
T_4 -K	2.15	0.64	0.22	0.12	0.39	1.85	0.30	0.15
T_5 -S	2.17	0.66	0.22	0.13	0.47	2.02	0.25	0.12
CD (P=0.05)	0.06	0.03	0.02	0.02	0.02	0.010	0.02	0.01

Quality

The protein content in grain and straw varied from 12.1 to 14.0% and 3.5 to 4.6%, respectively. The optimum fertilization had significantly higher protein content in grain and straw at all the sites. The increase in protein content with balanced fertilization might be due to improved nutritional environment in the

rhizosphere as well as in plant system leading to enhanced translocation of N and P to reproductive parts (Dhaka and Pathan 2013). The nitrogen and phosphorus omissions had significantly lower protein content than the optimum fertilization treatment. The reductions in protein content in grain and straw were higher due to N omission followed by P omission. Omissionof K and S also reduce the protein percentage in wheat grain and straw over OPT treatment. Mean protein yield was 756 kg ha^{-1} under balanced fertilization (T_1) compared 391.7 kg ha^{-1} under N omission. Among the omission treatments, mean higher protein yield (673.2 kg ha^{-1}) was under S omission and minimum (391.7 kg ha^{-1}) in N omission. This may be attributed to lower grain yield and protein content as a result of nutrient omission.

Uptake of nutrients

The uptake of nutrients in grain and straw was significantly influenced by the application of nutrients in balanced form. The maximum uptake of N, P, K and S in grain and straw was recorded with T_1 (NPKS) treatment. It was due to the fact that added nutrients increased the N, P, K and S content in grain and straw of the crop by providing balanced nutritional environment inside the plant, higher photosynthetic efficiency, which favoured higher yields, resulted in more uptakes of nutrients (Gupta *et al.* 2009). These results again emphasize the importance of balanced fertilization in providing adequate nutrition to the plants. By comparison, total uptake of nutrients under nutrient omission treatments appeared to decrease. In general, the lowest uptake of N, P, K and S were recorded under OPT – N, OPT – P OPT – K and OPT – S treatments, respectively. Among these omission treatments, N omission had far greater impact on the uptake of nutrients by wheat crop. This was because the N omission strongly depressed the grain and straw production of wheat (Hussain and Kumar, 2013).

Table 4: Effect of nutrients on the uptake of nutrients (kg ha^{-1}) in grain and straw of wheat

Treatments	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Artoni								
T_1 NPKS	124.0	60.5	14.0	12.7	27.5	173.0	17.9	13.6
T_2 -N	67.2	29.8	7.5	6.2	16.2	103.8	10.0	7.3
T_3 -P	109.5	40.6	8.3	6.0	20.2	132.0	13.2	9.3
T_4 -K	110.5	48.7	11.4	9.4	20.7	144.4	15.5	11.7
T_5 -S	108.4	49.9	12.8	9.3	24.6	156.7	13.3	8.6
CD (P=0.05)	6.2	2.7	1.2	1.7	1.2	9.8	1.8	1.1
Panwari								
T_1 NPKS	120.0	59.7	12.9	11.2	26.2	167.0	17.1	12.9
T_2 -N	61.7	27.0	6.7	5.5	14.4	93.6	8.9	6.4
T_3 -P	84.5	37.8	7.9	5.9	18.2	119.4	11.9	8.2
T_4 -K	103.1	46.8	10.5	8.6	18.7	133.2	14.8	10.8
T_5 -S	106.8	48.7	13.2	9.5	22.5	150.5	12.7	7.3
CD (P=0.05)	4.7	2.1	0.97	1.9	1.4	10.2	2.0	1.0
Nanpur								
T_1 NPKS	120.5	58.7	12.9	11.4	27.0	163.9	16.7	13.0
T_2 -N	64.2	27.0	6.7	5.3	15.1	95.2	9.3	6.7
T_3 -P	88.6	37.7	7.5	5.6	20.0	123.9	12.5	8.8
T_4 -K	102.4	44.8	9.5	7.9	18.6	130.1	14.3	10.8
T_5 -S	107.8	47.9	10.5	8.9	24.1	148.3	13.0	7.4
CD (P=0.05)	7.5	2.4	1.1	1.4	1.1	8.8	1.7	1.2
Sahara								
T_1 NPKS	120.7	58.2	12.9	11.3	26.9	165.1	17.2	13.7
T_2 -N	58.2	25.0	6.7	5.1	13.6	86.9	8.4	6.0
T_3 -P	83.7	36.5	7.4	5.8	17.9	114.4	11.7	8.7
T_4 -K	103.0	45.9	10.5	8.6	18.6	132.9	14.3	10.7
T_5 -S	107.0	48.7	10.8	9.5	23.1	149.1	12.3	8.8
CD (P=0.05)	5.8	1.9	1.3	1.6	1.4	11.1	1.9	1.5

Crop efficiency parameters

The performance of wheat with various rates of fertilizer application was quantified through different crop efficiency parameters viz. EE, CP and PFP. The economic efficiency of wheat under different treatments varied from `. 157.30 to `. 389.10, ` 154.87 to `. 361.79, `. 169.10 to `. 387.12 and `. 137.18 to `. 364.48 ha^{-1} day^{-1}, respectively at Artoni, Panwari, Nanpur and Sahara (Table 5). The omission of N, P, K and S from the OPT (T_1) reduced the mean economic efficiency by `. 221.0, `. 47.4, `. 135.6 and `. 119.3 ha^{-1} day^{-1}, respectively. Thus, the EE in omission plots was relatively lower than that of T_1 treatment at all the sites emphasizing the need of all the nutrients for higher crop production. Among the treatments, the lower values of EE at all the sites were noted under nitrogen omission. The crop productivity of wheat was 38.7, 37.0, 37.3 and 37.1;/ kg ha^{-1} day^{-1} under T_1 treatment at Artoni, Panwari, Nanpur and Sahara, respectively. On the other hand, the lowest values of crop productivity were noted under nitrogen omission. The crop productivity of wheat under S omission was relatively higher than those under P,K and N omissions. These results substantiate the positive influence of balanced use of nutrients in wheat crop. The influence of the combined effect of all nutrients on grain yield is quantified through partial factor productivity. The results revealed that PFP for wheat grown with ample amounts of fertilizers (N, P, K, S) varied from 13.4 to 14.0 kg/kg at different locations and was markedly higher under K and S omissions. The PFP decreased due to balanced levels of NPKS (T_1) indicating poor rate of utilization of nutrients by the crop at higher level. The behavior of these characters due to fertilizer treatments may be explained on the basis of their effect on the economic yield.

Table 5: Effect of different treatment on crop efficiency (mean of 2 years)

Treatments	Protein Content in grain (%)	Protein content in straw (%)	Protein yield (kg ha^{-1})	Economic efficiency (`. ha^{-1} day^{-1})	Crop productivity (kg ha^{-1} day^{-1})	Partial factor productivity (kg/kg)
			Artoni			
T_1 NPKS	13.8	4.4	774.8	389.10	38.7	14.0
T_2 -N	12.1	3.6	417.3	157.30	23.8	15.7
T_3 -P	13.2	3.7	685.3	354.66	35.8	16.7
T_4 -K	13.8	3.9	608.2	270.60	30.4	14.7
T_5 -S	13.2	4.0	678.7	346.79	35.5	13.9
CD (P=0.05)	0.3	0.09	29.5	-	-	-
			Panwari			
T_1 NPKS	14.0	4.6	750.1	361.79	37.0	13.4
T_2 -N	12.5	3.7	385.6	154.87	21.3	14.0
T_3 -P	13.3	4.0	638.2	313.66	33.1	15.5
T_4 -K	13.4	4.1	531.7	224.24	27.4	13.2
T_5 -S	13.6	4.1	668.2	322.16	33.9	13.3
CD (P=0.05)	0.4	0.11	28.7	-	-	-
			Nanpur			
T_1 NPKS	13.9	4.5	751.7	367.12	37.3	13.5
T_2 -N	12.4	3.5	400.1	169.10	22.2	14.6
T_3 -P	13.2	3.7	632.0	331.36	33.0	15.4
T_4 -K	13.4	3.8	560.1	246.85	28.8	13.9
T_5 -S	13.4	4.0	675.0	322.44	34.7	13.6
CD (P=0.05)	0.2	0.12	26.5	-	-	-
			Sahara			
T_1 NPKS	14.0	4.5	747.3	364.48	37.1	13.5
T_2 -N	12.5	3.6	364.0	137.18	20.0	13.2
T_3 -P	13.4	3.9	642.2	313.00	33.1	15.5
T_4 -K	13.4	4.0	524.2	218.22	27.0	13.0
T_5 -S	13.6	4.1	671.1	323.91	34.0	13.3

CD (P=0.05)	0.5	0.08	28.0	-	-	-

It may be concluded from the results that there was significant improvement in crop yield with highest gross and net returns and improved uptake of nutrients by crops with balanced use of fertilizers. The highest EE and crop productivity of wheat achieved with ample use of fertilizers emphasized the need of balanced use of fertilizers. Thus, the balanced fertilizer use in wheat crop results in achieving economically viable crop yield in Agra region of Uttar Pradesh. Nitrogen is the most limiting nutrient and its omission resulted in drastic reduction in yield and profitability of wheat.

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