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Research Article

Effect of Organic and Inorganic Fertilizers Co-Applied with Effective Microorganism (EM) on Growth and Yield of Spinach (*Spinachia olerace*)

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Abstract | A two years pot experiment was conducted using loamy textured soil to study the effect of organic manure and complex chemical fertilizer (NPK) with or without effective microorganism (EM) on the agronomic performance of spinach crop, at Gomal University D.I. Khan during 2009-11. A commercial product called Bio-Aab was used as a source of EM. Organic manure was first mixed with Bio-Aab, left for 7 to 15 days at room temperature (20°C) and then applied to appropriate pots. The treatments of farm yard manure (FYM) @ 10 t ha^{-1}, press mud @ 20 t ha^{-1}, compost @ 0.7 t ha^{-1} and poultry manure @ 5 t ha^{-1} were applied with half of the recommended dose of NPK @ (75:60:30 kg ha^{-1}) with or without EM. In 2009-10, the application of EM with Press mud @ 20 t ha^{-1} significantly enhanced spinach growth by exhibiting higher average spinach plant height (35 cm), number of leaves (16.4), fresh foliage yields (330 g pot^{-1}), dry foliage yields (32 g pot^{-1}), leaf length (40.5 cm) and leaf area (238.4 mm^2) relative to poultry manure, compost or FYM treatments. Similar trend was observed during 2010-11. Over all, press mud with EM was more effective in improving soil quality and enhancing spinach growth and quality followed by FYM and poultry manure. These results suggested that Press mud applied with EM have the most potential to increase yield and quality of spinach. Our results also suggest of taking integrating approach by applying organic wastes with readily available source of chemical fertilizer to minimize the risk of reduced plant growth due to immobilization and with EM to enhance mineralization of organic nutrients, therefore warrant testing under field conditions.

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Introduction

Soil microorganisms play a key role in enhancing soil quality, plant growth and yield (Zaman and Chang, 2014). Beneficial microorganisms are capable to fix atmospheric nitrogen (N_2), decompose organic wastes and residues to release plant essential nutrients, detoxify pesticides, suppress plant disease and soil borne pathogens, enhance nutrient cycling, and produce bioactive compounds such as vitamins, hormones and enzymes that stimulate plant growth (Kurepin et al., 2014). The product of effective microorganisms (EM) was developed by a Japanese Professor, Teruo Higa, University of the Ryukyu, in the early1980s and claim to have a suite of certain species of photosynthetic bacteria (*Rhodopseudomonas plastris* and *Rhodobacter sphacrodes*), lactobacilli (*Lactobacillus plantarum*, *L. casei*, and *Streptococcus lactis*), yeasts (*Saccharomyces* spp.), and actinomycetes (*Strptomyces* spp.). Numerous glasshouse and field trials in Pakistan using EM showed increased crop yield, enhanced composting and mineralization of municipal/industrial wastes and effluents (Sivasubramanian and Namasivayam, 2013). Organic manures like farmyard manure, compost and poultry manures have long been used by farmers to meet the plant demand for essential nutrients, especially N and improve soil quality (Zaman et al., 2004). Compared to chemical fertilizers, organic manures contain most essential plant nutrients especially N in lower amount in organic form which mineralizes at a slow rate thereby not meeting the plant nutrient demand at critical growth stages and thus carry the risk of lowering productivity (Zaman et al., 2004); however, they have the potential to improve both soil quality and health if used correctly for long time (Ahmad et al., 2013). Press mud, an industrial waste produced by the sugar processing plants, has the potential to be used as soil amendment to provide essential plant nutrients (N, P and K) when applied to soil (Khan et al., 2012); however limited information is available on the use of these organic wastes co-applied with chemical fertilizers and EM on spinach growth and productivity. Thus this study was undertaken to investigate the effect of organic manure and chemical fertilizer co-applied with effective microorganism (EM) on the agronomic performance of spinach crop under controlled environmental conditions in glasshouse.

Materials and Methods

Pot experiments were conducted under glasshouse conditions to study the effect of effective EM co-applied with 4 commonly available organic wastes including farm yard manure (FYM) (10 t ha^{-1}), press mud (20 t ha^{-1}), compost (0.7 t ha^{-1}) and poultry manure (5 t ha^{-1}), on growth and quality of spinach at Gomal University D.I. Khan Pakistan, during 2009-10 and 2010-11. The five treatments were control or T1 (no N or EM), T2 (FYM applied at 10 t ha^{-1}), T3 (press mud applied at 20 t ha^{-1}), T4 (compost applied at 0.7 t ha^{-1}) and T5 (poultry manure applied at 5 t ha^{-1}) co-applied with half of the recommended dose of chemical fertilizer of NPK (75:60:30 kg ha^{-1}) and EM. Each treatment was replicated 3 times in in a completely randomized design. EM was provided by Bio-Aab EM Foundation, Faisalabad, Pakistan. Soil physical and chemical properties including moisture content, texture, particle density, bulk density, organic matter, total N, available P, potassium (K), pH, and EC were determined using standard lab methods (Olsen and Watanabe 1954; MAFF, 1986; Ryan et al., 2001; Jaiswal 2003). In year-1 experiments (i.e. 2009), a total of 30 pots, each pot of 0.005385 m^3 area with 20 kg of moist soil, were set up in a glasshouse. EM was first, mixed with 4 organic wastes and kept for 7-15 days at room temperature to ensure full inoculation of EM followed by applying the mixture to appropriate pots. After this step, spinach seed at 10 g pot^{-1} was sown on November 4, 2009. After emergence, spray irrigation using a watering cane was carefully applied at regular interval to maintain soil moisture level under glasshouse condition. Spinach crop was harvested 3 times to simulate farmer practices. The time (days) from seed germination of spinach till the 1st harvest was recorded. After harvest, plant physiological characteristics including spinach height, number of leaves, leaf length and area and foliage yield (fresh and dried), were recorded. The same trail was repeated during 2010-11 with same inputs and cultural practices. After harvesting the experimental soil was analyzed for physical and chemical characteristics and nutrients concentration to investigate the EM effect on experimental soil. The rest of the parameters were statistically analyzed for comparison and scientific discussion.

Statistical analysis

Analysis of variance (ANOVA) was performed to compare treatments with respect to spinach yield, and other measured parameters using Statistix 9 software. Least significant difference (LSD) values at Alfa less than 0.05 were calculated when the treatment effect was significant.

Results and Discussion

Key post-harvest soil properties

After harvesting spinach, soil samples collected from each pot were analyzed for nutrients concentration. The application of organic manures with EM increased plant nutrients levels of N, P and K in soils compared with no EM treatments (Table.1). These results are in line with those of Namasivayam and Kirithiga (2010). Organic wastes are rich sources of carbonaceous and proteinaceous compounds (C, protein, amino acids), and micro-nutrients (Zaman et al., 1999 a, b), therefore when they were co applied with EM and NPK, their application enhanced soil fertility and quality and availability of these nutrients. However most of these nutrients are in organic forms and need to be mineralised by a wide range of microorganisms (bacteria, fungi etc.) to plant available form like ammonium, nitrate, phosphate, potassium and others. The applied EM is likely to have enhanced the

Table 1. *The effect of applying EM with organic wastes on Physical and chemical characteristics of the soil used in the 2 experiments.*

Treatment	EC (dsm^{-1})		pH		Organic Matter (%)		Saturation (%)	
	-EM	+EM	-EM	+EM	-EM	+EM	-EM	+EM
Control	0.50	0.50	7.8	7.8	0.95	0.95	26	35
FYM + ½ RDF of NPK	0.66	0.75	6.7	6.98	0.93	0.99	39	45
Press mud + ½ RDF of NPK	0.68	0.68	6.8	7.45	0.94	0.98	40	49
Compost + ½ RDF of NPK	0.55	0.68	7.86	7.94	0.99	1.3	38	44
Poultry + ½ RDF of NPK	0.66	0.72	7.9	7.98	0.96	1.2	42	48

Treatment	N ($mg\ kg^{-1}$)		P ($mg\ kg^{-1}$)		K ($mg\ kg^{-1}$)	
	-EM	+EM	-EM	+EM	-EM	+ EM
Control	440	440	4	4	47	47
FYM + ½ RDF of NPK	356	432	8	9	75	101
Press mud + ½ RDF of NPK	485	502	11	13	93	108
Compost + ½ RDF of NPK	635	630	10	12	90	99
Poultry + ½ RDF of NPK	634	655	11	12	95	105

-EM = Without EM, +EM = With EM

Table 2. *The effect of applying EM with organic wastes on spinach growth.*

Treatments	Without EM	With EM		
	Date of germination	Days taken to first cutting	Date of germination	Days taken to first cutting
Control	12-11-09	69 days	12-11-09	69 days
FYM + ½ RDF of NPK	9-11-09	66 days	7-11-09	60 days
Press mud + ½ RDF of NPK	8-11-09	65 days	5-11-09	59 days
Compost + ½ RDF of NPK	9-11-09	66 days	7-11-09	60 days
Poultry + ½ RDF of NPK	8-11-09	65 days	6-11-09	60 days
FYM + RDF of NPK	11-11-09	68 days	9-11-09	63 days

Table 3. *Plant height (cm) of spinach as influenced by applying EM with organic wastes during 2009-10 and 2010-11.*

Treatment	1st cutting		2nd cutting		3rd cutting		Average	
	-EM	+EM	- EM	+ EM	-EM	+ EM	-EM	+ EM
2009-10								
Control	13.5	14.2	16.2	15.3	14.9	15.1	14.9	14.8
FYM + ½ RDF of NPK	16.5	19.7	20	22.7	17.2	20.6	17.9	21
Press mud + ½ RDF of NPK	35	37.8	35.3	38.4	27.3	29.2	32.5	35
Compost + ½ RDF of NPK	12.8	20.3	16.4	19	15.4	16.4	14.9	18.6
Poultry + ½ RDF of NPK	17.1	20.6	23	25.4	20.6	23.4	20.2	23.2
LSD for EM at $P_{0.05}$ = 2.508 LSD for treatments X EM at $P_{0.05}$ =4.72		LSD for EM at $P_{0.05}$ =2.74925 LSD for Treatments X EM at $P_{0.05}$ =2.912		LSD for EM at $P_{0.05}$ =3.1526 LSD for Treatments X EM at $P_{0.05}$=3.4549				
2010-11								
Control	13	13	16.5	16.5	15	15	14.8	14.8
FYM + ½ RDF of NPK	17.4	20.6	23.5	25.6	21	24	20.6	23.4
Press mud + ½ RDF of NPK	32.6	37.5	40.5	45.8	38.4	42.7	37.2	42
Compost + ½ RDF of NPK	15.4	23	18.5	26.1	16.9	23.8	16.9	24.3
Poultry + ½ RDF of NPK	19.5	25.4	25.6	29	22.7	27.7	22.6	27.3
LSD for EM at $P_{0.05}$ =3.6514 LSD for Treatments X EM at $P_{0.05}$=3.9391		LSD for EM at $P_{0.05}$ = 3.3245 LSD for Treatments X EM at $P_{0.05}$ =3.3936		LSD for EM at $P_{0.05}$ =2.8370 LSD for Treatments X EM at $P_{0.05}$ =3.4512				

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rate of mineralisation and made them available in soil for plant uptake. Organic wastes if applied correctly, also the most potential to improve soil physical fertility including enhanced water retention, water filled pore spaces and structure stability.

Seed germination and time (days) taken to reach first harvest of spinach

Time taken from seed germination to the first harvest of spinach is given in table 2. Treatments applied with EM enhanced spinach growth compared to no EM and thus narrowed the harvesting time by 5 days. This could be attributed to the stimulating effect of EM by providing plant growth hormones like GA, Auxins, Cytokinin, brassinsterioid etc (Kurepin et al 2014). Growing spinach in a short period is economical and also has impact on its quality which will be discussed later.

Plant Height (cm):

Plant height was significantly influenced ($P<0.05$) by the organic wastes applied with EM (Table 3). During 2009-10 growth season, press mud applied with EM produced plant height of 37.8, 38.4 and 29.20 cm in 1st, 2nd and 3rd harvest respectively. Similar trend was observed in 2010-11, when press mud co-applied with EM resulted in plant height of 37.5, 45.8 and 42.7 cm in 1st, 2nd and 3rd harvest respectively. These results suggest that organic wastes like press mud application with EM have the large potential to increase spinach growth as seen in this glasshouse trial. Most organic wastes contain less N (i.e. high C: N ratio), therefore applying on their own may immobilize N and thus reduce plant growth. However when organic wastes are co-applied with chemical fertilizer like NPK in our experiment, the added nutrients in chemical fertilisers not only stimulate the mineralization of organic nutrients in organic wastes (Zaman et al., 2002a) and thus enhance plant growth through adequate supply of essential plant nutrients in the presence of sufficient C inputs. Our results also support earlier findings of Chantal, et al. (2013) who reported that bio-organic fertilizers with EM significantly increased plant height of flue-cured tobacco.

Fresh Foliage Yield (g pot^{-1})

Fresh foliage yield of spinach was also significantly ($P< 0.05$) affected by the organic wastes applied with EM inoculation as well as their interaction (Table 4). During 2009-10, press mud applied with EM produced significantly ($P<0.05$) high fresh foliage yield of 285.2, 369 and 336.2 g pot^{-1} in 1st, 2nd and 3rd harvest respectively. In 2010-11, similar trend of increased fresh foliage yield by press mud with EM was

Table 4. *The effect of applying EM with organic wastes on spinach Fresh Foliage yield (g pot-1) during 2009-10 and 2010-11.*

Treatment	1st cutting		2nd cutting		3rd cutting		Average	
	-EM	+EM	-EM	+EM	-EM	+ EM	-EM	+ EM
2009-10								
Control	15.9	17.8	17.6	18.2	21.6	20.9	18.4	18.9
FYM + ½ RDF of NPK	64.67	113.15	80.66	136.80	65.77	116.12	70.4	122
Press mud + ½ RDF of NPK	190.6	285.2	345.2	369	318.5	336.2	284.8	330.2
Compost + ½ RDF of NPK	34.3	83.4	82.3	158.4	34.2	120.4	50.2	120.7
Poultry + ½ RDF of NPK	136.5	166.1	184	220.7	119.7	174.7	146.8	187.2
LSD for EM at $P_{0.05}$ =51.2915 LSD for Treatments X EM at $P_{0.05}$ =76.87			LSD for EM at $P_{0.05}$ =47.086 LSD for Treatments X EM at $P_{0.05}$ =58.649			LSD for EM at $P_{0.05}$ = 53.9665 LSD for Treatments X EM at $P_{0.05}$=60.084		
2010-11								
Control	15	15	18.5	18.5	17.3	17.3	16.94	16.95
FYM + ½ RDF of NPK	58.7	75.8	70.7	125.6	106.9	120.5	78.8	107.3
Press mud + ½ RDF of NPK	186.7	281.3	228.3	350.5	309.7	345.6	241.6	325.8
Compost + ½ RDF of NPK	85.5	125.7	109.6	169.6	98.5	140.7	97.9	145.3
Poultry + ½ RDF of NPK	125.4	140.6	190.7	207.4	187.1	198.4	167.8	182.1
LSD for EM at $P_{0.05}$ =6.3443 LSD for Treatments X EM at $P_{0.05}$ =9.288			LSD for EM at $P_{0.05}$ = 91.945 LSD for Treatments X EM at $P_{0.05}$ =111.945			LSD for EM at $P_{0.05}$ =14.156 LSD for Treatments X EM at $P_{0.05}$=15.033		

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Table 5. *The effect of applying EM with organic wastes on spinach Dry Foliage yield (g pot^{-1}) during 2009-10 and 2010-11.*

Treatment	1st cutting -EM	1st cutting +EM	2nd cutting -EM	2nd cutting +EM	3rd cutting -EM	3rd cutting + EM	Average -EM	Average + EM
2009-10								
Control	3	2.7	3.7	3.1	3.4	2.8	3.4	2.9
FYM + ½ RDF of NPK	8.3	10.5	11.4	14.2	5.2	11.4	8.3	12
Press mud + ½ RDF of NPK	26.8	30.3	25.6	34.6	31	31	27.8	32
Compost + ½ RDF of NPK	7.7	12.2	8.62	18.1	5.6	14.6	7.3	15
Poultry + ½ RDF of NPK	14.6	17	17.6	18.1	13.4	18.8	15.2	18
LSD for EM at $P_{0.05}$ =3.9429 LSD for Treatments X EM at $P_{0.05}$ =5.2579			LSD for EM at $P_{0.05}$ =3.25845 LSD for Treatments X EM at $P_{0.05}$ =3.1135			LSD for EM at $P_{0.05}$ = 3.1025 LSD for Treatments X EM at $P_{0.05}$ =3.656		
2010-11								
Control	2.4	2.4	3.8	3.8	3.6	3.6	3.3	3.3
FYM + ½ RDF of NPK	9	10.5	11.6	13.3	10.5	12.4	10.4	12
Press mud + ½ RDF of NPK	20.6	28.7	30.6	35.3	25.5	33.5	25.6	32.5
Compost + ½ RDF of NPK	10.4	12.6	13.5	16.4	12.5	15.4	12.1	14.8
Poultry + ½ RDF of NPK	12.5	13.2	16.6	20.5	15.5	18.2	14.9	17.3
LSD for EM at $P_{0.05}$ =1.8149 LSD for Treatments X EM at $P_{0.05}$ = 3.334			LSD for EM at $P_{0.05}$ =1.7914 LSD for Treatments X EM at $P_{0.05}$ =2.127			LSD for EM at $P_{0.05}$ =2.1161 LSD for Treatments X EM at $P_{0.05}$ =2.306		

Table 6. *The effect of applying EM with organic wastes on spinach number of leaves per plant during 2009-10 and 2010-11.*

Treatment	1st cutting -EM	1st cutting +EM	2nd cutting -EM	2nd cutting +EM	3rd cutting -EM	3rd cutting + EM	Average -EM	Average + EM
2009-10								
Control	11.2	11.8	12.7	13.6	12	13.6	11.9	13
FYM + ½ RDF of NPK	6	10.1	10.1	16.2	6.3	10.9	7.5	12.4
Press mud + ½ RDF of NPK	10	12	15	20.6	14	16.6	13	16.4
Compost + ½ RDF of NPK	6	9.1	7	12.3	6.8	9.2	6.6	10.2
Poultry + ½ RDF of NPK	6.7	11.3	10.3	16	9	12.3	8.6	13.2
LSD for EM at $P_{0.05}$ =4.52265 LSD for Treatments X EM at $P_{0.05}$ =5.1476			LSD for EM at $P_{0.05}$ = 4.5202 LSD for Treatments X EM at $P_{0.05}$ = 4.45755			LSD for EM at $P_{0.05}$ =3.8938 LSD for Treatments X EM at $P_{0.05}$ = 4.3927		
2010-11								
Control	10	10	14	14	12	12	12	12
FYM + ½ RDF of NPK	7.3	9.6	8	12.7	7.5	11	22.8	11.1
Press mud + ½ RDF of NPK	11.3	12.3	14.3	22	12	18	12.5	17.4
Compost + ½ RDF of NPK	7.1	10	10.7	17	8.8	14	8.8	13.7
Poultry + ½ RDF of NPK	8	11	10.5	14.5	9.4	13	9.3	12.8
LSD for EM at $P_{0.05}$ =1.2615 LSD for Treatments X EM at $P_{0.05}$ = 1.9773			LSD for EM at $P_{0.05}$ = 1.5957 LSD for Treatments X EM at $P_{0.05}$ =2.9357			LSD for EM at $P_{0.05}$ = 1.3288 LSD for Treatments X EM at $P_{0.05}$ = 2.1295		

seen. Press mud with EM produced 281.3, 350.5 and 345.6 g pot^{-1} in 1st, 2nd and 3rd harvest respectively. Poultry manure applied with EM also increased fresh foliage yield, but such increases were lower than those of the press mud treatment. Organic wastes are known to improve soil physical, chemical and biological fertility of the soil. Organic matter serves not only as a source of essential plant nutrients, but also improves soil physical, chemical and biological fertility which is essential for recycling of nutrients. Our findings are in line with Kurepin, et al (2013) who reported that the inoculation of wheat plants in salt affected soil with PGPRs significantly increased straw yield.

Table 7. *The effect of applying EM with organic wastes on spinach Leaf length (cm) during 2009-10 and 2010-11.*

Treatment	1st cutting		2nd cutting		3rd cutting		Average	
	-EM	+EM	-EM	+EM	-EM	+ EM	-EM	+ EM
2009-10								
Control	13.9	14.6	16.9	16.3	14.9	15.8	15.2	15.5
FYM + ½ RDF of NPK	24.8	22.5	28.3	38.8	27.4	30.6	26.8	30.6
Press mud + ½ RDF of NPK	35.5	41.4	37.4	39.4	36.3	40.7	36.4	40.5
Compost + ½ RDF of NPK	19.5	19.6	18.2	25.6	17.1	21.3	18.3	22.2
Poultry + ½ RDF of NPK	29.1	35.7	33.4	39.6	31.6	37.2	31.4	37.5
LSD for EM at $P_{0.05}$ =3.4981 LSD for Treatments X EM at $P_{0.05}$ =3.628			LSD for EM at $P_{0.05}$ =1.39985 LSD for Treatments X EM at $P_{0.05}$ = 2.8694			LSD for EM at $P_{0.05}$ =2.3633 LSD for Treatments X EM at $P_{0.05}$ =2.1652		
2010-11								
Control	13.5	13.5	15.8	15.8	14	14.5	14.4	14.6
FYM + ½ RDF of NPK	17.7	20.7	20.8	23.5	19.1	22.6	19.2	22.3
Press mud + ½ RDF of NPK	33.5	37.3	38.6	41.5	36.3	39.7	36.1	39.5
Compost + ½ RDF of NPK	25.5	32.4	27.9	36.6	26.6	33.5	26.7	34.2
Poultry + ½ RDF of NPK	28.4	34.2	35.7	37.5	31.9	35.5	32	35.7
LSD for EM at $P_{0.05}$ =3.7202 LSD for Treatments X EM at $P_{0.05}$ = 4.5236			LSD for EM at $P_{0.05}$ = 4.8463 LSD for Treatments X EM at $P_{0.05}$ =5.0005			LSD for EM at $P_{0.05}$ = 3.2592 LSD for Treatments X EM at $P_{0.05}$ =8.0789		

Table 8. *The effect of applying EM with organic wastes on spinach Leaf area (mm^2) during 2009-10 and 2010-11.*

Treatment	1st cutting		2nd cutting		3rd cutting		Average	
	-EM	+EM	-EM	+EM	-EM	+ EM	-EM	+ EM
2009-10								
FYM + ½ RDF of NPK	28.3	27.6	22.9	31.7	7.1	26.9	19.4	28.7
Press mud + ½ RDF of NPK	126.4	139.8	151	192.5	131.3	141.2	136.2	157.9
Compost + ½ RDF of NPK	145.2	173.8	206.2	372.1	164.4	169.2	171.9	79.5
Poultry + ½ RDF of NPK	118.4	137.9	135.5	142.5	125.5	125.7	126.4	135.4
Poultry	137	165.8	158.4	215.1	141.6	147.6	145.7	176.2
LSD for EM at $P_{0.05}$ =70.0365 LSD for Treatments X EM at $P_{0.05}$ =92.317			LSD for EM at $P_{0.05}$ =34.5965 LSD for Treatments X EM at $P_{0.05}$ =48.527			LSD for EM at $P_{0.05}$ = 36.464 LSD for Treatments X EM at $P_{0.05}$ =71.012		
2010-11								
Control	22.2	22.2	25.7	25.7	23.7	23.7	23.9	23.9
FYM + ½ RDF of NPK	121	135.5	152.5	160.6	122.6	147.5	132	147.9
Press mud + ½ RDF of NPK	141.6	168.8	221.8	350.6	176.7	298.5	180	272.6
Compost + ½ RDF of NPK	125.5	140.7	150.5	170.7	135.6	152.5	137.2	154.6
Poultry + ½ RDF of NPK	133.6	157.4	197.6	206.5	139.7	162.7	157	175.5
LSD for EM at $P_{0.05}$ =6.7660 LSD for Treatments X EM at $P_{0.05}$ =7.0416			LSD for EM at $P_{0.05}$ =8.4962 LSD for Treatments X EM at $P_{0.05}$ =7.8919			LSD for EM at $P_{0.05}$ =8.4435 LSD for Treatments X EM at $P_{0.05}$ =7.6276		

Dry Foliage Yield (g pot^{-1})

Like the fresh foliage yield, dry foliage yield was significantly (P<0.05) influenced by organic wastes applied with EM and their interaction (Table 5). During 2009-10, press mud applied with EM produced the highest dry yield of 30.3, 34.6 and 31 g pot^{-1} in 1st, 2nd and 3rd cuttings respectively. In 2010-11, somewhat similar trend was observed in the treatment of press mud with EM and the dry foliage yields were 28.7, 35.5 and 33.5 g pot^{-1} for the 1st, 2nd and 3rd harvests respectively. Poultry manure and FYM applied with EM also significantly (P<0.05) increased dry foliage yield of spinach. The average effect of treatments and EM was also significant. The highest dry foliage yield was recorded in pots where press mud was applied with EM. It varied statistically from

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all other combinations. Our results are in line with Chantal, et al. (2013) who reported that EM with bio-organic fertilizers significantly increased dry biomass of flue-cured tobacco. Kurepin, et al. (2013) also reported that inoculation with *Azospirillum* sp. caused increased grain yield and shoot dry matter in cereals.

Number of leaves plant^{-1}

The number of leaves per plant was significantly ($P<0.05$) affected by different organic wastes applied with EM (Table 6). The highest number of leaves of 12, 20 and 16 plant^{-1} was exhibited by the press mud treatment with EM in 1st, 2nd and 3rd harvests during 2009-10 respectively. The numbers of leaves during 2010-11 were 12, 22 and 18 plant^{-1} in 1st, 2nd and 3rd harvest for the same treatment. Poultry manure and FYM applied with EM also resulted in high number of leaves compared to these treatments with out EM. These two treatments were not significantly different from each other, but they were significantly ($P<0.05$) higher than where no EM was applied with these treatments. The average effect of treatments and EM was also significant. Organic wastes enhance cation exchange capacity of the soil thereby improving the nutrient availability as well as minimize the potential of nutrients losses by leeching and surface runoff. Similar results were shown by Chantal, et al. (2013) who reported that EM with bio-organic fertilizers significantly increased fresh leaf yield of flue-cured tobacco.

Leaf Length (cm)

The length of leaf per plant was significantly ($P<0.05$) affected by different organic manures and inorganic fertilizers in presence of EM (Table 7). Significantly ($P<0.05$) highest leaf length were 41.4, 39.4 and 40.7 cm in 1st, 2nd and 3rd harvests during 2009-10, while 37.3, 41.53 and 39.7 cm in 1st, 2nd and 3rd harvests respectively during 2010-11 were reported in press mud with EM followed by poultry manure and FYM, which differed statistically from one another. Application of EM significantly increased number of leaves of spinach. The average effect of treatments and EM was also significant. Organic matter also improves the permeability of root cell membrane by humic acids, increasing the uptake of water and other nutrients. Therefore the added press mud resulted in high plant growth and yield in our experiment. Same results were shown by Chantal, et al (2013) who reported that EM with bio-organic fertilizers significantly increased fresh leaf yield of flue-cured tobacco.

Leaf Area (mm^2)

The leaf area was significantly ($P<0.05$) affected by various organic wastes in combination with EM (Table 8). Significantly ($P<0.05$) greatest leaf area of 174, 372, and 169 mm^2 in 1st, 2nd and 3rd harvest was observed during 2009-10, while in 2010-11, maximum figures of 169, 350 and 298 mm^2 in 1st, 2nd and 3rd harvest were noticed in press mud with EM which was followed by poultry manure with EM. The data indicated that among organic wastes, press mud enhanced plant height more than other sources of organic wastes. The data revealed that EM may be used along with organic manures for achieving better results. Similar results were shown by Chantal, et al (2013) who reported that EM with bio-organic fertilizers significantly increased fresh leaf yield of flue-cured tobacco.

Conclusion and Recommendations

The application of EM in combination with press mud (20 ton ha^{-1}) and ½ NPK (75: 60:30 kg ha^{-1}) considerably enhanced the spinach yield and growth parameters on a loamy soil. Such increase in plant growth and yield of spinach could be attributed to supply of essential plant nutrients by press mud. These results warrant further testing under variable field conditions.

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