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Effects of Nitrogen Application Rates on the Yield of Radish (*Raphanus sativus* L.) in Kitchen Gardens

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Abstract: Healthy eating habits in urban lifestyles can be encouraged by mobilizing communities to grow vegetables in kitchen gardens. This study focuses to economically optimized dosage for radish production in our backyards. Nitrogen fertilizers at the six different rates (i.e. 0, 50, 100, 150, 200 and 250 kg ha⁻¹) were tested in kitchen gardens of radish. A direct relation of quality and yield of radish with rate of nitrogen application was identified. Although the highest yield of radish was obtained with the application of 200 kg ha⁻¹ nitrogen (99.98 t ha⁻¹), the most effective dose of nitrogen was identified to be 150 kg ha⁻¹ because at this rate highest increase in yield per unit fertilizer applied (25.78%) was recorded where as nitrogen application at 250 kg ha⁻¹ had the least yield increase ratio (14.21%) with a negative MRR. A direct correlation was observed between rate of nitrogen applied number of leaves and root-shoot which ultimately increased the yield. Hence it is concluded that application of nitrogen at 150 kg ha⁻¹ could be a best both in terms of biological and economical yield of radish in backyards.

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1. Introduction

Organic and economic cultivation of vegetables has great significance to adapt to healthy eating habits. Inclusion of salads and fresh vegetables that are contaminant free could induce great health benefits to a common household. Encouraging kitchen gardening is the first step in mobilizing rural and urban community for consuming freshly grown healthy vegetables in their diet. Kitchen gardening approach is receiving great appreciation among urban population of Pakistan quite recently (Awan et al., 2015). Growing vegetables in backyard for making salads in urban houses of Pakistan is getting popular as a hobby as well as a source of fresh food. Radish (*Raphanus sativus* L.) is one of the preferred vegetable for kitchen gardens (Pervez et al., 2003) due to high vitamin contents in its roots and leaves (van Bueren et al., 2011). It also upsurges appetite, prevents constipation and its leaves and roots are very appetizing when cooked together. It is consumed as medicine for curing jaundice, different liver disorders, piles and enlarged spleen problems (Kim et al., 2013). It was first originated in China and Indo-Pak subcontinent. Having temperature requirement of 12-15°C for its better development and growth, cultivating it in cooler months in urban backyards

without any special arrangement makes it an ideal crop for kitchen gardening.

The typical yield of radish is less than its potential especially when grown in backyards as kitchen crop because most of the time the soil is deficient in macro nutrients (Khan et al., 2011). This deficiency can be eliminated by judiciously supplementing with nitrogen fertilizers. Hence application of nitrogen containing fertilizers can be considered as one of the easiest and quickest method for yield enhancement in kitchen gardens (Shirazi et al., 2014, Shivay et al., 2015). Nitrogen application establishes healthier roots (Jilani et al., 2010, Singh et al., 2011) with increased root weight and leaf production (Islam et al., 1999, El-Desuki et al., 2005). But to get optimum utility of nitrogen application, a precise quantity should be applied as most of the time the response of the crop is very much dose dependent (Hegde, 1987, Kang and Wan, 2005, Singh et al., 2011, Ghosh et al., 2014). Similarly, it has been reported that increasing nitrogen level at the rate of 100 kg/ha may increase the leaf size by 60% (Kakar et al., 2002) and produces 20% more leaves (Ali et al., 2006).

As most of these nitrogen optimization studies have been conducted in open field condition, it was felt vital to optimize nitrogen rates for radish in

kitchen gardens so that the green enthusiasts may enjoy the best quality produce within their own back yards. Hence the present study compared the response of radish crop to different doses of nitrogen applied on domestic scales.

2. Data and Methodology

Kitchen gardens from three urban homes in District Faisalabad, Punjab, Pakistan were selected for the study in 2014. Each site was considered as an individual replication. Mino early long white commercial cultivar was selected for the studies. The gardens were divided into small plots (1.5 m × 3 m) and the soil was prepared for radish cultivation. Well pulverized soils in the back yards of participating household were mixed with starting doses of potassium in the form of potassium nitrate and phosphorus in the form of diammonium phosphate (DAP) at the rate of 100 and 65 kg/ha, respectively. All basic cultural practices such as hoeing, irrigation, weeding, disease and pest control etc. were observed uniformly when required. The seeds were sown on ridges (30 cm apart) maintaining plant distance of 10 cm. The experiment consists of five rates of nitrogen (50, 100, 150, 200 and 250 kg ha⁻¹) in the form of urea as treatment while the control plot received no nitrogen fertilizer. All of these doses were applied in two splits; where the first half was applied at sowing and the remaining half at 30 days after sowing.

The experiment was laid out in a Split-Randomized Complete Block Design with three replications. At the time of harvest, the data for number of leaves, leaf length (cm), root length (cm), root diameter (cm), root weight (g), root-shoot ratio and overall yield were recorded. Yield increment (%) was calculated to express cost benefit of applying each unit of nitrogen fertilizer. Yield increment was calculated according to formula in equation [1].

$$\text{Yield Increment (\%)} = \frac{\Delta \text{yield (kg)}}{\Delta N \text{ applied (kg)}} \times 100 \quad [1]$$

The data were analyzed statistically using analysis of variance (ANOVA) technique (Steel et al., 1980) with 0.05 probability and where the significant results were observed, the means were separated by Duncan's Multiple Range (DMR) test (Duncan, 1955) using SPSS computer application (SPSS, 2008).

For assessment of each treatment in economic terms to find out most economically optimum dose we conducted the marginal analysis (Evans, 2013) to calculate marginal rate of return. This economic tool explains the feasibility of alternatives in terms of increased productivity where only those alternatives will be adopted for which the cost of producing one extra unit of product would be equal or less than the marginal revenue earned due to that particular change. For this analysis we used a conservative estimate of total yield (kg ha⁻¹) by deducting 10% from the actual obtained yield (this was done to compensate for any loss in yield in farmer's field due to low precision than this trial). The actual sale price of the produce was noted to be PKR 2 kg⁻¹ and the prevailing price of Urea fertilizer was PKR 39 kg⁻¹.

3. Results

The results indicated that nitrogen application in kitchen garden had a highly significant effect on number of leaves ($F_{5, 12} = 9.55$, $p = 0.001$). The highest number of leaves was produced on the plants treated with all level of nitrogen in par as compared to the control (Table 1). However number of leaves was positively and significantly ($R^2_{\text{adj.}} = 0.55$; $F_{1, 16} = 21.24$, $p < 0.001$) correlated to different doses of nitrogen applied (Fig. 1A). The result demonstrated that leaf size showed significant ($F_{5, 12} = 209.14$, $p < 0.001$) variation to nitrogen application. The significantly largest leaves were developed on plants treated with nitrogen at the rate of 200 kg ha⁻¹ and 250 kg ha⁻¹. Whereas minimum size of leaves were observed on plants grown in control (Table 1).

Table 1. Effect of nitrogen application in kitchen gardens to increase yield and vegetative growth of radish.

Variables	Nitrogen levels (kg ha ⁻¹)					
	T ₀ : 0	T ₁ : 50	T ₂ : 100	T ₃ : 150	T ₄ : 200	T ₅ : 250
Leaves plant ⁻¹	9.67 ± 1.47 b	15.67 ± 0.41 a	16.67 ± 1.08 a	18.33 ± 1.78 a	18.67 ± 1.78 a	18.33 ± 1.08 a
Leaf length (cm)	19.83 ± 0.93 e	25.30 ± 0.32 d	27.80 ± 0.07 c	31.20 ± 0.37 b	33.43 ± 0.16 a	32.70 ± 0.15 a
Root length (cm)	11.13 ± 0.18 e	22.80 ± 0.18 b	19.50 ± 0.11 d	22.20 ± 0.03 c	23.87 ± 0.08 a	22.20 ± 0.13 c
Root diameter (cm)	1.92 ± 0.01 e	2.83 ± 0.04 d	2.74 ± 0.04 d	4.25 ± 0.15 c	4.53 ± 0.11 b	4.97 ± 0.10 a
Root – shoot (ratio)	1.43 ± 0.07 d	1.63 ± 0.08 c	1.39 ± 0.12 c	0.89 ± 0.06 ab	0.89 ± 0.09 a	0.97 ± 0.04 b
Root weight (g)	83.2 ± 0.71 e	108.8 ± 3.1 d	119.9 ± 2.94 c	128.2 ± 1.54 b	143.3 ± 3.25 a	123.7 ± 4.91 bc
Yield (t ha ⁻¹)	49.67 ± 2.86 e	60.37 ± 3.49 d	70.62 ± 2.75 c	88.33 ± 4.60 b	99.98 ± 0.05 a	85.2 ± 2.12 b
Yield increment* (%)	-	21.41 ± 1.67 a	20.95 ± 0.78 a	25.78 ± 3.64 a	25.16 ± 1.16 a	14.21 ± 1.47 b

Means, in the same row, that share the same superscript letters do not differ statistically from one another ($p < 0.05$; Duncan Multiple Range Test for post hoc pairwise comparisons).

* Percent increase in yield per kilogram of nitrogen applied (with reference to no-nitrogen applied plots). A dash indicates that no data were generated.

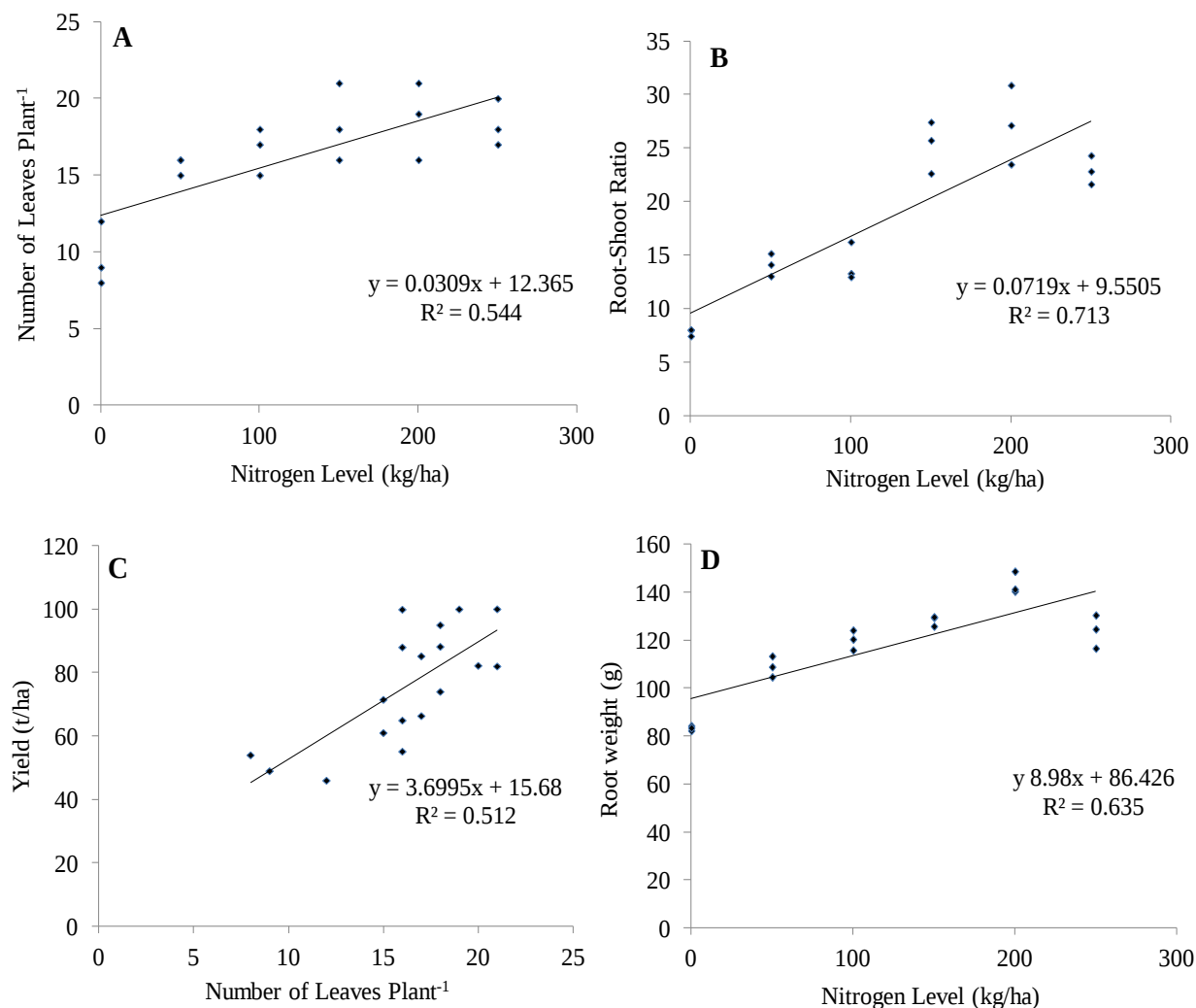


Fig. 1 Relationship between rate of nitrogen application and number of leaves plant⁻¹ (A), root-shoot ratio (B), number of leaves plant⁻¹ and yield of radish roots and (C) and root weight (D) in kitchen gardens. The coefficient values are adjusted.

The relationship of nitrogen application to the size of leaves seems to be directly correlated ($R^2_{(adj.)} = 0.942$, $n = 18$, $p < 0.01$) where increase in the amount of applied nitrogen increased the size of leaves significantly (Table 1). The ANOVA showed that nitrogen application significantly affected the growth of root both in terms of its length ($F_{5, 12} = 2006.83$, $p < 0.001$) and diameter ($F_{5, 12} = 267.75$, $p < 0.001$) (Table 1). Maximum increase in root length was observed in the plots treated with 200 kg ha⁻¹ nitrogen compared to plants treated with 50 kg ha⁻¹ nitrogen. Whereas plants received 150 or 250 kg ha⁻¹ nitrogen have similar in root length values, while least effect was noticed in plants treated with 100 kg ha⁻¹ but even this was significantly higher root length value as compared to the check. Significantly highest root

width was recorded when the plants received 250 kg ha⁻¹ followed by 200 kg ha⁻¹. Significantly least diameter of root was observed in plants grown on check plots (Table 1).

Nitrogen application also demonstrated significant effect on root-shoot ratio ($F_{5, 12} = 40.71$, $p < 0.001$). Significantly highest ratio was observed in plants treated with 200 kg ha⁻¹ nitrogen and it was significantly similar to the plants treated with 150 kg ha⁻¹ nitrogen (Table 1). Surprisingly, significantly similar root-shoot ratio, was observed in plants treated both 100 and 250 kg ha⁻¹ nitrogen (Table 1). The regression analysis (Fig. 1B) has also presented a significant ($R^2_{(adj.)} = 0.713$; $F_{1, 16} = 43.23$, $p < 0.001$) strong positive correlation of root-shoot ratio to nitrogen rates.

Table 2 Marginal analysis of costs and revenues for different rates of nitrogen application to determine marginal rate of return (MRR) for each switch

Descriptions	Unit	Nitrogen Application (kg ha ⁻¹)				
		50	100	150	200	250
Revenues (R)						
Average Field Yield	kg ha ⁻¹	10707	20953	38667	50310	35533
Adjusted Yield (Y)	kg ha ⁻¹	9636	18858	34800	45279	31980
Unit Sale Price of Radish (P _r)	PKR/kg	2.0	2.0	2.0	2.0	2.0
Total Revenue (YP _r)	PKR ha ⁻¹	19272	37716	69600	90558	63960
Costs (C)						
Amount of Urea Used (N)	kg ha ⁻¹	109	217	326	435	544
Unit Price of Urea Fertilizer (P _n)	PKR/Kg	39.4	39.4	39.4	39.4	39.4
Cost of Urea Used (NP _n)	PR ha ⁻¹	4283	8566	12848	17131	21414
Marginal Analysis						
Marginal Return per Switch (ΔR)	PKR ha ⁻¹	19272	18444	31884	20958	-26598
Marginal cost per Switch (ΔC)	PKR ha ⁻¹	4283	4283	4283	4283	4283
Marginal Rate of Return (MRR)	%	450	431	744	489	-621

PKR: Pakistani Rupees

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ANOVA revealed that yield related expressed in terms of root weight and overall production (yield) had also been significantly affected by application of nitrogen at different rates ($F_{5, 12} = 67.11$, $p < 0.001$ and $F_{5, 12} = 59.72$, $p < 0.001$, respectively) (Table 1). Different rates of nitrogen application has demonstrated a positive correlation with increase in root weight (Pearson's co-efficient: $R^2_{(adj.)} = 0.635$, $n = 18$, $p < 0.01$) (Figure 1D) was observed in both variables that significantly highest values were obtained at 200 kg ha⁻¹ nitrogen application followed by 150 kg ha⁻¹. On the other hand, minimum root yield was obtained with 50 kg ha⁻¹ nitrogen application even though it was significantly higher root yield as compared to the check plots (Table 1). The yield in different plots have been found strongly and significantly correlated to number of leaves induced due to nitrogen application ($R^2_{(adj.)} = 0.512$; $F_{1, 16} = 18.83$, $p = 0.001$) (Fig. 1C).

These results have indicated that the more the nitrogen fertilizer is added to the soil in kitchen garden, the net benefit (expressed in terms of yield increment / unit fertilizer added) differs significantly ($F_{5, 12} = 28.031$, $p < 0.001$). Maximum increment in crop yield per unit of fertilizer added was observed in the plots treated with the only 150 kg ha⁻¹ nitrogen while in contrast the highest dose of nitrogen fertilizer resulted into least unit increment in radish yield (Table 1).

Marginal Rate of Return

Highest marginal rate of return was observed in the plots treated with 150kg ha⁻¹ which is 744% (Table 2). This means that for every rupee spent on

nitrogen fertilization has yielded and extra 744 rupees as a return. While on the other hand, the highest rate of nitrogen application *i.e.* 250 kg ha⁻¹ had a negative rate of return demonstrating that if nitrogen fertilizer is applied beyond 150 kg ha⁻¹ the marginal rate decreases and ultimately results into economic losses (Table 2).

4. Discussion

In general the present study clearly demonstrated that radish grown in kitchen gardens respond strongly to variable application of nitrogen fertilizers. As expected, nitrogen applications increased number of leaves and hence increase in the size (both length and width) of the roots. This positive correlation is mainly due to excessive storage of carbohydrates due to increased photosynthetic activity in the plant (Usuda and Shimogawara, 1998). The same finding have been reported earlier in other horticultural crops such as garlic (Kakar et al., 2002) where incremental nitrogen application have significantly improved the leaf numbers per plant and leaf sizes. Since gradual increment of nitrogen can only help the plants to increase physiological parameters to improve yield up to a certain level, beyond which negative impact is observed (Kakar et al., 2002). Similar results have been noticed here in the current study where nitrogen applied at the rate of 250 kg ha⁻¹ made less improvement in physiological yield improving parameters compared to relatively less amount (see Table 1) and had significantly lower yields. These results second the similar findings of Pervez et al. (2004) where highest size of radish was recorded in plots treated with 200 kg ha⁻¹ nitrogen.

Although the study noticed an increase in yield with the increased dosage of nitrogen fertilizer our priority here is to produce fresh food in the back yards with least chemical fertilizer application and maximum rate of return. Hence, if we see the unit increment (%) in yield per unit increase in nitrogen application and the MRR% values, we recommend the use of 150 kg ha⁻¹ nitrogen application to get the maximum cost benefit compared to all other application rates.

5. Conclusion

The use of higher levels of nitrogen i.e. 150, 200 and 250 kg ha⁻¹ showed a favourable effect not only on fresh top weight but also on root yield of radish. However, if we see in economic terms the rate of 150 kg ha⁻¹ is found to be the best to obtain the maximum cost benefit ratio while at the application rates above 200 kg ha⁻¹ the cost of fertilizer exceeds the marginal revenue generated hence is not feasible in economic terms.

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Competing Interests: The authors declare no potential conflict of interest.

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