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Integrated nutrient management of Spinach

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Abstract: A field experiment was conducted (at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh, during December, 2006 to February, 2007) to study the effect of various combinations of organic manures and chemical fertilizers on growth, yield and quality of spinach (*Spinacia oleracea* L.). The experiment was laid out in randomized complete block design with three replications using control (T_1), sole application of 10 t ha^{-1} cowdung (T_2), 5 t ha^{-1} poultry manure (T_3), full recommended dose of chemical fertilizers (T_4), 5 t ha^{-1} cowdung + 1/2 of the recommended dose of chemical fertilizers (T_5), 2 t ha^{-1} poultry manure + 1/2 of the recommended dose of chemical fertilizers (T_6), 7.5 t ha^{-1} cowdung + 1/3rd of the recommended dose of chemical fertilizers (T_7) and 3 t ha^{-1} poultry manure + 1/3rd of recommended dose of chemical fertilizers (T_8). The integrated use of organic and inorganic fertilizers showed significant variation for most of the parameters studied. The combined application of 7.5 t ha^{-1} cowdung + 1/3rd of the recommended chemical fertilizers rate (T_7) produced the highest plant height, number of leaves plant^{-1}, moisture content, yield, N, Fe and protein contents and their uptake by spinach. The highest P, K, Ca and Mg contents and their uptake were recorded in the treatment receiving 3 t ha^{-1} poultry manure with 1/3rd of the recommended chemical fertilizers rate (T_8). Application of organic manures and inorganic fertilizers alone and in combination had a significant effect on soil properties in terms of nutritional status. Thus, the overall result suggests that spinach can be cultivated in soil treated with chemical fertilizer in combination with cowdung and poultry manure for higher yield and to improve the soil fertility and productivity.
Key words: Organic fertilizer, Yield, Nutrient uptake, Spinach.

Introduction

Spinach (*Spinacia oleracea* L.) is an important vegetable crop of Bangladesh and gaining its popularity to all kinds of people due to its high carotene and vitamin C contents. In our country, most of the people, especially the children suffer from malnutrition tremendously, which affect their national life. According to WHO and FAO, an adult person's diet should contain 250 g vegetable per day. Nevertheless, we, the Bangladeshis take only 28 g (bating potato and sweet potato) on an average. Only 21.5 lac ton vegetables are produced at present which are too low against our demand (DAE, 1995). Fertilizers are essential part of modern farming system, about 50% of the world production being attributed to fertilizer use and it may be a source of the environmental and soil degradation (Pradhan, 1992). Indiscriminate use of chemical fertilizers affects the texture and structure of soil, decreases the soil organic matter content and hinders the microbial activities in soil. In our country, the organic matter status of soil is in so critical position that if the present rate of its degradation is continued, in near future our soil would become barren. The use of organic manures in field helps in improving soil texture, structure, aeration, and keeps the soil environment pollution free. Cowdung as organic manure has been using since long time but due to modernization of agricultural practices its availability is becoming scarce. On the other hand, with the development of the poultry industry in Bangladesh in recent the availability of poultry litter is increasing. As organic manure, it is superior to cowdung regarding the quality. The above discussion will suffice to understand the importance of giving adequate attention in the production of spinach using organic fertilizers integrated with chemical fertilizers for maintaining soil fertility and sound environment as well as human health. The present study was therefore, carried out to study the effect of integrated use of organic and inorganic fertilizers on the yield, quality and nutrient uptake by spinach.

Materials and Methods

The study was carried out at the field of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh, during December, 2006 to February, 2007 to examine the response of spinach to organic and inorganic fertilizers. The soil was silt loam in texture having pH 6.8 with 0.97% organic matter, 0.98% nitrogen, 11.2 µg g^{-1} soil Olsen P, 9.5 µg g^{-1} available S, 0.14 cmol kg^{-1} exchangeable K. The experiment consisted of eight treatments *viz.*, control (T_1), sole application of 10 t ha^{-1} cowdung (T_2), 5 t ha^{-1} poultry manure (T_3), full recommended rate of chemical fertilizers (T_4), 5 t ha^{-1} cowdung + 1/2 of the recommended dose of chemical fertilizers (T_5), 2 t ha^{-1} poultry manure + 1/2 of the recommended dose of chemical fertilizers (T_6), 7.5 t ha^{-1} cowdung + 1/3rd of the recommended dose of chemical fertilizers (T_7) and 3 t ha^{-1} poultry manure + 1/3rd of recommended dose of chemical fertilizers (T_8). Triple super phosphate, muriate of potash, gypsum, borax, cowdung and poultry manure were applied according to the fertilizer recommendation guide (BARC, 2005).The experiment was laid out in RCBD with three replications. Thus the total numbers of plots were 24 and the size of a unit plot was 1m × 1m. Well decomposed cowdung and poultry manure were incorporated in the plots as per treatment at four days before sowing. All the chemical fertilizers and half of total urea were applied during the final preparation and the rest part was applied at 15 days after sowing. The seeds were soaked in water for 24 hours and sown on the 24th December, 2006. Intercultural operations like thinning, weeding, irrigation, pest control were done as and when necessary. The crop was harvested on the 4th February, 2007, 42 days after sowing the seeds. Soil and plant nutrients were analyzed following the standard methods (Page *et al.*, 1982). Analysis of variance was done with the help of computer package MSTATC developed by Russel (1986) and the mean differences of the treatments were adjudged by LSD test.

Results and Discussion

Growth i.e. plant height and number of leaves plant^{-1} were significantly influenced by organic and inorganic fertilizers (Table 1). The tallest plant (23.59 cm) was recorded from the plot treated with 7.5 t ha^{-1} cowdung and 1/3rd of the recommended dose of chemical fertilizer and the shortest plant (11.73 cm) from the unfertilized control

plot (Table 1). Jin *et al.* (1996) reported that the application of cattle manure increased plant height of red amaranth. Similar results were also found by Koboyoshi *et al*. (1989) applying FYM + fertilizer N in rice. Data presented in Table 1 showed that the highest number of leaf (20.54) was obtained in treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) and the lowest number (10.39) was in control. The reason might be the addition of available N, P and exchangeable K from cowdung and poultry manure. A similar finding was reported by Jin *et al.,* 1996. The leaf size was measured by the length and breadth of the blade of the largest leaf and their horizontal spread. The variation in size of leaf under various treatments was not significant. No significant variation was observed in moisture content of spinach due to the application of organic and inorganic fertilizers (Table 1). Significant variations in yield were obtained due to the application of organic manure and inorganic fertilizer alone and their combination. Maximum yield (15.17 t ha^{-1}) was recorded in treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) and minimum yield (8.83 t ha^{-1}) was found in treatment T_1 (Table 1). Dixit (1997) noted better vegetative growth and higher tuber yield when treated with inorganic fertilizer and FYM.

Table 1. Influence of organic and inorganic fertilizers on the growth and yield of Spinach

Treatment	Plant height (cm)	Leaves $plant^{-1}$	Leaf size (L : B)	Moisture content %)	Yield (t ha^{-1})
T_1 (CD_0 + PM_0 + CF_0)	11.73	10.39	2.02 : 1	93.70	8.83
T_2 (CD_3 + PM_0 + CF_0)	18.93	13.61	2.60 : 1	93.36	11.67
T_3 (CD_0 + PM_3 + CF_0)	15.56	13.09	2.39 : 1	92.27	10.83
T_4 (CD_0 + PM_0 + CF_{full})	19.79	14.57	2.72 : 1	92.99	13.17
T_5 (CD_1 + PM_0 + $CF_{1/2}$)	21.33	16.29	2.60 : 1	92.98	12.67
T_6 (CD_0 + PM_1 + $CF_{1/2}$)	18.08	15.95	2.49 : 1	93.09	12.50
T_7 (CD_2 + PM_0 + $CF_{1/3rd}$)	23.59	20.54	2.46 : 1	94.66	15.17
T_8 (CD_0 + PM_2 + $CF_{1/3rd}$)	22.27	17.92	2.38: 1	94.52	14.50
LSD (0.05)	1.71	1.99	0.31	3.81	1.98
CV (%)	5.17	7.45	7.29	2.36	9.13

Organic and inorganic fertilizers significantly influenced the mineral contents of spinach (Table 2) Nitrogen content in spinach resulting from different treatments varied significantly from 0.45 to 0.82%. Maximum N content (0.82%) was observed in 7.5 t ha^{-1} cowdung + $1/3^{rd}$ recommended dose of chemical fertilizer which was identical with treatment T_8 and T_6. The minimum N content (0.45%) was found in control treatment (T_1). This result showed that organic manure in combination with chemical fertilizer treated spinach plant contained higher N % than control and organic or inorganic fertilizer alone treated. Phosphorous content was highest (0.52%) and lowest (0.29%) in T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and T_1 (CD_0 + PM_0 + CF_0), respectively (Table 2). It was found that P content significantly increased with the combined application of organic manure than with the inorganic fertilizer application (Rosen, *et al*., 1994). Maximum potassium (0.49%) was obtained from T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and minimum (0.25%) was from T_1. Rosen *et al*. (1994) found the higher amount of K content in organic spinach over inorganically cultivated or conventional spinach.

Table 2. Influence of organic and inorganic fertilizers on the nutrient contents of Spinach

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (%)
T_1 (CD_0 + PM_0 + CF_0)	0.45	0.29	0.25	0.13	0.79	0.19	0.09
T_2 (CD_3 + PM_0 + CF_0)	0.61	0.37	0.39	0.14	1.33	0.25	0.12
T_3 (CD_0 + PM_3 + CF_0)	0.68	0.32	0.43	0.16	1.04	0.32	0.16
T_4 (CD_0 + PM_0 + CF_{full})	0.64	0.42	0.45	0.15	1.24	0.32	0.14
T_5 (CD_1 + PM_0 + $CF_{1/2}$)	0.70	0.41	0.39	0.18	1.39	0.37	0.12
T_6 (CD_0 + PM_1 + $CF_{1/2}$)	0.66	0.39	0.31	0.17	1.28	0.33	0.14
T_7 (CD_2 + PM_0 + $CF_{1/3rd}$)	0.82	0.47	0.47	0.21	1.42	0.28	0.18
T_8 (CD_0 + PM_2 + $CF_{1/3rd}$)	0.79	0.52	0.49	0.25	1.56	0.29	0.16
LSD (0.05)	0.13	0.06	0.06	0.05	0.23	0.04	0.04
CV (%)	9.92	7.74	7.63	3.97	10.81	7.63	4.36

Calcium content in spinach varied from 0.13% to 0.25% due to the application of different treatments. The treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) showed the highest value (0.25%) of Ca content than the others and the lowest (0.13%) content was obtained from the unfertilized plot. Rashid (1999) stated that spinach contained 0.3% Ca per 100 g of its edible portion. Results indicated that Mg content in spinach ranged from 0.79 to 1.56% which was statistically significant. Maximum Mg content (1.56%) was observed in T_8 treatment where poultry manure and chemical fertilizer combinedly applied at the rate of 3 t ha^{-1} and $1/3^{rd}$ of recommended dose and the minimum content (0.79%) was recorded from the unfertilized control plant. Aykroyd (1963) observed 247 mg Mg 100 g^{-1} of edible portion of red amaranth. The highest (0.37%) was obtained in T_5 (CD_1 + PM_0 + $CF_{2/3rd}$) and lowest S content (0.19%) was noted in control. Aykroyd (1963) observed that red amaranth contained 0.061% S 100^{-1} g of its edible portion.

The treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) yield the highest Fe content (0.18%) and the lowest (0.09%) in T_1. Spinach contained 0.01-0.16% Fe of its edible portion (Rashid, 1999).

The nutrient uptake by spinach was also significantly influenced by organic and inorganic fertilizers (Table 3). Nitrogen uptake by spinach ranged from 2.51 to 6.64 kg ha^{-1}. The highest N uptake (6.64 kg ha^{-1}) was found in treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) and the lowest (2.51kg ha^{-1}) in control. Karim *et al.* (1991) observed that N uptake increased due to addition of organic manure with or without chemical fertilizers. The highest (4.10 kg ha^{-1}) and lowest P (1.58 kg ha^{-1}) uptake were obtained in the treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) and T_1 (control), respectively (Table 3). Sharma *et al*. (2000) observed that P uptake increased by integrated application of FYM and chemical fertilizer but only recommended dose of chemical fertilizers decreased nutrient uptake by rice plant. Potassium uptake by spinach ranged from 1.43 to 4.15 kg ha^{-1}. The treatment T_4 which comprised of only full recommended dose of chemical fertilizer, showed maximum (4.15 kg ha^{-1}) K uptake and T_1 (control) showed minimum (1.43 kg ha^{-1}) K uptake. Chipeva *et al*. (1998) observed higher K uptake by spinach from soils amended with organic manure i.e. sludge. Calcium uptake varied from 0.75 to 1.92 kg ha^{-1}. Maximum Ca uptake was found from the treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and minimum (0.75 kg ha^{-1}) in the control. The possible reason of higher Ca uptake was the addition of organic manure to soil. Magnesium uptake by spinach varied from 4.45 to 12.38 kg ha^{-1}. Maximum Mg uptake was obtained from the treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and the minimum uptake was recorded in the unfertilized control plant. From the results, it is noted that the addition of organic manure to soils increased the Mg uptake by spinach. The variation in S uptake ranged from 1.03 to 3.29 kg ha^{-1}. The treatment T_5 (CD_1+ PM_0+ $CF_{1/2}$) showed the highest (3.29 kg ha^{-1}) S uptake and the control treatment gave the lowest (1.03 kg ha^{-1}) S uptake by spinach. Sing *et al*. (1999) reported that the application of organic manure alone or in combination with chemical fertilizer increased the S uptake by plants.

Table 3. Influence of organic and inorganic fertilizers on nutrient uptake by spinach

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	S (kg ha^{-1})
T_1 (CD_0 + PM_0 + CF_0)	2.51	1.58	1.43	0.75	4.45	1.03
T_2 (CD_3 + PM_0 + CF_0)	4.72	2.87	3.02	1.08	10.31	1.94
T_3 (CD_0 + PM_3 + CF_0)	5.69	2.68	3.60	1.34	8.70	2.68
T_4 (CD_0 + PM_0 + CF_{full})	5.91	3.88	4.15	1.38	11.45	2.95
T_5 (CD_1 + PM_0 + $CF_{1/2}$)	6.22	3.65	3.47	1.60	12.36	3.29
T_6 (CD_0 + PM_1 + $CF_{1/2}$)	5.70	3.36	2.68	1.47	11.06	2.85
T_7 (CD_2 + PM_0 + $CF_{1/3rd}$)	6.64	3.81	3.81	1.70	11.50	2.67
T_8 (CD_0 + PM_2 + $CF_{1/3rd}$)	6.11	4.10	3.81	1.92	12.38	2.32
LSD (0.05)	1.38	1.06	0.73	0.27	2.30	0.53
CV (%)	12.20	16.16	11.08	9.40	10.92	10.74

Data incorporated in table-4 presents the influence of organic and inorganic fertilizers on some chemical properties and nutrient status of post harvest soil. The pH of post harvest soil was not significantly influenced by the application of different organic and inorganic fertilizer. Maximum pH value (6.77) was obtained from the unfertilized plot and minimum pH value (6.49) was recorded in plot treated with only 10 t ha^{-1} cowdung (T_2). Decrease in soil pH within 1 to 4 months was probably due to the production of organic acids during organic manure decomposition or by nitrification (Chen and Avenimatlech, 1986). The organic matter content of post harvest soil was significantly influenced by different treatments. The highest value (1.44%) was recorded from the treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and the lowest (0.92%) was recorded from the unfertilized plot. Application of organic manures increased the organic matter content in soil (Azim, 1999). The highest N content (0.49%) was obtained in (CD_0 + PM_2 + $CF_{1/3rd}$) and the lowest value (0.09%) was recorded in control. The interaction of organic and conventional farming also increased total nitrogen content of soil over conventional. Application of organic manure increased the total N concentration in soil (Abdel and Hussain, 2001).

Available P content of post harvest soil due to the application of different organic and inorganic fertilizers varied from 10.81 to 15.84 µg g^{-1} soil. The highest available P content was observed in the treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and the lowest content was found in T_1. Soils treated with organic manures gave higher available P compared to conventional and control. The release of more available P from the decomposition of poultry manure and cowdung might be a cause of higher value in soils treated with organic manure. Application of organic manures increased the available P in soil (Abdel and Hussain, 2001). Results also showed that the highest exchangeable K content (0.46 cmol kg^{-1} soil) was obtained in T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) and the lowest K content (0.09 cmol kg^{-1} soil) was found from the unfertilized plots. Results indicated that exchangeable K content was higher in soils treated with organic manures with chemical fertilizers compared to chemical fertilizers alone. Abdel and Hussain (2001) showed that organic manures increased the exchangeable K in soil. Due to the effect of organic manure alone or in combination with chemical fertilizers, the exchangeable Ca content in soil varied significantly from 1.81 to 2.9 cmol kg^{-1} soil. Maximum value was given by the treatment T_7 (CD_2 + PM_0 + $CF_{1/3rd}$) and minimum value was noted from the treatment T_1. The results

showed that the soils amended with organic manure alone or in combination with chemical fertilizer increased the exchangeable Ca content in post harvest soil. Similar results also observed by Mban *et al.* (2002). The exchangeable Mg content of post harvest soil ranged from 0.87 to 1.28 cmol kg^{-1} soil as significantly influenced by the addition of organic manure to soil. The highest exchangeable Mg content (1.28) was recorded from the treatment T_3 (CD_0 + PM_3 + CF_0) and the lowest content (0.87) was observed from the unfertilized plots. The higher content of Mg was found in organic manure amended soils by Mban *et al.* (2002).Significant variation was found in available S content in post harvest soil due to the application of organic and inorganic fertilizers. Maximum S content (16.74 µg g^{-1} soil) was showed by the treatment T_8 (CD_0 + PM_2 + $CF_{1/3rd}$) where poultry manure (3 t ha^{-1}) was applied with 1/3rd of recommended dose of chemical fertilizer, and minimum S content (9.12 µg g^{-1} soil) was obtained in control treatment (Table 4). Hossain (1996) found that the combined use of organic manure with NPKS improved the level of available S in soil. Similar results were obtained by Azim (1999).

Table 4. Influence of organic and inorganic fertilizers on chemical properties and nutrient status of post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (µg g^{-1})	Exchangeable K (cmol kg^{-1})	Exchangeable Ca (cmol kg^{-1})	Exchangeable Mg (cmol kg^{-1})	Available S (µg g^{-1})
T_1 (CD_0 + PM_0 + CF_0)	6.77	0.92	0.09	10.81	0.09	1.81	0.87	9.12
T_2 (CD_3 + PM_0 + CF_0)	6.49	1.18	0.26	12.72	0.27	2.42	1.22	12.69
T_3 (CD_0 + PM_3 + CF_0)	6.56	1.25	0.34	13.43	0.33	2.69	1.28	13.03
T_4 (CD_0 + PM_0 +CF_{full})	6.62	0.71	0.45	11.28	0.32	2.21	0.91	11.91
T_5 (CD_1 + PM_0 + $CF_{1/2}$)	6.67	1.19	0.39	14.11	0.32	2.63	1.09	13.87
T_6 (CD_0 + PM_1 + $CF_{1/2}$)	6.64	1.21	0.39	12.98	0.27	2.26	1.12	12.92
T_7 (CD_2 + PM_0 + $CF_{1/3rd}$)	6.73	1.32	0.46	14.77	0.38	2.90	1.14	14.98
T_8 (CD_0 + PM_2 + $CF_{1/3rd}$)	6.66	1.44	0.49	15.84	0.46	2.37	1.19	16.74
T_1 (CD_0 + PM_0 + CF_0)	0.89	0.18	0.05	1.659	0.06	0.28	0.12	1.48
CV (%)	7.68	8.48	1.06	7.15	9.01	6.27	6.71	6.43

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