EVALUATE THE EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZER DOSES ON GROWTH AND YIELD OF SPINACH (*SPINACIA OLERACEA* L.)

Majeeduddin Solangi*, Velo Suthar, Bakhtawar Wagan***, Abdul Ghafoor Siyal***, Asadullah Sarki***, and Rajesh Kumar Soothar*****

*Faculty of Crop Production, Sindh Agriculture University, Tandojam

**Faculty of Social Sciences, Sindh Agriculture University, Tandojam

*** Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam

Corresponding Author: Rajesh Kumar Soothar, Email: rk_engr195@yahoo.com

ABSTRACT: *To evaluate the effect of different levels of nitrogen and phosphorus fertilizers on the growth and yield of spinach, experiment was laid out in a three replicated RCB Design testing seven treatments such as:T_1=Control, T_2=25-50 kg ha^{-1}, T_3=50-60 kg ha^{-1}, T_4=75-70 kg ha^{-1}, T_5=100-80 kg ha^{-1}, T_6=125-90 kg ha^{-1} and T_7=150-100 kg ha^{-1}. The results revealed that the significant (P<0.05) effect of various N-P levels on plant height, leaves plant^{-1}, fresh weight of leaves plant^{-1}, days to 1st cut, leaf length, yield plot^{-1} and yield ha^{-1}. The highest N-P level of 150-100 kg ha^{-1} resulted in 29.79 cm plant height, 33.67 leaves plant^{-1}, 220.67 g fresh weight of leaves plant^{-1}, took 19.00 days to 1st cut, 25.92 cm leaf length, 9.27 kg yield plot^{-1} and 8826.67 kg yield ha^{-1}. Crop fertilized with N-P @ 125-90 kg ha^{-1} produced 28.12 cm plant height, 34.00 leaves plant^{-1}, 220.10 g fresh weight of leaves plant^{-1}, took 18.00 days to 1st cut, 24.47 cm leaf length, 9.25 kg yield plot^{-1} and 8804.00 kg yield ha^{-1}; while under 100-80 kg ha^{-1} there was 24.69 cm plant height, 30.33 leaves plant^{-1}, 179.44 g fresh weight of leaves plant^{-1}, took 20.00 days to 1st cut, 21.48 cm leaf length, 7.54 kg yield plot^{-1} and 7177.60 kg yield ha^{-1}. Spinach receiving lower N-P rates (75-70, 50-60, 25-50 kg ha^{-1}) and control resulted lower performance than the higher N-P levels, but the decrease in the performance was dose dependent. The values for almost all the spinach characters studied showed similarity (P>0.05) under N-P levels of 150-100 kg and 125-90 kg ha^{-1} and assumed that N-P application beyond 125-90 kg ha^{-1} was uneconomical; and 125-90 kg ha^{-1} was considered as an optimum N-P level.*

Key words: Spinach, *Spinacia oleracea*, nitrogen, phosphorus, growth, yield

INTRODUCTION

Spinach is extremely rich in antioxidants, especially when fresh, steamed, or quickly boiled. It is a rich source of vitamin A, vitamin C, vitamin E, vitamin K, magnesium, manganese, folate, betaine, iron, vitamin B_2, calcium, potassium, vitamin B_6, folic acid, copper, protein, phosphorus, zinc, niacin, selenium and omega-3 fatty acids. Spinach, along with other green leafy vegetables is considered to be rich in iron [1,2]. A 180g serving of boiled spinach contains 6.43 mg of iron, whereas a 170gram ground hamburger patty contains at most 4.42 mg. However, spinach contains iron absorption-inhibiting substances, including high levels of oxalate, which can bind to the iron to form ferrous oxalate and render much of the iron in spinach unusable by the body. In addition to preventing absorption and use, high levels of oxalates remove iron from the body [3].

Fertilizer application to the plants greatly affects their growth, production and plant constituents. Nitrogen strongly stimulates growth, expansion of the crop canopy and interception of solar radiation [4]. Nitrogen is an essential macronutrient needed by all plants to thrive. It is an important component of many structural, genetic and metabolic compounds in plant cells. Increasing the levels of nitrogen during the vegetative stage can strengthen and support plant roots, enabling plants to take in more water and nutrients; and allows a plant to grow more rapidly and produce large amounts of succulent, green foliage, which in turn can generate bigger yields, tastier vegetables, and a crop that is more resistant to pests, diseases, and other adverse conditions [5]. Similarly, Phosphorus (P) is an essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants. P stimulated root development, increased stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, improvements in crop quality, and increased resistance to plant diseases [6].

Leafy vegetables, particularly, the spinach is highly responsive to fertilization [7] and oxalates which are the main indexes of the quality due to a very efficient uptake system and inefficient reductive systems [8]. Spinach requires a high level of fertility, especially nitrogen. Early spring spinach may require larger quantities of fertilizer than fall crops. The fertilizer requirements on sandy and sandy loams are 85 to 120 kg N, 75 to 85 kg P_2O_5, and 85 to 150 kg K_2O. On heavier clay soils, 75 kg ha^{-1} of each nutrient should be adequate. Fertilizer is often broadcast and worked into the soil prior to seeding. If the fertilizer is banded at seeding it should be placed along each side of the rows 2 to 3 inches below the level of the seed and 6 inches to the side of the row; fertilizer should never come in contact with the seed and two or three splits of 85 to 120 kg ha^{-1} N would be adequate as side-dressing [9].

Application of nitrogen and phosphorus fertilizers has essential role in the development of crop yield and quality of the produce. Farmers have increased application of nitrogen fertilizers to their land year by year without considering the response of different species to rate of nutrients and their forms. Adequate supply of fertilizers can promote plant growth and increase crop production, but excessive and inappropriate use of chemical fertilizers causes accumulation of compounds in the edible products which have a detrimental impact on human health, cause an environmental pollution and economical losses [10]. El-Fadaly [11] found that N increased the spinach yield and enhanced the accumulation of N and P in leaves. Luyen [12] concluded that spinach is a vegetable with a high potential to convert efficiently the nitrogen in urea into edible biomass with high nitrogen content. El-Assiouty [13] reported that application of 40 kg N + 15.0 kg P_2O_5 increased plant fresh yield by 27.2

and 42.3% and 16.3 and 10.4% in seed yield over the control in the first and second seasons, respectively. Boroujerdnia [14] achieved highest yield with 120 kg ha^{-1} N. Odueso [15] reported that NPK 20-10-10 was observed to be better for growth and yield of spinach. The present study was carried out to investigate the influence of different nitrogen and phosphorus levels on the growth and yield of spinach.

MATERIALS AND METHODS

The experiment was conducted at the experimental area of Horticulture Department, Sindh Agriculture University, Tandojam in RCB Design, replicated thrice having net plot size of 3 x 3.5m (10.5m^2). The land was prepared by giving 2 dry plowings; and clods were crushed followed by leveling to eradicate the weeds and to make the soil surface for uniform distribution of irrigation water. Seven nitrogen and phosphorus levels (including a control) were examined against spinach. The nitrogen and phosphorus were applied in the form of urea and single super phosphate (SSP). 1/3rd of N along with all P was applied at the time of land preparation by mixing in the soil, while the remaining N was divided into two equal doses and were applied with a fortnight interval. For recording observations, normal looking five plants in each plot were selected and tagged.

Growth parameters

The observations were taken as, Plant height (cm), Number of leaves plant^{-1}, Fresh weight of leaves plant^{-1} (g), Number of days taken to first cut, Leaf length (cm) and Yield ha^{-1} (kg).

The data on the above characters were collected randomly and statistical analyses were performed by using statistical computer software package [16].

RESULTS AND DISCUSSION

The agriculture soils are inadequate in nutrients essentially required for crop production, particularly N and P; so to develop soil adequacy of these nutrients, inorganic N and P are the major sources to improve the situation at the time of cropping [17] and the crop requirement for nitrogen may change with the time even on the same soil [4]; while phosphorus requirement may increase due to deteriorating situation regarding the soil P availability [18]. Hence, the study was carried out to evaluate the effect of different levels of nitrogen and phosphorus fertilizers on the growth and yield of spinach.

Plant height (cm)

There was a significant ($P<0.05$) effect of different N-P levels on spinach plant height and values shown in the Table 1 and 2. The spinach fertilized with highest N-P level of 150-100 kg ha^{-1} resulted in maximum plant height of 29.79 cm, and with decrease in N-P fertilizer levels i.e. 125-90 and 100-80 kg ha^{-1}, the plant height of spinach simultaneously decreased to 28.12 and 24.69 cm, respectively. The crop receiving N-P fertilizers at the lower rates of 75-70, 50-60 and 25-50 kg ha^{-1} showed adverse effects on the crop with declining plant height of 22.38, 20.15 and 16.58 cm, respectively; while the minimum plant height of 10.39 cm of spinach was observed in control receiving no N-P fertilizers. Significantly taller plants under higher N-P levels were mainly because of N-P application at higher rates, which make the experimental soil adequate of these nutrients, and hence plant height increased substantially. The LSD tested suggested that there was a linear response of spinach to each increased N-P level, which indicated that the experimental soil was severely deficient of these nutrients and with each additional N-P supply, the plant height increased concurrently. However, the increase in the plant height was proportional to the rate of N-P application.

Number of leaves plant^{-1}

The analysis of variance showed that the differences in the number of leaves plant^{-1} of spinach under different N-P fertilizer levels were statistically significant ($P<0.05$) and values are presented in the Table 1 and 2. It is evident from the results that the spinach crop fertilized with N-P level of 125-90 kg ha^{-1} resulted in maximum number of leaves plant^{-1} (34.00), followed by N-P levels of 150-100 and 100-80 kg ha^{-1} with 33.67 and 30.33 average number of leaves plant^{-1}, respectively. The application of lower N-P levels of 75-70, 50-60 and 25-50 kg ha^{-1} resulted in 26.00, 25.00 and 22.00 average number of leaves plant^{-1}, respectively. However, the minimum number of leaves (16.67) plant^{-1} was achieved from the plots receiving no N-P fertilizers (control). It was noted that the number of leaves plant^{-1} increased significantly with increasing N-P levels up to 125-90 kg ha^{-1}; further increase in N-P fertilizers showed adverse effects a slight decrease in the number of leaves was noted. From Table 1, the LSD test suggested that the differences in the number of leaves plant^{-1} between N-P levels of 125-90 and 150-100 kg ha^{-1} were statistically non-significant ($P>0.05$) which suggested that 125-90 kg ha^{-1} N-P was an optimum level for achieving higher number of leaves plant^{-1}. Moreover, the differences in leaves plant^{-1} under N-P levels of 50-60 and 75-70 kg ha^{-1} were also non-significant.

Fresh weight of leaves plant^{-1} (g)

The results in regards to fresh weight of leaves plant^{-1} of spinach were significantly ($P<0.05$) affected by varying N-P levels. The results showed that the maximum fresh weight of leaves plant^{-1} (220.67 g) was recorded in plots given N-P fertilizers at the rate of 150-100 kg ha^{-1}, closely followed by N-P application at the rate of 125-90 kg ha^{-1} with 220.10 g average fresh weight of leaves plant^{-1}. Lowering N-P rates up to 100-80 and 75-70 kg ha^{-1} resulted in a negative effect on this character with 179.44 g and 162.18 g average fresh weight of leaves plant^{-1}, respectively. The spinach crop when supplied with 50-60 or 25-50 kg ha^{-1} N-P rates, the fresh weight of leaves plant^{-1} was declined to 130.73 g and 106.04 g, respectively. The minimum fresh weight of leaves (68.38 g) plant^{-1} was observed from the control plots receiving no N-P fertilizers (Table 1). The results clearly indicated that application of N-P fertilizers beyond 125-90 kg ha^{-1} was not beneficial as the differences in fresh weight of leaves plant^{-1} under N-P levels of 125-90 and 150-100 kg ha^{-1} were non-significant ($P>0.05$). However, this higher fresh weight of leaves plant^{-1} under higher N-P levels was connected with increased plant height and the higher number of leaves plant^{-1}.

Table 1. Plant height, number of leaves and weight of leaves plant^{-1} of spinach as influenced by different doses of nitrogen and phosphorus levels

Treatments (N-P levels)	Plant height (cm)	No. of leaves plant^{-1}	Weight of leaves plant^{-1} (g)
0–0 kg ha^{-1} (control)	10.39	16.67	68.38
25-50 kg ha^{-1}	16.58	22.00	106.04
50-60 kg ha^{-1}	20.15	25.00	130.73
75-70 kg ha^{-1}	22.38	26.00	162.18
100-80 kg ha^{-1}	24.69	30.33	179.44
125-90 kg ha^{-1}	28.12	34.00	220.10
150-100 kg ha^{-1}	29.79	33.67	220.67
S.E.±	0.6718	1.4402	6.2757
LSD 0.05	1.4637	3.1378	13.674
LSD 0.01	2.0520	4.3990	19.169

Table 2. Mean squares corresponding to plant height, number of leaves and weight of leaves plant^{-1} of spinach as influenced by different doses of nitrogen and phosphorus levels

Source	Degrees of freedom	Plant height (cm)	No. of leaves plant^{-1}	Weight of leaves plant^{-1} (g)
Replications	2	0.265	2.333	66.58
Treatments	6	136.328**	136.328**	9843.31**
Error	12	0.677	3.111	59.08

Number of days taken to first cut

The spinach crop was ready for first cutting in minimum time period (18 days) when fertilized with N-P level of 125-90 kg ha^{-1}, followed by the crop receiving N-P levels of 150-100 and 100-80 kg ha^{-1} that took 19.00 and 20.00 days to reach the first cut stage, respectively. Table 3 and 4 shown that the spinach crop given N-P levels of 75-70 and 50-60 kg ha^{-1} extended period to reach first cutting stage i.e. 20.33 and 21.00 days, respectively; while crop given N-P fertilizers at the lowest rate of 25-50 kg ha^{-1} took 23.67 days to reach the stage of first cutting. However, the unfertilized spinach crop (control) reached at the stage of first cutting in maximum time period of 26.00 days. It was observed that as the N-P application rate to spinach increased, there was an obvious earliness to reach the first cut stage, and lower N-P levels and control resulted in delayed reaching of crop to first cut stage. The LSD test suggested that the differences in the number of days taken to first cut between N-P levels of 125-90 and 150-100 kg ha^{-1} were non-significant (P>0.05) suggesting that 125-90 kg ha^{-1} N-P was an optimum level. Moreover, the differences in the number of days to first cut under N-P levels of 100-80, 75-70 and 50-60 and kg ha^{-1} were also non-significant (P>0.05).

Leaf length (cm)

The analysis of variance demonstrated that the differences in the leaf length of spinach under different N-P levels were statistically significant (P<0.05). The spinach crop fertilized with highest N-P level of 150-100 kg ha^{-1} resulted in maximum leaf length of 25.92 cm, and with decrease in N-P fertilizer levels i.e. 125-90 and 100-80 kg ha^{-1}, the leaf length of spinach decreased to 24.47 cm and 21.48 cm, respectively. The crop receiving N-P fertilizers at the lower rates of 75-70, 50-60 and 25-50 kg ha^{-1} exposed adverse impacts showing decreased leaf length of 19.47, 17.53 and 14.42 cm, respectively; while the minimum leaf length of 10.39 cm of was observed in control receiving no N-P fertilizers. From Table 3 and 4 indicated that there was a significant increase in the leaf length with each increment in the N-P application. However, the increase in N-P level beyond 125-90 kg ha^{-1} was not beneficial, because statistically the differences between 150-100 and 125-90 kg ha^{-1} for length of leaves were non-significant (P>0.05). Hence, 125-90 kg ha^{-1} N-P level was an optimum fertilizer rate for achieving higher leaf length in spinach.

Yield ha^{-1} (kg)

The analysis of variance described that the spinach yield ha^{-1} was significantly (P<0.05) affected by application of N-P fertilizers at different levels. It is evident from the results that the highest spinach yield ha^{-1} (8826.67 kg) was obtained from the plots supplied with highest N-P level of 150-100 kg ha^{-1}, closely followed by 8804.00 kg yield ha^{-1} under N-P application of 125-90 kg ha^{-1}. The application of N-P fertilizers at the rates of 100-80 and 75-70 kg ha^{-1} resulted in a decreased yield of 7177.60 kg and 6487.20 kg ha^{-1}, respectively. The spinach yield ha^{-1} was further diminished to 5229.20 kg and 4241.60 kg ha^{-1} when the crop was supplied with 50-60 or 25-50 kg ha^{-1} N-P levels, respectively. However, the lowest yield ha^{-1} (2733.33 kg) was observed from the control plots where no N-P fertilizers were applied. This higher yield ha^{-1} under higher N-P levels was coupled with increased plant height, more leaves plant^{-1}, greater fresh weight of leaves, higher leaf length and increased yield plot^{-1}. The application of N-P fertilizers beyond 125-90 kg ha^{-1} was uneconomical, because statistically the differences in yield ha^{-1} between N-P levels of 125-90 and 150-100 kg ha^{-1} were non-significant (P>0.05). Hence, for achieving economically higher spinach yield ha^{-1} the optimum N-P level would be 125-90 kg ha^{-1}.

Table 3. Days taken to 1st cutting, leaf length and spinach leaf yield ha^{-1} of spinach as influenced by different N-P levels

Treatments (N-P levels)	Days taken to 1st cut	Leaf length (cm)	Spinach leaf yield (kg ha^{-1})
0–0 kg ha^{-1} (control)	26.00	9.08	2735.33
25-50 kg ha^{-1}	23.67	14.42	4241.60
50-60 kg ha^{-1}	21.00	17.53	5229.20
75-70 kg ha^{-1}	20.33	19.47	6487.20
100-80 kg ha^{-1}	20.00	21.48	7177.60
125-90 kg ha^{-1}	18.00	24.47	8804.00
150-100 kg ha^{-1}	19.00	25.92	8826.67
S.E.±	0.6746	0.7711	251.03
LSD 0.05	1.4697	1.6800	546.94
LSD 0.01	2.0605	2.3552	766.78

Table 4. Mean squares corresponding to Days taken to 1st cutting, leaf length and spinach leaf yield ha^{-1} of spinach as influenced by different N-P levels

Source	Degrees of freedom	Single tuber weight (g)	Marketable tubers plant^{-1}	Marketable tuber yield (ton ha^{-1})
Replications	2	0.5714	1.234	106523
Treatments	6	23.2063**	102.848**	15749422**
Error	12	0.6825	0.892	94523

The indings of thge study revealed significant effect of various N-P levels on plant height, leaves plant^{-1}, fresh weight of leaves plant^{-1}, days to 1st cut, leaf length, yield plot^{-1} and yield ha^{-1}. The highest N-P level of 150-100 kg ha^{-1} resulted in 29.79 cm plant height, 33.67 leaves plant^{-1}, 220.67 g fresh weight of leaves plant^{-1}, took 19.00 days to 1st cut, 25.92 cm leaf length, 9.27 kg yield plot^{-1} and 8826.67 kg yield ha^{-1}. Crop fertilized with N-P @ 125-90 kg ha^{-1} produced 28.12 cm plant height, 34.00 leaves plant^{-1}, 220.10 g fresh weight of leaves plant^{-1}, took 18.00 days to 1st cut, 24.47 cm leaf length, 9.25 kg yield plot^{-1} and 8804.00 kg yield ha^{-1}; while under 100-80 kg ha^{-1} there was 24.69 cm plant height, 30.33 leaves plant^{-1}, 179.44 g fresh weight of leaves plant^{-1}, took 20.00 days to 1st cut, 21.48 cm leaf length, 7.54 kg yield plot^{-1} and 7177.60 kg yield ha^{-1}. Spinach receiving lower N-P rates (75-70, 50-60, 25-50 kg ha^{-1}) and control resulted lower performance than the higher N-P levels, but the decrease in the performance was dose dependent. The values for almost all the spinach characters studied showed similarity (P>0.05) under N-P levels of 150-100 kg and 125-90 kg ha^{-1}and assumed that N-P application beyond 125-90 kg ha^{-1} was uneconomical; and 125-90 kg ha^{-1} was considered as an optimum N-P level. These results are in accordance with those of Canali [9] they suggested that spinach requires a high level of fertility in soils. Biemond [19] stated that fertilizer should be applied in two or three splits and 85 to 120 kg ha^{-1} N would be adequate as side-dressing. Chat [20] tested 0, 10, 20, 30, 40, 50, 60 kg N ha^{-1} in spinach and reported that increasing N rates simultaneously improved spinach growth and yield. Canali [9] suggested N application upto 150 kg ha^{-1} for spinach, while Patel [21] suggested partial use of farm yard manure at the cost of reduced N application for spinach. Popat [22] reported that NPK application at higher rates produced higher leaf yields in spinach as compared to lower levels or control. Dua [23] suggested the application of 30 tons farm yard manure, 150 kg N, 83 kg P and 43.7 kg K ha^{-1} for spinach. Odueso [15] reported that NPK at the rates of 20-10-10 was observed to be better for growth and yield of spinach. Sajirani [24] suggested 300 kg urea ha^{-1} in addition to 45 ton manure ha^{-1} for achieving higher spinach yields. Darani [25] reported that application of nitrogen from 75 to 150 kg ha^{-1} would ensure better crop growth in spinach. The experimental results achieved from the present study, and research findings of the past workers are well in agreement with each other and the suggestions came from almost all sides for careful application of N and P fertilizers according to the soil status and requirement of the crop in a particular soil and climatic condition.

CONCLUSIONS

The values for almost all the spinach characters studied showed similarity (P>0.05) under N-P fertilizer levels of 150-100 kg and 125-90 kg ha^{-1} and assumed that N-P application beyond 125-90 kg ha^{-1} was uneconomical, because statistically the differences in yield ha^{-1} between N-P levels of 125-90 and 150-100 kg ha^{-1} were non-significant (P>0.05). Hence, for achieving economically higher spinach yield ha^{-1} 125-90 kg ha^{-1} N-P level was considered as an optimum level.

LITERATURE CITED

[1] Toledo, M. E. A., Y. Ueda, Y. Imahori and M. Ayaki. "L-ascorbic acid metabolism in spinach (*Spinacia oleracea* L.) during postharvest storage in light and dark". *Postharvest Biol. Terminol.,* **28**: 47-57 (2003).

[2] Ahmed, A. A., M.M.H. Abd El-Baky, Faten S. Abd El-Al and A.M. Shaheen. "The productivity of Jew's mallow plant as influenced by different NPK fertilization". *J. Agric. Sci., Mansoura Univ.,* **29**(10): 5773-5783 (2004).

[3] USDA. "USDA National Nutrient Database for Standard Reference, Release 18. Nutrient Data Laboratory". *U.S. Department of Agriculture, Agricultural Research Service. http://www.nal.usda.gov/fnic/foodcomp* (2005).

[4] Milford, G. F. J., Armstrong, M. J., Jarvis, P. J., Houghton, B. J., Bellett-Travers, D. M., Jones, J. and Leigh, R. A. "Effects of potassium fertilizer on the yield, quality and potassium offtake of sugar beet

crops grown on soils of different potassium status". *Journal of Agricultural Science*. **135**: 1-10 (2000).

[5] Eckert, D. "Efficient Fertilizer Use of Nitrogen (2nd Ed.)." *John Willy and Sons, New York*, pp. 1-19 (2010).

[6] Griffith, B. "Efficient Fertilizer Use - Phosphorus (2nd ed.)". *McMillan Co. Amsterdam*, pp. 1-7 (2010).

[7] Cantliffe, D. "Nitrate accumulation in vegetable crops as affected by photoperiod and light duration (beets, radish, spinach, beans)". *J. Am. Soc. Hort. Sci.*, **97**: 414-418 (1992).

[8] Jaworska, G. "Content of nitrates, nitrites, and oxalates in New Zealand spinach". *Food Chem.*, **89**:235-242 (2005).

[9] Canali, S., F. Montemurro, F. Tittarelli and O. Masetti. "Effect of nitrogen fertilisation reduction on yield, quality and N utilisation of processing spinach". *Journal of Food, Agriculture & Environment*, **6**(3&4): 242-247 (2008).

[10] Wang, Z. H., Z. Q. Zong, S. X. Li and B. M. Chen. "Nitrate accumulation in vegetables and its residual in vegetable fields". *Environ. Sci.*, **23**: 79-83 (2002).

[11] El-Fadaly, K. A. and J. F. Mishriky. "Effect of nitrogen sources and levels on growth, yield and mineral composition of spinach". *Bulletin of Faculty of Agriculture, University of Cairo*, **41**(3): 973-988 (2000).

[12] Luyen, L. T. and T. R. Preston. "Effect of level of urea fertilizer on biomass production of water spinach (*Ipomoea aquatica*) grown in soil and in water". *Livestock Research for Rural Development*, **16**(10): 67-73 (2004).

[13] El-Assiouty, F. M. M. and S. A. Abo-Sedera. "Effect of Bio and Chemical Fertilizers on Seed Production and Quality of Spinach (*Spinacia oleracea* L.)". *International Journal of Agriculture & Biology*, **7**(6): 947–952 (2005).

[14] Boroujerdnia, M. and N. A. Ansari. "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): 47-53 (2007).

[15] Odueso, O. O. "The effects of fertilizers on the growth and yield of Indian spinach (Basella alba)". *Journal of Science and technology in Greenhouse Culture*, **1**(2): 4-5 (2011).

[16] Gomez, K. A. and A. A. Gomez. "Statistical procedures for agricultural research". (2nd Ed.), John Wiley and Sons. *International Science Publisher, New York, USA.* pp. 457-423 (1984).

[17] Shaheen, A. M., F. A. Rizk, E. H. Abd El-Samad and Z. S. A. El-Shal. "Growth, yield and chemical properties of spinach plants as influenced by nitrogen fertilizer forms and micro-elements foliar application". *Journal of Applied Sciences Research*, **8**(2): 777-785 (2012).

[18] Thompson, B. "Efficient Fertilizer Use – Potassium (1st ed.)". *John Willy and Sons, New York*, pp. 1-13 (2010).

[19] Biemond, H. "Effects of nitrogen on development and growth of the leaves of vegetables. 3. Appearance and expansion growth of leaves of spinach". *Wageningen Journal of life Sciences*, **43**(2): 19-26 (1995).

[20] Chat, T. H., N. T. Dung, D. V. Binh and T. R. Preston. "Effect on yield and composition of water spinach *(Ipomoea aquatica),* and on soil fertility, of fertilization with worm compost or urea". *Livestock Research for Rural Development*, **17**(10): 20-25 (2005).

[21] Patel, K. C., K. P. Patel, V. P. Ramani and J. C. Patel. "Effect of Pb and FYM application on spinach yield, Pb uptake and different fractions of Pb in sewage irrigated Fluventic ustochrepts soils of peri urban area of Vadodara". *Asian Journal of Soil Science*, **3**(2): 230-235 (2008).

[22] Popat, J. R., M. Deshmukh and V. K. Mahorkar. "Effect of NPK through foliar application on growth and yield of Indian spinach". *Annals of Plant Physiology*, **23**(2): 201-203 (2009).

[24] Sajirani, E. B., M. J. Shakouri and S. Mafakheri. "Response of spinach (*Spinacia oleracea*) yield and nutrient uptake to urea and manure". *Indian Journal of Science and Technology*, **5**(1): 98-103 (2012).

[23] Dua, V. K., P. M. Govindakrishnan and S. S. Lal. "Effect of FYM and n levels on spinach yield, N-use efficiency and soil fertility in potato – spinach sequence". *Potato Journal*, **37**(3/4): 151-156 (2010).

[25] Darani, F. H., H. Zeinali, A. H. S. Rad, A. Khourgami and H. Nasrollahi. "Effect of planting date and nitrogen fertilizer on two varieties (inner and outer) of spinach". *Annals of Biological Research*, **4**(2): 56-59 (2013).