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IMPACT OF BIO-FERTILIZER OR NUTRIENT SOLUTION ON SPINACH (*SPINACEA OLERACEA*) GROWTH AND YIELD IN SOME PROVINCE SOILS OF P.R. CHINA

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ABSTRACT. A study was conducted to assess the effects of a bio-fertilizer and an inorganic fertilizer on growth, yield of spinach vegetable, on four cultivated soils, representing different agro-ecological zones of Chengdu, Hunan, Xiaotangshan and Shaanxi. Three replicates soil samples mixed with bio-fertilizer 100 g per pot and nutrient solution ($MgSO_4$, $Ca(NO)_2$, KNO_3) 633 ml based on container volume. Spinach seeded directly ten per pot, thinned to five watered to plant water requirement until maturity. RCBD of three replication used, data for growth, yield and other agronomic characters and soil physicochemical properties evaluated. Soil results showed substantial differences in physicochemical properties from the four agro-ecological zones (Ferrod Arenosol, Entisol, Aridisol and Vertisol). Plant emergence percent were Xiaotangshan (74.8%), Chengdu (74.5%), Hunan (72.4%) and Shaanxi (70.7%), plant height at six week, Xiaotangshan (17.8 cm), Hunan (17.1 cm), Shaanxi (16.8 cm) and Chengdu (16.1 cm) the least, number of leaves at six weeks were Xiaotangshan (21), Hunan (19) and (16) Shaanxi, leaf area Hunan (89.5 cm²), Shaanxi (83.7 cm²), Chengdu (79.4 cm²) and Xiaotangshan (78.1 cm²), dry biomass of 4.88, 4.35, 3.83 and 3.03 g obtained for Hunan, Chengdu, Shaanxi and Xiaotangshan, respectively. Percentage plant emergence based on soil layers were 0-25 cm (75.8%), 25-50 cm (75.3%), 50-75 cm (71.6%) and 75-100 cm (69.6%), respectively; highest plant emergence percentage were obtained from top soil layer of Hunan, treated with bio-fertilizer. Substantial differences were observed for plant height, biomass and other agronomic characters in all the soils. The results show that Hunan soil is the most suitable for cultivation of spinach under bio-fertilizer treatment, compared to other types. The study underpins the importance soil

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types and fertilizer evaluation for a sustainable vegetable production in China.

Keywords: inorganic fertilizer; physicochemical properties; dry biomass; agro-ecological.

INTRODUCTION

Spinach vegetable is among the oldest vegetable crops in the world and success stories of its cultivation is attributed to the plant genetic physiological flexibility, that allows for adaption to wide range of environments. The nutritional value of this vegetable is highly rated (Khandaker *et al.,* 2008). It's high rate nutritional value coupled with easy environmental adaption make the vegetable crop suitable for improving vegetable food security and reducing micro nutrients malnutrition globally (Soleymani *et al.,*2011a,b; Ogbaji *et al.,* 2013; Soleymani & Shahrajabian, 2011). Research has shown that vegetable cultivation can be improved under good soil management and ideal fertilization (Turan & Sevimli, 2005; Khoshkharam *et al.,* 2010; Moradi *et al.,* 2010; Soleymani *et al.,* 2011b). Organic fertilizers has been recognized as the best natural soil amendment, especially poultry manure, because of its high nitrogen content (Bok *et al.,* 2006). Organic manures are natural sources for macro and micro nutrients, which also improve soil physical properties (Chescheir *et al.,* 1986; Duncan, 2005; Davis *et al.,* 2006; Soleymani *et al.,* 2012; Shahrajabian & Soleymani, 2017). Production of organic fertilizer constituted means of livelihood for many rural and urban dwellers, mostly in developing countries. It is undisputable fact, fertilizers enhanced vegetable crop yield (Edwards *et al.,* 1992), but application must be based on comprehensive soil properties evaluation. With the rapid population growth and limited land resources, soil need to be properly manage for a sustainable crop production (Soleymani *et al.,* 2010; Soleymani & Shahrajabian, 2012a,b).

According to Prasad *et al.* (1997), soil fertility management is pivotal to development of sustainable food system. Fertilizer efficiency depends more on soil properties, in respect of vegetable crops cultivation (Soleymani *et al.,* 2013; Soleymani *et al.,* 2016). Bio-fertilizer couple with good soil environment influence plant growth and dry biomass yield, as a result of active hormonal root development simulation with high nitrogen supply power (Gharib *et al.,* 2008). Soil microbial activities are greatly enhanced in soil with good physicochemical properties. Thus, fertilizers use should be handled with adequate precautions mostly in high clay content soils, due to adverse effects on crops (Edwards *et al.,* 1992). Spinach often tolerate frost and can be cultivated throughout the whole year. The crop performed well in sandy loam texture soil, pH range of 6.6 to 6.8. Although spinach can be cultivated on wide range of soils (Van Antwerpen & Aves, 2000; Bok *et al.,* 2006), soil of poor properties should be avoided since plant nutrients are in soluble salts form, excessive absorption will have adverse effect on plant growth. Soil electrical conductivity of approximately 11 dS m^{-1} is too high for spinach normal growth, which is sensitive to salinity (Stephenson *et al.,* 1990). The presence of high amount of Na^{+} and Cl^{-} ions affects absorption of other vitals ions, such as Ca^{2+}, K^{+}, Mg^{2+}, even N or P, which are very important for plant growth.

This study was carried out as to evaluate the effect of soil properties, bio-fertilizer and inorganic fertilizer on growth and yield of spinach in selected provincial of China for a sustainable vegetable production.

MATERIALS AND METHODS

A greenhouse pot experiment conducted at the National Experiment Station for Precision Agriculture Xiaotangshan (40º10´N, 116º27´E), Beijing, China, during summer growing season, 2013. Soils sampled from four provinces Chengdu, Hunan, Shaanxi and Xiaotangshan to a depth of 0-100 cm, crops rooting zones. These agro-ecological zones are characterized with different climates ranged from continental monsoon in semi-arid region of Shaanxi and Xiaotangshan to sub-tropical humid of Chengdu and Hunan. Soil samples properly labeled and forwarded to National Experiment Station for Precision Agriculture greenhouse for preparation and laboratory soil analysis. Three kilogram (3 kg) weight of soil per soil layer (0-25, 25-50, 50-75, 75-100 cm) weighed in three replicates include controls in equal size plastic containers of 30 cm diameter. The soils samples were mixed with bio-fertilizer (BF) of 100 g per pot and nutrient solution of $MgSO_4$, $Ca(NO_3)_2$, $K_2(NO_3)_2$ of 633 ml based on container volume, which was one-third of soil volume. Containers watered to field capacity and Goldfox spinach seeds obtained from Shun Yuan seed co Ltd, directly seeded ten per pot later thinned to five. Each treatment was replicated thrice in a completely randomized design (CRD). The soil texture varied from loamy sand, sandy loam, clay loam and clay for Chengdu, Hunan, Xiaotangshan and Shaanxi, respectively. Mechanical soil analysis determined by hydrometer method, while the soil pH measured with glass electrode using a 1:1, suspension ions of calcium, potassium and sodium were determined in ammonium acetate leachate with a Beckman flame photometers. Uniform seeds germination, activated through pre-soaked of seeds, placed on a moist tissue paper in a glass ware then oven dry at optimum temperature of 2^{o}C for thirty hours. 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. Physiological process, in respect of data collection during growth stages carefully monitored and harvested at six weeks. The plant yields from each soil layer and treatment evaluated in terms of edible parts leaves, shoot length, biomass (dry) weighed. Shoot length measured using 30 cm ruler and growth monitored on weekly bases until maturity. Three leaves of plants were sub-sampled per pot to determine leaf area (cm^2/plant). The leaves per plant pot collected then oven dried at 70ºC 48 hrs to constant weight for dry biomass determination. Statistical analysis: Data obtained in the experiment were subjected to variance analysis (ANOVA), appropriate to the experimental design. The relationships between soil properties, growth and yield of spinach were determined.

RESULTS AND DISCUSSION

A. Comparison of spinach growth and yield on different soils under bio-fertilizer and inorganic fertilizer treatments

Soil basic properties at different depths presented in (*Table 1*) showed significant influence on growth and yield of spinach. On soil pH however, variation in soil profile with respect to depth was found to be significant, soil pH varied from 4.8 to 7.3 in Hunan (sub-humid climate) and Xiaotangshan in arid region, respectively. Electrical conductivity was non-significant for locations and varies from 0.1 to 0.3 and 20.0 mS/cm for bio-fertilizer. Soil electrical conductivity is important for facilitating a spatial understanding of soil-water-plant relationships. The soils were predominantly alkaline, except Hunan soil that was acidic, due to leaching of cations caused by precipitation. The content of exchangeable sodium varies from 0.1 to 0.4 cmol/kg and showed non-significant different for the location and 0.8 cmol/kg for bio-fertilizer. Potassium varies from 0.1 to 0.4 for location and 1.6 cmol/kg for BF, calcium ranges from 3.5 to 5.5 and 9.9 cmol/kg, while magnesium varies from 0.6 to 1.8 and 0.7 cmol/kg for locations and bio-fertilizer. No consistent trend of increase or decrease in nutrient content in soil depth was observed for exchangeable cations in the locations studied. Similar results had been reported for Ca, Mg, and Na by Sharma *et al.* (2009). Available N and P content were significantly influenced by locations and soil depths (*Table 1*). Nitrogen content tends to be same in all the locations, decrease with soil depths and nitrogen buildup in the top layer is attributed accumulation of biomass (Juo & Lal, 1977; Srinivasan & Caulfield, 1989). Phosphorus varies from 0.5 to 13.0 and 8.5 mg/kg for location and bio-fertilizer, respectively, low phosphorus attributed to acidic nature and low biomass for P recycling.

Hunan and Shaanxi soils were highly deficient in phosphorus (*Table 1*). In acid soils, phosphate ions tends to react with soluble iron and aluminum ions to form insoluble phosphates adsorbed to surfaces of insoluble iron, aluminum and manganese hydrous oxides. Although bio-fertilizer and inorganic fertilizer are very important to augment soil natural fertility in agricultural productivity, it should be noted inorganic fertilizers are not too environment friendly. Public and private sectors have made observations about the unsustainability of inorganic fertilizers on farm operations from economic and ecological point of view. Soil physicochemical properties had significant effect on spinach physiological development and yield. Various stages of growth under different soils, fertilizer and control are presented on (*Table 2*). The results illustrated soil locations had no significant effect on plant emergence, Soil depths and treatments were significance on emergence with depths highly significant (*Table 3*).

Table 1 - Soil physicochemical characteristics for Chengdu, Hunan, Shaanxi, Xiaotangshan and bio-fertilizer basic properties used for the experiment

Soils types	Sand	Silt	Clay	T - Class	pH	EC (ms/cm)	Na^{+} (Cmol Kg^{-1})	K^{+} (Cmol Kg^{-1})	Ca^{++} (Cmol Kg^{-1})	Mg^{++} (Cmol Kg^{-1})	N	P (mg)
Ferrod A	58.37	32.50	9.13	L S	7.2a	0.1a	0.06a	0.10a	3.47a	0.79a	0.10a	10.5a
Entisol	61.49	20.00	18.51	S L	4.8b	0.01a	6.06a	0.39b	3.49b	0.64b	0.05b	0.45b
Aridisol	40.30	30.00	30.90	C L	7.3a	0.2a	0.39b	0.14c	5.49c	6.09c	0.07c	12.96c
Vertisol	26.12	35.00	38.88	C	7.2a	0.3a	0.09c	0.22d	4.85d	1.83d	0.06d	1.89d
Bio - fertilizer					7.3a	19.8b	0.82d	1.63e	9.87e	0.72e	0.03e	8.49e

LS = Loamy sand, SL = Sandy loam, CL = Clay loam, C = Clayey. Values with same letter in each column are not significantly different (p>0.05) from each other.

Table 2 – Spinach emergence, plant height, leaf number, leaf area and dry biomass across four locations, soil depths under bio-fertilizer and nutrient solution

Locations	Emergence (%)	Plant height (cm)			Leaf number			Leaf area (cm^2)	Dry biomass (g/pot)
		2 Weeks	4 weeks	6 Weeks	2 Weeks	4 Weeks	6 Weeks		
Chengdu	74.5	4.4	9.6	16.07	7.05	12.81	18.55	79.36	4.35
Hunan	72.4	4.2	9.5	17.12	5.42	12.14	19.72	89.45	4.88
Xiaotangshan	74.8	4.2	9.0	17.78	4.75	16.87	21.8	78.38	3.03
Shaanxi	70.7	3.8	8.4	16.81	4.69	13.94	16.86	83.66	3.83
L.S.D (0.05)	0.0644	0.0001	0.001	0.0001	0.0001	0.0001	0.0146	0.0001	0.0001
Soil depth									
A	75.8	4.4	9.4	18.61	5.94	14.25	19.58	87.67	4.38
E	75.3	4.0	9.5	17.59	5.61	14.03	21.22	84.99	4.23
B	71.6	4.2	8.9	16.11	5.30	13.50	18.31	81.53	3.92
C	69.6	3.6	8.5	15.45	5.05	13.19	17.67	76.36	3.57
L.S.D (0.05)	0.008	0.0001	0.0001	0.0001	0.0001	0.0036	0.0710	0.0001	0.0001
Treatment									
Bio-fertilizer	74.5	4.7	10.4	21.2	6.33	14.29	21.85	96.35	4.96
Control	70.7	3.4	7.9	13.3	4.77	13.21	16.96	66.80	3.01
Nutrient Solution	74.2	4.1	9.0	16.3	5.33	13.73	18.77	84.76	4.09
L.S.D (0.05)	0.0222	0.0001	0.0001	0.0001	0.0001	0.006	0.066	0.0001	0.0001
Interaction									
L*D	NS	**	**	**	*	*	NS	**	*
L*T	NS	*	**	**	**	**	*	**	**
D*T	NS	**	*	**	NS	NS	NS	**	**
L*D*T	NS	NS	**	**	NS	NS	NS	**	**

B. Soil physicochemical properties through and spinach development and yield

Results showed differences in soil physicochemical properties from agro-ecological zones reflected on spinach physiological development and yield. *Table 1* presented varied soil properties from the four agro-ecological zones. Chengdu and Hunan soils were characterized with low to moderate clay (10-19%). Soil physicochemical properties variations accounted for differences in plant growth and other agronomic characters. Effects of bio-fertilizer and inorganic fertilizer on plant emergence percent, plant high, leaf number, leaf area and dry biomass exerted inconsistent but significant effect ($p<0.05$) on spinach growth (*Table 3*). Soil depths and treatments exhibited highly significance and significance effects on percentage emergence ($p<0.01$). The plant heights at two, four and six weeks were almost the same statistically for location, depth and treatment ($p<0.01$), but interactions at week two, location and depth ($p<0.01$), location and treatment ($p<0.05$), at week four both were ($p<0.01$) and same trend at six week, including location, depth and treatment. The leaf number at two, four and six weeks had ($p<0.01$) highly significance effects on location, depth and treatment. While leaf numbers showed differences in interaction effect of location and treatment ($p<0.01$) on week two, week four, location and depth had ($p<0.05$) significant effect, but location and treatment were ($p<0.01$) highly significant, the only significant interaction effect on leaf number at six week was location and treatment ($p<0.05$). The location, depth and treatment with the interactions exhibited highly significant effect ($p<0.01$) on leaf area. Soil location, depth and treatment were highly significant ($p<0.01$) on dry biomass exception of location and depth interaction that were ($p<0.05$) significant *Table 3*. The highest plant height was from Xiaotangshan, with a mean height of 17.9 cm, leaf number of 21, followed by Hunan with plant height of 17.1 cm, leaf number of 20, Shaanxi was least with 17 cm, leaf number of 17, least plant height of 16 cm, from Chengdu, with high leaf number of 19, compared to Shaanxi (*Table 2*). The leaf area mean of 89.5 cm^2 was highest from Hunan soil under bio-fertilizer, followed by 83.7 cm^2 for Shaanxi, Chengdu with 79.4 cm^2, Xiaotangshan with 78.1 cm^2 least (*Table 2*).

Another study by Xu *et al.* (2005) showed that vegetables treated with organic (fertilizers) grows better and produce higher yield than ones treated with inorganic fertilizer or treatment. The dry biomass weights were 4.9, 4.4, 4.0 and 3.0 g per container for Hunan, Chengdu, Shaanxi and Xiaotangshan, respectively (*Table 2*), stunted growth observed among plants without treatment. The soil depths and treatments had significant effect on plant emergence percentage. The average number of leaves per plant was significant (at $p<0.05$) different across all treatments and soil types. The highest leaf numbers were from plants grown on top soil under bio-fertilizer treatments. Hunan soil produced the highest leaf number per plant, leaf area followed the same trend with a significant effect of $p<0.05$ for location, depth and treatment with interactions. Also, significant effect of $p<0.05$ for location, depth and treatment on dry biomass, however location, depth interaction showed highly significant effect of $p<0.01$. The interactions of location × treatment, depth × treatment and location × depth × treatment exhibited significant effect of $p<0.05$ on dry biomass (*Table 3*). Top soils plants treated with bio-fertilizer produced high dry biomass due to greater canopy formation and leaf area expansion attributed to adequate soil fertility (Tollenaar & Wu, 1999). Also, presence of some micro nutrients, such as zinc in bio-fertilizer under favorable soil properties accounted for high yield (Khan *et al.,* 2004). In low phosphorus, soil favorable phosphorus-zinc ratio will promote balance plant nutrition, better root development and vigorous growth (Gutierrez-Boem & Thomas, 1999; Rajaie *et al.,* 2009; Soleymani *et al.,* 2016).

Table 3 - ANOVA table on plant emergence (%), height, leaf no, leaf area and dry biomass of spinach across four locations and depth under bio-fertilizers and nutrient solution

Source	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		3.77**	11.01**	18.23**	43.64**	107.64**	135.28*	950.37**	22.49**
Depth	318.33**	2.76**	8.43**	73.37**	5.32**	8.38**	88.65*	858.03**	4.6**
Treatment	209.69*	19.85**	70.18**	475.75**	30.06**	14.09**	294.09**	10634.87**	46.04**
L×D		0.45**	10.14**	7.45**		5.03*		98.24**	0.39*
L×T		0.32*	2.70**	5.62**	6.03**	11.94**	102.04*	346.17**	1.46**
D×T		0.72**	1.35*	14.99**				350.05**	1.11**
L×D×T				5.51**				143.85**	0.68**

*Significant at 0.05 significance in F-test; **Significant at 0.01 significance in F-test.

CONCLUSION

According to the results of the experiment, we infer that bio-fertilizer vigorously stimulate spinach development and growth on slight acidic/ alkaline soils irrespective of treatments over control. It is evident from the study that Hunan soils gave the overall best result in terms of yield, this soil have the capacity for sustainable vegetable cultivation, compared to other soil types, due to moderate to high fertility status, good aeration, adequate soil moisture content and soil tilt. The soil is characterized with ideal physicochemical properties, which under good management practice will sustain large scale vegetable cultivation. It should be advocated for farmers to take advantage of Hunan soil and embark on commercial vegetable crop production. In general, spinach vegetable grown on alluvial soil amended with bio-fertilizer yielded best results than soil amended with inorganic nutrient solution. This study will provide valuable input data for managing land in semi-arid and arid regions of China and also serve as a guide to future vegetable growers in respect of fertilizers and soil properties evaluation for sustainable vegetable production.

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