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EFFECT OF DIFFERENT LEVELS OF NITROGEN AND FARMYARD MANURE ON THE GROWTH AND YIELD OF SPINACH (*Spinacia oleracea* L.)

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ABSTRACT. The application of nitrogen (N) and farmyard manure (FYM) greatly affects the growth and production of spinach. The objective of this study was to evaluate the effect of various levels of nitrogen and farmyard manure on the growth and yield of spinach. This study was conducted in the research field of the Institute of Agriculture and Animal Science, Lamjung, Sundarbazar, Lamjung, Nepal from November 2019 to January 2020. The treatments were: 0 kg N ha^{-1}, 30 kg N ha^{-1}, 60 kg N ha^{-1}, 60 kg N ha^{-1} + 10 t FYM ha^{-1}, 60 kg N ha^{-1} + 20 t FYM ha^{-1}, 90 kg N ha^{-1} and 120 kg N ha^{-1}. These treatments were laid out in a randomized complete block design (RCBD) with three replications. The results showed that higher N levels gave better results for all parameters studied. The increasing N fertilization rates increased the vegetative characters and yield of spinach. The maximum plant height (22.68 cm), leaf width (6.69 cm), number of leaves (12.93), fresh weight of leaves (17.07 g) and leaf length (14.94 cm) were recorded with the application of the highest level of nitrogen (120 kg N ha^{-1}). The spinach yield (3.2 t ha^{-1}) was the highest with the application of 120 kg N ha^{-1}. However, the growth and yield traits were not significantly differed with the application of 60 kg N ha^{-1} + 20 t FYM ha^{-1}. Therefore, this study suggests that spinach production can be maximized by the application of 60 kg N ha^{-1}+ 20 t FYM ha^{-1}.

Introduction

Soil fertility is one of the key factors that have a direct effect on the yield of horticultural crops (Sherchan, Karki, 2006). Spinach (*Spinacia oleracea* L.) due to its shallow root system is more susceptible to nutrient deficiency than any other crops (Schenk *et al*., 1991). Heavy feeder Spinach demands high nutrients nitrogen (N) in particular, to grow rapidly and to ensure a high and profitable yield (Zaman *et al*., 2018). The productivity of spinach in Nepal (10.10 t ha^{-1}) is comparatively lower than that of its neighbouring countries (MOALD, 2017). Inadequate application of the nutrients including N and organic matter in the soil is believed to be the main reason for low spinach yields in Nepal (Sherchan, Karki, 2006).

Nitrogen is one of the most yield-limiting nutrients in plants (Dehariya *et al*., 2019). It is a constituent of protein that builds cell material and chlorophyll which are known to enable photosynthesis. This most vital biochemical process accelerates the growth process in spinach (Torres-Olivar *et al*., 2014). Smolders and Merckx (1992) demonstrated the linear relationship between the relative growth rate and the N level in the spinach for exponentially growing plants. Abdelraouf (2016) and Zaman *et al.* (2018) found that higher N levels resulted in a higher number of leaves, leaf area, plant height, and yield in spinach. Different Iranian spinach varieties also showed significantly greater vegetative attributes and yield attributes at the application of higher N compared to no application of N (Ahmadi *et al*., 2010). When N deficiency occurs, it affects the function of enzymes, causes the breakdown of nucleic acids and proteins, hastens senescence, and inhibits plant growth resulting in reduced quality and quantity of spinach. N deficiency in spinach plants is often expressed as stunted growth and leaf yellowing (Torres-Olivar *et al*., 2014). The amount of N and chlorophyll per unit leaf area was decreased by 60% by N deficit in spinach (Evans, Terashima, 1988). There was a two-fold decrease in the number of leaves per plant in the control application of N compared to 130 kg N ha^{-1}(Shormin, Kibria, 2018). The deficiency of N in the plant can be attenuated by the application of inorganic and organic sources of N into the soil. Mineral nutrients due to their readily available N are widely popular. Readily available farmyard manure (FYM) in rural areas for marginal farmers contains all the nutrients needed for crop growth including N (0.5–1.5%) is also used widely for soil N fertility enhancements. Along with N, FYM makes other elements more readily available to the plants increasing soil fertility status of soil (El-Habet, 2018).

Most Nepalese farmers have low financial resources to purchase a sufficient amount of inorganic fertilizers to supply N nutrients adequately which hinder achieving the desired yield. Further, financially well-being farmers lack proper knowledge about the optimum dosages of N fertilization in spinach. They tend to rely on the misconception of using higher dosages of N fertilizer for higher productivity. This irrational use of N causes toxic compound accumulation on edible products which may be harmful to humans and cause environmental pollution. Moreover, it increases the cost of production and causes economic loss (Canali *et al*., 2008). Thus, knowledge of the judicious use of N is required to overcome these challenges. A study by Hashimi *et al*. (2019) indicated that application of the N and FYM singly or combined on soil improve soil N and positively influenced the overall growth parameters and yield parameters in spinach. However, little research is conducted on the effective level of N usages for spinach in the context of Nepal. So, it is best to have rational knowledge about the optimum dosage of N fertilizer as well as look for an alternative approach to alleviate such problems.

The objective of this study was to determine the effects of different levels of nitrogen and FYM on vegetative growth and yield characteristics of the spinach plant.

Materials and Methods

Description of the study area

This experiment was carried out in the research field of the Institute of Agriculture and Animal Science (IAAS), Lamjung Campus, Sundarbazar, Lamjung, Nepal from November 1 2019 to January 1 2020 to investigate the effect of N and FYM on the growth and yield of spinach plant. The research field is located at 28.13°N latitude, 84.42°E longitude and 630.02 m altitude. The maximum and the minimum temperature recorded during the experiment was given in Figure 1. Similarly, the average relative humidity and rainfall were 44%, and 3 mm respectively.

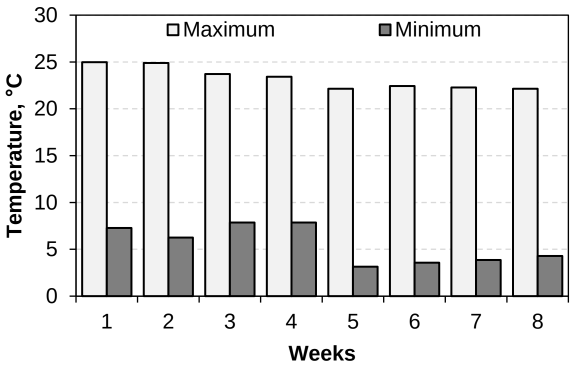

Figure 1. Meteorological data during the experiment (November 1, 2019, to January 1, 2020).

Baseline soil samples were taken from the different homogenous units of the field by driving the auger to a plough depth of 15 cm. 20 samples were collected and thoroughly mixed and foreign materials like roots, stones, pebbles and gravels were removed. Then the thoroughly mixed sample was divided into four equal parts. The two opposite quarters were discarded and the remaining two quarters were remixed out until we reached the required amount of sampled soil. Finally, it was air-dried under room conditions and the sample was analyzed at National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal for soil physicochemical analysis (Table 1).

Table 1. Soil physical and chemical properties of the experimental site

Soil Component	Values	Remarks
pH	5.93	Acidic
N%	0.18	Medium
P, kg ha^{-1}	35.5	Medium
K, kg ha^{-1}	1098.8	High
OM	3.63	Medium
Sand	56.0	
Slit	29.7	
Clay	14.3	
Soil texture	Sandy Loam	

Description of experimental materials

The spinach variety 'All Green' was used for the experiment. This variety can be grown in the Lamjung district of Nepal. The seeds were obtained from Dawadi Agrovet, Narayangarh, Chitwan, Nepal. The source of the nitrogen fertilizer was urea (46% N). The urea was obtained from the same Agrovet.

Treatments, experimental design and cultural practices

There were seven different levels of treatments: T1: 0 kg N ha^{-1}, T2: 30 kg N ha^{-1}, T3: 60 kg N ha^{-1}, T4:

60 kg N + 10 t FYM ha^{-1}, T5: 60 kg N + 20 t FYM ha^{-1}, T6: 90 kg N ha^{-1}and T7: 120 kg N ha^{-1}. The area of 98 m^2 field was divided into 21 plots with each plot having an area of 4 m^2 and the spacing between each plot was 0.5 m. Three replications of the treatments were arranged in Randomized complete block design (RCBD). Before sowing seeds of spinach var. (30 × 20 cm spacing), P (20 kg ha^{-1}; Di-Ammonium Phosphate) and K (40 kg ha^{-1}; Murate of Potash) and 50% of N (Urea and Di-Ammonium Phosphate) and as per treatment listed full dosages of FYM was supplied. The remaining N (Urea) was supplied in equal proportion in the 2nd and 4th weeks after sowing as per treatment level. The farmyard manure (FYM) used in this experiment was cattle FYM. It was matured after 5 months of decomposition. The FYM consisted of 1.33% total nitrogen, 0.23% available phosphorous, 0.5% K_2O, 2.38% exchangeable K, 0.14% exchangeable Fe, 0.78% exchangeable Ca and 0.38% exchangeable Mg.

Data observation

Fifty-six days after sowing, observations were carried out in randomly selected five plants per plot in the following parameters: plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), leaf fresh weight per plant (g), yield per hectare (t ha^{-1}) (Eq. 1). The plant height was measured as a distance from the ground level to the maximum vertical point of the foliage. The leaf length was measured as the distance between the petiole and leaf apex. Leaf width was measured as the average of three expansions in the 25%, 50%, and 75% parts of the leaf.

The fresh weight of leaves was taken and yield per hectare was computed by using the following formula:

$$\text{Yield, t ha}^{-1} = \frac{\text{Leaves weight, g plant}^{-1} \times \text{total plant popul. ha}^{-1}}{1000 \times 1000} \quad (1)$$

Data analysis

Data were recorded and entered into MS-Excel 2016. The data were analyzed using SPSS 16.0 and R studio. Data were statistically analyzed according to RCB design, One-way ANOVA was used to analyze data. The differences among treatments were separated using Duncan at a 5% level of significance.

Results and Discussion

Growth Attributes

Table 2 illustrates the results of the effects of various levels of N and FYM on plant height, number of leaves, leaf length and leaf width. Plants were the tallest at 120 kg N ha^{-1} (22.68 cm) and the value was not significantly different from those at 90 kg N ha^{-1}, 60 kg N + 20 t FYM ha^{-1}. More or less similar trends appeared in the case of the number of leaves and leaf length in the plants. In 8th weeks after sowing, the significantly higher no. of leaves (12.93) was observed when the plants were grown with 120 kg N ha^{-1} which was statistically par with 90 kg N ha^{-1} (12.16) and 60 kg N + 20 t FYM ha^{-1} (11.4). Leaf length was also found the longest at 120 kg N ha^{-1} (14.94cm) which was statistically par with 90 kg N ha^{-1} and 60 kg N + 20 t FYM ha^{-1}. Similarly, significantly wider leaves were observed at 120 kg N ha^{-1} (6.69 cm) which was statistically par with 90 kg N ha^{-1} (5.94 cm), 60 kg N + 20 t FYM ha^{-1} (5.39 cm) and 60 kg N + 10 t FYM ha^{-1} (5.35 cm). Hence, the values for these parameters improved with the addition of the nutrients tended to level off at 60 kg N+ 20 t FYM ha^{-1}. Compared to the Control of no N and FYM application, an increase in the value of mean plant height and mean number of the leaves were found to be 40% and 68% higher at 60 kg N + 20 t FYM ha^{-1}. Similarly, mean leaf length and mean leaf width was found to be 56% and 14% higher respectively at 60 kg N + 20 t FYM ha^{-1} over control treatment of no nutrient addition.

Table 2. Effect of different levels of nitrogen and FYM on the growth attributes of spinach (*Spinacia oleracea* L.)

Treatments	Plant height, cm	No. of leaves	Leaf length, cm	Leaf width, cm	Fresh weight per leaf, g	Yield, t ha^{-1}
0 kg N ha^{-1}	15.18 ± 2.76^{c}	6.77 ± 1.38^{d}	7.62 ± 1.90^{d}	4.65 ± 0.93^{c}	8.94 ± 1.82^{d}	1.68 ± 0.34^{d}
30 kg N ha^{-1}	16.35 ± 2.36^{bc}	8.55 ± 1.52^{cd}	8.41 ± 2.57^{cd}	5.02 ± 1.49^{bc}	11.29 ± 2.00^{cd}	2.12 ± 0.37^{cd}
60 kg N ha^{-1}	19.17 ± 1.80^{ab}	9.79 ± 1.23^{bc}	9.68 ± 0.83^{cd}	5.28 ± 0.74^{ab}	12.92 ± 1.63^{bc}	2.42 ± 0.30^{bc}
60 kg N +10 t FYM ha^{-1}	20.01 ± 1.40^{ab}	10.13 ± 2.61^{bc}	10.73 ± 2.26^{bcd}	5.35 ± 1.09^{ab}	13.37 ± 3.44^{bc}	2.51 ± 0.64^{bc}
60 kg N + 20tFYM ha^{-1}	21.28 ± 1.80^{a}	11.40 ± 0.91^{ab}	11.91 ± 1.72^{ab}	5.39 ± 0.29^{a}	15.04 ± 1.20^{ab}	2.82 ± 0.22^{ab}
90 kg N ha^{-1}	21.67 ± 2.05^{a}	12.16 ± 1.18^{ab}	13.50 ± 1.35^{ab}	5.94 ± 1.56^{ab}	16.06 ± 1.56^{ab}	3.01 ± 0.29^{ab}
120 kg N ha^{-1}	22.68 ± 1.47^{a}	12.93 ± 0.61^{a}	14.94 ± 1.37^{a}	6.69 ± 1.32^{a}	17.07 ± 0.80^{a}	3.20 ± 0.15^{a}
Mean	19.48	10.25	10.97	5.47	13.53	2.53
SEM±	4.17	2.00	3.50	1.20	0.986	0.184
CV %	10.48	13.82	17.06	19.99	12.60	12.60
LSD (0.05)	3.63	2.52	3.33	1.95	3.039	0.569
F test	**	**	**	**	**	**

Means in a column followed by different lowercase letter/s are significantly different according to Duncan multiple range test at P = 0.05. ** Highly significant at 0.01 level of significance, SEM± – standard error of the mean, CV – coefficient of variation. Mean in a column followed by ± standard deviation.

The obtained results align with the findings of Mirdad (2009) where plant height and number of leaves per plant with the addition of high N level resulted in significant increments in these characters of spinach plants. Similarly, Zaman *et al.*(2018), Solangi *et al.* (2015) and Shormin and Kibria (2018) recorded taller plant height and higher number of leaves per plant with the higher application of 150 kg N ha^{-1} compared to other lower levels of N treatment. Zheng (2009) reported that N plays a pivotal role in cellular carbon and N metabolism, which must be tightly coordinated to sustain optimal growth and development for plants. Application of N to spinach might have favoured vegetative growth increasing plant vigour and shoot growth rate increasing spinach growth attributes overall. Nevertheless, beyond the optimum level of N, it will be harmful to plants as it creates osmotic imbalances due to luxury nitrogen absorption (nitrogen accumulation) in plant tissue leading to toxic effects of nitrates on the plants (Ng'etich *et al*., 2014). It also can create favourable conditions for the development of various diseases due to its lush foliage and succulent (Torres-Olivar *et al*., 2014). Gülser (2005), Nemadodzi *et al* (2017) and Rodríguez-Hidalgo *et al*. (2010) reported that N treated plant has significantly higher leaf length compared to no nutrient treatments. Cytological development and differentiation for the development of the leaf are dependent on the availability of N and it has a significant effect on the leaf size (Roggatz *et al*., 1999). Thus, the observed increase in leaf length might be due to adequate N for plant growth rate. Also, a significant response was shown in leaf width at a different level of N treatments and the highest leaf width value was obtained at 120 kg N ha^{-1} (6.69 cm). Güsewell (2004) suggested that adequate input of N increases the level of cytokinin in the plant. This increased level of cytokinin may have stimulated shoot growth rate resulting in leaf length and leaf breadth of the plant. Our findings confirm with Cruz and Boval (2009) where leaf width increases along with nutrient increment.

Crop yield

The results showed the significant differences (P<0.01) were observed in the fresh weight of leaves and yield of spinach at different levels of treatments. However, the significantly higher fresh weight observed in 120 kg N ha^{-1} (17.07 g) compared to control, showed non-significant differences with 90 kg N ha^{-1} (16.06 g) and 60 kg N + 20 t FYM ha^{-1} (15.04 g) (Table 2). Concomitant to the fresh yield, spinach yield was obtained significantly higher at treatment 120 kg N ha^{-1} (3.20 t ha^{-1}) over control treatment but was significantly par with a yield of 90 kg N ha^{-1} (3.01 t ha^{-1}) and 60 kg N + 20 t FYM ha^{-1} (2.82 t ha^{-1}) (Table 2). These results indicated that adding nutrients to boost yield trait has a beneficial impact to some degree, but that it eventually levels out at 60 kg N + 20 t FYM ha^{-1}. The increase in the yield and fresh weight of spinach at 60 kg N + 20 t FYM ha^{-1} were 67.8% and 68.2% higher compared to control where the application of N and FYM was not done.

These results are in line with Zaman *et al*.(2018) where they showed an increase in fresh weight of leaves and yield along with increasing N fertilizer rates, which was added to the spinach plants. The highest weight of the fresh leaves and yield was observed at 240 kg N ha^{-1}. Similar to our findings, Hashimi *et al.* (2019) reported that spinach yield was significantly higher than other lower level N treatments, but no significant difference was observed at 150 kg N ha^{-1} and 5 t CM + 80 kg N ha^{-1}, concluding that the non-significant difference in yield is correlated with increased N nutrients supply from FYM source. This is supported by Sajirani *et al*. (2012) where they reported a higher yield in spinach in the combination of N and FYM. Conforming preceding statements, Stagnari *et al*. (2007) result showed that N fertilizers significantly increased yield concerning the untreated control even when sources were different. Since photosynthesis rates are N-dependent, an increase in photosynthetic rates has a direct impact on plant growth and biomass accumulation (Zheng, 2009). This rapid plant growth may have resulted in significantly increased plant height, the number of leaves, and the fresh weight of leaves, all of which led to increased yield. But the application of N above the optimum level may not improve the crop growth, or even damages the plant. Greenwood *et al.* (1980) indicated that although the yield of each crop initially increased with an increase in N fertilizer compared to the control, the yield later remained the same or decline with further increment.

Conclusion

The growth and yield of spinach were influenced by different levels of nitrogen and FYM. The increasing application rate of N fertilization up to 120 kg N ha^{-1} increased the growth and yield of spinach, however, these traits are not significantly differed from the application of 60 kg N + 20 t FYM ha^{-1}. Therefore, the application of 60 kg N + 20 t FYM ha^{-1} was found to be the optimum level for the cultivation of spinach.

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Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

PT – study conception and design, analysis and interpretation of data, literature search, drafting of the manuscript and approval of the final manuscript.
RKS, KK, JS – critical revision on the initial draft and approval of the final manuscript.
All the authors read and approved the final manuscript.

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