



Effect of organic manures and soil moisture regimes on residual soil fertility and biological properties under mustard crop with saline water irrigation

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Abstract: The field experiment was conducted to work out the effect of organic manures, moisture regimes and different saline water on physico-chemical properties, nutrient availability, dynamics of soil microbial biomass and enzymes activities, yield, nutrient concentration and quality of mustard in loamy sand soil at Agronomy Farm, S.K.N. College of Agriculture, Jobner during *rabi* seasons of 2010-11 and 2011-12. The experiment comprising 27 treatment was laid out in split plot design with three levels of organic manures (control, FYM @ 10 t ha⁻¹, and vermicompost @ 5 t ha⁻¹), three levels of moisture regimes (0.4, 0.6 and 0.8 IW/CPE) and three levels of saline water (control, 6, and 12 dSm⁻¹). Result revealed that application of vermicompost @ 5 t ha⁻¹ significantly increased the available N(137.39), P (10.01) and K (156.29) kg ha⁻¹ of soil at harvest, during *rabi* seasons first month after sowing in year of 2010-11 and 2011-12 NH₄⁺-N (9.13 and 9.93) and NO₃⁻-N (15.89 and 16.51) mg kg⁻¹, soil dehydrogenase(18.21 and 18.57) pKat kg⁻¹soil, alkaline phosphatase enzyme activity(12.24 and 13.04) µg pNP produced g⁻¹ soil h⁻¹ at different months under vermicompost applied @ 5 t ha⁻¹. Significant increase was noted in seed (14.42) and stover (35.94) q ha⁻¹ yield of mustard under all the organic manures over control. Application of irrigation at 0.8 IW/CPE moisture regimes significantly increased the P(9.93) and K(155.47) kg ha⁻¹ of soil at harvest while available N(127.48) kg ha⁻¹, NH₄⁺-N(7.49 and 8.20), NO₃⁻-N(14.14 and 14.64) mg kg⁻¹ during *rabi* seasons first month after sowing in year of 2010-11 and 2011-12 decreased significantly under 0.8 W/CPE moisture regime. At different months, soil dehydrogenase (17.49 and 14.19) pKat kg⁻¹soil, alkaline phosphatase enzyme activity (12.24 and 12.85) µg pNP produced g⁻¹ soil h⁻¹ increased significantly under 0.8 IW/CPE moisture regime. The seed (12.54) and stover (31.95) q ha⁻¹ yield of mustard increased significantly with increasing moisture regimes. The available N(127.98), P(8.88), K(131.50) kg ha⁻¹, during *rabi* seasons first month after sowing in year of 2010-11 and 2011-12 NH₄⁺-N(7.81 and 8.53), NO₃⁻-N(14.23 and 14.55) mg kg⁻¹ at different months decreased significantly due to increasing level of saline water during both the years and in pooled mean. The soil biological activity like soil dehydrogenase (14.92 and 15.25) pKat kg⁻¹soil and alkaline phosphatase activity (10.25 and 15.25) µg pNP produced g⁻¹ soil h⁻¹ at different months was reduced significantly due to increasing level of saline water.

Key words: Available N, P, K, NH₄⁺-N, NO₃⁻-N, Dehydrogenase, Alkaline phosphatase enzyme activity, Yield, Mustard

Introduction

Water for irrigation creates salinity or sodicity in soil. The soil degradation due to salinity and sodicity problems had affected significant areas of fertile tracts particularly in arid and semi-arid regions of country and caused significant loss to crop productivity. These salt affected soils are found in majority of states in the country. Salt affected soils cover an area of nearly 13.8 M ha in the country (Yadav, 2007) and 1.24 M ha in Rajasthan and occurs to a greater or lesser extent in practically all the district of state (Sharma *et al.*, 2004). The ground water of north-western Rajasthan is typical water with problem of high salinity flanked with high chloride and sulphates. Such water is continuously in use for agriculture depending on the extent of hazardous constituents. Salinity in ground water ranged from 2.1 to 9.1 dSm⁻¹ in wells of Rajasthan (Agrawal *et al.*, 2002). Unscientific and indiscriminate usages of saline water for irrigation causes on accumulation of soluble salts in root zone and adversely affects the physical and chemical properties of irrigated soils which in turn decreases crop productivity due to reduced water availability to plants (Chauhan *et al.*, 1988). Plant growth is either depressed or entirely prevented due to excessive build-up of salinity in soil due irrigation with saline water. In addition to the osmotic stress, crop productivity is adversely affected due to specific ion toxicities, inadequate nutrient availability and cationic imbalances within the plants. These soils, which are underlain with poor quality ground waters in the arid and

semi-arid regions tested low in organic matter and hence are poor in fertility (Bajwa *et al.*, 1998). Therefore, the importance of judicious management of irrigation water in these soils is as important as their reclamation. For the last few years, farmers in this region have been increasingly using organic materials such as FYM and vermicompost which holds a good promise to accelerate the process of decomposition as well as ready energy source for microbial proliferation in maintaining soil fertility to provide sustainability. Vermicompost is now available easily on commercial scale. Sustenance of cropping systems through use of organics, crop residues, industry waste and chemical fertilizers is therefore, vital for rehabilitation of the deteriorated saline soil and safer use of the saline water for irrigation. Soil organic matter is central to soil quality assessment since it influences many soil properties related to a number of key soil functions. The organic matter content of a soil reflects the balance between additions and losses due to decomposition. The sustainability of agricultural production systems depends on maintaining the reserves of soil organic matter at the minimum levels necessary to protect the soil and maintain productivity. In nature, it is widely recognized that maintenance of an adequate level of soil organic matter should be a guiding principle in developing appropriate soil management practices. If the quantity of soil organic matter is declining, then it is usual to find that soil productivity is also deteriorated (Nambiar and Abrol, 1989).

Organic matter dynamics and nutrient cycling are closely related through the microbial driven processes of nutrient

immobilization and mineralization. The soil microbial biomass is defined as the living part of the soil organic matter, excluding plant roots, soil and animals larger than $5 \times 10^3 \mu\text{m}^3$ (Jenkinson and Ladd, 1981). It is a reservoir of potentially available plant nutrients and comprises 1-3 % of total organic carbon in soil. The soil microbial biomass acts as a source and sinks for the plant nutrients playing a crucial role in nutrient cycling and soil organic matter dynamics. It is the prime agent involved in plant residue decomposition, nutrient conservation and cycling processes in the soil (Smith and Paul, 1990). Due to the role of microbial biomass as most sensitive indicator of changes in organic matter turnover, its measurements are valuable tools for understanding and predicting the long-term effects of changes in farming systems on soil organic matter (Powlson and Jenkinson, 1981). Maintenance of a diverse and functioning microbial community is important for soil sustainability. Loss of microbial diversity makes biological systems less able to adapt to environmental stresses. Low soil microbial diversity indicates stressed conditions in soil while high diversity is an indicator of a healthy soil, (Rao, 2007). In view of the significance of soil organic carbon, adoption of judicious management practices to restore and upgrade soil organic carbon is essential in saline environment.

Rapeseed and mustard is one of the important edible oilseed crops of India next to groundnut and soybean. It alone accounts for about one-third of the total oilseeds production in the country. India ranked second during 2008-09 both in terms of production and area under rapeseed and mustard in the world with 17.4 per cent of production and 25.6 per cent of area. India produced 7.36 million tones of rapeseed and mustard from 6.0 million hectares of area with an average yield of 1145 kg ha^{-1} during 2012-13. Green stems and leaves are a good source of green fodder for cattle. The fresh leaves of young plants are used as green vegetable which serve as a good source of sulphur and minerals in the human diet. In the industry, mustard oil is used for softening the leather. Besides, the production of rapeseed and mustard provide substantial jobs to the working force in the primary, secondary and tertiary sectors of the economy. The present study was, for such motives, undertaken with the objective to find out and determine the effect of organic manures and soil moisture regimes on Available N, P, K, $\text{NH}_4^+\text{-N}$, $\text{NO}_3^-\text{-N}$, Dehydrogenase, Alkaline phosphatase enzyme activity and yield of mustard under saline water irrigation.

Materials and Methods

Field experiments were conducted on loamy sand soil, belonging to hyperthermic family of *Typic Ustipsamment* with mustard crop in *rabi* season of 2010-11 and 2011-12. The experimental soil (0.0-0.15 m depth) had pH 8.50, EC 2.5 dSm^{-1} , organic carbon 1.80 g kg^{-1} , available N 133 kg ha^{-1} , available P 9.48 kg ha^{-1} and available K $159.15 \text{ kg ha}^{-1}$. The experiment was laid out in a split plot design with 27 treatment combinations involving three levels of organic manures (0, FYM @ 5 t ha^{-1} and vermicompost @ 5 t ha^{-1}) and three moisture regimes (0.4, 0.6 and 0.8 IW/CPE ratio) in main plot and three levels of saline irrigation water ($1.22, 6$ and 12 dSm^{-1}) in sub plot and replicated thrice. The irrigation water was applied from a volumetrically graduated cylindrical tank through hose pipe and flow rate was regulated by a control valve keeping irrigation of 50 mm and applied as and when the cumulative pan evaporation equated to 125, 83.3 and 62.5 mm for 0.4, 0.6 and 0.8 IW/CPE, respectively. The irrigation water of different salinity level were synthesized by dissolving required

quantities at NaCl, Na_2SO_4 , NaHCO_3 , CaCl_2 , MgCl_2 in base water keeping the ratio of Na:Ca:Mg as 60:25:15 and $\text{Cl}:\text{SO}_4:\text{HCO}_3$ as 2:1:1. Each plot was separated by one meter non experimental buffer space to check seepage from the neighboring plots.

Undisturbed soil samples were collected with the help of cores (0.07 m diameter and 0.08 m in length) to determine the bulk density and saturated hydraulic conductivity. Soil water content was determined gravimetrically at harvest. At the harvest of mustard crop, soil samples (0.0 to 0.15 m) were drawn to assess the soil properties, Available N, P, K, $\text{NH}_4^+\text{-N}$, $\text{NO}_3^-\text{-N}$, Dehydrogenase, Alkaline phosphatase enzyme activity following standard methods. Dehydrogenase activity was assayed by the method given by Casida *et al.* (1964). An estimate of the alkaline phosphatase was carried out according to the method of Tabatabai and Bremner (1969) with borax-NaOH buffer (pH 9.4) using *p*-nitrophenyl phosphate disodium salt as substrate at 35°C .

Results and Discussion

Nutrient availability: Addition of organic manures to soil had beneficial effect on the nutrient availability (Table 1). All the treatments resulted in increasing the available nutrients in soil over control. Vermicompost showed the highest increase in available nutrients. The same treatment resulted maximum decrease in soil pH explaining the increase in available nutrients in soil. The use of organic manures for increasing the fertility status of soil and improving problematic salt affected soils has been in practice since long back. The organic manure in addition to being a store house of almost all the nutrients required for plant growth, improved the soil environment by way of improving physico-chemical properties of soil. The availability of most of the plant nutrients increased owing to reduction in pH as well as improvement in cation exchange capacity of soil (More, 1994). Thus, on addition of organic manures, the available nutrient status of soil increased considerably due to mineralization of native as well as applied nutrients through organics. The increased availability is also due to the formation of organic chelates of higher stability with organic legends, which have lower susceptibility to adsorption, fixation and precipitation in soil. (Reddy and Reddy, 1998).

Table-1: Effect of organic manures, moisture regimes and salinity levels on available N, P and K content (kg ha^{-1}) in soil at harvest (pooled over two years)

Treatments	Available N	Available P	Available K
Organic manures			
M ₀ (No manure)	126.25	9.02	127.74
M ₁ (FYM)	133.51	9.64	152.14
M ₂ (Vermicompost)	137.39	10.01	156.29
SEm+	1.66	0.17	2.68
CD (P=0.05)	4.76	0.49	7.69
Moisture regimes			
I ₁ (0.4 IW/CPE)	136.71	8.99	127.25
I ₂ (0.6 IW/CPE)	132.96	9.75	153.45
I ₃ (0.8 IW/CPE)	127.48	9.93	155.47
SEm+	1.66	0.17	2.68
CD (P=0.05)	4.76	0.49	7.69
Salinity levels			
C ₀ (Control)	138.67	10.58	163.20
C ₁ (6 dSm^{-1})	130.51	9.21	141.48
C ₂ (12 dSm^{-1})	127.98	8.88	131.50
SEm+	1.96	0.18	2.62
CD (P=0.05)	5.52	0.51	7.38

Table-2: Effect of organic manures, moisture regimes and salinity levels on $\text{NH}_4^+\text{-N}$ (mg kg^{-1})

Treatments	2010-11				2011-12			
	(month after sowing)				(month after sowing)			
	I	II	III	IV	I	II	III	IV
Organic manures								
M_0 (No manure)	7.41	6.79	6.04	5.58	7.91	7.22	6.58	5.90
M_1 (FYM)	8.49	7.41	6.24	6.21	9.09	8.29	7.12	6.73
M_2 (Vermicompost)	9.13	8.73	7.16	6.74	9.93	8.91	7.80	7.34
$\text{SEm}+$	0.17	0.14	0.14	0.11	0.17	0.12	0.14	0.14
CD ($P=0.05$)	0.50	0.42	0.42	0.34	0.51	0.35	0.43	0.42
Moisture regimes								
I_1 (0.4 IW/CPE)	9.21	8.65	6.90	6.55	9.80	9.09	8.21	7.73
I_2 (0.6 IW/CPE)	8.33	7.36	6.60	6.39	8.93	8.09	7.00	6.42
I_3 (0.8 IW/CPE)	7.49	6.91	5.94	5.57	8.20	7.25	6.28	5.81
$\text{SEm}+$	0.17	0.14	0.14	0.11	0.17	0.12	0.14	0.14
CD ($P=0.05$)	0.50	0.42	0.42	0.34	0.51	0.35	0.43	0.42
Salinity levels								
C_0 (Control)	8.79	8.12	7.41	6.61	9.49	8.91	8.31	7.91
C_1 (6 dSm^{-1})	8.42	7.61	6.22	6.19	8.91	7.99	6.79	6.22
C_2 (12 dSm^{-1})	7.81	7.19	5.81	5.72	8.53	7.53	6.39	5.84
$\text{SEm}+$	0.14	0.12	0.11	0.08	0.13	0.09	0.11	0.11
CD ($P=0.05$)	0.41	0.33	0.31	0.23	0.38	0.25	0.32	0.31

Table-3: Effect of organic manures, moisture regimes and salinity levels on $\text{NO}_3^-\text{-N}$ (mg kg^{-1})

Treatments	2010-11				2011-12			
	(month after sowing)				(month after sowing)			
	I	II	III	IV	I	II	III	IV
Organic manures								
M_0 (No manure)	14.08	13.68	13.02	12.01	14.64	13.91	13.38	12.50
M_1 (FYM)	14.78	14.06	13.48	12.82	15.12	14.41	13.75	12.94
M_2 (Vermicompost)	15.89	15.10	14.79	13.23	16.51	15.69	15.15	13.70
$\text{SEm}+$	0.24	0.24	0.23	0.23	0.25	0.25	0.24	0.24
CD ($P=0.05$)	0.70	0.71	0.69	0.68	0.74	0.74	0.72	0.70
Moisture regimes								
I_1 (0.4 IW/CPE)	15.73	15.24	14.91	13.40	16.16	15.71	15.16	14.08
I_2 (0.6 IW/CPE)	14.88	14.11	13.81	13.05	15.47	14.49	14.09	13.22
I_3 (0.8 IW/CPE)	14.14	13.51	12.57	11.61	14.64	13.81	13.03	11.82
$\text{SEm}+$	0.24	0.24	0.23	0.23	0.25	0.25	0.24	0.24
CD ($P=0.05$)	0.70	0.71	0.69	0.68	0.74	0.74	0.72	0.70
Salinity levels								
C_0 (Control)	15.73	15.33	14.59	13.69	16.19	15.49	14.82	13.91
C_1 (6 dSm^{-1})	14.79	14.19	13.78	12.88	15.53	14.69	14.09	13.33
C_2 (12 dSm^{-1})	14.23	13.33	12.92	11.49	14.55	13.83	13.37	11.89
$\text{SEm}+$	0.18	0.19	0.18	0.18	0.18	0.19	0.19	0.21
CD ($P=0.05$)	0.50	0.53	0.52	0.52	0.52	0.53	0.55	0.58

The increase in nitrogen fractions ($\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$), Available N content in soil due to (Table 2 and 3) application of organic manures over control may be attributed to the mineralization of N by organics in soil (Yaduvanshi, 2001) and the greater multiplication of soil microbes which could convert organically bound N to inorganic form (Bhardwaj and Omanwar, 1994). These results of the present investigation are in conformity with Gupta *et al.* (2005) who reported that the manuring resulted in more accumulation of total mineral-N in soil. The increase in ammonical nitrogen may also be due to favourable influence of organic manures on exchangeable ammonical nitrogen build-up and increase in organic carbon content of the soil. Moreover, the N released has been reported to get

incorporated in the soil humic material thereby accounting for higher total N build-up (Bhandari *et al.*, 2000). It is well known that organic manures besides being the direct source of P also solubilized the insoluble and fixed P in soil through release of various organic acid. Amending soil with organic manures help in increasing the P concentration in soil solution through mineralization of native soil P compounds (Pattanayak *et al.*, 2009). Thus, the appreciable build-up of total and available phosphorus may be due to the direct effect of organic matter in increasing the labile P in soil through complexing of cations like Ca^{2+} and Mg^{2+} which mainly responsible for fixation of P (Bajpai *et al.*, 2006). The build-up of available soil potassium due to organic manures application was result of additional K supplied through organics. The solubilizing action of certain organic acids produced during decomposition and its greater capacity to hold K in the available form (Yaduvanshi, 2001). The higher availability of nutrients in soil in vermicompost treated plot may be attributed to its inherent capacity to add good amount of organic carbon content to soil which hastens the process of mineralization of organically bound macro and micronutrients present in the native soil and formation of organic chelates (Yadav and Jha, 1988). An increased proportion of microbial C and N in the total soil organic carbon pool indicates greater potential of nutrient availability to plants was also reported by Kaur *et al.* (2000). The beneficial effect of organic manures on soil K with addition of organic manure was also reported by Chesti *et al.* (2013).

From the results (Table 1, 2 and 3) it reveals that available P and K in soil increased significantly with the increasing frequency of irrigation. In case of total and available N as well as nitrogen fraction ($\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$) a general trend was found that increased levels of irrigation gradually decreased the total and available N and highest value was recorded with lower moisture regime (0.4 IW/CPE). This trend was quite dissimilar in case of total and available P and K, in which highest concentration of P and K was recorded with I_3 (0.8 IW/CPE) level, which was probably due to solubilization of insoluble phosphorus through the reduction of Al-P and Fe-P or dissolution of Ca-P and Mg-P in Soil. These results clearly indicated that increased in frequency of irrigation resulted in decrease in total and available N as well as $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ in soil mainly by increasing greater loss of N from soil through leaching, deep percolation in light textured loamy sand experimental soil. Similar results more also reported by Puste *et al.* (2013). The data given in Table 1, 2 and 3 show that the available N, P, K, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ content of soil decreased significantly with increasing levels of salinity during both the years as well as in pooled analysis. This may be explained on the basis that increasing irrigation with saline water, the pH of soil decreased accordingly resulting into decreased availability of N, P and K in soil. The higher amount of salts may adversely affect the physico-chemical and biochemical properties. Soil productivity not only depends on the type of soil, organic matter and nutrient status but also on the load of different micro-organisms and their activities. Micro-organisms play a significant role in the transformation of various elements through biochemical transformations and make the nutrients available to the plants. Activities of dehydrogenase and alkaline phosphatase were significantly lower with increasing levels of salinity in present investigation is also strengthen the statement.

Enzymes activity: Activities of enzymes (Table 4 and 5) increased significantly due to incorporation of organic materials in to soil. In

Table-4: Effect of organic manures, moisture regimes and salinity levels on soil dehydrogenase activity (pKat kg⁻¹ soil)

Treatments	2010-11 (month after sowing)				2011-12 (month after sowing)			
	I	II	III	IV	I	II	III	IV
Organic manures								
M ₀ (No manure)	14.65	13.69	12.64	11.92	14.90	13.60	12.59	11.38
M ₁ (FYM)	16.54	15.55	15.49	13.84	16.68	15.46	14.42	13.47
M ₂ (Vermicompost)	18.21	17.18	16.14	15.61	18.57	17.10	16.06	15.10
S \bar{E} m+	0.22	0.25	0.27	0.29	0.28	0.28	0.28	0.27
CD (P=0.05)	0.66	0.76	0.81	0.87	0.83	0.83	0.83	0.80
Moisture regimes								
I ₁ (0.4 IW/CPE)	15.23	14.18	13.49	12.72	15.91	14.11	13.15	12.08
I ₂ (0.6 IW/CPE)	16.69	15.68	15.04	13.69	16.80	15.58	14.54	13.53
I ₃ (0.8 IW/CPE)	17.49	16.56	15.74	14.96	17.44	16.47	15.38	14.35
S \bar{E} m+	0.22	0.25	0.27	0.29	0.28	0.28	0.28	0.27
CD (P=0.05)	0.66	0.76	0.81	0.87	0.83	0.83	0.83	0.80
Salinity levels								
C ₀ (Control)	17.91	17.05	16.50	15.30	18.00	17.00	16.10	14.91
C ₁ (6 dSm ⁻¹)	16.58	15.67	15.00	14.10	16.90	15.55	14.35	13.49
C ₂ (12 dSm ⁻¹)	14.92	13.69	12.77	11.97	15.25	13.61	12.63	11.55
S \bar{E} m+	0.20	0.20	0.18	0.22	0.18	0.19	0.18	0.18
CD (P=0.05)	0.58	0.56	0.52	0.61	0.51	0.53	0.51	0.51

Table-4: Effect of organic manures, moisture regimes and salinity levels on alkaline phosphatase activity (μ g pNP produced g⁻¹ soil h⁻¹)

Treatments	2010-11 (month after sowing)				2011-12 (month after sowing)			
	I	II	III	IV	I	II	III	IV
Organic manures								
M ₀ (No manure)	9.80	8.71	8.15	7.68	10.94	9.63	8.58	7.50
M ₁ (FYM)	10.77	9.69	9.11	8.60	11.61	10.64	9.58	8.57
M ₂ (Vermicompost)	12.24	11.16	10.96	9.87	13.04	12.13	11.00	10.86
S \bar{E} m+	0.26	0.18	0.18	0.20	0.23	0.15	0.16	0.17
CD (P=0.05)	0.79	0.55	0.55	0.60	0.69	0.46	0.48	0.51
Moisture regimes								
I ₁ (0.4 IW/CPE)	9.42	8.33	7.95	7.33	10.91	9.33	8.19	7.30
I ₂ (0.6 IW/CPE)	11.15	10.08	9.93	8.90	11.82	11.03	9.10	8.67
I ₃ (0.8 IW/CPE)	12.24	11.15	10.34	9.92	12.85	12.02	11.87	10.97
S \bar{E} m+	0.26	0.18	0.18	0.20	0.23	0.15	0.16	0.17
CD (P=0.05)	0.79	0.55	0.55	0.60	0.69	0.46	0.48	0.51
Salinity levels								
C ₀ (Control)	11.98	10.91	10.07	9.86	12.81	11.87	11.29	10.69
C ₁ (6 dSm ⁻¹)	10.58	9.50	9.20	8.59	11.55	10.41	9.11	8.29
C ₂ (12 dSm ⁻¹)	10.25	9.15	8.95	7.70	11.22	10.11	8.76	7.95
S \bar{E} m+	0.17	0.19	0.19	0.20	0.14	0.14	0.15	0.18
CD (P=0.05)	0.48	0.53	0.53	0.55	0.40	0.40	0.44	0.52

general, there was an increase in microbial growth and activities of enzymes with the addition of carbon substrate and declined as the available carbon exhausted. (Manna *et al.*, 1996) and enzyme activities was maximum under manuring with vermicompost followed by FYM application and reached minimum at the later stages of crop growth under the same treatments. The availability of carbonaceous materials and substrates such as sugars, amino acids and organic acids to the soil from the decomposing organic materials and decay of roots under the plant canopy are important for supplying energy for microbial population (Bowen and Rovira, 1991).

Application of organic manure significantly increased the dehydrogenase and alkaline phosphatase enzyme activity during

both the years in all the four months. The highest dehydrogenase and alkaline phosphatase enzyme activity of soil recorded with vermicompost during both the years. On addition of organic materials, the contents of humic substances which are conventionally known to provide adsorption sites are increased. Thus, the amount of adsorbed enzymes is also increased. Often the level of soil enzyme activity increased with increasing soil organic matter content in the soil (Speir, 1977). Soil enzyme activities increased by the incorporation of organic material was also reported by Nanniperi *et al.* (1983). This increased activity has generally been attributed to increased microbial biomass resulting from organic matter enrichment in the soil. Increase in activity may be due to protection to the enzymes fraction upon increase in the soil humus content was also reported by Pareek and Yadav (2011) and Nath *et al.* (2012). Results revealed that the activities of enzymes increased significantly due to application of irrigation at different moisture regimes. In general, there was an increase activity of enzymes with the maintenance of optimum moisture in soil as available water. The enzyme activities during entire growing period of crop. Rao and Tarafdar (1998) also reported maximum activities of dehydrogenase and phosphatase enzyme at higher soil water level. Activities of dehydrogenase and alkaline phosphatase enzymes were significantly lower with increasing level of salinity over normal water and with intervals of time. This might be due to the build-up of salinity and accumulation of salts in soils. Reduced enzyme activities in saline soil may be due to the osmotic desiccation of microbial cells releasing intracellular enzymes which become vulnerable to attack by soil proteases, a "salting-out" effect modifying the ionic conformation of the active site of the enzyme protein and specific ion toxicities causing nutritional imbalances for microbial growth and subsequent enzymes synthesis (Frankenber and Bingham, 1982). The reduced dehydrogenase activity in saline soils was due to toxic effect of Cl and SO₄ ions was also reported by Batra (2004).

Crop yield: Organic manure substantially increased the seed and stover yield of mustard over control in both the years as well as in pooled analysis (Table 6). The increase in yield due to addition of organics might be the result of overall improvement in soil physico-chemical properties of soil. These beneficial effects favoured greater availability of plant nutrients and their steady supply throughout growth for optimum development. Application of vermicompost @ 5 t ha⁻¹ produced maximum pooled seed and stover yield over control and FYM @ 10 t ha⁻¹. The reasons for distinct response to vermicompost over FYM may be explained partially by circumstantial evidence that vermicompost has high status of available nutrients and optimum C:N ratio and may contains hormones and has enhanced level of enzymes (Tan *et al.*, 1971). The irrigation at I₃ moisture regimes produced the highest seed and stover yield. This might be due to higher photosynthesis and translocation of photosynthates towards reproductive structures owing to adequacy of soil moisture in the rhizosphere of mustard crop. Contrary to it, less frequent irrigation aggravates moisture stress and intensifies the growth inhibition associated with a given level of salinity.

From the present study, it is evident that under irrigation with varying levels of saline water, the changes assessed for physicochemical properties, nutrient availability and enzymes activities, incorporation of organic manure and maintenance of higher soil moisture regime has been found a viable soil management option for enhancing

Table-6: Effect of organic manures, moisture regimes and salinity levels on seed and stover yield (q ha⁻¹) of mustard

Treatments	Grain yield			Stover yield		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Organic manures						
M ₀ (No manure)	8.24	7.58	7.91	20.11	18.97	19.54
M ₁ (FYM)	11.77	12.19	11.98	28.08	30.56	29.32
M ₂ (Vermicompost)	14.24	14.61	14.42	35.07	36.81	35.94
SEM+	0.22	0.23	0.18	0.48	0.56	0.42
CD (P=0.05)	0.66	0.68	0.53	1.43	1.67	1.22
Moisture regimes						
I ₁ (0.4 IW/CPE)	9.89	9.76	9.82	24.82	24.26	24.54
I ₂ (0.6 IW/CPE)	11.84	12.05	11.95	27.04	29.57	28.30
I ₃ (0.8 IW/CPE)	12.52	12.57	12.54	31.40	32.50	31.95
SEM+	0.22	0.23	0.18	0.48	0.56	0.42
CD (P=0.05)	0.66	0.68	0.53	1.43	1.67	1.22
Salinity levels						
C ₀ (Control)	11.95	11.94	11.95	30.02	31.05	30.54
C ₁ (6 dSm ⁻¹)	13.20	13.25	13.23	30.90	32.10	31.50
C ₂ (12 dSm ⁻¹)	9.10	9.18	9.14	22.34	23.19	22.77
SEM+	0.18	0.18	0.20	0.40	0.48	0.48
CD (P=0.05)	0.51	0.50	0.56	1.12	1.36	1.34

productivity and fertility of soil under irrigation with high saline water. Moisture regimes have a positive effect on nutrient availability and enzymes activities ultimately crop yield. Thus, keeping in view the above results the farmers of the region having high saline water for irrigation are advised to apply 5 t ha⁻¹ of vermicompost for sustaining soil and crop productivity.

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