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Effect of Chicken Manure on the Growth and Uptake of N, P and K by Spinach (*Spinacia oleracea* L.) Grown in Three Different Soils

Md. Enamul Haque*, Md. Abul Kashem and Khan Towhid Osman

Department of Soil Science, University of Chittagong, Chattogram-4331, Bangladesh.

* Correspondence to: Md. Enamul Haque, Email: md.enamulhaque94@yahoo.com

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Abstract

Chicken manure was applied at 0, 5, 10, 20 and 30 t.ha^{-1} in pots containing 5Kg soil separately of three different soil series- Bijipur, Pahartali and Mirsarai and spinach (*Spinacia oleracea* L.) was grown in them. The growth parameters and concentrations of N, P and K in plant samples were determined. The pot experiment was carried out in the glass house of the Department of Soil Science, University of Chittagong. The soils were acidic in nature and low in CEC, organic matter, N, P and K contents. The growth of spinach significantly increased with increasing rates of chicken manure application. The 30 t.ha^{-1} chicken manure application produced the highest root and shoot dry matter yield. Nutrients such as N, P and K concentrations in root and in shoot and their uptake by both parts increased significantly (p=0.01) with increasing rates of manure applications irrespective of soil types.

Keywords: Soil series, chicken manure, spinach, nutrient uptake.

Introduction

The development of sustainable production systems that would enable food production of the appropriate quality without endangering environmental resources is one of the main challenges of modern agriculture[1]. Inorganic fertilizers have played an important role in increasing agricultural production and improving world food security[2]. However, the intensive uses of inorganic fertilizers in crop production systems have negative agricultural and environmental consequences[3]. Over time, increased use of inorganic fertilizer under crop production systems results in soil degradation in the form of soil acidification, heavy metal accumulation, loss of organic matter, deterioration of the soil structure, and reductions in biological activities and fertility which leads to a reduction in crop production[4, 5].

The decrease in organic matter (OM) content in agricultural soils is another serious threat to food safety around the world[6]. Organic matter content in Bangladesh soil is alarmingly low around 1% in most and 2% in few soils, where it should be maintained at least 3%[7]. A decrease in the concentration of soil organic matter (SOM) worsens the retention capacity, aggregation, structure, mechanical strength and compaction of the soil while also lowering fertility which directly affects agricultural productivity[6].

Organic manures that have been known for centuries can be an effective solution to these problems. The long-term application of organic manure helps to intensify the sequestration of carbon in the soil and increase food safety[8]. Their main purpose is to improve soil fertility by increasing the availability of nutrients and water for plants, limiting soil drying, maintaining high microbiological activity in the soil, and increasing the uptake of nutrients by plants[1,9]. Nevertheless, the effect of organic manure on soil and crop productivity varies with its quality.

The poultry sector is among the fastest-growing agro-based industries worldwide due to the increasing demand for egg and meat products. The amount of chicken manure increases day by day due to the

increase in chicken breeding. Poultry manure is the best quality animal manure in terms of nutrient content and availability[10]. Similar to other livestock droppings, chicken manure is a nutrient rich organic waste that contains substantial amounts of nitrogen (N), phosphorus (P) and potassium (K) and is commonly used untreated as organic fertilizer in agricultural fields[11]. Repeated application of poultry manure to cropland has the potential to improve soil health characteristics such as soil organic matter and soil fertility[12].

Food security does not only refer to availability, but also the quality of food. Organically produced vegetables are increasingly preferred for their perceived wholesomeness and safety[13]. Spinach (*Spinacia oleracea* L.) is an annual leafy vegetable crop and can be harvested within a very short time. Nutritionally, spinach is a significant source of vitamins and minerals[14]. Apart from food and nutrition, spinach also possesses medicinal attributes. Spinach is an important source of total phenolic content and has an antioxidant capacity, which is beneficial for human health[15]. The organic manure can also affect the quality of the spinach leaves. The slow-release organic manure maintains low-moderate nitrate concentrations in leaves during spinach growth[16]. High levels of leaf nitrate concentrations are harmful to human health[17].

In addition, application of chicken manure to soil enhances the concentration of water-soluble salts in the soil. Plants absorb plant nutrients in the form of soluble salts, but excessive accumulation of soluble salts suppresses plant growth. Therefore, application rates of fertilizers organic or inorganic, are very important for different types of soils. If applied correctly chicken manure act as a good soil amendment and/or fertilizer and can also increase the soil productivity and uptake of major nutrients by plants[18]. Therefore, this study investigated the effectiveness of using chicken manure as a soil amendment for spinach growth, nutrient uptake and production.

Materials and Methods

Chicken manure, soil sampling and sample preparation

Chicken wastes including excreta and feed wastes were collected from a poultry farm in Jobra village near Chittagong University campus composted for two months to produce chicken manure and precaution was taken to avoid contamination. The manure was dried under the sun for 4 days. Three soil series namely Bijipur, Pahartali and Mirsarai were selected on the basis of their land types, drainage condition, textures and parent materials and covering major soils of the Hathazari Upazilla of Chittagong district. Characteristics of these soil series have been defined by the Soil Resource Development Institute of Bangladesh[19]. The soils were classified as Typic Endoaquepts (Bijipur, Mirsarai) and Aeric Endoaquepts (Pahartali) according to the USDA soil classification system 1998[20]. Soil samples were collected from a fallow area, in order to avoid the influence of other residual fertilizers on the outcome of this study. Samples were collected randomly at a depth of 0-15 cm covering the rooting zone of the spinach crop. The collected soil samples were ground and passed through a 4 mm sieve for using it in the pot experiment. For laboratory analysis, sub-samples were air-dried and passed through a 2 mm sieve and stored.

Pot experiment

The pot experiment was conducted in the crop field of the Department of Soil Science. Five kilograms of air-dried soil was mixed with 0, 5, 10, 20 and 30 $t.ha^{-1}$ chicken manure and filled in each pot. The treatments were replicated three times. The pots were then arranged in a completely randomized design. After pot preparation, the pots were watered up to the field capacity and were kept for a week to be in an equilibrium. The water at approximate field capacity on air-dry sample was determined through draining the previously saturated soil for 48 hours and then followed

by gravimetric method. Eight spinach (*Spinacia oleracea)* seeds were sown in each earthen pot. One week after emergence, 5 seedlings were kept. Water was added periodically roughly up to 60% of the water holding capacity by weighing each pot. At 40 days of growth, plants were harvested and separated into roots and shoots. The shoots and roots were air-dried to remove the moisture. After then, the shoots and roots were oven dried at 65°C for 72 hours and dry masses were recorded.

Analysis

Particle size analysis was made by the hydrometer method as described by Day[21]. Textural classes were determined by Marshall's Triangular coordinates as designed by the USDA[22]. Soil bulk density was determined by using a bulk density calculator based on the Canadian texture triangle[23]. Soil pH was measured electro-chemically by using corning (Model-7) glass electrode pH meter from soil water suspension at the ratio of 1: 2.5. Soil organic carbon (OC) was determined by Walkley and Black's wet oxidation method[24]. The cation exchange capacity (CEC) of the soils was determined by using 1N NH_4OAC solution at pH 7.0[25]. Nitrogen, phosphorus and potassium (N, P and K) in the dry plant tissue were determined after digestion with conc. H_2SO_4 + H_2O_2 + $LiSO_4$ digestion mixture.[26] Nitrogen (N) in the extract was determined by micro-Kjehdahl distillation method. Spectrophotometer determined the P contents in the extract through vanadomolybdate yellow colour method. Potassium (K) in the extract was determined by using a flame photometer. The nutrient (N, P and K) uptake was derived by multiplying the relevant nutrient content and the dry weight of biomass.

Statistical analysis

Statistical analyses were done by using Microsoft Excel and the Minitab program[27]. Analysis of variance (ANOVA) was performed to compare treatments with respect to spinach yield, and other measured parameters.

Results and Discussion

Properties of chicken manure and soil samples used

Results of soils and chicken manure analyses before the experiment are presented in Table 1 which shows that generally the soils are characterized by relatively low pH, low CEC, low total N, P, K and organic carbon (OC). Mean manure properties were 1.73% N, 0.27% P and 2.39% K. The results indicate that the pH of chicken manure and all the soils Bijipur, Pahartali and Mirsarai were acidic in nature. The acidity of the soils was in decreasing order Bijipur>Pahartali>Mirsarai (Table 1). The textural class of the soils ranges from loamy sand to loam. The highest percentage of clay (25%) was found in Mirsarai series and the lowest of 5% was recorded in Bijipur series. The organic carbon contents of different soil series were 0.45%, 0.94% and 0.68% in Bijipur, Phartali and Mirsarai series, respectively. The soils are, therefore, poor in organic matter contents as most other soils of Bangladesh[28]. The CEC of the soils were 6.11, 9.87 and 13.63 $cmol.kg^{-1}$ in Bijipur, Pahartali and Mirsarai series, respectively. The higher CEC of Mirsarai soils suggests that soils were carrying a higher negative charge associated with the relatively higher amounts of clay. Based on the results, Mirsarai series is likely to have a higher capacity to adsorb cations than the other soil types[29]. The bulk densities of different soil series were 1.70 $g.cm^{-3}$, 1.44 $g.cm^{-3}$ and 1.36 $g.cm^{-3}$ in Bijipur, Pahartali and Mirsarai series, respectively. Adekiya and Ojeniyi[30] observed that an increase in soil bulk density reduced the uptake of N, P, K, Ca and Mg by tomato plants in Alfisols of southwestern Nigeria.

The fertility status of the soils is expected to benefit from chicken manure application since the manure is known to improve soil organic matter and macro-nutrient status and micro nutrient qualities of the soil[31]. Adesodun *et al*.[32] found that application of poultry manure to soil increased soil organic matter, N and P and aggregate stability. The improvement in soil physical properties is attributable to the mulching effect

Table 1: Some physico-chemical properties of selected soils along with some characteristics of chicken manure.

Parameter	Soil series			Chicken manure
	Bijipur	Pahartali	Mirsarai	
Sand (%)	85	50	30	-
Silt (%)	10	32	45	-
Clay (%)	5	18	25	-
Textural class	Loamy sand	Loam	Loam	-
pH	4.57	4.92	5.28	6.27
OC (%)	0.45	0.94	0.68	19.0
CEC ($cmol.kg^{-1}$)	6.11	9.87	13.63	
Total N (%)	0.09	0.14	0.19	1.73
Total P (%)	0.02	0.03	0.04	0.27
Total K (%)	0.19	0.24	0.29	2.39
Bulk density (gcm^{-3})	1.70	1.44	1.36	-

of organic matter and improved moisture retention as a result of improved soil structure and macro porosity.[33]

Effects of chicken manure on the growth and yield of spinach

To assess the impact of chicken manure on the yield of spinach, the harvested plants were weighed and dry biomass was derived. The dry biomass yields in response to applications of chicken manure are presented in Figure 1. Application of chicken manure significantly (p = 0.01) increased root and shoot dry weight for all the selected soils. Considerable variations in root and shoot dry matter of spinach crops were observed among the treatments.

Our study indicated that there was a positive trend for chicken manure application rate on the growth of spinach. Higher levels of chicken manure application had higher root and shoot dry matter yield observed in this study regardless of soil types. The mean dry weights of roots and shoots of spinach grown in manure-amended soils were 0.72 and 3.38 g in Bijipur, 0.86 and 4.08g in Pahartali and 1.01 and 5.14g in Mirsarai soil series. Among the applied rates of manure, the 30 $t.ha^{-1}$ had the highest root and shoot dry matter and the 5 $t.ha^{-1}$ manure had the lowest dry matter yield (Figure 1). The plant growth response among the soil series was in the order of Mirsarai >Pahartali >Bijipur (Figure 1).

Several previous studies indicated that the application of organic manure has positive effects on crop production. Magkos *et al.*[34] established that vegetables cultivated on soils with higher amounts of organic fertilizers had higher dry matter as compared to those produced conventionally. Adekiya *et al.*[35] reported that poultry manure has positive effects on crop production. According to Emede *et al.*,[36] poultry manure positively influenced the plant growth and yield of *Amaranthus cruentus L*. Sistani *et al.*[37] observed that dry-matter yield increased significantly with increasing rates. Lin *et al.*[12] reported that crop yield increased with increasing poultry litter application rates.

Crop growth can be affected by manure-induced changes in soil nutrient conditions. Kumar *et al.*[38] showed that the application of FYM, poultry manure and sugarcane filter cake alone or in combination with chemical fertilizers improved the total N, P, and K status of soil. Sarma *et al.*[39] showed that the SOC, total N and available P content increased significantly due to the application of manure alone or in combination with

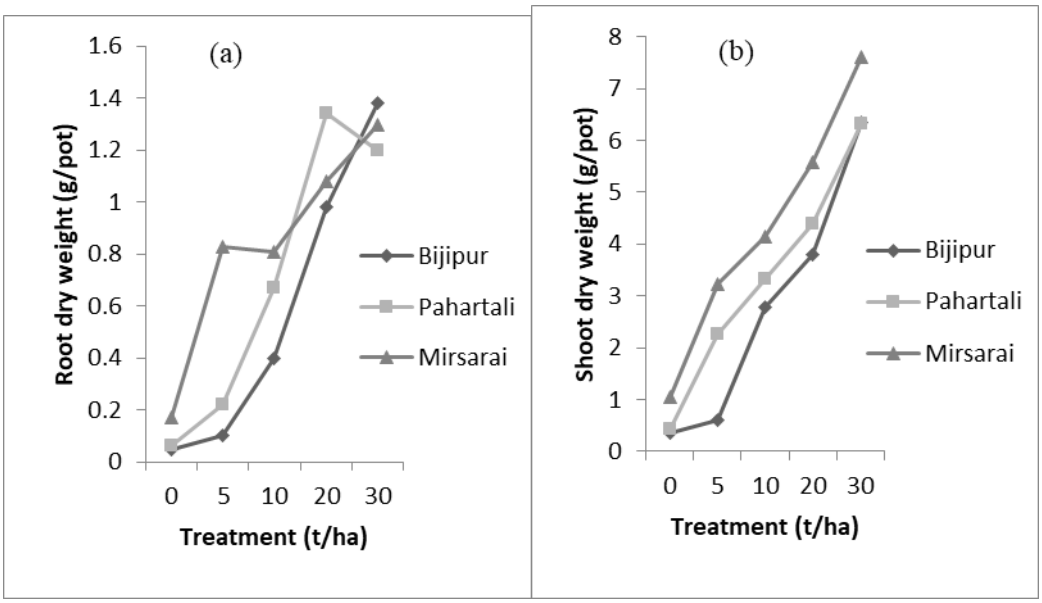

Figure 1. Effect of chicken manure on (a) root and (b) shoot dry weight of spinach grown in different soil series (significant at $p = 0.01$ level)

chemical fertilizers. These nutrients may be already present in amendments or may have been mineralized from organic forms after amendment addition[40,41]. Ahmad *et al.*[42] reported that poultry manure could be used as a potential source of organic fertilizer containing considerable amounts of OC and P. Narwal and Antil[43] reported that the addition of organic manure increase in available N content might be due to the release of nitrogen through the decomposition of organic manures. The decomposition of organic matter produces acid which is also responsible for the decomposition of certain primary minerals leading to the release of nutrients[44]. As a result, soils treated with chicken manure may have this advantage and can respond better to crop production.

Crop growth can also be affected by manure-induced changes in soil chemical, physical and biological conditions. Mahmood *et al.*[45] found that organic amendments improve soil chemical properties. Diacono and Montemurro[46] also reported that the long-term benefits of organic amendments are increased cation exchange capacity (CEC) and humic acid buffering capacity in soil. Dhaliwal and Walia[47] reported that incorporation of manures in the soil has a beneficial effect on soil health by improving physico-chemical properties besides supplying the macronutrients like nitrogen (N), phosphorus (P), and potassium (K) and increasing the availability of the micronutrients like Zn, copper (Cu), Fe, and Mn. Arriaga and Lowery[48] reported that long-term manure addition was linked to lower soil bulk density and higher water retention capacity. Zhang *et al.*[49] also indicated that inorganic N applied along with poultry manure not only enhances microbial activity in the soil but also increases the availability of K and P and reduces N loss as compared to a single inorganic fertilizer application.

Effects of chicken manure on the concentration of N, P and K in spinach

To observe the effects of chicken manure on the uptake of N, P and K in spinach crops, the N, P and K content of spinach (*S. oleracea*) were measured. The result shows that there was a positive trend in dry tissue nutrient concentrations at different manure levels for all the selected soils (Table 2 and -3). Root and shoot N, P and K concentrations were increased significantly with all manure levels as compared to the control.

The root N content at different manure levels ranged from 0.36 to 0.74% in Bijipur, 0.38 to 0.82% in

Pahartali and 0.46 to 0.77% in Mirsarai soil series. The shoot N content ranged from 0.94 to 1.52% in Bijipur, 0.82 to 1.35% in Pahartali and 0.77 to 1.75% in Mirsarai soil series. The highest root N and shoot N contents were observed at 30 $t.ha^{-1}$ manure level and the lowest contents were observed at controls in all studied soils. The root N content in Mirsarai soil series significantly increased with the increasing levels of chicken manure. In Pahartali soil series, the root N content somewhat inconsistently increased from 0 to 30 $t.ha^{-1}$ and 10 $t.ha^{-1}$ and 20 $t.ha^{-1}$ manure levels did not differ significantly from each other for root N content. The root N content in Bijipur soil series increased with the increasing levels of chicken manure with the facts that the manure levels 5 $t.ha^{-1}$ and 10 $t.ha^{-1}$ were statistically similar as were 20 $t.ha^{-1}$ and 30 $t.ha^{-1}$. The shoot N content in all soil types increased significantly ($p< 0.05$) with the increasing levels of chicken manure.

The root P content at different manure levels ranged from 0.20 to 0.47% in Bijipur, 0.24 to 0.44% in Pahartali and 0.22 to 0.46% in Mirsarai soil series. The highest root P content was observed at 30 $t.ha^{-1}$ manure level both in Bijipur and Pahartali soil series while the lowest content was observed at controls of all soils. In Mirsarai soil series, the highest root P content was observed at 20 $t.ha^{-1}$ manure level that was statistically similar to 30 $t.ha^{-1}$ manure level. The shoot P content ranged from 0.11 to 0.34% in Bijipur, 0.22 to 0.47% in Pahartali and 0.32 to 0.56% in Mirsarai soil series. The shoot P content in Bijipur and Mirsarai soil series increased with the increasing rates of chicken manure and the highest content was observed at 30 $t.ha^{-1}$ manure application level. In Pahartali soil series, the highest shoot P content was observed at 20 $t.ha^{-1}$ manure level and this P content was significantly different from 30 $t.ha^{-1}$ manure level. The lowest shoot P content was observed at controls of all soils. The shoot P content in Mirsarai soil series significantly increased with increasing manure levels. In Pahartali soil series, the shoot P content significantly increased from 0 $t.ha^{-1}$ up to 20 $t.ha^{-1}$ and then decreased at higher levels of input.

The root K content at different manure levels ranged from 0.09 to 0.23% in Bijipur, 0.08 to 0.17% in Pahartali and 0.11 to 0.19% in Mirsarai soil series. The shoot K content ranged from 0.11 to 0.38% in Bijipur, 0.11 to 0.27% in Pahartali and 0.21 to 0.55% in Mirsarai soil series. The highest root K and shoot K contents were observed at 30 $t.ha^{-1}$ manure level and the lowest content were observed at controls in all soils. The root K contents were increased from 0 to 30 $t.ha^{-1}$ manure levels in all three types of soil. In Bijipur soil series, the root K content at 5 $t.ha^{-1}$ and 10 $t.ha^{-1}$ manure levels were the same in value. The root K content in Pahartali soil series at 10 $t.ha^{-1}$ and 20 $t.ha^{-1}$ manure levels were also the same. In Mirsarai soil series, the root K content at 0 $t.ha^{-1}$ and 5 $t.ha^{-1}$ chicken manure levels were statistically the same and root K content at 10 $t.ha^{-1}$ and 20 $t.ha^{-1}$ manure levels were also not significantly different with each other. The shoot K content in Bijipur and Mirsarai soil series were increased significantly ($p< 0.05$) with the increasing levels of chicken manure. In Pahartali soil series, the shoot K content were somewhat inconsistently increased from 0 to 30 $t.ha^{-1}$ manure levels. The shoot K content in Pahartali soil series at 5 $t.ha^{-1}$, 10 $t.ha^{-1}$ and 20 $t.ha^{-1}$ manure levels were not significantly different with each other (Table 2 and -3).

Determination of nutrient concentrations in plant tissues is an important tool to manage a crop fertility program. Tissue nutrient concentrations may be used to diagnose the nutrient status of a plant at the time of sampling, estimate the potential for a crop to reach optimum yield, and to time fertilizer applications[50]. However, plant age, genotype, type of tissues sampled, and environmental conditions affect tissue nutrient concentrations in vegetables[51].

According to Abdelrazzag,[52] increasing the rate of sheep and chicken manure increased the N content of onion significantly. Preusch *et al.*[53] indicated that leaf-

Table 2: Effect of chicken manure on root N, P, K concentration (%) of spinach grown in different soil series.

Treatment (t/ha)	Bijipur			Pahartali			Mirsarai		
	N	P	K	N	P	K	N	P	K
0	0.36d	0.20d	0.09d	0.38d	0.24e	0.08d	0.46e	0.22d	0.11c
	±0.03	±0.02	±0.01	±0.02	±0.03	±0.02	±0.02	±0.04	±0.02
5	0.57bc	0.23cd	0.12c	0.55c	0.37b	0.11c	0.53bd	0.26c	0.12c
	±0.08	±0.03	±0.02	±0.30	±0.08	±0.03	±0.03	±0.01	±0.01
10	0.61b	0.31bc	0.12c	0.71b	0.31d	0.13b	0.55c	0.44b	0.14b
	±0.02	±0.01	±0.01	±0.25	±0.03	±0.02	±0.00	±0.01	±0.01
20	0.73a	0.33b	0.15b	0.70b	0.35c	0.13b	0.67b	0.46a	0.15b
	±0.07	±0.01	±0.02	±0.10	±0.00	±0.03	±0.03	±0.01	±0.01
30	0.74a	0.47a	0.23a	0.82a	0.44a	0.17a	0.77a	0.45ab	0.19a
	±0.23	±0.00	±0.15	±0.11	±0.01	±0.01	±0.09	±0.01	±0.02

*Means with the same letter in columns are not significantly different at p= 0.05 level

Table 3: Effect of chicken manure on shoot N, P, K concentration (%) of spinach grown in different soil series.

Treatment (t/ha)	Bijipur			Pahartali			Mirsarai		
	N	P	K	N	P	K	N	P	K
0	0.94e*	0.11d	0.11e	0.82e	0.22e	0.11c	0.77e	0.32e	0.21e
	±0.11	±0.00	±0.01	±0.11	±0.08	±0.01	±0.07	±0.06	±0.03
5	1.16d	0.20c	0.18d	0.86d	0.26d	0.23b	1.02d	0.39d	0.29d
	±0.06	±0.02	±0.02	±0.14	±0.09	±0.03	±0.03	±0.02	±0.02
10	1.36c	0.21c	0.21c	0.92c	0.35c	0.24b	1.33c	0.44c	0.34c
	±0.07	±0.04	±0.04	±0.05	±0.02	±0.03	±0.10	±0.02	±0.01
20	1.42b	0.26b	0.27b	1.22b	0.47a	0.23b	1.54b	0.53b	0.43b
	±0.03	±0.03	±0.04	±0.02	±0.02	±0.02	±0.02	±0.05	±0.01
30	1.52a	0.34a	0.38a	1.35a	0.38b	0.27a	1.75a	0.56a	0.55a
	±0.15	±0.02	±0.01	±0.10	±0.03	±0.05	±0.17	±0.01	±0.02

*Means with the same letter in columns are not significantly different at p= 0.05 level

P in strawberry plants treated with composted and fresh poultry litter was higher than synthetic fertilizer, but the effect mainly depends on soil type. Fatma *et al.*[54] observed that a mixture of chicken manure and biofertilizer increased onion yield and nutrient content in tuber. Similarly, according to Adekiya and Agbede[55] all levels of poultry manure alone and NPK fertilizer + poultry manure increased leaf N, P and K contents significantly. Tewolde *et al.*[56] mentioned that poultry litter increased soil total N and extractable P, K, Mg, Cu, Mn, and Zn and also increased concentration of N, P, Cu, and Zn in leaves and stems.

However, often the mineral nutrient concentration is not proportional to plant biomass because increasing yields often cause a 'biomass dilution' of mineral nutrient concentration in the plant which results in a smaller nutrient concentration[57]. Generally, there is a rapid uptake of mineral during early growth and a gradual dilution as the plant matures[58]. Vimala *et al*.[59] indicated that N content in cabbage and bird-chilli did not show significant increase in N content with increasing rates of organic fertilizer.

Effects of chicken manure on the uptake of N, P and K on spinach

The root and shoot uptake of N, P and K by spinach was significantly influenced (p= 0.001) by different treatments of chicken manure (Table 4 and Table 5). The results showed that both root and shoot N, P and K uptake of spinach were significantly increased with increasing rates of the treatments in all three soils we used in this study. The highest root and shoot N, P and K uptake were observed at 30 t.ha^{-1} manure level and the lowest uptake in the studied soils were observed at their controls (0 t.ha^{-1}) (Table 4 and -5).

The root N uptake by spinach at different manure levels ranged from 0.18 to 10.21 mg/pot in Bijipur, 0.23 to 9.84 mg/pot in Pahartali and 0.78 to 10.01 mg/pot in Mirsarai soil series. The shoot N uptake ranged from 3.29 to 96.37 mg/pot in Bijipur, 3.61 to 85.45 mg/pot in Pahartali and 8.08 to 133.17 mg/pot in Mirsarai soil series. The root P uptake by spinach varied from 0.1 to 6.49 mg/pot in Bijipur, 0.14 to 5.28 mg/pot in Pahartali and 0.37 to 5.85 mg/pot in Mirsarai soil series. Shoot P uptake varied from 0.38 to 21.56 mg/pot in Bijipur, 0.97 to 24.05 mg/pot in Pahartali and 3.36 to 42.62 mg/pot in Mirsarai soil series.

The root K uptake by spinach ranged from 0.05 to 3.17 mg/pot in Bijipur, 0.05 to 2.04 mg/pot in Pahartali and 0.19 to 2.47 mg/pot in Mirsarai soil series. Shoot K uptake ranged from 0.38 to 24.09 mg/pot in Bijipur, 0.48 to 17.09 mg/pot in Pahartali and 2.2 to 41.85 mg/pot in Mirsarai soil series.

Several studies showed that plant nutrient uptake and biomass could be significantly increased by the application of manure. Sengar *et al.*[60] reported that N, P, K uptake by rice significantly increased by the application of manure. Kumar and Sharma[61] reported a maximum nutrient uptake in cabbage and tomato with FYM + 150 % NPK treatment. Meena and Gautam [62] reported that the application of FYM resulted in higher nutrient concentration and higher nutrient uptake.

Verma *et al*. [63] also found a significantly higher NPK uptake by maize-wheat cropping system by the application of 100% NPK + FYM 10 t.ha^{-1}.

Table 4: Root uptake of N, P and K (mg/pot) by spinach grown in different soils as influenced by chicken manure.

Treatment (t/ha)	Bijipur			Pahartali			Mirsarai		
	N	P	K	N	P	K	N	P	K
0	0.18e*	0.1e	0.05e	0.23e	0.14e	0.05e	0.78d	0.37e	0.19e
5	0.57d	0.23d	0.12d	1.21d	0.81d	0.24d	4.4c	2.16d	1d
10	2.44c	1.24c	0.48c	4.76c	2.08c	0.87c	4.46c	3.56c	1.14c
20	7.15b	3.23b	1.47b	9.38b	4.69b	1.74b	7.24b	4.97b	1.62b
30	10.21a	6.49a	3.17a	9.84a	5.28a	2.04a	10.01a	5.85a	2.47a

*Means with the same letter in columns are not significantly different at p= 0.05 level

Table 5: Shoot uptake of N, P and K (mg/pot) by spinach grown in different soils as influenced by chicken manure.

Treatment (t/ha)	Bijipur			Pahartali			Mirsarai		
	N	P	K	N	P	K	N	P	K
0	3.29e*	0.38e	0.38e	3.61e	0.97e	0.48e	8.08e	3.36e	2.2e
5	7.08d	1.22d	1.1d	19.44d	5.88d	5.2d	32.95d	12.6d	9.37d
10	37.67c	5.82c	5.82c	30.54c	11.62c	7.97c	55.06c	18.22c	14.08c
20	53.96b	9.88b	10.26b	53.68b	20.68b	10.12b	85.93b	29.57b	23.99b
30	96.37a	21.56a	24.09a	85.45a	24.05a	17.09a	133.17a	42.62a	41.85a

*Means with the same letter in columns are not significantly different at p= 0.05 level

Alabadan *et al.*[64] reported that poultry manure increased availability and supply of P, K, and Mg in the soil as well as the solubility of Ca and Mg, enhancing uptake. In a study conducted by Kundu *et al.*[65] observed that incorporation of farmyard manure (along with chemical NPK fertilizers) increased the N uptake over 100% NPK. Highest uptake of K was also reported by Dhaliwal *et al.*[66] under combined use of FYM and recommended dose of fertilizers which might be attributed to the conditions that are favorable for crop growth and supply of K through FYM in addition to chemical fertilizers.

Conclusions

Applications of chicken manure enhanced growth parameters and uptake of N, P and K in spinach over the controls irrespective of soil types. Among the rates, the highest dose (30 $t.ha^{-1}$) used had the highest effect. However, chicken manure may also contain toxic heavy metals and its application may accumulate in soil and increase uptake in plants as well. Therefore, for optimum utilization of chicken manure and food safety, future research will be needed to investigate the level of toxic metal contamination in chicken manure and its potential bioavailability to plants.

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No potential conflict of interest was reported by the authors.

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