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Survey Yield Components of Spinach under Influence of Biofertilizer and Nutrient Solution in Soils of Chengdu, Hunan, Shannxi and Xiaotanshan, China

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ABSTRACT

Several studies in the temperate region have indicated that biofertilizer have the potential to improve soil properties but may also cause serious reduction in soil productivity. We studied the effects of biofertilizer and nutrient solution application on soil properties and yield of spinach (*Spinacea oleracea* L.) on four soil types of Chengdu, Hunan, Shannxi and Xiaotangshan, Beijing, China. Two profile pits were sited on each of the location of the soil unit and were described before soil samples collection from the genetic horizons of each pit for analysis of soil properties. Soil total nitrogen, available phosphorus, calcium, magnesium, potassium and CEC were significantly ($p<0.05$) enhanced with biofertilizer treated soils of Chengdu and Hunan and spinach performance was significant compared to nutrient solution treated soils. The growth of salt-sensitive spinach was very poor on Shannxi and Xiaotangshan soils with biofertilizer. Spinach height and dry matter yield after six weeks were significantly improved ($p<0.05$) on the biofertilizer treated soils of Chengdu and Hunan compared to Shannxi and Xiaotangshan soils and soil with nutrient solution. These results indicated that the application of biofertilizer and nutrient solution application should done with better understanding of soil properties because of its negative effects on soils and crops.

Keywords: Biofertilizer, Nutrients solution, Spinach, Soil properties.

INTRODUCTION

The use of biofertilizer to promote spinach (*Spinacea oleracea* L.) vegetable cultivation and enhancing soil fertility has significant implications in agricultural sector. Organic manure is widely accepted as the most desirable fertilizer types because of its high nitrogen content (Ghanbarian *et al*., 2008). They constitute good source of micro nutrients and soil amendment when adequately and timely incorporated into soil (Ouda *et al*., 2008). The natural soil organic matter content varies with soil type, temperature, amount of rainfall, drainage, and microbial soil organisms (Chen *et al*., 2013; Soleymani *et al*., 2016; Shahrajabian *et al*., 2017; Yong *et al*., 2017). Organic manure is a good soil amendment by enhancing soil moisture, stability of soil aggregates (Soleymani and Shahrajabian, 2012; Soleymani *et al*., 2012; Ogbaji *et al*., 2013). Organic manure has tremendous effects on growth and dry matter yield of vegetable (Gharib *et al*., 2008). There are excellent sources for macro and micro nutrients that can be easily obtain from raw annual wastes, animals beddings materials, sawdust, grasses and rice husks. Similar nitrate increased was reported in silty loam textural soil to a depth of 1.2 m (Adams *et al*., 1994). Spinach is an annual crop with short life cycle, which thrives well in warm environment can stand frost. The soil pH which is the degree of acidity or alkalinity can affect nutrient availability and element toxicity. Soil salinity is mostly associated with high application of biofertilizer which spinach is sensitive to, especially soil with electrical conductivity (EC) above 4 dSm^{-1} (Stephenson *et al*., 1990). There is dearth of relevant information on soil physico–chemical properties and organic manure uses, and we hope this work will shade more light on all the relevant information on soil physico-chemical properties and organic manure application. The objectives of this study were to characterize the soil physico-chemical properties in response to biofertilizer and nutrient solution application and to assess beneficial and adverse effects of these fertilizers on yield of spinach in four soil types.

MATERIALS AND METHODS

This experiment was conducted in National Experimental Station for Precision Agriculture greenhouse Xiaotangshan (40º10´N, 116º27´E) Beijing China, during summer growing seasons. Prior to the greenhouse, experiment selected sites were visited and two profile pits sited on identifiable soil units base on their elevations, GPS readings and vegetation changes. Soil samples were collected from undisturbed walls of the profile pits to a depth of 1.5 m from genetic horizons 0–30, 30–60, 60–90, 90–150 cm. The locations where soil samples were collected were characterized by Continental Monsoon Climates especially in semi-arid regions and sub-tropical climates of southern region. All soil samples were properly labeled and transported to National Experiment Station for Precision Agriculture greenhouse. Routine laboratory soil analysis carried out in Nercita. Three kg weight of soil samples from all the soil layers were weighed in three replicates including controls into plastic containers of 30 cm diameter. The soils were treated with biofertilizer at a blanket rate of 100 g per pot and 600 ml nutrient solution and were thoroughly mixed and watered. Spinach seeds, Goldfox was obtained from Shun Yuan seed Co. Ltd. Soil samples from the four different locations used for more detailed studies of physico-chemical properties were soils of different parent materials. Chengdu soil developed from highly weathered glacial drift, Hunan is a wet alluvium soil, Shannxi soil developed on colluvial material of loessial origin, which is characterized with heavy clay, and Xiaotangshan soil formed from colluvium materials of semi-arid region with massive clay-pan formation.

Mechanical analysis was done by the hydrometer method. Soil pH was measured with a glass electrode using a 1:1, suspension ions of calcium, potassium and sodium were determined in ammonium acetate leachate with a Beckman flame photometers. Magnesium was determined by the method of Yien and Chesnin (1953) while Hydrogen ions were identified by the method of Woodruff (1938). CEC was measured by Kjeldahl determination of absorbed NH_4^+ after leaching with N ammonium acetate.

Uniform seeds germination activated through pre-soaked of seeds, placed on a moist tissue paper in a glass ware and oven dry at optimum temperature of 2 ^oC for thirty hours, Spinach seeded directly at rate of ten seeds per pot and later thinned to five stands per pot which grow to maturity. The pots manually weeded, irrigated thrice a week as per specific crop water requirement to field capacity. The mean application volume of irrigation water was 1000 cm^3 per pot thrice a week. Planting date was may, 14, 2013 and monitoring period lasted for 60 days (8 weeks)

Plant growth and yield components from biofertilizer, nutrient and solution treatments and soil types were evaluated in terms of plant percentage emergence, height, leaves number of, leaf areas and dry biomass in three replicates. Plant height was measured using metallic tape ruler, growth rate (cm/week) monitored on weekly basis. Five leaves randomly sampled per pot for leaf areas determination (cm^2/pot) using leaf areas meter. Dry biomass was determined by collection of leaves per pot stored in a pre- weighed sampling bag labeled and oven dry at a temperature of 40 ^oC for at least 48hrs to a constant weight. Data were analyzed using ANOVA to compare treatment means for each at 5% probability, level significance (using Statview statistical software program).

RESULTS AND DISCUSSION

The extreme variations which occur among the soil types are illustrated by soils from four locations in Table 1. Mechanical soil analysis and cations level of various horizons are also shown in Table 1. The main textural characteristics of soils from the four locations were as follows: Chengdu, sandy loam; Hunan, sandy clay loam; Shannxi, clay loam and Xiaotanshan, sandy clay loam (Table 1).

Table 1. Mechanical analysis, pH, total nitrogen (%), available phosphorus, exchangeable cations and cation exchange capacity of Chengdu, Hunan, Shannxi and Xiaotanshan soils at different depths.

Depth (cm)	Mechanical Analysis						Exchangeable Cations cmol kg^{-1}				Exchangeable Acidity		CE (cmolkg)	ECEC ($cmolkg^{-1}$)
	% Sand	% Silt	% Clay	pH	Total N(%)	Av. Phosph (mg kg^{-1})	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}	Al^{3+}		
Sandy Loam (Chengdu)														
0-30	66.2	30	3.8	6.8	0.18	27.5	5.87	0.54	0.15	-	0.72	1.75	8.31	9.03
30-60	64.2	32	3.8	6.9	0.07	7.3	1.89	0.08	0.01	0.05	0.77	3.55	5.58	6.35
60-90	54.2	34	11.8	7.1	0.09	6.1	2.37	0.7	0.12	0.08	1.19	3.35	6.62	7.81
90-150	48.2	32	19.8	7.1	0.07	2.4	2.86	1.96	0.14	0.09	0.77	3.14	8.19	8.96
0-30	64.2	32	3.8	6.9	0.17	26.7	6.25	0.49	0.14	0.01	0.72	1.67	8.55	9.27
30-60	62.2	34	3.8	7.2	0.07	6.54	3.68	0.05	0.02	0.05	0.77	2.57	6.37	7.13
60-90	56.2	32	11.8	7.2	0.09	5.25	2.37	0.68	0.11	0.08	1.15	2.24	5.47	6.62
90-150	52.5	34	13.8	7.1	0.05	2.35	2.36	1.87	0.14	0.09	0.16	2.17	6.63	6.76
Sandy Clay Loam (Hunan)														
0-30	52.2	26	21.8	5.8	0.07	0.6	5.31	0.74	0.12	0.03	0.73	1.76	8.34	9.01
30-60	56.2	22	21.8	5.7	0.05	0.4	1.43	0.06	0.06	0.05	0.78	3.55	5.59	6.35
60-90	76.2	16	21.8	5.6	0.05	0.4	2.11	0.64	0.12	0.07	1.19	3.37	6.6	7.75
90-150	62.2	18	19.8	5.5	0.04	0.4	2.74	1.57	0.15	0.1	0.77	3.11	8.2	8.75
0-30	54.2	24	21.8	5.8	0.07	0.56	6.2	0.39	0.11	0.05	0.72	1.68	8.56	9.27
30-60	61.2	18	20.8	5.6	0.05	0.42	3.68	0.03	0.05	0.07	0.76	2.58	6.35	7.14
60-90	74.2	20	5.8	5.4	0.04	0.4	2.37	0.64	0.14	0.08	1.15	2.22	5.45	6.61
90-150	56.2	16	27.8	5.3	0.03	0.4	2.46	1.78	0.14	0.04	0.19	2.17	6.62	6.76
Clay Loam (Shannxi)														
0-30	30.2	34	35.8	7.2	0.09	2.46	57.74	1.72	0.1	0.04	0.62	1.55	61.2	61.8
30-60	28.2	36	35.8	7.1	0.05	1.6	60.45	1.87	0.08	0.02	0.57	1.43	63.9	64.4
60-90	24.2	32	43.8	7.1	0.03	1.8	32.66	2.03	0.12	0.29	0.36	1.49	36.6	36.9
90-150	26.2	38	35.8	6.2	0.02	2.15	35.85	1.87	0.11	0.11	0.16	0.88	36.8	36.9
0-30	28.2	36	35.8	7.2	0.07	2.38	58.63	1.69	0.09	0.1	0.64	1.57	62	62.7
30-60	26.2	38	35.8	7.1	0.05	1.57	63.15	1.78	0.09	0.13	0.54	1.53	66.7	67.2
60-90	24.2	32	43.8	7.1	0.04	1.51	28.16	1.84	0.11	0.12	0.34	1.38	31.6	31.9
90-150	22.2	34	43.8	6.9	0.03	1.64	24.18	1.83	0.1	0.1	0.23	1.21	27.4	27.7
Sandy Clay Loam (Xiaotanshang)														
0-30	56.2	22	21.8	7.3	0.14	47.15	16.4	4.63	0.13	0.12	0.36	1.49	22.8	23.1
30-60	30.2	30	39.8	7.1	0.06	1.4	32.3	6.72	0.19	0.59	0.16	1.49	41.31	41.5
60-90	18.2	36	45.8	7.2	0.06	0.15	70.24	7.96	0.24	0.55	0.21	0.88	79.9	80.1
90-150	62.2	32	15.8	7	0.03	2.2	83.3	5.28	0.03	0.36	0.16	0.67	89.7	89.9
0-30	53.2	25	21.8	7.2	0.13	48.06	15.5	5.54	0.11	0.14	0.38	1.39	22.7	23.3
30-60	27.2	33	39.8	7.3	0.05	1.27	31.63	5.93	0.18	0.49	0.15	1.51	39.8	39.8
60-90	17.2	37	45.8	7.2	0.04	0.87	71.34	8.16	0.22	0.56	0.23	0.9	81.2	81.4
90-150	59.2	22	28.8	6.9	0.02	1.94	82.2	4.49	0.63	0.35	0.15	0.67	85.7	88.7

Soil physical properties of Shannxi revealed higher clay content percent in its surface layer and lower total nitrogen content than other locations (Table 1). Chengdu and Hunan soils were fine structured, Hunan soil although acidic had nice mineral nutrients distribution through its depth of 1.5m. The exchangeable bases were quite sufficient for plant nutrition and organic matter nitrification. Chengdu soil total nitrogen ranked highest among the studied soils. Available phosphorus was low in almost all the soils but quite sufficient to promote growth. The Calcium and Magnesium content of Shannxi and Xiaotangshan soils were optimum for plant growth but potassium level was lower than all the studied soils. The degree of soil development or nutrients depletion within certain horizons is an expression of the varying intensity with which physical and chemical forces have operated at varying soil depths. Nutrients deficiency has become a major constraint to productivity and sustainability of soils.

Soil types and Spinach Development

The physico-chemical variability of soils properties of four locations was reflected on spinach physiological development. The results of variance analysis for different traits is shown in Table 2. Plant growth relative to soil properties is presented in Table 3. The fine surface soil structure of Chengdu and Hunan were the results of their moderate clay content with low to high nutrient contents. Physical and Chemical properties variability account for differences in plant growth and yield components. The effects of biofertilizer and nutrient solution on plant emergence percent, plant high, leaf number, leaf area and dry biomass exerted in consistent but significant difference ($p<0.05$) on spinach growth (Table 3). The differences in horizonation between soils used for the potted experiment had some influences on spinach yield. A marked difference in spinach yield of the different soils was a reflection of variability in soil physico-chemical properties.

Most of the top soil layers were more favorable to seeds emergence than the sub surface soils. The mean growth and yield components were statistically different ($p<0.05$). The highest plant height obtained from Chengdu top soils treated with biofertilizer while the least height were found for sub soil layers and nutrients solution treated soils. Shannxi soil plants were stunted compared to other soils which may be as result of high clay percentage, poorly drained sub surface layers and high salinity which is in contrast to other studies (Davis *et al*., 2006; Ouda and Mahadeen, 2008). The soils from different depths and treatments have significant effect on plant emergence percent. The average number of leaves per plant was significantly ($p<0.05$) different across all treatments and soil types. The highest leaf numbers was obtained from top soil plants treated with biofertilizers. Hunan soil produced the highest leaf number per plant. Leaf area similarly, follow the same trend with a significant effect of ($p<0.05$) of location, soil depth and treatment including their interactions (Table 2). There was significant effect ($p<0.05$) of location, soil from different depth and treatment on dry biomass, however location x soil depth showed significant effects ($p<0.01$). The interactions of location x treatment, depth x treatment and location x depth x treatment had significant effect ($p<0.05$) on dry biomass (Table 2). Top soils potted plants treated with biofertilizer produced high dry biomass due to greater canopy formation and leaf area expansion (Tollenaar and Wu, 1999). The highest amount of biomass was from Hunan soil, which was influenced by micro nutrients presence such as zinc in biofertilizer (Khan *et al*. 2004). In low phosphorus soil content such as the studied soils, favorable phosphorus-zinc ratio could promote balance plant nutrition, better root development, and vigorous growth (Zhu *et al*., 2001; Rajie *et al*., 2009).

Table 2. Summary of ANOVA for plant emergence (%), height, leaf No, leaf area and dry biomass of spinach across four location soils and depth under biofertilizers and nutrient solution.

Source of variation	Df	Plant emergence	Plant height (2 wk) (cm)	Plant height (4 wk) (cm)	Plant height (6 wk) (cm)	Leaf No. (2 wk)	Leaf No. (4 wk)	Leaf No.(6 wk)	Leaf area (cm^2)	Dry biomass (g/pot)
Location	3	131.99ns	3.77**	11.01**	18.23**	43.64**	107.64**	135.28*	950.37**	22.49**
Depth	3	318.33**	2.76**	8.43**	73.37**	5.32**	8.38**	88.65*	858.03**	4.6**
Treatment	2	209.69*	19.85**	70.18**	475.75**	30.06**	14.09**	294.09**	10634.87**	46.04**
Location × Depth	9	43.87ns	0.45**	10.14**	7.45**	1.43ns	5.03*	44.73ns	98.24**	0.39*
Location × Treatment	6	73.28ns	0.32*	2.70**	5.62**	6.03**	11.94**	102.04*	346.17**	1.46**
Depth × Treatment	6	27.56ns	0.72**	1.35*	14.99**	0.85ns	3.07ns	37.49ns	350.05**	1.11**
Location × Depth × Treatment	18	33.82ns	0.12ns	3.42ns	5.51**	0.60ns	1.96ns	31.20ns	143.85**	0.68**

Ns , * and **: non significant a significant at 5 and 1 % probability levels.

Table 3. Plant emergence, plant height, leaf number, leaf area and dry biomass of spinach across four locations and depth under biofertilizers and nutrient solution.

Experimental factors	Plant emergence (%)	Plant height 2 wk (cm)	Plant height 4 wk (cm)	Plant height 6 wk (cm)	Leaf No. 2 wk	Leaf No. 4 wk	Leaf No. 6 wk	Leaf area (cm^2)	Dry biomass (g/pot)
Location soil									
Chengdu	74.5	4.4	9.6	16.07	7.05	12.81	18.55	79.36	4.35
Hunan	72.4	4	9.5	17.12	5.42	12.14	19.72	89.45	4.88
Xiaotanshan	74.8	4.2	9	17.78	4.75	16.08	21.38	78.06	3.03
Shannxi	70.7	3.6	8.4	16.81	4.69	13.94	16.86	83.66	3.83
LSD (5%)	3.4	0.15	0.36	0.47	0.36	0.62	2.83	2.28	0.16
Dept (D)									
A	75.8	4.4	9.45	18.61	5.94	14.25	19.58	87.67	4.38
B	75.3	4.2	9.55	17.59	5.61	14.03	21.22	84.99	4.23
C	71.6	3.9	8.9	16.11	5.31	13.5	18.31	81.53	3.92
D	69.6	3.7	8.5	15.45	5.06	13.19	17.67	76.36	3.57
LSD (5%)	3.4	0.15	0.36	0.47	0.36	0.62	2.83	2.28	0.16
Treatment (t)									
Biofertilizer	74.5	4.6	10.37	21.15	6.33	14.29	21.85	96.35	4.96
Control	70.7	3.4	7.95	13.34	4.77	13.21	16.96	66.8	3.01
Nutrient Solution	74.2	4.1	9.04	16.32	5.33	13.73	18.77	84.76	4.09
LSD (5%)	2.9	0.13	0.32	0.41	0.31	0.53	2.45	1.98	0.14
Interaction									
Location×depth	ns	**	**	**	*	**	ns	**	**
Location×treatment	ns	**	**	**	**	**	*	**	**
Depth×treatment	ns	**	*	**	ns	ns	ns	**	**
Location×depth×treatment	ns	ns	**	**	ns	ns	ns	**	**

CONCLUSION

The effect of some physical and chemical properties of Chengdu, Hunan, Shannxi and Xiaotangshan soils relative on spinach growth with biofertilizer and nutrient solution was carryout in greenhouse, Beijing China. Limited growth of spinach was observed in soils of Shannxi due to high percentage of heavy vertic clay with poor drainge and aeration, high salinity, low phosphorus and nitrogen content. The shrinking, cracking and subsequent damage to plant root as the result of reactive nature of this clay may be a which limiting factor for growth. Xiaotangshan soils were characterized by clay pan formation in the sub surface layers poses problem to root development and growth. Phosphorus nutrient distribution within the soil layers was limited due to clay pan. There were no adverse effects on spinach yield in Chengdu and Hunan soils. These soils are characterized by moderate phosphorus distribution level throughout their profiles and have fine structures. Spinach grown in soil medium amended with biofertilizer exhibited a more vigorous growth (seeds emergence, height, number of leaves, leaf areas and dry biomass) than those amended with nutrient solution. Based on the results and conclusions from this study, vegetable farmers from Chengdu and Hunan should take advantage of the soil properties and engage on large scale vegetables cultivation. This study demonstrated the importance of soil properties relative to application of biofertilizer and nutrient solution on vegetables.

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