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RESEARCH ARTICLE

VERMICOMPOST AND FARMYARD MANURE INCREASE FERTILITY OF SODIC SOIL AND THE PRODUCTIVITY OF GREEN VEGETABLES.

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Abstract

Soil degradation due to salinization and sodication in arid and semiarid region is of global concern and studies on management of such soils can provide pragmatic solutions. In this study, we used different organic and inorganic amendments to investigate their likely effects of sodic soil properties (pH, electrical conductivity; EC, exchangeable sodium percentage; ESP) and productivity (growth and seed production) of two vegetables crops Spinach (*Spinacia oleracea*) and the Pea (*Pisum sativum*). We have selected a patch of sodic soil (sodicity: pH 9.04, EC 1.05 dSm^{-1}, ESP 78.5) divided into six blocks and each block with eight unit plots (total 48 unit plots). Dietary crops were grown with eight different amendments of chemical fertilizers and organic manures (Control, T1; NPK, T2; farmyard manure (FYM), T3; vermicompost (VC), T4; NPK+VC, T5; FYM+VC (1:1), T6; FYM+VC (1:2), T7; FYM+VC (2:1), T8). The combined use of FYM and VC showed approximately 5.97, 41.9 and 48% respective decrease in soil pH, EC and ESP and 33.2, 78.3, 29.5 and 152 increase in soil nitrogen, phosphorus, potassium and soil organic carbon (OC), respectively. This decrease in soil sodicity and the increase in soil fertility showed significant increase at $P < 0.05$ in crops' different morphological growth parameters and growth indices such as the relative growth rate (RGR), root shoot ratio (RSR), leaf weight ratio (LWR) and leaf area ratio (LAR). We also observed a remarkable increase in seed yield of spinach and pea by 186 and 72.35 % in organic amended soil. The study reveals that combined use of FYM and VC in sodic soil might be adopted as alternate farming technology to diminish the unproductive effect of sodicity in the Indian agricultural economy.

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Introduction:-

Land degradation has now become a burning issue at a global level as its spatial distribution varies from 1 billion ha to over 6 billion ha (Gibbs and Salmon, 2015). Deforestation, accelerated soil erosion, lost of biodiversity pollution, lost of soil fertility and the accumulation of salt on the soil surface are some major causes of degraded land (Keesstra, 2007; Dai et al., 2015; Eskandari et al., 2016; Kasem and Mohamed, 2016; Prosdocimi et al., 2016; Rodrigo et al., 2016). Salt induced land degradation is one of very important issues as affecting the status of food, productivity as well as health along the planet (Wicke et al., 2011; Ivits et al., 2013; Murtaza, 2013). According to recent data, the world salt affected area (saline 397×10^6 and sodic soils 434×10^6 ha) may lead about 27.3 $ billion current annual economic losses and 441 ha^{-1} $ inflation-adjusted cost at global level (Qadir et al., 2014). In case of India, this scenario is more critical as India (329 Mha geographical area) with only 2.4 % world land area, supports 18% and 15% world human and livestock population respectively and provide employment for 54.6% Indian people (Bhattacharya, 2015). India has INR 10714 annual potential losses and INR 7737 annual actual losses ha^{-1} due to 3.77 Mha acidic soils of 6.73 Mha salt affected land area. With respect to crops in Rice about a 33 % yield reduction in slight and 57% in moderate acidic soil is reported (Dwivedi and Qadar, 2011). However, 45% in slight and 100% yield loss is noted for wheat crop (Sharma et al., 2010; Thimmappa et al., 2014).

Application of slow release fertilizers, biological nutrient sources, organic matter management, natural predators, crop rotations and manual weed control are some key characteristics of organic farming to maintain agriculture sustain. In 2013 India occupies about 1.18% (5,10,000 ha) organic agricultural land 15th world position which in 2014 become 7.20,000 ha (1.64%) with 11th rank in the world (FiBL, 2016). Based on extensive research it has been scientifically and undoubtedly established, that organic farming systems are most productive, environment-friendly system, sustain natural resources and agriculture and reducing the impact of agriculture on the atmosphere. In this direction a lot of patches of literature based on reclamation of sodic soil with organic amendments using various agricultural crops such as cereals, millets, pulses except dietary vegetable crops are existing in the last five years (Walpola and Arunakumara, 2010; Cha-um and Kirdmanee, 2011; Diacono and Montemurro, 2015; Drake et al., 2016; Mbarki *et al.,* 2016). Thus this study reflects whole picture of growth pattern through relative growth rate (RGR), relative shoot ratio (RSR), leaf weight ratio (LWR), leaf area ratio (LAR), plant biomass and productivity status of common Indian dietary crops such as *Spinacia oleracea* (leafy vegetable) and *Pisum sativum* (fruit vegetable) along with sodic soil properties which is very significant in direction to overcome the losses of agricultural economy due to salt affected soil in India as well as vegetable crop cultivation in sodic soil.

Materials and Methods:-

The study area:-

A large area of sodic soil was selected as the study field in Babasaheb Bhimrao Ambedkar University, campus Lucknow (26^0 50’21” N, 80^0 55’23” E and 126 m above sea level) during year 2014 – 2016. The meteorological data of the study area were obtained from the Indian Meteorological Department (IMD), Amausi, Lucknow (3 km away from the experimental site) during the study period. On this basis an average annual rainfall during the last five years was measured as 789.4 ± 100 mm, the minimum-maximum temperature varied from 19.2 ± 1.08^{0}C to 40.1 ± 0.16^{0}C, and the average annual relative humidity was recorded as 60.7 ± 2.01%.

Experimental Design:-

The experiment was designed with eight soil amendments. (1) T1, Control (without amending soil); (2) T2, NPK (a synthetic fertilizer with recommended dose); (3) T3, FYM (farmyard manure); (4) T4, VC (vermicompost) (5) T5, NPK + VC; (6) T6, FYM: VC (1:1); (7) T7, FYM: VC (1:2); (8) T8, FYM: VC (2:1). Synthetic fertilizers (NPK) were used as per established recommended practices at the rate of 40 kg ha^{-1} y^{-1} for N, 20 kg ha^{-1} y^{-1} for P and 15 kg ha^{-1} y^{-1} for K. FYM and VC were used @ 30 t ha^{-1} and 5 t ha^{-1} respectively. Soil without any amendment was taken as a control (C) for data comparison with other treatments. All amendments were applied in the study area as a randomized complete block design (18 x 18 m) with six blocks (18 m x 3 m). Each block was again divided into eight plots (2 m x 2 m) and hence there were 48 (6 x 8) unit plots. The distance between two adjacent blocks and plots were 1 m and 0.5 m, respectively. The eight treatments were randomly assigned to each plot within the individual blocks with a separate randomization for each block.

Soil sampling and Analysis:-

Random soil samples from 0-25 cm depth was collected in triplicate form from each block of sampling sites with the help of an auger before and after the amendment application and before and after the cultivation of the crops at 15 days intervals from 2014-2016. Soil pH and conductivity (EC) were analyzed by pH and conductivity meter respectively. Phosphate – P and total Nitrogen – N were determined by the Olsen's sodium bicarbonate method (Mackereth, 1963) and Micro-Kjeldahl distillation assembly (Misra, 1968), respectively. Available potassium K^+ was estimated with the help of a flame photometer. Exchangeable sodium percentage was calculated as follows: ESP = (exchangeable sodium concentration (cmol/kg)/cation exchange capacity (cmol/kg)) × 100. The titrimetric method (wet digestion method) was used for determination of soil organic carbon (OC).

Vegetal sampling and analysis:-

Two dietary vegetables such as Spinach (*Spinacia oleracea* L.*)* and the Pea (*Pisum sativum* L.) were selected as experimental test crops. These vegetables are among the most important/common dietary vegetables of north India because of their high nutritional values. Seeds of test crops were sown uniformly in differently amended sodic soil plots. After cultivation six random plant samples were taken at 15 day intervals of each crop for plant analysis. Before analysis, plant samples should be properly washed with tap water to remove the dust. To study the effect of different amendments on crop growth variables, four different growth indices such as a relative shoot ratio (RSR), relative growth rate (RGR), leaf area ratio (LAR) and leaf weight ratio (LWR) was computed. For computation of these indices formulae given by Hunt (1982) were used.

$$RGR\ (g\ g^{-1}\ d^{-1}) = \frac{In\ W_2 - In\ W_1}{t_2 - t_1}$$

$$LAR\ (cm^2\ g^{-1}) = \frac{\text{Leaf Area}}{\text{Total Biomass}}$$

$$LWR\ (g\ g^{-1}) = \frac{\text{Leaf Dry Weight}}{\text{Total Biomass}}$$

$$RSR\ (g\ g^{-1}) = \frac{\text{Root Dry Weight}}{\text{Shoot Dry Weight}}$$

Where,

W_1 = total plant dry weight at time t_1 (initial)

W_2 = total plant dry weight at time t_2 (final)

In = natural logarithm

Statistical analysis:-

All the obtained data were subjected in IBM SPSS statistics 21 for the measurement of mean, standard error, range, variance $P \leq 0.05$ as significant, followed by a post hoc Tukey test. All the graph designing and regression analysis employed to determine the relationship between the ESP, OC and crop yield was accomplished using Sigma Plot 11.0.

Results and Discussion:-

Physico-chemical properties and soil nutrient status as influenced by organic Amendments:-

After about 4.5 months of application of organic amendments soil pH, EC and ESP (an important indicator of sodicity) were decreased significantly from 0.11% – 5.97 %; 9.5 – 41.9% and 3.56 – 48.0% respectively in soils amended together with FYM and VC in comparison to control (Table I). The highest decrease in soil pH, EC and ESP were observed in FYM and VC (T8) treated plots. The soil nutrients N, P, K and SOC contents were significantly higher in organic amendments sodic soils than soils amended with chemical fertilizers (T3; NPK amended soil) and control soil. The highest soil nutrients were observed in FYM and VC treated plots (T8). The increased values were N (2.62% - 33.2%), P (3.69% – 78.3%), K (2.72% - 29.5%) and OC % (16%-152%) in comparison to pre harvest values. Various physico-chemical properties of used organic amendments such as FYM and VC were also analyzed and given in Table II.

Reduction of pH in sodic soil on the application of organic amendments is likely due to higher production of CO_2 and organic acids in soil followed by solublization of $CaCO_3$ and sodicity neutralization is well reported (Ansari, 2008; Rai et al., 2010; Shaimaa et al., 2012; Rehman and Nath, 2013) but this phenomenon found more efficient here with the application of FYM and VC in 2:1 ratio may with their some acidic pH values in this study (Table II). Reduction at the level of 41.5% of EC in organically amended sodic soil may attribute to improved physical properties of soil as well as an increased leaching process with the resourceful coupling of FYM and VC in T8 treatment (Kahlown and Azam, 2003; Shaimaa et al., 2012; Wang et al., 2014). After harvesting, ESP reduction was 48% in experimental soil leads to increase organic carbon content and humic acid in soil. These contents in turn reduce redox potential and increase the replacement of Na^{+} to Ca^{++} leaching (Ansari and Ismail, 2008; Wang et al., 2014; Diacono and Montemurro, 2015). Thus, these results indicate that organically amended soil have efficient potential to reduce the sodic effect of soil in the direction to make them fertile. Moreover FYM and VC in 2:1 may act as boosting element to reduce the dispersion effect of soil to improve the soil structure which facilitates the growth of microbial population in sodic soil.

Available N, P, K (primary macronutrients) and OC are the fertile soil indicator. Use of biological nutrient resources, organic matter management and slow release fertilizer are key functions of organic amendments which might be the results of high level of micro and macronutrients in T8 (FYM+VC, 2:1) (Ros et al., 2003; Clark et al., 2007). On the other hand, production of organic acid and products of mineralization during decomposition solubilizes the insoluble compounds also and enhances the N, P and K availability in soil (Bhandari et al., 1992; Rahman and Nath, 2013). On account of literature, organic amendments promote the high binding ability of micronutrients as well as their slow release (Cooperband, 2002; Withers and Bailey, 2003) in the atmosphere which enhance the OC% in organically amended soil.

Table 1:- Physico-chemical properties of sodic soil as influenced by organic amendments in sodic soil. Values are in means and range. Values in parenthesis represent % increase (+) or decrease (-) with respect to pre-harvest values over 2014.

Variables	Pre harvest	T1	T2	T3	T4	T5	T6	T7	T8
pH	9.04	9.03 (-0.11) 9.01-9.06	9.03 (-0.11) 9.00-9.05	8.64 (-4.42) 8.62-8.66	8.64 (-4.42) 8.62-8.68	8.72 (-3.50) 8.71-8.74	8.55 (-5.42) 8.55-8.66	8.53 (-5.64) 8.52-8.55	8.50 (-5.97) 8.50-8.51
Ec (dSm^{-1})	1.05	0.95 (-9.5) 0.95-0.96	0.94 (-10.4) 0.90-0.95	0.75 (-28.5) 0.70-0.79	0.71 (-32.3) 0.70-0.73	0.77 (-26.6) 0.77-0.78	0.65 (-38.0) 0.64-0.66	0.64 (-39.0) 0.63-0.65	0.61 (-41.9) 0.60-0.62
N ($kgha^{-1}$)	268	264 (-1.49) 257-272	275 (+2.61) 264-283	317 (+18.2) 311-324	322 (+20.1) 315-327	294 (+9.70) 291-298	351 (+30.9) 343-359	353 (+31.7) 346-357	357 (+33.2) 344-363
P ($kgha^{-1}$)	21.7	22.5 (+3.69) 21.2 -23.8	24.4 (+12.4) 23.3-25.7	33.6 (+54.8) 25.5-39.7	35.3 (+62.6) 27.4-42.8	30.6 (+41.0) 23.7-34.6	36.8 (+69.5) 27.4-39.3	38.1 (+75.5) 26.8-49.4	38.7 (+78.3) 28.6-46.4
K ($kgha^{-1}$)	184	182 (-0.76) 174-185	189 (+2.72) 167-196	205 (+11.5) 188-218v	214 (+16.6) 187-233	196 (+6.68) 178-216	225 (+22.2) 199-140	231 (+25.8) 195-258	238 (+29.5) 197-248
OC (%)	0.25	0.24 (-4.0) 0.23-0.25	0.29 (+16) 0.23-0.33	0.53 (+112) 0.51-0.55	0.55 (+120) 0.54-0.56	0.43 (+72) 0.42-0.44	0.56 (+124) 0.55-0.58	0.64 (+156) 0.62-0.65	0.63 (+152) 0.61-0.64
ESP	78.5	75.7 (-3.56) 74.3-77.2	81.3 (+3.56) 78.4-83.2	63.3 (-19.3) 61.3-66.3	66.4 (-15.4) 63.4-68.5	74.4 (-5.22) 71.6-77.4	54.1 (-30.1) 51.6-57.3	47.68 (-39.3) 44.8-50.6	40.8 (-48.0) 38.5-52.6

T1=control; T2=NPK; T3=FYM (farmyard manure); T4=VC (Vermicompost); T5=NPK+VC; T6=FYM+VC (1:1); T7=FYM+VC (1:2); T8 =FYM+VC (2:1)

Table 2:- Chemical and nutrient status of used organic amendments applied in sodic soil.

Parameters	Farmyard Manure (FYM)	Vermicompost (VC)
pH	6.4	7.1
Ec (dSm^{-1})	10.24	8.3
N %	1.98	1.42
P %	0.63	0.66
K %	2.84	1.72
Na^+ ($meql^{-1}$)	-	18.5
OC %	17.4	12.6
Ca^{2+}	4.68	2.95
Mg^{2+}	0.33	0.27

Table 3:- Yield of Spinach and Pea as influenced by soil amendments in sodic soil.

Treatments	Spinach (t ha^{-1})	% increase	Pea (t ha^{-1})	% increase
T1	2.07		4.34	
T2	3.12	50.72	5.67	30.65
T3	3.87	86.96	6.13	41.24
T4	4.11	98.55	6.46	48.85
T5	3.56	71.98	5.84	34.56
T6	5.65	172.9	7.24	66.82
T7	5.78	179.2	7.48	76.73
T8	5.94	186.9	7.67	72.35

Effect of organic amendments on dry matter allocation pattern:-

Dry matter distribution in between root and shoot in Spinach and Pea crops under organic soil amendments in sodic soil is shown in Figure 1. The dry matter allocation is more than 70% in the shoot than root in both the crops which is statistically significant in different soil amendments ($p \leq 0.01$). In Spinach, shoot biomass distribution was increased from 0.76 g/plant in control to 2.37 – 2.70 g/plant in organically amended soil grown crops (FYM and VC i.e., T6, T7 and T8) in comparison to NPK amended grown crops (1.02 -1.08 g/plant) which is very significant as their high nutritional value in the daily diet. In case of pea, dry mass allocation was maximum in T8 treated grown crops (4.02 g/plant) which is approx double than chemically amended grown crop. Therefore, this biomass percentage increase in combination of FYM + VC in acidic soil is very effective in view of soil fertility as well as economic agriculture in salt affected soil.

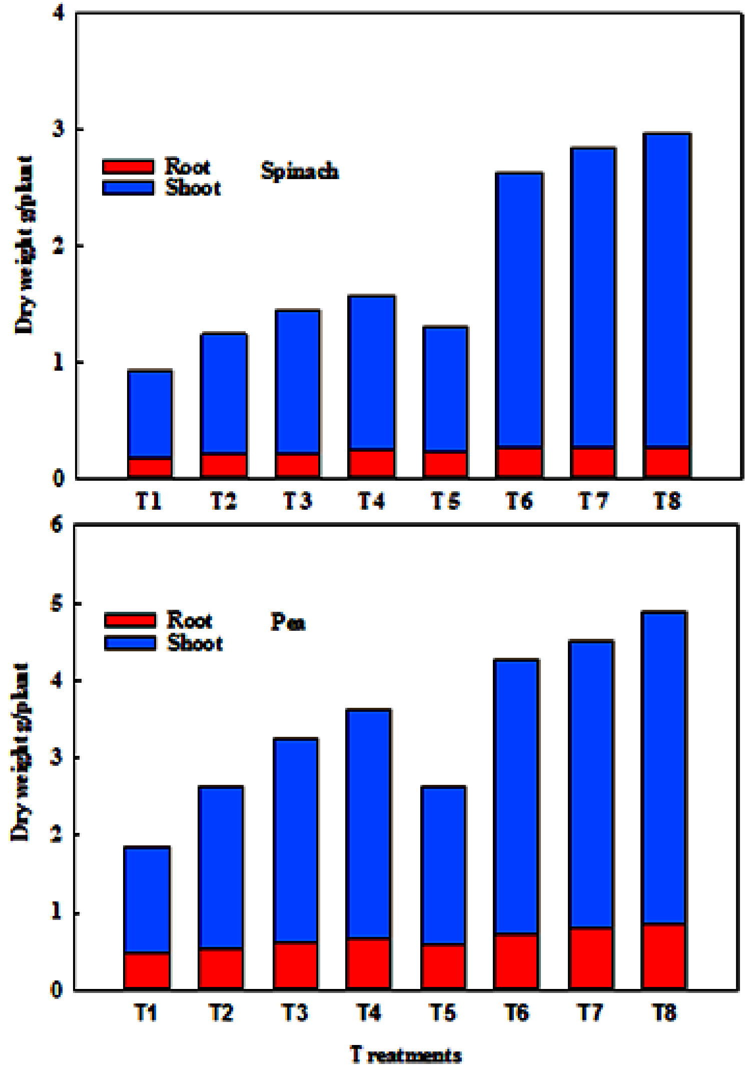

Figure 1:- Dry matter distribution in root and shoot parts under the influence of different amendments in sodic soil in Spinach and Pea crops. Values are means (n=6). T1=control; T2=NPK; T3=FYM (farmyard manure); T4=VC (Vermicompost); T5=NPK+VC; T6=FYM+VC (1:1); T7=FYM+VC (1:2); T8 =FYM+VC (2:1).

Adequate amount of nitrogen in soil and their availability in soil to uptake are different views of biomass allocation in plants. On account of Harris (1992), high level of nitrogen promote, shoot growth while phosphorous stimulates root growth. As in this study amount of phosphorus in preharvest soil as well as in using amendments were lower than nitrogen, which may attribute to higher shoot biomass than root. Organic amendments on soil not only enhance the amount of NPK in soil as well as increase their availability in the form of slow release in the soil is more than other used treatments (Khalilzadeh et al., 2012; Singh and Agarwal 2007) which may leads the maximum shoot dry biomass in T6, T7 and T8 in comparison to control and NPK treated sodic soil.

Growth Indices in terms of RGR, LAR, LWR and RSR as influenced by organic amendments:-

Relative growth rate, RGR is the total dry weight increase in comparison to initial dry weight in unit time interval. In both crops, RGR is reduced with increasing plant age in all the treatments (Figure 2). In spinach, crop grown under T8 treatment have the highest RGR value (0.02 – 0.082 g g^{-1} day^{-1}) followed by T7 and T6 i.e., other combinations of FYM and VC. Meanwhile in case of pea the maximum RGR was found in T7 (0.046 – 0.088 g g^{-1} day^{-1}) in comparison to other FYM and VC combinations and control treatment. To analyze the allocation of biomass between leaf and plant dry weight, LWR (leaf weight ratio) is considered. In Spinach leaf weight ratio indicated not much significant variation in different treatments and found high in T8 (0.378-0.429 g g^{-1}), however in pea maximum LWR (0.378-0.590 g g^{-1}) was reported in T6 with significant increase in comparison to T1 (Figure 2). To evaluate amount of leaf area per unit total mass LAR (leaf area ratio) is a valuable factor. Highest LAR was noticed in T3 (426 cm^2 g^{-1}) and T4 (420 cm^2 g^{-1}) in spinach with the trend of T3>T4>T7>T8>T6>T5>T2>T1. However in pea LAR was maximum in T5 (1777 cm^2 g^{-1}) followed by T8>T7>T4>T6>T1>T3>T2 (Figure 2). Root shoot ratio (RSR) is ratio of distribution of plant biomass in root and shoot. In this study, maximum RSR was reported in T3 (0.716 g g^{-1}) followed by T4, T2, and T5 in spinach crop. On the other hand in pea, highest RSR was reported in T6 (0.754 g g^{-1}) with the trend of T2>T3>T1>T4>T8>T7>T5 (Figure 2).

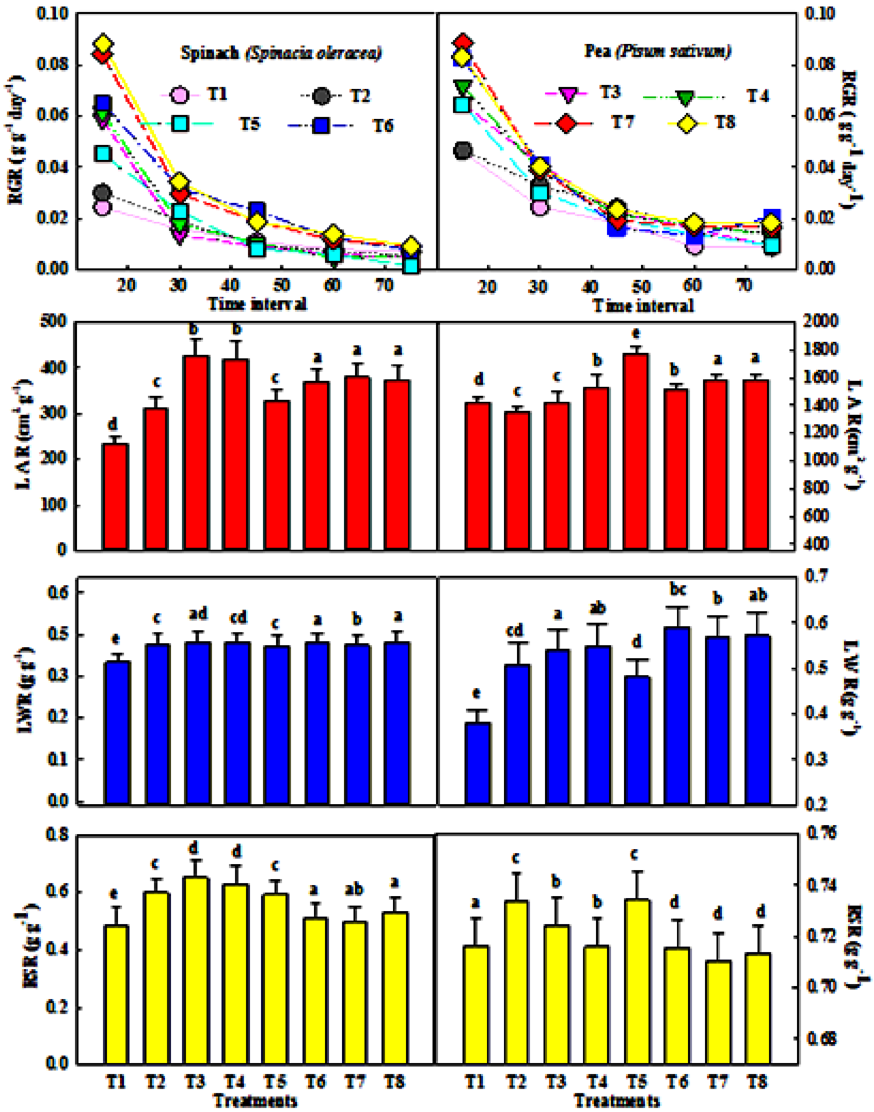

Figure 2:- Effect of soil amendments on growth indices of spinach and pea crop. Values are mean (n=6). Means in on each bar followed by different letters are significantly different (LSD at 0.05). T1=control; T2=NPK; T3=FYM (farmyard manure); T4=VC (Vermicompost); T5=NPK+VC; T6=FYM+VC (1:1); T7=FYM+VC (1:2); T8 =FYM+VC (2:1).

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Highest relative growth rate of pea and spinach in FYM and VC combinations such as T7 and T8 is attributed with positive and significant correlation of RGR with LWR in both spinach (r = 0.6612, p<0.0001) and pea (r = 0.555, p<0.0001). The result is also attributed in the study of Riccardi et al., 2014. In case of the Leaf weight ratio (LWR), T6, T7 and T8 due to the highest soil fertility improvement of FYM and VC biomass of the plant is also high which leads to higher LWR. LWR shows significant positive correlation with RGR. In spinach and pea, leaf area ratio was noticed highest in T3 or FYM and T5 NPK+VC amended grown vegetables respectively. In both the amendment T3 and T5 plant biomass is low in comparison to T6, T7 and T8 due to slow effect of organic amendment, however the high leaf area has already reported in NPK treatment (Gairola et al., 2009). Thus, increased leaf area and reduced plant biomass lead to highest LAR. The root shoot ratio is a photosynthetic translocation between above and below ground parts. Soil fertility is directly proportional to the reduced root shoot ratio (Harris, 1992; Fageria and Moreira 2011). The lowest root shoot ratio was found in organic amended soil in both crops explain its own efficient fertility potential.

Effective combination study of FYM and VC in terms of yield:-

The effects of organic amendments on vegetable crops were also considered in terms of economic yield (Table III). For this purpose fresh weight of edible components was taken as the response variable. Economic yield shows an increase from 86.96 to 186.96 % in organically amended grown spinach vegetable in comparison to 50.72 % to 71.98 % in chemically amended crop. The similar yield pattern was found in case of pea also although the maximum yield was reported in T7 amendment i.e., 76.73% in pea**.**

In yield of spinach and pea, the highest yield in T8 and T7, respectively, may be attributed to the significant effect of increased organic carbon and decreased ESP after application of a combination of FYM and VC in acidic soil. A linear regression equation was also plotted (Figure 2) which clearly indicates the reclamation effect of organic amendments to reduce the sodicity of soil. In fact, due to the higher production of CO_2 and humic acids in vermicompost application introduce a drop in redox potential and the replacement of exchangeable Na^+ ions by Ca^{+2} ions leaching out of the root zone (Ansari, 2008). It reduces the level of ESP and increase SOC. Therefore a significant increase in crop yield was reported.

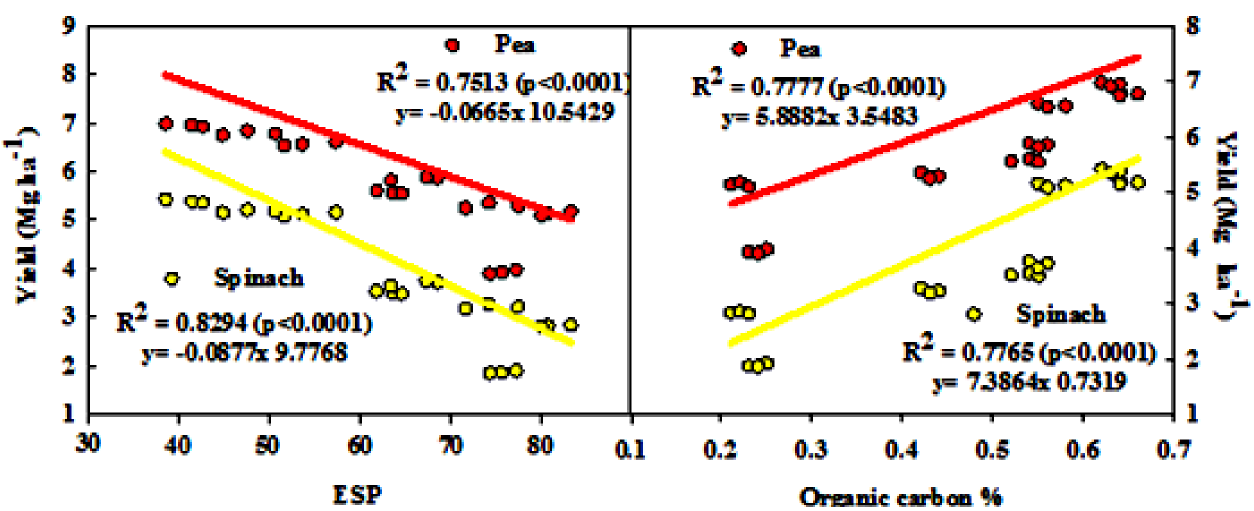

Figure 3:- Correlation coefficient between ESP and OC% with economic yield in Spinach and Pea crops.

Conclusions:-

The study concludes that combined use of organic amendments of farm yard manure and vermicompost significantly decreases the soil sodicity and increased soil fertility. These changes in sodic soil properties have a profound effect on crop productivity and therefore such combinations of organic amendments can be promoted to enhance the crop productivity on widely distributed sodic soils in India and other arid and semiarid regions in the world.

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