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Effect of FYM, Zn and *Trichoderma spp.* on growth, yield and soil properties after harvest of the spinach beet grown in cd contaminated soil

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Abstract
An investigation entitled "Effect of FYM, Zn and *Trichoderma spp*. applications on growth, yield and cadmium uptake by spinach beet grown in Cd contaminated soil" was carried out during *Rabi* 2016 at Department of Natural Resources Management, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The present pot trial consisting of 18 treatment combinations involving three levels of FYM (F_0: control, F_1: 10 t ha^{-1} and F_2: 20 t ha^{-1}), two levels of *Trichoderma* (T_0:- Control, T_1:- 2 kg ha^{-1}) and three levels of Zinc (Z_0: control, Z_1: 2.5 mg kg^{-1} and Z_2: 5.0 mg kg^{-1}) using Factorial Complete Randomize Design with three repetitions. The experimental results revealed that plant height, number of leaves, leaf area, fresh weight of leaves during 1st, 2nd and 3rd cuttings and dry weight of root after 3rd cutting were significantly highest with treatment F_2 over F_1 and F_0 with a tune value of 20.14, 22.01 and 18.33 cm; 5.68, 6.04 and 7.33; 205.58, 201.52 and 230.71 cm^2; 122.79, 133.86 and 106.13 g pot^{-1}; 9.82 g pot^{-1}respectively. Similar trends in results with respect to growth and yield were found with application of Zn @ 5 mg kg^{-1}(Z_2) over Z_1 and Z_0. However, fresh weight of leaves was found significantly highest with application of *Trichoderma spp.* @ 2 kg ha^{-1} over T_0. Application of FYM @ 20 t ha^{-1} were found to be significant in SOC, Available N, P_2O_5, K_2O, DTPA extractable Fe, Cu and Zn. In case of available K_2O, F_2 was at par with F_1 (590.32 kg ha^{-1}). The SOC, DTPA extractable Cu and Zn were significantly affected due to application of *Trichoderma* @ 2 kg ha^{-1}(T_1) over no application (T_0). However, SOC, available N, P_2O_5, K_2O, Fe, Cu and Zn were significantly higher in Z_2 treatment as compared to Z_1 and Z_0 treatment with a tune value of 0.73 per cent, 150.95 kg ha^{-1}, 68.28 kg ha^{-1}, 609.41 kg ha^{-1}, 12.50 ppm, 2.53 ppm and 1.59 ppm, respectively. Further, Z_2 was at par for available N and Fe with Z_1 with corresponding value of 146.72 kg ha^{-1} and 12.08 ppm. The Cd was significantly lower with treatment F_2, T_1 and Z_2 over the F_1 and F_0, T_0 and Z_1 and Z_0, respectively. The data further showed that treatment T_0 and Z_0 recorded significantly highest Cd content in soil and remain at par with T_1 (3.38 ppm) and Z_1 (3.48 ppm), respectively after harvest the spinach beet. The result revealed that the maximum fungal and bacterial count recorded in treatment $F_2T_1Z_0$ with a tune value of 16 x 10^4 and 32 x 10^4cfu, respectively.

Keywords: Spinach beet, FYM, Zn, *Trichoderma*, content, uptake, soil properties, microbial count

Introduction
Water, soil and sediment contamination through heavy metals by industrial and natural processes is a global problem. These heavy metals are toxic for organism, affect their biochemical activities, morphology and reduce biomass and its variety. Bacteria are among the most abundant organism present on earth. Among which, remarkable concentration of Cd is reported in cultivated lands due to continues application phosphatic fertilizers. Consequently, it is absorbed by plants and thus enters the food chain and becomes hazardous to humans and animals. Major sources of heavy metal inputs to ecosystems are mining, smelting and metallurgical industries, sludge disposal and agricultural practices (Horak and Friesl, 2007) [6]. Cd accumulation in plants has a positive correlation with their availability and plant growth inhibition (Greger and Bertell, 1992; Kibria *et al*., 2006; Kibria *et al*., 2007) [4, 10, 11].
Spinach (*Spinacea oleracea* Linn) a member of the chenopodiaceae family, is also known as "Palak". Spinach is an annual plant. It is a nutritive leafy vegetable. It is rich in vitamins especially vitamin A and other vitamins like ascorbic acid, riboflavin, and thiamine. There are also appreciable quantities of minerals like iron and calcium. Spinach is an important vegetable in our daily food intake. Food should fulfill the daily requirements without creating health problems. Though low in calories; it contains higher concentration of minerals, vitamins and other amino acids. It has high contain of niacin and zinc and also a very good source of dietary fiber, protein and vitamins (A, C, K, thiamine, riboflavin, B6 and foliate) and essential micronutrients (Ca, Fe, Mg, P, K, Cu, Mn). Being a leafy vegetable, spinach beet is widely grown in kitchen garden especially in urban areas.

Material and Methods

Pot experiment was conducted during *Rabi* season of 2016 at polyhouse, Department of Natural resources Management, ASPEE college of Horticulture & Forestry, Navsari Agricultural University, Navsari, Gujarat. Total 18 treatment combinations comprising of three levels of FYM (F_0: control, F_1: 10 t $ha^{-1}$and F_2: 20 t ha^{-1}) and two levels of *Trichoderma* (T_0:- Control, T_1:- 2 kg ha^{-1}) and three levels of Zinc (Z_0: control, Z_1: 2.5 mg kg^{-1} and Z_2: 5.0 mg kg^{-1}) were evaluated in Factorial CRD with three replications. The soil of experiment pot was collected from the Vapi industrial area having *verisols* order. The soil was clayey in texture having EC (0.56 dS m^{-1}) and soil pH (7.98). The soil is medium in organic Carbon (0.58 %), low in available nitrogen (124.90 kg ha^{-1}), available phosphorus (54.70 kg ha^{-1}) and fairly rich in available potassium (570.17 kg ha^{-1}). The Cd content of experimental soil was 5.42 ppm. Spinach beet variety palak all green were sown at 20 seed per pot, the entire dose of Nitrogen and phosphorus applied at basal application just before sowing and nitrogen was applied after each cutting. FYM, *Trichoderma* and Zn were applied as per the treatment. Urea and DAP were taken as fertilizer sources for N and P, respectively.

Result

Growth parameters and Yield: Growth parameters viz., plant height, number of leaves, leaf area, leaves fresh weight recorded during 1st, 2nd and 3rd cutting and dry root weight at harvest are presented in Table 1.

Plant height: The plant height, measured at first, second and third cutting of spinach beet which was significantly affected due to individual effect of different levels of FYM, *Trichoderma* and Zinc. The plant height measured at 1st, 2nd and 3rd cuttings was significantly higher with treatment F_2 over F_1 and F_0 with a tune value of 20.14, 22.01 and 18.33 cm, respectively. In case of *Trichoderma spp*. application, plant height was significantly affected due to application of *Trichoderma spp.* (T_1) over control (T_0) during 1st and 2nd cutting except 3rd cutting. However, significant increase in magnitude of plant height was 3.47 and 5.28 per cent over T_0 during 1st and 2nd cutting, respectively. Among the three levels of Zinc, application of Zinc @ 5 mg kg^{-1}(Z_2) significantly influenced the plant height over Z_1 and Z_0 during 1st, 2nd and 3rd cutting.

Leaf Area: The data pertaining to leaf area found during the 1st, 2nd and 3rd cutting of spinach beet shown in table 1. The results revealed that leaf area recorded during 1st, 2nd and 3rd cutting was significantly affected due to different levels of FYM, *Trichoderma* and Zinc. The highest leaf area was significantly found due to application of FYM @ 20 t ha^{-1} over F_1 and F_0 during 1st, 2nd and 3rd cutting with a tune figure of 205.58, 201.52 and 230.71 cm^2 respectively. However, leaf area significantly affected due to application of *Trichoderma* @ 2 kg ha^{-1}(T_1) over no application (T_0) except during 1st and 2nd cutting. Significantly highest leaf area was recorded during 1st, 2nd and 3rd cutting due to application of Zinc @ 5 mg kg^{-1}(Z_2) over Z_1 and Z_0 with corresponding value of 209.72, 216.35 and 234.57 cm^2 during 1st, 2nd and 3rd cutting, respectively.

Number of Leaves: The results (Table 1) revealed that significantly highest number of leaves was found due to application of FYM @ 20 t ha^{-1} over F_1 during 1st, 2nd and 3rd cutting with an increase in magnitude of number of leaves was 9.44, 20.08 and 11.57 per cent over F_0 during 1st, 2nd and 3rd cutting, respectively. However, number of leaves significantly affected due to application of *Trichoderma* @ 2 kg ha^{-1}(T_1) over no application (T_0) except during 1st and 3rd cutting. However, the magnitude of significant increase in number of leaves during 2nd cutting was 7.32 per cent over T_0 with a tune value of 5.72. Significantly highest number of leaves was found due to application of Zinc @ 5 mg kg^{-1}(Z_2) with corresponding value of 5.75, 6.05 and 7.26 during 1st, 2nd and 3rd cutting, respectively over Z_1 and Z_0.

Fresh and dry weight of leaf: The fresh weight of leaves recorded during 1st, 2nd and 3rd cutting was significantly affected due to individual effect of FYM, *Trichoderma* and Zinc. The significantly highest fresh weight of leaves was found due to application of FYM @ 20 t ha^{-1} over F_1 and F_0 during 1st, 2nd and 3rd cutting with a tune figure of 122.79, 113.86 and 106.13 g pot^{-1}, respectively. In case of *Trichoderma spp.* T_1 recorded significant increased in magnitude of fresh weight of leaves were with a tune value of 4.45, 3.17 and 5.45 per cent over T_0 during 1st, 2nd and 3rd cutting, respectively. Among the different Zinc treatments, application of 5.0 mg kg^{-1}(Z_2) produced significantly higher fresh weight of leaves with corresponding values of 121.32, 112.86 and 104.84 g pot^{-1} during 1st, 2nd and 3rd cutting, respectively. As compared to control, the extent of increase in magnitude with Z_2 was 16.00, 10.43 and 16.79 per cent over Z_0, respectively.

Dry weight of root: The data pertaining to dry weight of root found after 3rd cutting of spinach beet shown in table 1. The data further revealed that dry weight of root recorded after 3rd cutting was significantly affected due to different levels of FYM except the levels of *Trichoderma* and Zinc. The highest dry weight of root was significantly found due to application of FYM @ 20 t ha^{-1} over F_0 after 3rd cutting with a tune figure of 9.82 g $pot^{-1}$and remain statistically at par with $F_1$with corresponding value of 9.21 g pot^{-1}.

Table 1: Effect of FYM, *Trichoderma* and Zinc on plant height, leaf area, number of leaves, leaves fresh weight and root dry weight of spinach beet

Treatment	Plant height (cm)			Leaf area (cm^2)			No of leaves			Leaves fresh weight (g pot^{-1})			Root dry weight (g pot^{-1})
	Cutting			cutting			Cutting			Cutting			At harvest
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	
F_0	16.77	17.35	16.07	180.17	170.81	177.90	5.19	5.03	6.57	105.24	102.08	90.00	8.81
F_1	17.67	18.41	17.36	196.00	198.62	206.34	5.38	5.51	6.90	113.48	107.86	95.99	9.21
F_2	20.14	22.01	18.33	205.58	201.52	230.71	5.68	6.04	7.33	122.79	113.86	106.13	9.82
S.Em.±	0.20	0.27	0.29	1.80	3.40	3.74	0.08	0.08	0.09	1.79	1.00	1.32	0.22
C.D.@5%	0.58	0.79	0.82	5.17	9.74	10.74	0.24	0.22	0.25	5.13	2.88	3.77	0.63
T_0	17.88	18.76	16.96	192.72	188.01	198.09	5.35	5.33	6.84	111.36	106.25	94.79	9.16
T_1	18.50	19.75	17.55	195.11	192.61	211.88	5.49	5.72	7.03	116.31	109.62	99.96	9.40
S.Em.±	0.17	0.22	0.23	1.74	2.77	3.06	0.07	0.06	0.07	1.46	0.82	1.07	0.18
C.D.@5%	0.48	0.64	NS	NS	NS	8.77	NS	0.18	NS	4.19	2.35	3.08	NS
Z_0	16.85	17.47	16.08	166.12	158.22	178.34	5.08	5.10	6.59	104.59	102.20	89.77	9.08
Z_1	18.47	18.82	17.15	205.91	196.38	202.05	5.41	5.43	6.95	115.60	108.75	97.51	9.24
Z_2	19.25	21.48	18.53	209.72	216.35	234.57	5.75	6.05	7.26	121.32	112.86	104.84	9.53
S.Em.±	0.20	0.27	0.29	1.80	3.40	3.74	0.08	0.08	0.09	1.79	1.00	1.32	0.22
C.D.@5%	0.58	0.79	0.82	5.17	9.74	10.74	0.24	0.22	0.25	5.13	2.88	3.77	NS
C.V.%	4.76	6.04	7.02	3.94	7.57	7.75	6.51	5.95	5.23	6.67	3.94	5.73	9.98

Soil properties and nutrient availability after harvest of Spinach beet

Chemical properties, physical properties and SOC: The results showed that chemical properties, SOC and Physical properties of soil did not differ significantly due to application of FYM, *Trichoderma* and Zinc. However, the pH, porosity and SOC were highest and EC and BD were lowest with application of FYM @ 20 t ha^{-1}.The pH, EC, SOC, BD and porosity did not significantly affected due to application of *Trichoderma*@ 2 kg ha^{-1}(T_1) over control (T_0) with tune value of 8.31 and 0.621 dSm^{-1}, 0.71%, 1.408 g/cc and 46.88 %respectively. The pH and EC did not differ significantly due to different levels of Zinc (Table 2). However, lowest EC was found due to application of Zinc @ 5 mg kg^{-1}(Z_2) over Z_1 and Z_0 with corresponding value of 0.618 dSm^{-1}. SOC was significantly higher in Z_2 treatment as compared to Z_1 and Z_0 treatment with a tune value of 0.73 per cent.

Table 2: Effect of FYM, *Trichoderma* and Zn on chemical and physical properties and SOC of soil after harvest the spinach beet

Treatment	pH (1: 2.5)	EC (dS m^{-1}) (1: 2.5)	SOC (%)	Bulk density (Mg m3)	Porosity (%)
F_0	8.25	0.627	0.58	1.419	46.46
F_1	8.31	0.629	0.67	1.414	46.62
F_2	8.32	0.615	0.75	1.408	46.88
S.Em.±	0.02	0.006	0.01	0.006	0.21
C.D.@5%	NS	NS	0.03	NS	NS
T_0	8.28	0.626	0.63	1.420	46.43
T_1	8.31	0.621	0.71	1.408	46.88
S.Em.±	0.02	0.005	0.01	0.005	0.17
C.D.@5%	NS	NS	0.03	NS	NS
Z_0	8.30	0.626	0.60	1.424	45.27
Z_1	8.26	0.628	0.67	1.409	46.81
Z_2	8.32	0.618	0.73	1.408	46.88
S.Em.±	0.02	0.006	0.01	0.006	0.21
C.D.@5%	NS	NS	0.01	NS	NS
C.V.%	1.26	6.08	6.88	1.66	1.90

Primary nutrient and secondry nutrient: The results presented in table 3 revealed that application of FYM @ 20 t ha^{-1} were found to be significant in, Available N, P_2O_5, K_2O, Ca, Mg and S. However, significantly higher Available N (158.54 kg ha^{-1}), P_2O_5 (69.00 kg ha^{-1}) and K_2O (602.24 kg ha^{-1}), Ca (24.54 me $100g^{-1}$), Mg (15.95 me $100g^{-1}$) and S (32.49 ppm) were recorded with F_2 as compared to F_1 and F_0. In case of available K_2O, F_2 was at par with of F_1 (590.32 kg ha^{-1}). The results reported in table 3 further revealed that application of *Trichoderma* failed to influence significantly on Available N, P_2O_5, K_2O, Ca, Mg and S of soil after harvesting the spinach beet.

Among the Zinc levels, available N, P_2O_5 and K_2O,Ca, Mg and S were significantly affected due to Z_2 and it ranges from 140.83 to 150.95 kg ha^{-1}, 60.37 to 68.28 kg ha^{-1}, 575.79 to 609.41 kg ha^{-1}, 23.86 to 24.37 me $100g^{-1}$, 14.82 to 15.90 me $100g^{-1}$ and 31.40 to 32.42 ppm, respectively.

Table 3: Effect of FYM, *Trichoderma* and Zn on primary and secondary nutrient of soil after harvest the spinach beet

Treatment	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Ca (me 100 g^{-1})	Mg (me 100 g^{-1})	S (ppm)
F_0	137.32	60.84	580.35	23.73	14.91	31.39
F_1	142.64	63.26	590.32	24.15	15.35	32.14
F_2	158.54	69.00	602.24	24.54	15.95	32.49
S.Em.±	1.69	1.08	5.92	0.25	0.35	0.72
C.D.@5%	4.86	3.10	16.98	NS	NS	NS
T_0	144.66	63.56	588.88	24.05	15.23	31.77
T_1	147.67	65.17	593.05	24.22	15.51	32.24
S.Em.±	1.38	0.88	4.83	0.21	0.29	0.58
C.D.@5%	NS	NS	NS	NS	NS	NS
Z_0	140.83	60.37	575.79	23.86	14.82	31.40
Z_1	146.72	64.45	587.70	24.19	15.39	32.21
Z_2	150.95	68.28	609.41	24.37	15.90	32.42
S.Em.±	1.69	1.08	5.92	0.25	0.35	0.72
C.D.@5%	4.86	3.10	16.98	NS	NS	NS
C.V.%	4.91	7.13	4.25	4.43	9.68	9.49

Micronutrient: An appraisal of the results presented in table 4 revealed that the DTPA extractable Fe, Zn and Cu status of the soil after harvesting of spinach beet were significantly affected due to individual effect of FYM, *Trichoderma* and Zinc levels except Fe due to application of *Trichoderma*. Application of FYM @ 20 t ha^{-1} showed significantly highest DTPA extractable Fe, Cu and Zn over F_1 and F_0 with a tune value of 12.91, 2.68 and 1.68 ppm, respectively. However, DTPA extractable Cu and Zn significantly affected due to application of *Trichoderma* @ 2 kg ha^{-1}(T_1) over T_0 with increase in magnitude of 7.66 and 12.88 per cent, respectively. The data further revealed that application of Zinc @ 5.0 mg kg^{-1}(Z_2) recorded significantly highest DTPA extractable Fe, Cu and Zn with increase in magnitude by 8.98, 21.05 and 27.2 per cent over Z_0. However, Z_2 was statistically remain at par with Z_1 with corresponding value of 12.08 ppm in case of DTPA extractable Fe.

Cd of soil: The Cd measured after harvesting of spinach beet which was significantly affected due to individual effect of different levels of FYM, *Trichoderma* and Zinc (Table 4).

The Cd measured was significantly lower with treatment F_2 over F_1 and F_0 with tune value 3.24 ppm. The data further showed that significantly highest Cd of soil was found in treatment T_0 over the T_1 treatment. However, application of Zinc @ 5 mg kg^{-1} (Z_2) recorded significantly lowest Cd content (3.31 ppm) of soil over Z_1 and Z_0 with a tune value of 3.48 and 3.61 ppm, respectively. The data further showed that treatment T_0 andZ_0 recorded significantly highest Cd content in soil and remain at par with T_1 (3.38 ppm) and Z_1 (3.48 ppm), respectively after harvest the spinach beet.

Table 4: Effect of FYM, *Trichoderma* and Zn on micronutrient and Cd status of soil after harvest the spinach beet'

Treatment	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Cd (ppm)
F_0	11.38	17.95	1.97	1.16	3.70
F_1	11.76	18.21	2.27	1.38	3.46
F_2	12.91	18.49	2.68	1.68	3.24
S.Em.±	0.28	0.33	0.05	0.03	0.07
C.D.@5%	0.81	NS	0.16	0.08	0.21
T_0	11.87	18.15	2.22	1.32	3.55
T_1	12.16	18.27	2.39	1.49	3.38
S.Em.±	0.23	0.27	0.04	0.02	0.06
C.D.@5%	NS	NS	0.13	0.07	0.17
Z_0	11.47	18.07	2.09	1.25	3.61
Z_1	12.08	18.21	2.30	1.39	3.48
Z_2	12.50	18.36	2.53	1.59	3.31
S.Em.±	0.28	0.33	0.05	0.03	0.07
C.D.@5%	0.81	NS	0.16	0.08	0.21
C.V.%	9.94	7.59	9.97	8.49	8.98

Microbial population

The maximum microbial count recorded (table 5) in treatment $F_2T_1Z_0$ as this treatment does not contain any heavy metals and other microbial culture which is harmful for the soil microbial population. The *Trichoderma* fungus has bioremediation characteristics and also contains mechanism tolerate to heavy metals like Cd, Zn (Waghunde *et al.* 2016) [20]. The FYM contains higher organic matter which promotes the microbial culture. The mcrobial count of fungi is more as compare to bacteria as it has different mechanisms to tolerate heavy metals. However, lowest microbial recorded in treatment receiving Zinc as these treatments did not contain *Trichoderma* culture.

Table 5: Effect of FYM, *Trichoderma* and Zn on soil microbial population (10^4cfu) of soil after harvest the spinach beet

S. No.	Treatment	Microbial population (10^4cfu)	
		Fungi	Bacteria
1	$F_0T_0Z_0$	6	10
2	$F_0T_0Z_1$	5	8
3	$F_0T_0Z_2$	4	7
4	$F_0T_1Z_0$	7	14
5	$F_0T_1Z_1$	4	9
6	$F_0T_1Z_2$	3	8
7	$F_1T_0Z_0$	8	16
8	$F_1T_0Z_1$	6	10
9	$F_1T_0Z_2$	4	9
10	$F_1T_1Z_0$	9	17
11	$F_1T_1Z_1$	7	13
12	$F_1T_1Z_2$	6	11
13	$F_2T_0Z_0$	11	19
14	$F_2T_0Z_1$	12	18
15	$F_2T_0Z_2$	9	14
16	$F_2T_1Z_0$	16	32
17	$F_2T_1Z_1$	8	16
18	$F_2T_1Z_2$	7	15

Discussion

Growth parameters and Yield

The plant height measured at 1st, 2nd and 3rd cutting was significantly higher with F_2 (20.14, 22.01 and 18.33 cm) as compared to F_1 (17.67, 18.41 and 17.36 cm), respectively. Here, F_2 recorded 13.98, 19.55 and 5.59 per cent higher plant height over the F_1, during 1st, 2nd and 3rd cutting, respectively. In the case of number of leaves, treatment F_2 registered significantly higher number of leaves of spinach beet (5.68, 6.04 and 7.33) over F_1 (5.38, 5.51 and 6.90) during 1st, 2nd and 3rd cutting, respectively. The leaf area was recorded at 1st, 2nd and 3rd cutting of spinach beet and an extent of increase in leaf area at 1st, 2nd and 3rd cutting of spinach with F_2 as compared to F_1 was 4.89, 1.46 and 11.81 per cent, respectively. The significant growth and yield response to increasing level of FYM may partly be due to the beneficial effect of organic manure, however, application of organic manure was useful not only in terms of nutrient supply but also improve physical and biological fertility of soil. This is in line with the report of Ajakaiye (1971) [1] that organic manure also improves soil physical and biological conditions. The obtained finding is in good harmony with Piramonti *et al.* (1997) [16]. Organic lettuce production reported that inorganic fertilizers resulted in lower yields compared to organic manures in lettuce production (Masarirambi *et al*., 2010; Maqueda *et al*., 2010) [13, 12]. Similar result was reported by Xu *et al.* (2005) [21] that vegetables grown with organic fertilizers grew better and resulted in a higher total yield than those grown with chemical fertilizers. Since chemical fertilizers do not posses good characteristics of aggregating the soil particles. However, the leaves fresh weight as well as root dry weight significantly affected due to different levels of FYM, *Trichoderma* and Zinc with similar trend was found as in case of growth parameters (Table 1). Here, significantly highest the leaves fresh weight of spinach beet was recorded in F_2 with a tune value of 122.79, 113.86, 106.13 g pot^{-1} during 1st, 2nd and 3rd cutting, respectively. Similar trend was observed in case of dry weight of root in case of different levels of FYM. However, yield attributing characters viz., number of leaves and leaf area increased which resulted in increase in yield. The above results are in conformity with that of Jana *et al*. (1999) [8] in palak.

The plant height, number of leaves and leaf area of spinach beet were significantly affected due to application of *Trichoderma* @ 2 kg ha^{-1} over the control (T_0) during 1st, 2nd and 3rd cutting of spinach beet (tables 1). Significantly highest plant height (18.50, 19.75 and 17.55 cm), number of leaves (5.49, 5.72 and 7.03) and leaf area (195.11, 192.61 and 211.68 cm^2) were recorded with treatment T_1 over T_0, during 1st, 2nd and 3rd cutting, respectively. Inmark (2000) [7] who stated that *T. harzianum* and other *Trichoderma spp*. could increase in yield of plant about 36% when compared to the control. The reasons why the yield could increase that can be explained by Suwan *et al*. (2004) [19] who reported that *T. harzianum* could elucidate to produce trichotoxins promoting plants. *Trichoderma* are known to produce a number of antibiotics such as trichodermin, trichodermol, polyketides, peptaiboils, sesquterpenes and steroids. They are frequently associated with both biocontrol activity and promotion of plant and root growth (Chen *et al.*, 2006, Harman *et al*., 2004) [2, 5]

Like FYM and *Trichoderma*, the effects of Zinc levels were also found to be significant on the growth parameters *viz.*, plant height, number of leaves and leaf area during 1st, 2nd and 3rd cutting of spinach beet. The addition of Zn enhanced the DMY of spinach by reducing its content in the soil, thereby

reducing its uptake. Similar results were also obtained by Singh and Nayyar (1994) [18] in corn; Sarkunan *et al* (1996) [17] in rice; Georgieva *et al* (1997) [3] in radish, pea and peeper and wheat. Foliar application with yeast extract and Zinc treatments improved seed yield of faba bean plants due to increasing flower formation and the reduction of flowers and pod shedding as well as increasing their ability to accumulate more bio constituents.

Soil properties, nutrient availability and microbial population

The chemical properties *viz.*, soil pH and EC of soil did not differ significantly due to effects of FYM, *Trichoderma* and Zinc. But, fertility parameters *viz.*, SOC, available N, P_2O_5, K_2O, Fe, Cu, Zn and Cd were influenced significantly due to application of FYM @ 20 t ha^{-1}. Here, Ca, Mg, S and Mn were not significantly affected due to the application of FYM. However, all the fertility parameters were highest with application F_2 except in Cd content. While in physical properties of soil, BD and porosity did not affected significantly due to the application of FYM @ 20 t ha^{-1}. The lowest BD and higher porosity were recorded at F_2 over the F_1 and F_0. Application of *Trichoderma* at different rates failed to influence significantly on available N, P_2O_5, K_2O, Ca, Mg, S, Fe and Mn content in soil except SOC and DTPA extractable Zn Cu and Cd. However, the highest SOC (0.71 %), Cu (2.39 ppm), Zn (1.49 ppm) Cd was found with T_1. On contrary to Cd status significantly highest value was found with T_0 (3.55 ppm) which was at par with T_1 (3.38 ppm) after harvesting the spinach beet. The improvement in soil pH, SOC and available N, P_2O_5, K_2O Fe, Zn and Cu were found to improve remarkably due to application of different levels of FYM, *Trichoderma* and Zinc. Whereas, remaining available nutrients content was increased up to certain extent after harvest of spinach beet than their respective initial values under all the treatments. This might be due to application of organic manures with effective microorganism increased plant nutrient levels of N, P and K in soils. These results are in line with those of Namasivayam and Kirithiga (2010) [15]. Organic wastes are rich sources of carbonaceous and proteinacrous compounds and micro- nutrients (Zaman *et al.*, 2014) [22] resulted in enhanced soil fertility and quality and availability of these nutrients. However most of these nutrients are in organic forms and need to be mineralized by a wide range of microorganism to plant available form like nitrate, phosphate, potassium and others. The applied microorganism enriched FYM is likely to have enhanced the rate of mineralization and made them available in soil for plant uptake besides immobilize Cd by complexion and reduced its assimilation by the leaves of spinach beet. Organic waste have potential to improve soil physical fertility including enhanced water retention, water filled pore spaces and structure stability. McBride (1994) [14] reported that soluble organics can increase the solubility of metal cation bound to organic molecules. Similar findings were in conformation with that observed by found that application of cow and pig manure decreased the Cd concentration in the exchangeable fraction of the soil.

The different levels of Zinc were significantly affected on the soil properties except on soil chemical properties except BD, porosity and secondary nutrient status of soil after harvest of spinach beet. The data further revealed that application of Zinc @ 5.0 mg kg^{-1}(Z_2) recorded significantly highest SOC (0.73%), available N (150.95 kg ha^{-1}), P_2O_5 (68.28 kg ha^{-1}), K_2O (609.41 kg ha^{-1}), DTPA extractable Fe (12.50 ppm), Mn (18.36 ppm), Zn (2.53 ppm), Cu (1.59 ppm) and significantly highest Cd was found with no Zinc application (Z_0) which was also remain at par with Z_1 i.e. 2.5 mg Zn kg^{-1}(3.48 ppm). The increase levels of FYM and Zinc positively correlate with Cd content of soil after harvest of the spinach beet. The Cd concentration in wheat grown in the cow manure amended soil was lower due to its good source of organic matter which is a determining factor for Cd distribution in soil and Cd uptake by plants. Kashem and Singh (2001) [9].

Conclusion

Application of FYM @ 20t ha^{-1} and Zn @ 5 mg kg^{-1} along with trichodema @ 2 kg ha^{-1} advisable to get higher yield of spinach beet in Cd contaminated soil with better soil fertility as well as microbial population.

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