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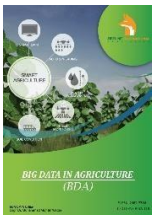

RESEARCH ARTICLE

EFFECTS OF NPK FERTILIZER AS FOLIAR SPRAY ON THE GROWTH AND YIELD OF SPINACH (*SPINACIA OLERACEA, L.*)

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ABSTRACT

Sustainable agriculture is a vital aspect of long-term development, as it contributes to food security and the conservation of natural ecosystem biodiversity through the efficient use of agricultural inputs. It accomplishes this through enhancing agro-technology such as the foliar application of agrochemicals, which should be implied to ensure agricultural sustainability. The purpose of this study was to determine the effects of foliar fertilizer application on plant growth and nutrition over soil application. A pot experiment was conducted to study the growth and yield response of spinach (*Spinacia oleracea, L.*) to foliar application of Urea-TSP-MoP. There were five treatments comprising of control, recommended NPK fertilizer dose applied in soil, and 0.002% level foliar spray NPK ratios 19:19:19, 10:20:30, and 30:10:10 respectively. A randomized complete block design (RCBD) with three replications was used to arrange the treatments. Results indicated that plant height (cm), number of leaves (plant^{-1}), leaf blade length (cm), leaf blade width(cm), leaf petiole length(cm) was higher in foliar treatments. However, fresh weight of leaf(g), the total biomass of plant(t/ha), dry weight of plant(g), fresh root biomass (g), and dry root biomass (g), were obtained significantly greater in recommended NPK fertilizer comparison to control and foliar treatments. Application of recommended NPK fertilizer dose in soil application produced the highest fresh leaf mass and total yield of spinach 26.03 t/ha followed by foliar treatments of 23.20 t/ha, 22.20 t/ha, 23.40 t/ha, compared to control where obtained yield about 16.77 t/ha. There were no significant differences between foliar application for yield parameters of spinach. It is concluded that foliar feeding produces nearly the same yield as conventional feeding and is more sustainable.

KEYWORDS

Spinach, Spinacia Oleracea, Foliar Spray, Foliar Feeding, Spinach Yield.

1. INTRODUCTION

Foliar applications are a method of feeding plants by spraying liquid fertilizers (macro and micronutrients) or other chemical or natural products directly onto the plant leaves, which are more effective in yielding and loss reduction. It is one of the most important fertilizing approaches for facilitating easy nutrient uptake by penetrating the stomata or leaf cuticle and accessing the cells. Foliar fertilization improves agricultural yields and increase plant mineral status during crop growth. Foliar feeding of mineral nutrients at different cropping stages is effective in nutrient utilization and yield growth (Rahman et al., 2014). Additionally, Foliar feeding is the quickest way of correcting nutrient deficiencies and improving crop yield and quality, also decreases environmental pollution and improves nutrient use by reducing the amount of fertilizer added to the soil (Roemheld and El-Fouly, 1999; Abou-El-nour, 2002). Through stomata, other specialized epidermal cells, and leaf hairs, foliar fertilizers deliver nutrients to vegetable and fruit crop tissues and organs almost immediately and at a greater rate. (Shabnam and Kuruwanshi, 2015; Baloch et al., 2008). Artificial inorganic fertilizers are created in specific concentrations to provide three essential elements: nitrogen, phosphorus, and potassium (N, P, and K) for various crop growing circumstances. N promotes plant growth especially leaves, P promotes root, flower, and fruit development, and K promotes stem and root growth and protein production (Mandal et al., 2009).

The most popular practice is to apply nutrients to the soil, although this has numerous limitations in terms of nutrient availability to the plants. For instance, inorganic nutrients become fixed as insoluble forms in soil and are also subject to leaching by rainfall or irrigation water (Alshaal and El-Ramady, 2017). In conventional fertilization practices, plants usually cannot absorb about 80–90% of the phosphorus, 40–70% of the nitrogen, and 50–70% of the potassium and thus lost to the environment, resulting in financial and resource losses as well as substantial environmental pollution (Saigusa, 2000). Spinach (Spinacia oleracea, L.) is a popular vegetable crop with a high chlorophyll content that gives it a dark green color and consumer acceptance, as well as a good nutritional source of high Fe and vitamins A, C, K, and B2.

It is also notable for its high potassium, iron, folic acid, magnesium, manganese, minerals, riboflavin, and low-calorie content (Hafez et al., 2015, Lamhamdi et al., 2013). Furthermore, spinach contains a high concentration of omega-3 fatty acids, vitamins E and B6, and dietary fiber, all of which improve, control, and maintain human tissues, and significant antioxidant activity too for the presence of flavonoids, which are a major component of water-soluble polyphenols (Maeda et al., 2010; Aehle et al., 2004). Meanwhile, intensive crop production aiming for high productivity levels requires additional plant nutrition, that can be supplied via soil application effectively and/or foliar applications. That is why the current study designed to investigate the foliar effects of NPK on spinach grown.

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2. MATERIAL AND METHODS

2.1 Soil Sample Collection and Preparation

Surface soil (0-15 cm) was collected from the Soil Resource and Development Institute (SRDI) crop field in Barishal. The sampling site is located at 22°44'13.1"N 90°19'36.1"E. The soil was then air dried, and all plant debris and unwanted materials were manually removed. For the pot experiment, the massive aggregates were gently crushed with a hammer and sieved with a 2 mm sieve. A part of it was taken for routine testing as well as major nutrient analysis.

2.2 Determining Soil Properties

Before the application of treatments, the pH, EC, and Organic Matter (OM) of the soil sample, as well as the major nutrients (N, P, and K), were determined using standard methods. The texture of the soil was also properly considered. The properties of soil are stated in the table.

Table 1: Soil Properties With The Nutrient Status of Soil Sample-

Serial no.	Soil properties	Values	Nutrient status (Upazilla Nirdeshika)	Method of determination
1	pH	6.4	Slightly Acidic	1:2.5 dilution (McLean, 1982)
2	EC (dS/m)	0.40	Non-Saline	1:5 dilution (USDA, 2004)
3	Organic matter %	0.41	Very Low	Wet Oxidation (Walkley and Black, 1934)
4	Exchangeable Potassium (meq/100g soil)	0.009	Very Low	Ammonium Acetate solution (Jackson, 1973)
5	Available Phosphorus- (µg/g soil)	5.9	Low	Revised Olsen extraction method (Olsen et al., 1954)
6	Nitrogen	0.1	Low	micro-Kjeldahl method (Bremmer and Mulvaney, 1982)

2.3 Treatments of The Experiment

The research was conducted between the 13th of January and the 15th of March 2021 at the Soil Research Development Institute (SRDI) in Barishal. A medium cement pot was chosen for growing spinach, and it was filled with 5kg of soil. To avoid experimental error, this study used 5 treatments with 3 replications for each treatment in the experiment.

Table 2: Treatments used in the Experiment-

Treatment No.	Treatments
T_0	Control (Soil)
T_1	Fertilizer added in soil (According to Fertilizer Recommendation Guide, Urea- 82.46 kg/ha, TSP- 65 kg/ha, MoP- 36 kg/ha)
T_2	Foliar spray NPK ratio 19:19:19
T_3	Foliar spray NPK ratio 10:20:30
T_4	Foliar spray NPK ratio 30:10:10

2.4 Layout of The Experiment

A pot experiment was carried out with a total of 15 (5 treatments*3 replications) following a randomized complete block design (RCBD).

2.5 Test Crop Used in The Experiment

For this experiment, a nitrogen-sensitive crop, spinach (Spinacia oleracea L.), a common vegetable that is consumed worldwide (local name- Palongshak, and variety- Kupipalong) was chosen. Germination rate and purity for this variety are respectively, 60-70% and 95%.

2.6 Pot Preparation and Sowing of Seeds

To apply the treatments, the processed sample was sieved with a 2 mm sieve and placed in medium cement pots. To experiment, 5 kg of soil was placed in each pot. Organic manure was not used in any of the treatments. According to Fertilizer Recommendation Guide (FRG), inorganic fertilizers were applied in the T1 soil with first irrigation before sowing seed. The seeds were planted on January 13th, 2021. 25 seeds were sown as evenly as possible to maintain uniformity, and the seeds were then covered with soil. The rate of seed germination was nearly the same in all treatment groups, including the control. Only 15 plants were kept in each pot after germination.

2.7 Intercultural Operation

During the growing period of the plants, intercultural operations such as irrigation and weeding were carried out as needed.

2.8 Harvesting

On March 15, 2021, the experimental plants were harvested at their vegetative stage, 61 days (almost 9 weeks) after sowing seed. After that, each harvested plant was tagged separately, and data on various agronomic parameters were collected at representative plant samples, which were then prepared for laboratory analysis using standard methods.

2.9 Data Collection

The following parameters were recorded from the sample plats after harvesting. Different agronomic growth parameters were estimated before and after harvesting Plant height (cm), no. of leaves (plant-1), leaf blade length (cm), leaf blade width (cm), plant petiole length (cm), leaf fresh mass (g), fresh biomass of plants (g), dry weight per plant (g) (oven-dried at 70ºc temperature for 72 hours), dry matter content (%), fresh yield (ton/ha), root fresh weight (g), root dry weight (g), and dry matter content (%) of the plants was calculated from the data obtained during moisture content estimation using the formula:

$$\text{Dry matter content (\%)} = \frac{Dry\ weight(g)}{Fresh\ weight\ (g)} \times 100$$

2.10 Statistical Analysis

Experimental data were subjected to one-way analysis of variance (ANOVA) with the Post Hoc Duncan test. *P-value ≤ 0.05 was accepted statistically significant. Statistical analysis was performed with the statistical package for social sciences (SPSS), Version 16.0 (Chicago, SPSS Inc. Released 2008).

3. RESULTS AND DISCUSSION

3.1 Plant Height

The result showed that plant height ranged between (8.73 ±0.62) cm to (18.28±2.61) cm where the highest and lowest value was found for T_2 (NPK ratio 10:20:30) and T0 (control) respectively. Figure i, shows that T_1, T_2, T_3, and T_4 significantly ($p<0.05$) varied higher with control, T2, and T4 indicate the significantly best result.

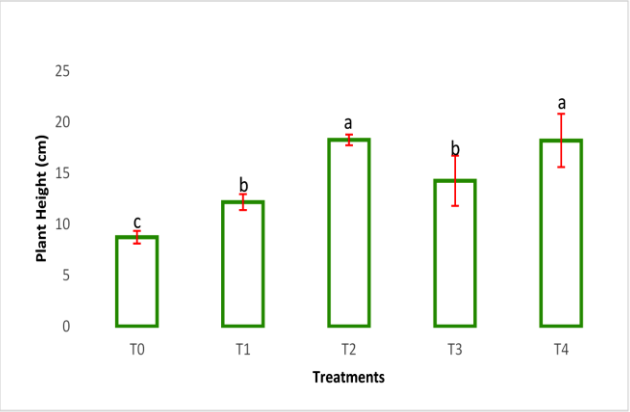

Figure 1: Plant height

It was also found that plant height increased where N fertilizer foliar ratio was higher compared to T1 (fertilizer recommended dose) and T3 (lowest nitrogen dose) Similarly, some researchers demonstrated that increasing the unit rate of nitrogen fertilizer used has a beneficial effect on spinach height when compared to no application (control) (Shafeek et al., 2020).

Other researchers found that increased N levels promote the vegetative growth of leafy vegetables (Magda et al., 2015; Nevruz et al., 2014; Maryam and Naser, 2007). A group researchers found that treatments with different NPK foliar sprays resulted in significantly higher maximum spinach plant height (Popat et al., 2009).

3.2 Number of Leaves

The outcome indicated that the number of leaves ranged between 9.62±0.38 to 12.33±0.67where the highest and lowest plant were found for T1 (NPK recommended dose) and T0 (control) respectively. Figure 2., shows that T1, T2, T3, and T4 significantly ($p<0.05$) varied with control (T0) though there is no significant difference among them.

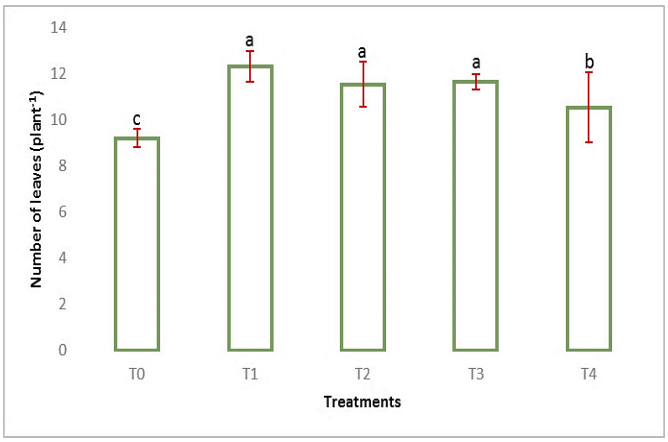

Figure 2: Number of leaves

Each fertilizer treatment increased the number of leaves compared to the control treatments when no fertilizer was applied. It is also found that fertilizer application to soil and foliar spray showed an almost similar result. Anburani observed that brinjal hybrids with 19:19:19 NPK foliar sprays at 1.0% concentration had the most leaves per plant and leaf area (Anburani, 2018). A group researcher also found that different fertilization approach enhanced the amount of spinach beet *(Beta vulgaris Linn.)* leaves compared to the control, where no fertilizer was applied (Gairola et al., 2009).

3.3 Leaf Blade Length

Leaf Blade Length ranged from (3.82±0.3) cm to (6.17±0.3) cm where the highest and lowest plant were found for T3 (NPK ratio 10:20:30) and T0 (control) respectively. Figure 3., indicates that all the treatments are a significant difference ($p<0.05$) compared to the control. Treatment T1, T2. T4 shows no significant difference among them.

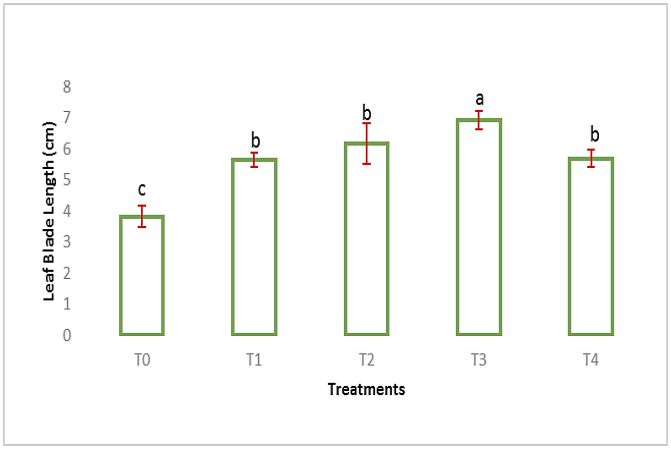

Figure 3: Leaf Blade Length

Here, the leaf blade length in T3 (NPK-10:20:30) was found bit longer. That might happen due to the high consumption of K. Jalali and Jafari observed in their study that the foliar potassium application increased leaf length (Jalali and Jafari, 2016). Moreover, researchers have found that in plants, K uptake is more prominent during vegetative and developmental stages, and foliar application of K quickly corrects deficiencies while also improving fruiting quality and nutrient contents in vegetables and fruits (Singh et al., 2016; Lester et al., 2006; Marschner, 1998; Chapagain and Wiesman, 2004).

3.4 Leaf Blade Width

The result showed that Leaf Blade Width ranged between (2.67±0.23) cm to (4.04±0.08) cm where the highest and lowest plant were found for T3 (NPK ratio 10:20:30) and T0 (control) respectively. Figure 4., shows that all the treatments are significantly different ($p<0.05$) compared to the control. Treatment T2, T3, and T4 showed no significant difference among them.

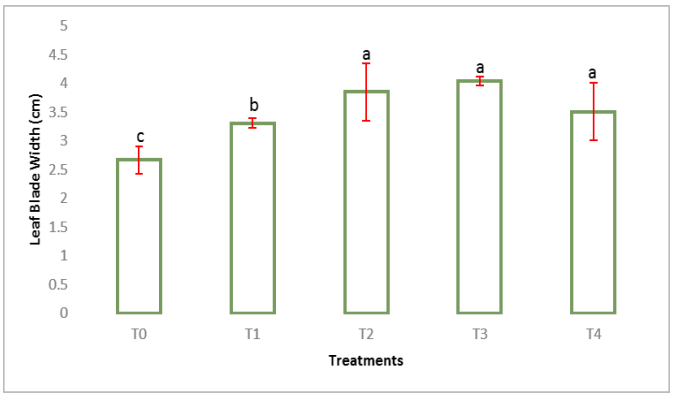

Figure 4: Leaf Blade width

It was also found that the treatments with foliar spray show greater leaf blade width than soil application which might be caused by the direct application of nutrients to the leaves. A group researchers found that foliar spraying in Indian spinach with varied NPK foliar ratios increased leaf area (Popat et al., 2009). In contrast, some researchers observed considerably better results in the leaf area when chemical fertilizers were applied to the soil (Mohamed et al., 2019).

3.5 Leaf Petiole Length

The result indicated that Leaf Petiole Length ranged between (2.4±0.27) cm to (4.80±0.28) cm where the highest and lowest plant were found for T4 (NPK ratio 30:10:10) and T0 (control) respectively. Figure 5., shows that all the treatments are a significant difference ($p<0.05$) compared to the control. Treatment T2, T3, and T4 showed statistically similar findings.

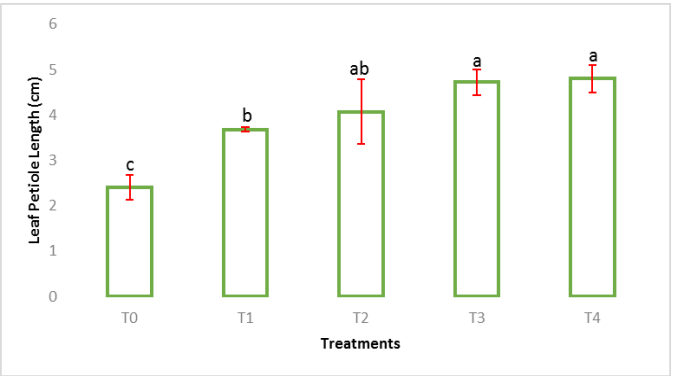

Figure 5: Leaf Petiole Length

It was also found that the treatments with foliar spray show greater leaf petiole length than soil application which might be caused by the direct application of nutrients to the leaves. El-saady (2016) demonstrated that varied NPK-fertilizer ratios enhanced leaf petiole.

3.6 Leaf Fresh Mass

The result showed that Leaf Fresh Mass ranged between (2.56±0.03) g to (5.35±0.17) g where the highest and lowest plant were found for T1 (fertilizer application in soil) and T0 (control) respectively. Figure 6., shows that all the treatments are a significant difference ($p<0.05$) compared to the control. Treatment T2 and T3 show no significant difference among them.

Some researchers found an increase in leaf fresh mass yield when applying NPK chemical fertilizer in the soil at the recommended rate (RR) (Aisha et al., 2013). Marvi observed in his study that the leaves' fresh weight increased significantly in using the nitrogen and phosphorus treatments comparing untreated leaves (Marvi, 2009). Soliman and Hamed also have demonstrated that mineral N ratios had a substantial impact on spinach leaf growth (Soliman and Hamed, 2019).

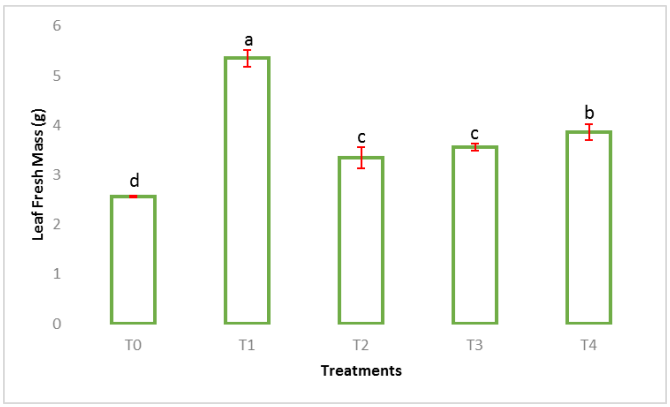

Figure 6: Leaf Fresh Mass

3.7 Total Fresh Yield

Spinach was harvested after 61 days of seed sowing in this study which agrees with the harvesting time of who also harvested the spinach plants after 60 days of sowing (Hassan et al., 2014). The result shows a Total Fresh Yield that is ranged between (16.77±0.25) t/ha to (26.03±1.25) t/ha where the highest and lowest plant were found for T1 and T0 (control) respectively. Figure 7., shows that all the treatments are significant differences ($p<0.05$) compared to the control. Treatment T2, T3, and T4 show no significant difference among them.

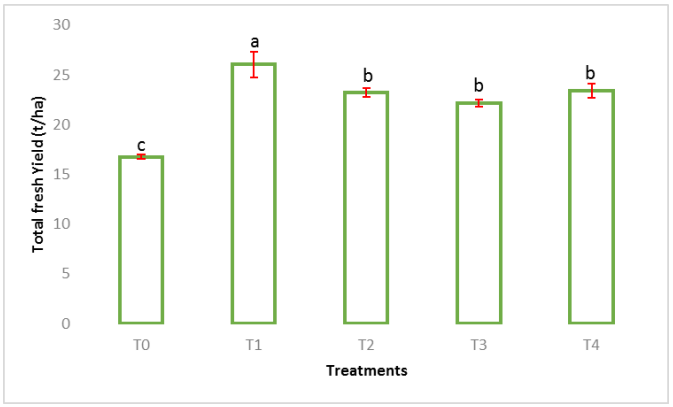

Figure 7: Total Fresh Yield

We find the best yield of 26.06 t/ha in T1 where fertilizer was incorporated into the soil three times directly according to FRG, which might be caused by the greater consumption of NPK by the roots.

Similarly, some researcher found that the recommended NPK fertilizers produced the maximum yield (Das et al., 2019). In their experiment with fertilizers and manures, observed comparable results, with NPK (Recommended dosage) fertilizers yielding the highest yield for Indian spinach (Islam et al., 2011; Olanrewaju 2011). This result might be due to the high and easily accessible nitrogen in the suggested fertilizer dose, which facilitated the sustaining of leafy vegetative growth in Indian spinach (Basella alba L.). A group researchers found that applying inorganic nitrogen from various sources directly to soil increased fresh yield of spinach (Machado et al., 2020). Foliar fertilization treatments yielded slightly less than soil application treatments. Other researchers suggested foliar nutrition as a supplement to soil application as it cannot meet plants' entire nutrition requirements, particularly when secondary and micronutrient deficiencies occur (Krishnasree et al., 2021; Singh et al., 2016, Ling and Silberbush, 2002). Haytova observed foliar feeding is also more environmentally friendly because it prevents the accumulation of toxic concentrations of nutrients in the soil (Haytova, 2013).

However, the predicted yield for this spinach variety is (40±4 t/ ha) as found in approximated yield was (40-45 t/ha) (BARC, 2012; BARI, 2018). We got less of this may be for soil quality, low soil moisture content, and sowing date. Spinach yield is much dependent on the sowing date. Environmental factors have a significant impact on plant growth, and yield. Sowing date is one of the most important limiting factors influencing plant production, and largely decided by the onset of significant rainfall, temperature, and humidity in the region. Many researchers have reported a significant decrease in spinach yield due to a delayed sowing date after October (Waseem et al., 2000; Waseem and Nadeem, 2001; Ramadan, 2004; Ibrahim et al., 2010). Long days, especially when combined with temperatures above 25° C, reason the plant to bolt and flower, which is deleterious to spinach crop production (Changhoo et al., 2001; Hata et al., 2006).

3.8 Dry Matter (%)

The result showed that Plant dry biomass ranged between (7.72±1.38) % to (12.53±0.95) % where the highest and lowest dry matter were found for T1 and T0 (control) respectively. Treatment T3 and T4 show no significant difference among them.

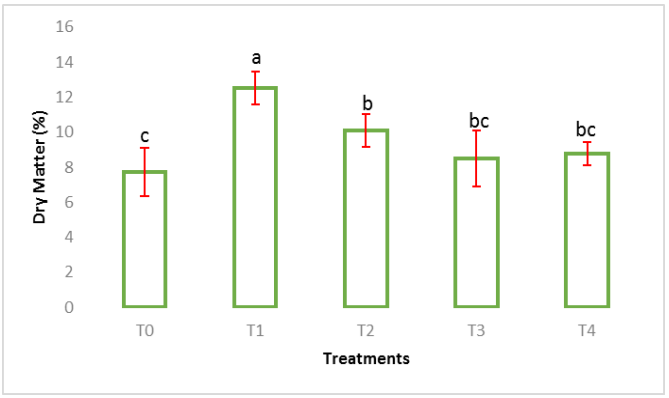

Figure 8: Dry matter (%)

El-Saady found in his experiment that NPK fertilizers applied in soil resulted in significant increases in fresh weight and dry matter% parameters in spinach at harvest time when compared to the other treatments (El-Saady, 2016).

3.9 Root Biomass (g)

Plant dry biomass ranged between (0.25±0.04) g to (0.47±0.03) g where the highest and lowest dry matter were found for T1 and T0 (control) respectively. Treatment T2 and T3 show no significant difference among them.

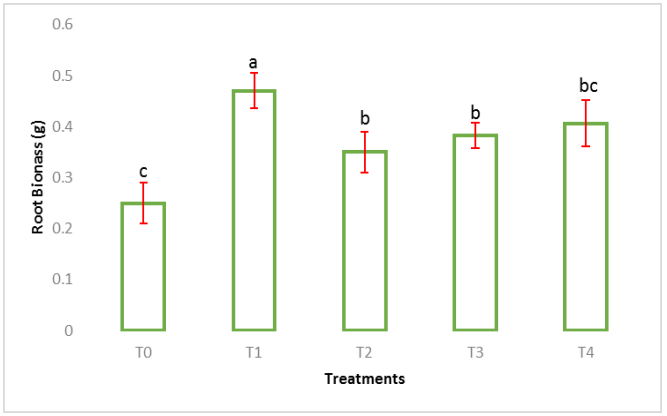

Figure 9: Root Biomass (g)

That might be due to the high consumption of NPK. Shormin and Kibria observed that nitrogen application resulted in the highest fresh weight of root as well as growth and yield properties of Indian spinach while control treatment resulted in the lowest (Shormin and Kibria, 2018). Aboveground biomass production is hindered within a few days if N availability at the root is limited, and deficiency symptoms such as yellowing on older leaves become apparent (Hochmuth et al., 2018; Buysse et al., 1996). However, Kannan stated that foliar nutrition, despite of soil condition, helps in the rapid and effective absorption of nutrients and also stimulates the ability of roots to absorb nutrients from soil (Kannan, 2010).

3.10 Dry Root Biomass (g)

The result showed that Plant dry biomass ranged between (0.08±0.01) g to (0.13±0.01) g where the highest and lowest dry matter were found for T1 and T0 (control) respectively. Where treatment result of T2 is almost similar to T1. Treatment T3 and T4 show no significant difference among them.

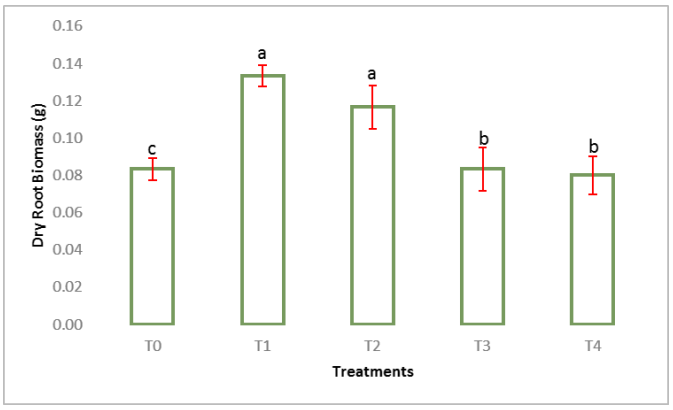

Figure 10: Dry Root Biomass (g)

Shormin and Kibria found that the fertilizer treatments had a substantial impact on the dry weight of Indian spinach roots (Shormin and Kibria, 2018). Nitrogen from urea application resulted in the maximum dry weight of leaves, stem, and root, whereas the control treatment resulted in the lowest dry weights. Foliar nutrient feeding had a significant impact on cruciferous vegetable growth and yield with five sprays of 19:19:19 NPK mixture, which was considerably better than the control (AICRP, 2006). A group researchers observed that NPK compound fertilizer administered the highest dry root weight of tomato plants (Hariyad et al., 2019). Their study also suggested using NPK compound fertilizer in tomato cultivation. Foliar nutrient feeding had a significant impact on cruciferous vegetable growth and yield with five sprays of 19:19:19 NPK mixture, which was considerably better than the control (AICRP, 2006).

4. Conclusions

It can be concluded that using the fertilizer dose recommended by the Ministry of Agriculture/ SRDI, Bangladesh resulted in the highest spinach yield grown. The vegetative growth of Indian spinach was enhanced by amending soils with recommended fertilizer applied in the soil. However, the spraying ratios also clearly showed a short-term effect on yield. The plant showed no visual health effects of direct fertilizer application as a foliar spray on the leaves. Although the foliar application did not produce the best yield, adjusting the application dose of NPK ratio might yield better growth. Therefore, further investigations are required.

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Conflicts of Interest

The authors declare that the publication of this study does not involve any conflicts of interest.

References

Abou El-Nour, E.A.A., 2002. Can supplemented potassium foliar feeding reduce. Pakistan Journal of Biological Sciences, 5 (3), Pp. 259-262.

Aehle, E., Raynaud-Le Grandic, S., Ralainirina, R., Baltora-Rosset, S., Mesnard, F., Prouillet, C., Fliniaux, M.A., 2004. Development and evaluation of an enriched natural antioxidant preparation obtained from aqueous spinach (Spinacia oleracea) extracts by an adsorption procedure. Food Chemistry, 86 (4), Pp. 579-585.

AICRP [All India Coordinated Research Project (Vegetable crops)] Annual Report 2005-06. XXIV AICRP (VC) Group meeting, UAS, Dharwad, Pp. 197-198.

Aisha, H.A., Hafez, M.M., Asmaa, R.M., and Shafeek, M.R., 2013. Effect of Bio and chemical fertilizers on growth, yield and chemical properties of spinach plant (Spinacia oleracea L.). Middle East Journal of Agriculture Research, 2 (1), Pp. 16-20.

Alshaal, T., and El-Ramady, H., 2017. Foliar application: from plant nutrition to biofortification. Environment, Biodiversity and Soil Security, 1, Pp. 71-83.

Anburani, A., 2018. Influence of water-soluble fertilizers on growth in brinjal hybrid (Solanum melongena L.). J. Plant Stress Physiol., 4, Pp. 1-3.

Baloch, Q.B., Chachar, Q.I., Tareen, M.N., 2008. Effect of foliar application of macro and micronutrients on production of green chilies (Capsicum annuum L.). Journal of Agricultural Technology, 4 (2), Pp. 177–184.

BARC. 2012. Fertilizer recommendation guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka, Bangladesh.

BARI. 2018. Krishi Projukti Hatboi (Handbook on Agro-Technology), 8th edition Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

Bramner, J.M., and Mulvaney, C.S., 1982. Nitrogen-Total. In: page, A.L.; Miller, R.H. and Keeney, D.R. (eds.) Methods of soil analyses, Part 2: chemical and microbiological properties, 2nd edn. American Society of Agronomy- Soil Science Society of America, Madison, Wisconsin, Pp. 595-624.

Buysse, J., Van den Broeck, H., and Merckx, R., 1996. Growth and growth substrate levels in spinach under non-steady state conditions of nitrogen nutrition and light. Physiologia Plantarum, 98 (4), Pp. 838–844.

Changhoo, C.M., Tominaga and Kozai, T., 2001. Floral development and bolting of spinach as affected by photoperiod and integrated photosynthetic photon flux during transplant production. HortScience, 36 (5), Pp. 889-892.

Chapagain, B.P., Wiesman, Z., 2004. Effect of Nutri-Vant-Pea K foliar spray on plant development, yield, and fruit quality in green house tomatoes. Sci. Hort., 102 (2), Pp. 177-188.

Das, A., Dash, P.K., Mannan, M.A., 2019. Performance of Indian Spinach Under Different Combinations of Organic and Inorganic Fertilizers.

El-saady, W.A., 2016. Spinach (Spinacia oleracea L.) growth, yield and quality response to the application of mineral NPK fertilizer ratios and levels. Middle East Journal of Agriculture, 5 (4), Pp. 908–917.

Gairola, S., Umar, S., Suryapani, S., 2009. Nitrate accumulation, growth, and leaf quality of spinach beet (Beta vulgaris Linn.) as affected by NPK fertilization with special reference to potassium. Indian Journal of Science and Technology, 2 (2), Pp. 35–40. https://doi.org/10.17485/ijst/2009/v2i2/29390

Hafez, M.M., Shafeek, M.R., Mahmoud, A.R., Ali, A.H., 2015. Beneficial Effects of Nitrogen Fertilizer and Humic acid on Growth, Yield and Nutritive Values of Spinach (Spinacia olivera L.). Pp. 597–603.

Hariyadi, B.W., Nizak, F., Nurmalasari, I.R., Kogoya, Y., 2019. Effect of Dose and Time of Npk Fertilizer Application on the Growth and Yield of Tomato Plants (Lycopersicum esculentum Mill). Agricultural Science, 2 (2), Pp. 101-111.

Hassan, W., David, J., 2014. Effect of lead pollution on soil microbiological index under spinach (Spinacia oleracea L.) cultivation. Journal of soils and sediments, 14 (1), Pp. 44-59.

Hata, N.K., Murakami, Y., Masuda, M., 2006. Effect of photoperiod after bolting on the expression of gyno monoecy in Spinacia oleracea L. J. Japan. Soc. Hort. Sci., 75 (2), Pp. 141-147.

Haytova, D., 2013. A review of foliar fertilization of some vegetable crops. Annu Rev Res Biol., 3 (4), Pp. 455-465.

Hochmuth, G., Maynard, D., Vavrina, C., Hanlon, E., Simonne, E., 2018. Plant tissue analysis and interpretation for vegetable crops in Florida. https: //edis.ifas.ufl.edu/publication/EP081

Ibrahim, E.A., Soher, E.A., El-Gendy, and Ramadan, A.Y., 2010. Effect of sowing date and some soil amendments on yield and quality of

spinach (Spinacia oleracea L.). The Sixth Inter. Conf. of Sustain. Agric. And develop. Fac. Of Agric., Fayoum Univ., 27-29, Pp. 191- 200.

Islam, M.M., Karim, A.J.M.S., Jahiruddin, M., Majid, M.N., Miah, M.G., Mustaque, A.M., and Hakim, M.A., 2011. Effects of organic manure and chemical fertilizers on crops in the RadishStem amaranth-Indian spinach cropping pattern in homestead area. Australian Journal of Crop Sciences, 5 (11), Pp. 1370-1378.

Jackson, M.L., 1973. Soil Chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi, India.

Jalali, A., and Jafari, P., 2016. Impact of Potassium Foliar Application in Alleviating the Harmful Effects of Salinity in Spinach. Journal Of Horticultural Science, 30 (2), Pp. 201-208.

Kannan, S., 2010. Foliar fertilization for sustainable crop production. In: Lichtfouse E (ed) Genetic engineering, biofertilization, soil quality and organic farming, Springer Dordrecht Heidelberg, New York, Pp. 371-402.

Krishnasree, R.K., Raj, S.K., and Chacko, S.R., 2021. Foliar nutrition in vegetables: A review. Journal of Pharmacognosy and Phytochemistry, 10 (1), Pp. 2393-2398.

Lamhamdi, M., El Galiou, O., Bakrim, A., Nóvoa-Muñoz, J.C., Arias-Estévez, M., Aarab, A., Lafont, R., 2013. Effect of lead stress on mineral content and growth of wheat (Triticum aestivum) and spinach (Spinacia oleracea) seedlings. Saudi journal of biological sciences, 20 (1), Pp. 29-36.

Lester, G.E., Jifon, J.L., Makus, D.J., 2006. Supplemental foliar potassium application with or without a surfactant can enhance netted muskmelon quality. Hortic Sci., 41 (3), Pp. 741-744.

Ling, F., Silberbush, M., 2002. Response of maize to foliar Vs. soil application of nitrogen-phosphorus potassium fertilizers. J. Plant Nutr., 11, Pp. 2333-2342.

Machado, R.M.A., Alves-Pereira, I., Lourenço, D., Ferreira, R.M.A., 2020. Effect of organic compost and inorganic nitrogen fertigation on spinach growth, phytochemical accumulation, and antioxidant activity. Heliyon, 6 (9), Pp. e05085.

Maeda, N., Yoshida, H., Mizushina, Y., 2010. Spinach and health: anticancer effect. In Bioactive foods in promoting health, pp. 393-405. Academic Press.

Magda, M.H., Shafeek, M.R., Mahmoud, A.R., and Ali, A.H., 2015. Beneficial Effects of Nitrogen Fertilizer and Humic acid on Growth, Yield and Nutritive Values of Spinach (Spinacia olivera L.). Middle East Journal of Applied Science, 05 (02), Pp. 597-603.

Mandal, K.G., Hati, K.M., Misra, A.K., 2009. Biomass yield and energy analysis of soybean production in relation to fertilizer-NPK and organic manure. Biomass Bioenerg., 33 (12), Pp. 1670-1679.

Marschner, H., 1998. Mineral nutrition of higher plants. Academic Press Gross, California.

Marvi, M.S.P., 2009. Effect of nitrogen and phosphorous rates on fertilizer use efficiency in lettuce and spinach. Journal of Horticulture and Forestry, 1 (7), Pp. 140-147.

Maryam, B., and Naser, A.A., 2007. Effect of Different Levels of Nitrogen Fertilizer and Cultivars on Growth, Yield and Yield Components of Romaine Lettuce (Lactuca sativa L.). Middle Eastern and Russian Journal of Plant Science and Biotechnology, 1 (2), Pp. 47-53.

McLean, E.O., 1982. Soil pH and Lime Requirement. In: Methods of soil analysis. Part 2 18 Chemical and microbiological properties. 2nd edn. Page, A.L.; Miller, R.H> and Keeney, D.R. (eds.). Americsn Society of Agronomy Inc., Madison, WI, USA. Pp. 199-224.

Mohamed, M.F., Thalooth, A.T., Elewa, T.A., Ahmed, A.G., 2019. Yield and nutrient status of wheat plants (Triticumaestivum) as affected by sludge,compost, and biofertilizers under newly reclaimed soil. Bulletin of the National Research Centre, 43 (3), Pp. 1-6. doi: 10.1186/s42269-019- 0069-y.

Nevruz, Z., Gjergji, M., Skenderasi, B., and Gjanci, S., 2014. Effects of nitrogen sources and levels on yield and nutritive values of spinach (Spinacia olivera L.) J. of International academic research for Multidisciplinary, 2 (2).

Olanrewaju, O.O., 2011. The effects of fertilizers on the growth and yield of Indian Spinach (Basella alba). University of Agriculture, Abeokuta, Ogun State, Nigeria. Matric no: Pp. 1607.

Olsen, S.R., Cole, C.V., Watanabe, F.S., and Dean, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington, D.C: U.S. Department of Agriculture.

Popat, J.R., Manisha, D., Mahorkar, V.K., 2009. Effect of NPK through foliar application on growth and yield of Indian spinach. Annals of Plant Physiology, 23 (2), Pp. 201-203.

Rahman, I.U., Aftab, R.A., Zafar, I., Shafiul, M., 2014. Foliar application of plant mineral nutrients on wheat: A Review. RRJAAS, 3 (2), Pp. 19-22.

Ramadan, A.Y., 2004. Effect of planting date and slow-release nitrogen fertilizer on yield and quality of spinach. Ph.D. Thesis, Fac. Agric., Mansoura Univ., Egypt.

Roemheld, V., and El-Fouly, M.M., 1999. Foliar nutrient application Challenge and limits in crop production. Proceedings of the 2 nd International Workshop on Foliar Fertilization, Bangkok, Thailand, Pp. 4-10.

Saigusa, M., 2000. Broadcast application versus band application of polyolefin-coated fertilizer on green peppers grown on andisol. J. Plant Nutr., 23 (10), Pp. 1485-1493.

Shabnam, K., Kuruwanshi, V.B., 2015. Foliar nutrition of plants. Rashtriya Krishi, 10 (1), Pp. 54-55.

Shafeek, M.R., Mahmoud, A.R., Helmy, Y.I., Khater, H.M.A., 2020. Effect of Nitrogen Fertilization and Foliar Application of Amino Acid on Growth, Yield and Nutritional Value of Spinach Plants. Current Science International, Pp. 641–648. https://doi.org/10.36632/csi/2020.9.4.57

Shormin, T., Kibria, M.G., 2018. Effects of nitrogen from different inorganic fertilizers on growth and yield of indian spinach (Basella Alba L.). IOSR Journal of Pharmacy and Biological Sciences, 13 (5), Pp. 43-48.

Singh, J., Singh, M., Jain, A., Bharadwaj, S., Singh, A., Singh, D.K., 2016. An introduction of plant nutrients and foliar fertilization: a review. Precision farming: a new approach Daya Publishing Company, New Delhi.

Soliman, M., and Hamed, L., 2019. Application of bio-stimulants in comparison with organic and mineral N fertilizers for growth promotion of spinach and common bean grown on sandy soil. Journal of Soil Sciences and Agricultural Engineering, 10 (1), Pp. 79-85.

USDA. 2004. Soil survey laboratory manual, soil survey investigation report no. 42, United States Department of Agriculture (USDA), version 4.0, USDA-NRCS, Nebraska, USA.

Walkley, A., and Black, I.A., 1934. An Examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37, Pp. 29-37.

Waseem, K., and Nadeem, M.A., 2001. Enhancement of spinach production by varying sowing dates, row spacing and frequency of cuttings. Journal of Biological Sciences, 1 (10), Pp. 902-904.

Waseem, K., Ghafoor, A., Khan, R.U., and Nadeem, M.A., 2000. Effect of sowing dates and row spacing on the yield of spinach (Spinacia oleracea L.). Pakistan J. Biolol. Sci., 3 (5), Pp. 822-823.