

RECOVERY AND EFFICIENCY OF APPLIED NUTRIENTS AFFECT YIELD AND RELATED TRAITS OF TURNIP CULTIVAR PURPLE TOP WHITE GLOBE

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Fertilizer application positively affects yield of most crops but needs special attention in root crops, including turnip (*Brassica rapa*) because of direct accumulation of nutrients, particularly nitrates, in root that can be harmful to consumers. So, determination of fertilizer dose that can give high yield, while avoiding nitrate accumulation, is very important. This experiment was carried out to find the best combination of nitrogen (N= 75 and 100 kg ha⁻¹) and phosphorus (P= 50 and 75 kg ha⁻¹), with respect to agronomic and physiological efficiency, apparent recovery of nutrients, and yield response, in comparison with control (recommended dose of N-P i.e., 50:50 kg ha⁻¹) for getting high yield of turnip roots, while keeping the nitrogen accumulation within permissible limits. Results revealed that high dose of nitrogen with moderate level of phosphorus (N-P@100-50 kg ha⁻¹) proved the best in promoting the growth (leaf and root size), leaf chlorophyll contents, fresh and dry weight of leaves and roots, and yield of turnip. But, further increase in dose of phosphorus (N-P@100-75 kg ha⁻¹) did not improve the values of these parameters. Nitrogen contents of leaves and root were highest in response to N-P @100-50 kg ha⁻¹. While, highest concentration of phosphorus in leaves and roots was recorded for N-P@100-75 kg ha⁻¹. Interestingly, the value of yield response (60.4%), agronomic efficiency (109 kg of root per kg of N and 218 kg root per kg of P), and physiological efficiency of phosphorus (296 kg of root per kg of P) were also higher for N-P@100-50 kg ha⁻¹ than N-P@100-75 kg ha⁻¹, which also implies more efficient use of fertilizer applied @ 100-50 kg ha⁻¹. Moreover, apparent recovery of nitrogen was also greatest for N-P@100-50 kg ha⁻¹ but, apparent recovery of phosphorus was highest for N-P@100-75 kg ha⁻¹. Furthermore, total nitrogen concentration in the roots was within permissible range even for the highest level of fertilizers. Therefore, farmers can use N-P @100-50 kg ha⁻¹ to get high yield at a high benefit:cost ratio, while keeping nitrate nitrogen within non-toxic range.

Keywords: *Brassica rapa*, mineral deficiency, nutrients availability, nitrate accumulation, yield potential, chlorophyll contents.

INTRODUCTION

Yield and quality of vegetables is affected by numerous factors viz., weather condition, soil type, irrigation water, nutrients availability, control of insect-pest and diseases etc. Continuous cropping without fallowing of agriculture lands has resulted in decreased availability of nutrients, which led to decline in yield potential of crops. This deficiency of mineral nutrients results 60% decline in growth of crops (Camak, 2002). The only way to cope with this deficiency is the use of synthetic fertilizers. Nitrogen based fertilizers are most commonly used because of its common deficiency and its role in plant growth and yield. Nitrogenous fertilizers are liberally applied to vegetables to enhance growth rates and yield (Baker, 1980; Jaskani *et al.*, 2006).

Turnip (*Brassica rapa*) is commonly cultivated in Pakistan during winter for its leaves and roots. Area under turnip grown for vegetable purpose was 0.01517 million hectares

and production 0.2625 million ton during 2014-2015 (Anonymous, 2016). Nitrogen uptake rate is high in turnips and therefore accumulate more nitrate than other crops such as carrot, oats, rape and ryegrass (Darwinkel, 1975), because of its high nutrient requirement (Salardini *et al.*, 2009). One of the major sources of nitrate accumulation in human body is consumption of vegetables, which accounts for 80% of nitrate supply to human body (Rathod *et al.*, 2016). Nitrate accumulation in most of the brassicas, used for forage, occurs when nitrogen is applied at higher rates than needed to attain highest yield (Fletcher and Chakwizira, 2012). Surprisingly, more nitrate accumulates in the edible part of turnip (root) than in leaves (Fletcher and Chakwizira, 2012), which is toxic to consumers. Unfortunately, most of the previous studies had focused on accumulation of nitrate in turnip greens (leaves) (Vieira *et al.*, 1998) or on forage turnip (roots) (Fletcher and Chakwizira, 2012).

The highest yield of edible turnip in response to application of nitrogen @ 110 kg ha⁻¹ was recorded by Wahocho *et al.* (2016), while Salardini *et al.* (2009) and Sadia *et al.* (2013a) obtained maximum root yield by applying nitrogen @ 100 kg ha⁻¹. But, there is scarcity of research regarding impact of various fertilizer application rates on recovery and efficiency of applied nutrients, yield response and root nitrogen contents of edible turnips. Moreover, appropriate ratio of nitrogen and phosphorus is very important for uptake of both nutrients. Li *et al.* (2016) stated that biomass production and phosphorus concentration in plant tissues was higher when nitrogen was applied at high rate up to certain extent, but P availability became limited beyond that level. Nitrogenous fertilizer application (@ 390 kg ha⁻¹) above recommended rate (90 kg ha⁻¹) led to 15% reduction in yield of melons (Cabello *et al.*, 2009), possibly because of reduced availability and/or uptake of other nutrient elements (Albornoz, 2016). Similar practices of nitrogen application at higher rates in cucumber reduced nitrate reductase activity (Ruiz and Romero, 1999).

Turk (2010) obtained the highest root yield of fodder beet in response to nitrogen and phosphorus application @ 225 and 50 kg ha⁻¹. While, Sadia *et al.* (2013b) obtained highest yield and size of turnip root in response to 100 kg P ha⁻¹ in Bangladesh. Wang and Li (2004) observed that application of phosphatic fertilizer increased yield of rape but also increased its nitrate contents. So, optimization of appropriate ratio of nitrogen and phosphorus seems to be necessary for turnip.

Therefore, the present study was carried out to explore the best dose of nitrogen and phosphorus for getting high yield, nutrient recovery and efficiency of nutrients applied to turnip cv. Purple Top White Globe, while, keeping the root nitrate contents within safe limits.

MATERIALS AND METHODS

This experiment was carried out during winter at Vegetable Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (latitude 31°30' N, longitude 73°10' E and altitude 213 m). Soil was analyzed, before crop cultivation, for pH, EC, N, P, K, and organic matter, which revealed 8.2, 0.32 dS/m, 0.03%, 3.01 ppm, 173 ppm and 1.19%, respectively.

Plant material and crop cultivation: Seeds of turnip cultivar Purple Top White Globe were obtained from Ayub Agricultural Research Institute, Faisalabad. Seeds were sown on both sides of ridges, which were spaced 2.5 ft apart, on October 15, winter 2014-15. The crop was fertilized with various combinations of nitrogen and phosphorus (mentioned under), while potassium was applied @ 50 kg ha⁻¹. Diammonium phosphate (DAP) and urea were used as a source of phosphorus and nitrogen, while potassium was applied in the form of sulfate of potash. All phosphorus and

potash were applied as basal dose at the time of final seed bed preparation. Nitrogen fertilizer was applied in three splits, one split in the form of DAP at the time of final seed bed preparation, while the remaining dose was applied, in the form of urea, after 20 and 40 days of sowing. All recommended cultural practices were followed uniformly in all experimental units except the dose of nitrogen and phosphorus. Crop was harvested on January 07, 2015.

Treatments and experimental design:

- T₀ = N-P@ 50-50 kg ha⁻¹ (control)
 T₁ = N-P@ 75-50 kg ha⁻¹
 T₂ = N-P@ 75-75 kg ha⁻¹
 T₃ = N-P@ 100-50 kg ha⁻¹
 T₄ = N-P@ 100-75 kg ha⁻¹

Data collection: Data were recorded for yield and yield related traits. Plant height was recorded before crop harvesting. Leaf chlorophyll contents (SPAD; Model CCM-200 Optic Science, UK), root length (cm), root diameter (mm), fresh and dry weight of root and leaves, and yield per plot (kg/32.5 ft²), as per procedure of Turk (2010). Moreover, agronomic efficiency, yield response (%), physiological efficiency, and apparent recovery were calculated as suggested by Jatav *et al.* (2012).

$$\text{Agronomic efficiency} = \frac{\text{Root yield in fertilized plot} - \text{Root yield in unfertilized plot}}{\text{Quantity of total nutrient applied}} \times 100$$

$$\text{Yield Response} = \frac{\text{Root yield in fertilized plot} - \text{Root yield in unfertilized plot}}{\text{Root yield in unfertilized plot}} \times 100$$

$$\text{Physiological Efficiency} = \frac{\text{Tuber yield in fertilized plot} - \text{Tuber yield in unfertilized plot}}{\text{Uptake in fertilized plot} - \text{Uptake in unfertilized plot}} \times 100$$

$$\text{Apparent Recovery} = \frac{\text{Uptake in fertilized plot} - \text{Uptake in unfertilized plot}}{\text{Quantity of total nutrient applied}} \times 100$$

Determination of minerals: For estimation of nitrogen in leaf and root, samples were digested with sulphuric acid and digestion mixture (K₂SO₄, CuSO₄ and FeSO₄ in ratio 10:5:1) in Kjeldahl's apparatus (Chapman and Parker, 1961). Samples for estimation of phosphorus and potassium were prepared as per method of Yoshida *et al.* (1976).

Experimental design and statistical analysis: Treatments were arranged according to randomized complete block design and replicated thrice. Analysis of variance technique was used for statistical analysis of the data (Steel *et al.*, 1997). Tukey's test at 5 % possibility level was used to compare the treatments for significant difference.

RESULTS

Growth, yield and yield response: Various fertilizer treatments significantly (P < 0.05) affected all parameters except potassium contents of root and leaves. Nitrogen and phosphorus applied @ 100-50 kg ha⁻¹ improved plant height (61.3 cm), chlorophyll contents (20.6 SPAD units), root length (12.2 cm) and root diameter (76.23 mm) over control (N-P@ 50-50 kg ha⁻¹) and N-P@ 100-75 kg ha⁻¹ (Table 1). Fresh and dry weight of root and leaves continued to

Table 1. Effect of phosphorus and nitrogen fertilizer on the plant height, root length and diameter, dry matter and number of leaves of turnip cv. Purple Top White Globe.

Treatments (kg ha ⁻¹)	Plant height (cm)	Leaf chlorophyll contents (SPAD units)	Root length (cm)	Root diameter (mm)
N-P@ 50-50	47.0d	14.7c	8.9d	49.27c
N-P@ 75-50	51.0cd	16.8b	9.9c	56.53bc
N-P@ 75-75	53.8bc	17.3b	10.4bc	64.06b
N-P@ 100-50	61.3a	20.6a	12.2a	76.23a
N-P@ 100-75	57.3ab	19.5a	11.0b	74.06a

Treatments sharing same letter were statistically non-significant at 5% probability level.

Table 2. Effect of phosphorus and nitrogen fertilizer on fresh and dry weight of leaves and roots, yield response and yield per plot of turnip cv. Purple Top White Globe.

Treatments (kg ha ⁻¹)	Dry weight plant ⁻¹ (g)		Fresh weight plant ⁻¹ (g)		Yield per plot (kg/32.5 sqft)
	Root	Leaves	Leaves	Root	
N-P@ 50-50	47.2d	81.9c	105.0e	125.6c	16.5d
N-P@ 75-50	51.7c	93.4b	115.4d	142.2bc	20.0c
N-P@ 75-75	59.0b	98.2b	123.7c	158.5ab	22.1b
N-P@ 100-50	65.8a	110.8a	137.7a	171.9a	25.9a
N-P@ 100-75	62.0b	101.7ab	130.4b	159.2ab	24.4a

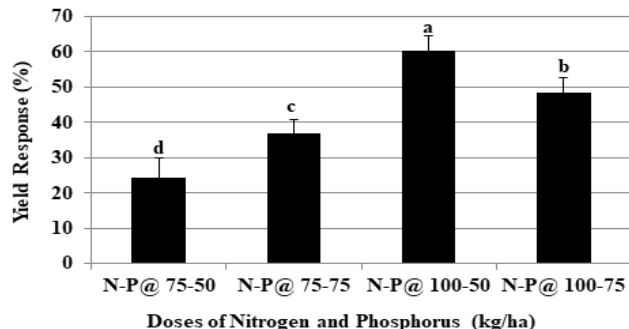
Treatments sharing same letter were statistically non-significant at 5% probability level.

Table 3. Effect of nitrogen and phosphorus on the mineral contents of turnip cv. Purple Top White Globe.

Treatments (kg ha ⁻¹)	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Leaf	Root	Leaf	Root	Leaf	Root
N-P@ 50-50	1.79c	1.91c	0.19c	0.20c	2.20a	2.38a
N-P@ 75-50	2.01bc	2.08bc	0.21b	0.24b	2.34a	2.42a
N-P@ 75-75	2.33ab	2.19b	0.29a	0.31a	2.27a	2.42a
N-P@ 100-50	2.57a	2.64a	0.22b	0.25b	2.24a	2.44a
N-P@ 100-75	2.52a	2.58a	0.30a	0.33a	2.44a	2.40a

Treatments sharing same letter were statistically non-significant at 5% probability level.

increase with increase in fertilizer dose, were highest for N-P@ 100-50 kg ha⁻¹, and then declined (Table 2). While, yield per plot (25.9 kg/32.5 ft²) was highest in response to N-P@ 100-50 kg ha⁻¹, but was statistically like N-P@ 100-75 kg ha⁻¹ (24.4 kg/32.5 ft²) (Table 2). The values of yield response were also changed in the same fashion as yield, being highest for N-P@ 100-50 kg ha⁻¹ followed by N-P@ 100-75 kg ha⁻¹, N-P@ 75-75 kg ha⁻¹ and N-P@ 75-50 kg ha⁻¹ (Fig. 1).

**Figure 1. Effect of various doses of nitrogen and phosphorus on yield response of turnip cultivar Purple Top White Globe.**

Nutrient contents of turnip and their apparent recovery:

Application of various combinations of nitrogen and phosphorus significantly affected nitrogen and phosphorus contents of turnip roots and leaves but did not affect their potassium contents (Table 3). Therefore, other calculations were not done for potassium. The highest nitrogen contents of leaves (2.57 %) and roots (2.64 %) were recorded for N-P@ 100-50 kg ha⁻¹, which were statistically like N-P@ 100-75 kg ha⁻¹. Nitrogen contents of roots (2.64%), equivalent to 0.8% nitrates, were within permissible limits that does not cause nitrate toxicity (4000 ppm) (Vieira *et al.*, 1998). In contrast to nitrogen, phosphorus contents in leaves and roots were high for those combinations of N and P that contained 75 kg ha⁻¹, i.e. N-P@ 75-75 kg ha⁻¹ (0.29% and 0.31%, respectively) and N-P@ 100-75 kg ha⁻¹ (0.30% and 0.33%, respectively). As a result of enhanced nutrient uptake in different combinations of nitrogen and phosphorus, the values of apparent recovery were also improved over the control. This increment was more pronounced for nitrogen compared with phosphorus (Fig. 2). Apparent recovery of nitrogen was highest in response to application of N-P@ 100-50 kg ha⁻¹ (24.16 %) and N-P@ 100-75 kg ha⁻¹ (22.18 %). Like phosphorus uptake pattern, apparent recovery of

phosphorus was high for combinations containing highest level of phosphorus (75 kg ha⁻¹), i.e. 4.85% and 5.73% for N-P@ 75-75 kg ha⁻¹ and N-P@ 100-75 kg ha⁻¹, respectively.

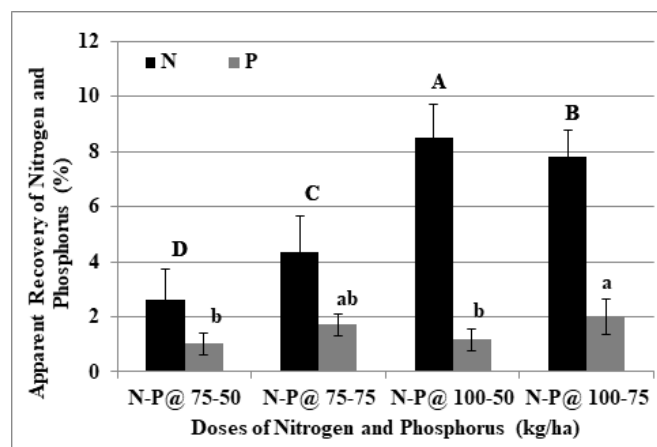


Figure 2. Effect of different fertilizer levels on apparent recovery of nitrogen and phosphorus by turnip cultivar Purple Top White Globe. Note: capital and small letters indicate significant differences for nitrogen and phosphorus among various treatments, respectively.

Agronomic and physiological efficiency: Agronomic efficiency shows the difference in root yield of fertilized and control plots per unit increment in applied mineral nutrient(s). Agronomic efficiency of applied nitrogen and phosphorus was higher in all treatments over the control (N-P@ 50-50 kg ha⁻¹) but combination of N-P@ 100-50 kg ha⁻¹ exhibited the highest value (311 and 622 kg/kg, respectively for N and P) (Fig. 3).

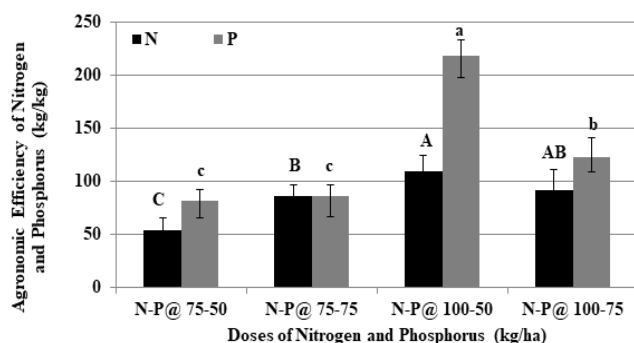


Figure 3. Agronomic efficiency of nitrogen and phosphorus in response to fertilizer doses applied to turnip cultivar Purple Top White Globe. Note: capital and small letters indicate significant differences for nitrogen and phosphorus among various treatments, respectively.

Further increase in fertilizer application rate (N-P@ 100-75 kg ha⁻¹) did not increased agronomic efficiency of both

nutrients. Physiological efficiency of nitrogen, which depicts the improvement in turnip root production per unit rise in nitrogen up-taken by plant over control plants, was not affected by different fertilizer treatments, rather it decreased slightly with increase in nitrogen level (@ 100 kg ha⁻¹). But, physiological efficiency of phosphorus was highest for N-P@ 100-50 kg ha⁻¹ (296 kg/kg), followed by N-P@ 75-50 kg ha⁻¹ (233 kg/kg), while N-P@ 75-75 kg ha⁻¹ and N-P@ 100-75 kg ha⁻¹ were statistically similar (Fig. 4).

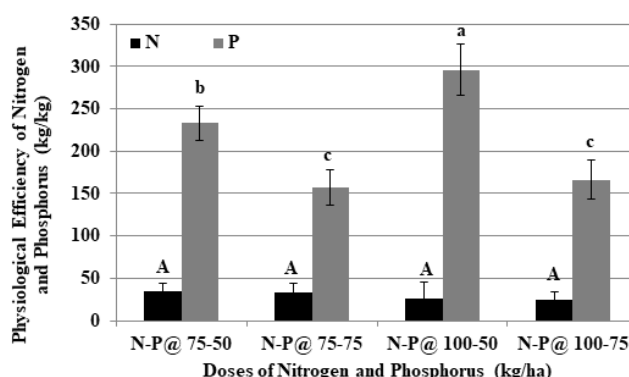


Figure 4. Physiological efficiency of nitrogen and phosphorus in response to fertilizers applied to turnip cultivar Purple Top White Globe. Note: capital and small letters indicate significant differences for nitrogen and phosphorus among various treatments, respectively.

DISCUSSION

The increased plant height due to various combinations of N and P can be attributed to concomitant increment in leaf chlorophyll contents. Nitrogen application increases mRNA level of nicotianamine synthase genes involved in iron uptake, component of chlorophyll, and its translocation within the plant body (Pich *et al.*, 2001). Enhanced uptake might have led to higher photosynthetic rates, which increased plant height, fresh and dry weight of turnip leaves and roots. Salardini *et al.* (2009) also observed tallest turnip plants in response to nitrogen application @ 100 kg ha⁻¹, which support our findings. Increase in fresh and dry weight of turnip due to application of inorganic fertilizers at higher rates (N @ 100 to 150 kg ha⁻¹, P @ 40 kg ha⁻¹) was also observed in previous studies (El-Sherbeny *et al.*, 2012; Jacobs *et al.*, 2004; Sadia *et al.*, 2013a,b; Sattar *et al.*, 2017), which validate our results. Therefore, yield was higher in plots receiving higher levels of N and P. Literature also supports our results as Wahocho *et al.* (2016) reported 110 kg N ha⁻¹ gave highest yield of turnip, while Sadia *et al.* (2013a,b) recorded highest yield of turnip roots from plots receiving 100 and 70 kg ha⁻¹ of nitrogen and phosphorus, respectively. Yield response, which compares the yield in

fertilized and control plots, followed the same pattern as yield but clearly demarcated the difference among various treatments. It was evident that although yield of plots receiving N-P@ 100-75 kg ha⁻¹ was statistically similar to those receiving N-P@ 100-50 kg ha⁻¹, but yield response of later was significantly higher than former treatment. Jatav *et al.* (2012) also reported that results of yield and yield response follow the same pattern in radish and potato as observed in this study.

Application of different combinations of nitrogen and phosphorus increased nitrogen and phosphorus contents of turnip leaves and roots. Apparent recovery was calculated to estimate the difference in uptake of nutrients in fertilized and control plots over total amount of applied nutrients. High apparent recovery for nitrogen might be due to high solubility and ready availability of urea. On the other hand, low phosphate recovery can be due to slow release nature of diammonium phosphate (DAP), which was applied at the time of seed bed preparation and might have been fixed in the soil due to high soil reaction.

Yield of plots receiving various treatments was compared with yield of control plots in response to amount of nutrient applied and expressed as agronomic efficiency. Although, all treatments showed increase in agronomic efficiency of applied nutrients but N-P@ 100-50 kg ha⁻¹ showed the highest value of both nitrogen and phosphorus, particularly for phosphorus. Physiological efficiency further elaborated that N-P@ 100-50 kg ha⁻¹ was the best treatment regarding phosphorus uptake and its impact on yield. Moreover, it is also evident from results that although recovery of nitrogen increased with increase in fertilizer doses but its conversion into yield did not increase correspondingly and therefore showed decline in physiological efficiency of applied nitrogen. In contrast to nitrogen, phosphorus recovery was less but was efficiently converted into photosynthates and therefore, its physiological efficiency was higher. Jatav *et al.* (2012) also recorded higher agronomic and physiological efficiency for phosphorus as compared with nitrogen that justify our assumption. Further, application of N-P@ 100-50 kg ha⁻¹ was also safe regarding nitrate accumulation in turnip roots in permissible limits (10 to 3400 ppm) as reviewed by Colla *et al.* (2018).

Conclusion: It can be inferred from the whole research work that N-P@100-50 kg ha⁻¹ improved yield, yield response, apparent recovery, agronomic and physiological efficiency and therefore, proved the best in promoting the growth, quantity and quality of the turnip. Further increase in phosphorus (@ 75 kg ha⁻¹) did not improve the values of these parameters. So, farmers can increase their benefit-cost ratio by using N-P@100-50 kg ha⁻¹, while retaining nitrate nitrogen in the permissible range.

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