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WHEAT YIELD AND NUTRIENT UPTAKE: THE IMPACT OF DIFFERENT NITROGEN LEVELS AND FOLIAR NUTRIENT TREATMENTS

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Abstract

Wheat is the second most crucial food grain in India, following rice, and plays a significant role in the country's staple diet, contributing 35% to the total food grain production. India cultivates wheat across 28.17 million hectares, achieving a production of 73.70 million tonnes and a productivity of 26.17 q/ha. The country is responsible for 13% of global wheat production. The Green Revolution significantly boosted India's food production over the past 50 years, transforming it from a major importer of wheat into a leading producer. Uttar Pradesh, a key wheat-growing state, contributes significantly with 9 million hectares of cultivation, yielding 22.51 million tonnes and a productivity of 25.02 q/ha. This study explores how different levels of nitrogen and foliar nutrient sprays influence the yield and nutrient uptake of wheat, aiming to enhance productivity and efficiency in this vital sector.

INTRODUCTION

Wheat is the second most important food grain of India next only to rice and it is a staple diet of people. It contributes 35% of the total food grain production of the country. In India, wheat is cultivated over an area of 28.17 million hectares with a production and productivity of 73.70 million tones and 26.17 qha^{-1}, respectively (Anonymous, 2007). India alone produces 13% of world's wheat. Green revolution has enabled India to make about four fold increase in food production during the last 50 years, whereas before green revolution annual wheat imported touched 10 million tones and India was a beggar bowl. Uttar Pradesh, an important wheat growing state of India, has an area of 9 million hectares under wheat cultivation with a production of 22.51 million tones and productivity of 25.02 q ha^{-1} (Anonymous, 2005). The lower productivity could be attributed to the fact that under intense cereal-cereal cropping system and immense use of inorganic fertilizers, especially nitrogen, there has been great depletion of soil fertility. The role of macro and micro nutrients is crucial in crop nutrition for achieving

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higher yields (Raun and Johnson, 1999). The soils of India are deficient in nitrogen and are supplemented with chemical fertilizer for enhancing the crop productivity. Nitrogenous fertilizers play a vital role in modern farm technology, however only 20-50% of the soil applied nitrogen is recovered by the annual crops (Bajwa, 1992). The left over nitrogen is lost from the soil system through denitrification, volatilization and leaching. The partial and in-efficient use of nitrogen results in lower crop harvests. Moreover, fertilizers are energy intensive to produce and are very expensive. The present price hike of fertilizers is one of the main constraints to increase the economic yield of crops. Thus efforts are needed to minimize its losses and to enhance its economic use. Foliar fertilization, that is nutrient supplementation through leaves, is an efficient technique of fertilization which enhances the availability of nutrients. A favourable balance of macro and micronutrients is required for optimum crop production. However, the nutrient imbalances can occur due to nonjudicious and liberal use of major nutrient and presence of low levels of micronutrients. Zinc is known to be involved in the synthesis of Indole-3-acetic acid thereby indirectly involved in elongation of stems, whereas manganese plays an active role in the photolysis of water in the light reaction of photosynthesis. Boron functions in cell wall formation, transport of sugars, flower retention and pollen formation thereby improving grain production. Maleic hydrazide, a known growth inhibitor, has been found to be involved in the improvement of growth at very low concentrations. Similarly salicylic acid improves the transport and uptake of ions, induces changes in chloroplast structure and is involved in growth and development, photosynthesis and respiration. Since the deficiency of micronutrients viz. zinc, boron and manganese is widely noticed in wheat so their foliar spray in a mixture can improve the yield.

MATERIALS AND METHODS

The experiment was conduct at Crop Research Farm, Department of Agronomy, Sam Higginbottom Institute of Agriculture, Sciences and Technology AllahabadIndia during *rabi*2007-2008 and 20082009. The soil of the experimental field was sandy loam in texture, low in available nitrogen (221 kg ha^{-1}), medium in available phosphorous (14.4 kg ha^{-1}) and potassium (253.0 kg ha^{-1}) with pH 7.9 (Alkaline) and 0.27% organic carbon. Variety PBW-443 was chosen for the study. The experiment comprised of two factors (four nitrogen levels *viz.* N_1:30 kg ha^{-1}, N_2:60 kg ha^{-1}, N_3:90 kg ha^{-1}, N_4:120 kg ha^{-1} and four foliar spray of nutrient mixture *viz*F_1: 2% DAP + 1% KCl, F_2: 2% DAP + 1% KCl + nutrient mixture, F_3: 2% DAP + 1% KCl + 100 ppm salicylic acid and F_4: 2% DAP + 1% KCl + 100 ppm maleic hydrazide) laid out in randomized block design replicated thrice (NB: Nutrient mixture = 0.5% $MgSO_4$, 0.2% ZnSO4, 0.2% MnSO4 and 0.1% Borax, DAP = Di-ammonium phosphate and MOP= Murate of potash). A uniform dose of phosphorous and potassium at the rate of 60 and 40 kg P_2O_5 and K_20/ha, respectively and half dose of nitrogen as per treatments was applied as basal at the time of sowing while as remaining half dose of nitrogen was applied in two equal splits, one each at 30 DAS and tillering stage as per treatment. Nitrogen, phosphorous and potassium was applied through urea, DAP and MOP. Foliar application of different nutrient mixtures was applied at full vegetative growth to each plot as per treatment. Nutrient analysis in grain and straw was carried out by taking five plants from each treatment at harvest and then oven dried at 60-65□C to a constant weight. The dried samples were finely ground and passed through 2mm sieve. Nitrogen content in grain and straw samples was determined by Macro Kjeldahl method, phosphorous content was determined by Colorimetric method (Jackson, 1973) and potassium content was determined by Flame photometer method (Toth and Prince, 1949). Soil sample from each plot was drawn to a depth of 15 cm after the harvest of crop and subjected to chemical analysis for available nitrogen (alkaline potassium permanganate method by Subbiah and Asija, 1956), available phosphorous (Olsen et al., 1954) and available potassium (Flame photometric method by Toth and Prince, 1949). Economics of different treatments was worked out on the basis of grain and straw yield per hectare. The cost of input and output was estimated as per prevailing market rates.

The data obtained in respect of various observations was statistically analysed by method described by Cochran and Cox (1963). The significance of "F" and "t" was tested at 5% level of significance.

RESULTS AND DISCUSSION

Grain, straw yield and biological yield (q ha^{-1})

Grain, straw and biological yield as presented in Tables 1, 2 and 3 increased significantly with application of nitrogen and foliar spray of nutrient mixture. The interactions between the two factors during two years were found to be significant.

Pooled data over two years indicates that, straw and biological yield increased significantly with nitrogen application at 120 kg N ha^{-1} over 90, 60 and 30 kg N ha^{-1}. N_{120} level marked grain yield superiority of 2.18, 6.12 and 14.9%, straw yield superiority of 2.70, 6.13 and 10.93% and biological yield superiority of 2.63, 5.91 and 10.20% over N_{90}, N_{60} and N_{30} levels, respectively. Different nitrogen levels increased the nutrient content in the plants that lead to increase in vegetative growth. Besides, nitrogen is an essential constituent of plant tissue and thus is involved in cell division and cell elongation. The increase in vegetative growth is evident from the plant height, tiller production and dry matter accumulation and the increase in different yield contributing characters viz., spikes per plant, spike length, grains per spike thereby consequently improving the straw and grain yield of crop. The increase in grain, straw and biological yield with application of nitrogen has also been reported by Akthar (2001); Naeem (2001) and Jatoi (2003). Comparatively lower grain, straw and biological yield obtained with 30 Kg Nha1 could be attributed to poor nutrition to the crop because of insufficient nitrogen uptake.

Maximum grain, straw and biological yield of 46.9 qha^{-1}, 74.7 qha^{-1} and 121.6 q ha^{-1} was realized with application of F_2 treatment followed by F_3 treatment recording 44.5 qha^{-1}, 72.7 qha^{-1}and 117.20 q ha^{-1}of grain, straw and biological yield, respectively, whereas the lowest grain, straw and biological yield of 43.4 q ha^{-1}, 70.1 qha^{-1} and 113.5 q ha^{-1}respectively was recorded with F_4 treatment. F_2 treatment marked grain, straw and biological yield superiority of 5.39, 6.10, 8.06 per cent, straw yield superiority of 2.75, 2.60 and 6.56 per cent and biological yield superiority of 3.61, 3.71 and 6.6 per cent over F_3, F_1 and F_4 treatments, respectively. Comparatively higher grain, straw and biological yield recorded with F_3 treatment over F_1 and F_4 treatments could be due to the fact that salicylic acid plays role in growth and development, photosynthesis, ion uptake and transport. Seed treatment / foliar spray of salicylic acid induces reduction in sodium absorption and toxicity which is further reflected in low membrane injury, high water content and high dry matter production (El-Tayeeb, 2005). Significantly lowest yield obtained with F_4 treatment even at lower concentration could be due to the fact that Maleic hydrazide may have limited the growth and development of the crop due to its inhibitory effect (Cathey, 2009).The interaction effect for grain, straw and biologicalyield between nitrogen levels and foliar spray of nutrient mixture was found significant. The highest grain, straw and biological yield of 49.2, 78.1and 123.2q ha^{-1} respectively was recorded with the treatment combination N_4F_2. Similar results were reported by Akthar (2001).

The pooled data (Table 3) showed that the harvest index recorded with 120, 90, 60 and 30 Kg Nha^{-1} application was statistically similar among them. The values of harvest ranged between 37.9 to 38.2 per cent at different nitrogen levels with highest value of 38.2% recorded with 90 Kg Nha^{-1} and the lowest 37.9% recorded with 30 Kg Nha^{-1}. Besides, foliar spray of nutrient mixture did not cause any significant influence on the harvest index. However, highest harvest index was recorded with foliar spray of 2% DAP + 1% KCl + Nutrient mixture (F_2) and the lowest with the foliar spray of 2% DAP + 1% KCl + Maleic hydrazide (F_4). The values ranged between 37.7 to 38.5% with different foliar sprays. It might be due the fact that the capacity of photosynthates to translocate from source to sink was

statistically similar amongst different nitrogen levels as well as amongst different foliar spray of nutrient mixtures.

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Table 1. Grain Yield of wheat (*Triticumaestivum L*) as influenced by different levels of nitrogen and foliar spray of nutrient mixture.

Nitrogen levels (Kg ha^{-1})		Foliar Spray of Nutrient Mixture			
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
N_{30}	41.5	44.2	41.7	40.6	42.0
N_{60}	43.6	46.3	43.9	42.8	44.1
N_{90}	45.3	47.9	45.5	44.4	45.8
N120	46.5	49.2	46.8	45.7	46.8
Mean	44.2	46.9	44.5	43.4	
			F-test	**SEd ±**	**CD (P=0.05)**
			S	0.441	0.9
Nitrogen Levels					
Foliar Spray of nutrient mixture			S	0.441	0.9
Interaction effect			S	0.882	1.8

F_1 = 2% DAP + 1% KCl; F_2 = 2% DAP + 1% KCl + Nutrient mixture *; F_3 = 2% DAP + 1% KCl + 100ppm Salicylic acid; F_4 = 2% DAP + 1% KCl + 100ppm maleic hydrazide; N_1 = 30 Kg ha^{-1}; N_2 = 60 Kg ha^{-1};N_3 = 90 Kg ha^{-1}; N_4 = 120 Kg ha^{-1}. *Nutrient mixture prepared by 0.5% $MgSO_4$, 0.25% $MnSO_4$, 0.25% $ZnSO_4$ and 0.1 % Boric acid

Table 2. Straw Yield of wheat (*Triticumaestivum L*) as influenced by different levels of nitrogen and foliar spray of nutrient.

Nitrogen levels(Kg ha^{-1})	**Foliar Spray of Nutrient Mixture**				
	F_1	**F_2**	**F_3**	**F_4**	**Mean**
N_{30}	68.8	70.6	68.9	66.1	68.6
N_{60}	72.0	73.8	72.1	69.1	71.7
N_{90}	74.3	76.2	74.4	71.7	74.1
N120	76.3	78.1	76.4	73.7	76.1
Mean	**72.8**	**74.7**	**72.7**	**70.1**	
		F-test	**SEd ±**	**CD (P=0.05)**	
Nitrogen Levels		S	0.90	1.85	
Foliar Spray of nutrient mixture		S	0.90	1.85	
Interaction effect		NS	1.05	2.10	

F_1 = 2% DAP + 1% KCl; F_2 = 2% DAP + 1% KCl + Nutrient mixture *; F_3 = 2% DAP + 1% KCl + 100ppm Salicylic acid; F_4 = 2% DAP + 1% KCl + 100ppm maleic hydrazide; N_1 = 30 Kg ha^{-1}; N_2 = 60 Kg ha^{-1};N_3 = 90 Kg ha^{-1}; N_4 = 120 Kg ha^{-1}. *Nutrient mixture prepared by 0.5% $MgSO_4$, 0.25% $MnSO_4$, 0.25% $ZnSO_4$ and 0.1 % Boric acid.

Table 3. Contd

	Biological yield			Harvest index		
	F-test	SEd ±	CD (P=0.05)	F-test	SEd ±	CD (P=0.05)
Nitrogen levels	S	0.93	2.85	NS	0.093	0.189
Foliar spray of nutrient mixture	S	0.93	2.85	NS	0.093	0.189
Interaction effect	NS	1.91	3.10	NS	0.186	0.378

F_1 = 2% DAP + 1% KCl; F_2 = 2% DAP + 1% KCl + Nutrient mixture *; F_3 = 2% DAP + 1% KCl + 100ppm Salicylic acid; F_4 = 2% DAP + 1% KCl + 100ppm maleic hydrazide; N_1 = 30 Kg ha^{-1}; N_2 = 60 Kg ha^{-1};N_3 = 90 Kg ha^{-1}; N_4 = 120 Kg ha^{-1}. *Nutrient mixture prepared by 0.5% $MgSO_4$, 0.25% $MnSO_4$, 0.25% $ZnSO_4$ and 0.1 % Boric acid.

Nitrogen content (%) and uptake (kg ha^{-1}) in grain and straw

Pooled data of two years shown in Table 4 reveals that nitrogen content and nitrogen uptake in grain increased significantly and consistently with increase in the nitrogen level up to 90 kg N ha^{-1}. However, increase in the nitrogen dose up to 120 kg N ha^{-1} did not differ statistically with that of 90 Kg N ha^{-1} dose. Nitrogen application at 60 kg N ha^{-1} significantly improved N content and uptake in straw over 30 kg N ha^{-1}, whereas it remained statistically similar with 90 and 120 Kg nitrogen levels in this respect. Amongst different nitrogen levels maximum nitrogen content in grain (1.33%) and straw (0.54%) was recorded with both 120 and 90 kg N ha^{-1} followed by 1.31% and (0.52%) with 60 kg N ha^{-1} whereas the lowest nitrogen content in grain (1.28%) and straw (0.49%) was recorded with 30 Kg Nha^{-1} application. Likewise, maximum nitrogen uptake in grain (63.20 Kg Nha^{-1}) and straw (41.72 Kgha^{-1}) was recorded with both 120 Kg Nha^{-1} whereas the lowest nitrogen content in grain (54.43 Kg ha^{-1}) and straw (33.97 Kgha^{-1}) was recorded with 30 kg N ha^{-1} application. Patel et al. (1996) working in Gujarat also reported significant improvement in the nitrogen content of wheat with increase in the nitrogen level up to 120 kg N ha^{-1}. Increase in nitrogen content with increase in nitrogen levels may be due to more absorption of nitrogen. Verma and Joshi (1998) also reported similar findings while working on Teosinte. The high nitrogen uptake might be due the higher grain and straw yield and higher nitrogen content in grain and straw recorded at higher levels of nitrogen application as nitrogen uptake by grain and straw is equivalent to the grain and straw yield multiplied by respective N content in grain and straw. These results corroborate the findings of Singh and Uttam (1994).

Nitrogen content and uptake in grain and straw wasincreased significantly over foliar spray of 2% DAP + 1% KCl + Nutrient mixture (F_2) and 2% DAP + 1% KCl + 100 ppm Maleic hydrazide (F_4). However, foliar spray of 2% DAP + 1% KCl + 100 ppm Salicylic acid (F_3) and 2% DAP + 1% KCl (F_1) remained statistically similar with F_2 treatment. Amongst different foliar spray mixtures, maximum nitrogen content in grain (1.33%) and straw (0.54%) was recorded in F_2 treatment, whereas, the least nitrogen content in grain (1.30%) and straw (0.51%) was observed in F_4 treatment. Maximum N uptake in grain (62.96 Kgha^{-1}) and straw (41.03 Kgha^{-1}) was observed in F_2 treatment, and lowest N uptake in grain (56.84 Kgha^{-1}) and straw (36.13 Kgha^{-1}) was observed in F_4 treatment. This could be attributed to the synergistic effect between phosphorous, potassium, zinc and magnesium with nitrogen tha is with increased supply of these nutrients, the availability of nitrogen to crop also increased thereby resulting in higher N content in grain and straw. Singh and Uttam (1994) working in Giza also reported that N and Zn application improved N and K content in grain and straw of wheat. Significantly higher N uptake by grain and straw observed with F_2 treatment was in fact the reflection of higher grain and straw yield and higher N content in grain and straw recorded by the said treatment. Significantly lower N uptake by grain and straw observed in F_4 treatment could be attributed to inhibitory effect of Maleic hydrazide on grain and straw yield as well as grain and straw N content (Singh and Uttam, 1994).

During both years and in the pooled data over two years the interaction between nitrogen levels and foliar spray of nutrient mixture remained non-significant.

Table 4. Response of different levels of nitrogen and foliar spray of nutrient mixture on nitrogen content (%) and nitrogen uptake (kg ha^{-1}) by wheat crop.

N Content (%)			**N uptake (Kg ha^{-1})**	
Nitrogen levels (Kg ha^{-1})	**Pooled**		**Pooled**	
Grain		**Straw**	**Grain**	**Straw**
N_{30}	1.28	0.49	54.43	36.93
N_{60}	1.31	0.52	58.46	40.45
N_{90}	1.33	0.54	61.27	42.82
N_{120}	1.33	0.54	63.20	44.03
Foliar spray of nutrient mixture				
F_1	1.32	0.52	58.56	41.03
F_2	1.32	0.54	62.96	38.9
F_3	1.32	0.53	56.86	36.13
F_4	1.32	0.51	56.86	41.05
SEd ±	0.009	0.0147	1.313	1.176
CD (P=0.05)	0.02	0.03	2.68	2.4

Phosphorus content (%) and uptake (kg ha^{-1}) in grain and straw

Phosphorous content and uptake in both grain and strawwas significantly influenced by the application of different nitrogen levels and foliar spray of nutrient mixture during both years and in the pooled data over two years as presented in Table 5. Pooled data over two years indicates that maximum phosphorous content and uptake in grain (0.31%, 14.91 Kgha^{-1}) was recorded with 120 Kg Nha^{-1} followed by 0.30% and 14.50 Kgha^{-1} with 60 Kg Nha^{-1} application and the least phosphorous content and uptake (0.28%, 12.30 Kgha^{-1}) in grain was observed with application of 30 Kg Nha^{-1}. Maximum phosphorous content and uptake in straw (0.21%, 16.25 Kgha^{-1}) was found with 120 Kg Nha^{-1} dose and the least phosphorous content and uptake in straw (0.19%, 13.66 Kg Nha^{-1}) was observed with 30 Kg Nha^{-1}dose. Improvement in phos-phorous content may be attributed to more availability of phosphorous to the crop because of synergistic effect between nitrogen and phosphorous. Infact, high concentration of ammonicalnitrogen is instrumental in formation of more soluble and available phosphate reaction products. These findings are in agreement with those of Dev (1992). The higher phosphorus uptake may be attributed to synergistic relationship between nitrogen and phosphorous. Besides, both grain and straw yield and phosphorous content in grain and straw improved with increase in nitrogen doses and thereby resulting in the improvement in phosphorous uptake in grain and straw as uptake is equal to the nutrient content multiplied by respective grain and straw yield.

Amongst different nutrient mixtures, the maximum phosphorous content and uptake in grain (0.31%, 14.77 Kgha^{-1}) was recorded by F_2 treatment, followed by 0.30%, 13.78 Kgha^{-1} in F_3, whereas maximum phosphorous content and uptake in straw (0.21% and 15.92 Kgha^{-1}) was found in F_2 treatment. This could be attributed to better nutrition of crop with DAP and other micronutrients like Mn, B and Mg and due to higher grain and straw yield and phosphorous content in grain and straw recorded by the F_3 treatment. The results corroborate the findings of Xu-Guohuaet al. (1999).

Table 5. Response of different levels of nitrogen and foliar spray of nutrient mixture on Phosphorous content (%) and Phosphorous uptake (kg ha^{-1}) by wheat crop.

Nitrogen levels (Kg ha^{-1})	**P Content (%)**		**P uptake (Kg ha^{-1})**	
	Pooled		**Pooled**	
	Grain	**Straw**	**Grain**	**Straw**
N_{30}	0.28	0.19	12.30	13.66
N_{60}	0.30	0.20	13.55	14.80
N_{90}	0.31	0.21	14.50	15.85
N120	0.31	0.21	14.91	16.25
Foliar Spray of nutrient mixture				
F_1	0.30	0.20	13.59	15.04
F_2	0.31	0.21	14.77	15.92
F_3	0.30	0.20	13.78	15.20
F_4	0.30	0.20	13.12	14.40
SEd ±	0.05	0.05	0.392	0.495
CD (P=0.05)	0.01	0.01	0.8	1.01

Table 6. Response of different levels of nitrogen and foliar spray of nutrient mixture on nitrogen content (%) and nitrogen uptake (kg ha^{-1}) by wheat crop.

K Content (%)			**K uptake (Kg ha^{-1})**	
Nitrogen levels (Kg ha^{-1})	**Pooled**		**Pooled**	
Grain		**Straw**	**Grain**	**Straw**
N_{30}	1.55	2.31	65.74	153.5
N_{60}	1.58	2.34	70.16	168.3
N_{90}	1.6.0	2.35	73.33	175.0
N_{120}	1.59	2.36	75.72	179.6
Foliar Spray of nutrient mixture				
F_1	1.58	2.34	70.2	169.4
F_2	1.61	2.36	75.79	175.3

F_3	1.61	2.34	71.16	169.9
F_4	1.55	2.32	67.79	161.9
SEd ±	0.0098	0.0098	1.029	1.519
CD (P=0.05)	0.02	0.02	2.1	3.1

Potassium content (%) and uptake (kg ha^{-1}) in grain and straw

Potassium content and uptake in both grain and straw was significantly influenced by the application of different nitrogen levels and foliar spray of nutrient mixture during both years and in the pooled data of two years (Table 6). Maximum potassium content in grain (1.60%) was recorded with 90 Kg Nha^{-1} whereas least potassium content (2.31%) was recorded with 30 Kg Nha^{-1}.Likewise, maximum potassium content in straw (2.36 %) was observed with 120 Kg Nha^{-1} whereas least value of 2.31% was recorded with 30 Kg Nha^{-1}. The maximum potassium uptake by grain (75.72% Kgha^{-1}) was observed with 120 Kg Nha^{-1} application, followed by 73.33 Kgha^{-1} with 90 Kg Nha^{-1} whereas maximum potassium uptake by straw (179.68 Kg ha^{-1}) was recorded with 120 Kg Nha^{-1} followed by 175.03 Kg ha^{-1} with 90 Kg Nha^{-1}. Improvement in the potassium content in grain and straw with increase in the levels of nitrogen could be attributed to the synergistic influence between nitrogen and potassium. Significant improvement in potassium content with increasing levels of nitrogen application could be attributed to higher potassium content in grain and straw and higher grain and straw yield realized with increasing nitrogen doses as uptake of nutrient is mathematically equal to the grain and straw yield multiplied by respective nutrient content (Singh and Uttam, 1994).

The maximum potassium content and uptake in grain (1.61%, 75.79 Kg ha^{-1}) was recorded with F_2, whereas maximum potassium content and uptake in straw (2.36 % and 175.29 Kg ha^{-1}) was recorded with F_2 treatment and the least (2.32% and 161.91 Kg ha^{-1}) with F_4 treatment. This could be attributed to better nutrition of crop with KCl and other micronutrients. Besides, significantly lowest potassium content recorded with F_4 treatment could be attributed to growth inhibitory influence of Maleic hydrazide (Xu-Guohuaet al., 1999).

Conclusion

Based on the results of the experiments carried out during two consecutive years, it may be concluded that nitrogen@ 120 Kg ha^{-1} and (2% DAP + 1% KCl + Nutrient mixture) was found best to increase the yield and nutrient content and uptake of nitrogen, phosphorus and potassium.

Conflict of interests

The author(s) did not declare any conflict of interest.

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