



Synergistic effect of halophytic compost in combination with farmyard manure and *Rhizobium* on soil microflora and yield parameters of black gram (*Vigna Mungo* L.)

Muzamil Ahmad Shah¹, KC Ravindran^{2*}, R Elango³

^{1,2} Department of Botany, Faculty of Science, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India

³ Department of Microbiology, Faculty of Agriculture Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India

Abstract

Soil has been a source of wealth for humans since thousands of years and it continues at present. But long-term application of chemical fertilizers has resulted in the degeneration of the soil quality parameters such as pH, EC, soil microbial biomass and nutrient content which in turn affects crop productivity. A field experiment was carried out to study the effects of halophytic compost along with farmyard manure and *Rhizobium* on soil microbial population and crop yield in *Vigna mungo*. Six treatments were set and were: Control (no application of halophytic compost), T₁ (*Sesuvium portulacastrum* @ 6.25 t ha⁻¹ compost), T₂ (*Suaeda maritima* compost @ 6.25 t ha⁻¹), T₃ (*Sesuvium portulacastrum* compost @ 6.25 t ha⁻¹ + Farmyard manure @ 3.13 t h⁻¹), T₄ (*Suaeda maritima* compost @ 6.25 t ha⁻¹ + Farmyard manure @ 3.13 t h⁻¹), T₅ (*Sesuvium portulacastrum* compost @ 6.25 t ha⁻¹ + Farmyard manure @ 3.13 th⁻¹ + *Rhizobium* @ 2 kg ha⁻¹) and T₆ *Suaeda maritima* compost @ 6.25 t ha⁻¹ + Farmyard manure @ 3.13 th⁻¹ + *Rhizobium* @ 2kg ha⁻¹. The results showed that soil microbial population as well as crop yield increased with the application of halophytic compost. Compared with control and other halophytic treatments, the application of *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure @ 3.13 t h⁻¹ + *Rhizobium* @ 2 kg h⁻¹ treated soil significantly increased the soil microbial population such as bacteria, fungi, actinomycetes and *Rhizobium* and crop productivity such as number of pods per plant, seeds per pod, pod length and seed weight per gram in black gram. The results demonstrate that continuous application of halophytic compost could increase soil biological fertility level.

Keywords: halophytic compost; soil microbial biomass; *rhizobium*; *vigna mungo* l

1. Introduction

The application of fertilizers of inorganic nature is one of the most adopted practices in developing intensive agriculture nowadays (Adesemoye and Kloepper, 2009 [1]; Da Costa *et al.*, 2013) [8]. Inorganic supplements reliably augment yield in harvest as crops directly or indirectly incorporate the nutrients provided by these supplements. However sustained use of these inorganic supplements leaves a negative impact on the soil ecosystem like as dilapidation of the soil quality, decrease in inherent diversity of crops, lessening of soil microbial diversity, pollution of soil water resources (Kaur *et al.*, 2008 [17]; Chaudhry *et al.*, 2009) [5]. Impact of organic manures has been comprehensively tested and determined quite promising in increasing nutrient availability to crops, thus improving grain yield in a cost-effective and environmentally friendly manner (Ahmad *et al.*, 2007 [2]; Leite *et al.*, 2010) [20]. Application of decompositional matter from organic compost can also up the scale of organic matter and improve soil porosity, texture, moisture and nutrient availability as well as biological activity (Francis *et al.*, 2010 [11]; Wang *et al.*, 2011) [36]. Microorganisms present in the soil have a vital say in mediating soil microcosm functioning and indicate quality of (Sharma *et al.*, 2010) [33]. In general, soil microbes link aboveground and belowground ecosystems by modulating organic matter decomposition, recycling nutrients, and their availability to plants. In turn, plant growth affects the activities of microbes in the soil. There is no doubt that crop plants and microbes work in tandem in soil microcosm, following a progressional outline and with

the result changes in microbial word are directly or indirectly related to plant growth (She *et al.*, 2018). In agro ecology, microorganisms present in soil have a great say in yield and agricultural sustainability (Lychuk *et al.*, 2019). Managing of modern agricultural practices like application of biofertilizers in a systematic way effect to a great extent microbial physiology, diversity and community structure (Ai *et al.*, 2018; Chenu *et al.* 2019) [6]. A number of investigations have revealed that bio-fertilizers like manures play a constructive role maintaining a balance between biotic and abiotic components of soil ecosystem (Francioli *et al.*, 2016) [12]. Bacterial richness and equilibrium is attained by bio fertilizer application when compared with inorganic supplements (Legrand *et al.*, 2018) [19].

Black gram is cosmopolitan in distribution, placed in family Fabaceae by taxonomists and gains substantial importance as claims are made that it can act as main food for developing world. The total land area under pulses around world amounts to almost about 211.03 million acres with annual yield of 87.40 million tonnes at 409.2 kg /acre. India, with greater than 71.66 million acres pulses cultivation area and occupies first position both in terms of area and yield i.e. 34 and 26 percent respectively. Preceding two years 2020 i.e. 2017-18 the country's productivity at 334 kg / acre with a substantial increase over eleventh year plan 264.8 kg/acre to 298 kg /acre in twelfth plan. Since 2015-16 there has been considerable increase in cultivation of black gram and this momental shift has been covered quite comprehensively. In the year 2017-18 the legume was cultivated on an area of greater than 50 hundred thousand

hectares with an annual yield touching 35 hundred thousand tonnes. In Tamil Nadu black gram is cultivated in 4.06 lakh hectares with production of 3.01 lakh tonnes (Rajender and Tiwari 2018) [29]. *Rhizobium* the N- fixing symbiotic microorganism from Rhizobiaceae family and has an ability of fixing at 40 kg/acre in leguminous plants and this is the reason that it is quite frequently suggested for all pulses bearing crops except *Parasponia*, a non-legume (Saikia and Jain, 2007) [32]. Being leguminous plant black gram has the innate nature of fixing Nitrogen from atmosphere in relationship with a soil inhabiting bacterium *Rhizobium* through symbiosis. Legume *Rhizobium* interactions are inimitable as they fulfill three fourths of total nitrogen supplements of legumes.

Halophytes are the salt cherishing plants which complete growth period in high saline environment. Halophytes are abundantly found in coastal saline arid, semi arid soil, having more evaporation than precipitation. (Cuevas 1997) [7]. recorded the nutritive content of halophytes and came to a conclusion that nutrient contents in salt cherishing plants are higher when compared to low salt content adaptable plants while obtained from some plants like brown hemp, Prickly sesban, lond bean and catjang. Nonetheless halophytes possess natural ability to amass common salt in their cells. The present endeavor has a basis in the idea that whilst halophytes are chosen for composting, it is quite probable that NaCl content present in the cells will decrease after decaying. Na⁺ cation in NaCl may coordinate with the ligands (organic acids) produced after decomposition and discharge the Cl⁻ anion, as a consequence reduction of NaCl levels. Decay quashes the constuience of NaCl present in crop tissues. Watson (2003) [37]. likewise has concluded that quantifying compost with water may diminish concentration of common salts. The objectives of this study were to determine the optimization of the different halophytic compost in combination with farmyard manure and *Rhizobium* on the soil microbial population and yield attributes of *Vigna mungo* L.

Methods AND METHODS

Experimental site

The field experiment was conducted at Experimental farm, Department of Agronomy, Faculty of Agriculture, Annamalai Nagar, Tamil Nadu, India during June-October (Kharif) 2019. The experimental farm is geographically located at 11° 24' N Latitude and 79° 44' E Longitude at an altitude of +5.79 M above mean sea level. The maximum temperature at 29.3 °C to 35.2 °C with mean of 32.82 °C. The relative humidity ranges from 81 to 96 percent with a mean of 85.78 percent and crop received at rain fall of 98.44 mm. The experimental outline was entirely randomised block design.

Compost preparation

Two fast growing and dominant halophytes such as *Suaeda maritima* (L.) Dumort., and *Sesuvium portulacastrum* L. were identified for making organic compost after a detailed survey. Well decomposed farmyard manure was collected from Dairy farm, Division of Animal husbandry, Annamalai university was mixed with halophytic compost and was applied to the experimental plots as per the treatment schedule. *Rhizobium* was obtained from Department of Microbiology, Faculty of Agriculture, Annamalai university, India. Three months healthy halophytes were harvested from nursery and used for preparation of halophytic compost. The plant materials as well as rice straw were chopped well. The substrates were piled loosely in a compost pit and bulky in nature which provide better aeration within the heap. The material was too compact and no heavy weights were put on top. Aeration was provided by placing perforated bamboo trunks horizontally and vertically at regular intervals, to carry air through the compost heap. The compost activator, consisting of a cellulolytic fungus (*Trichoderma harzianum*) was broadcast onto the substrates during pilling. The amount of activator used was usually 1% of the total weight of the substrate (i.e. about 1 kg compost activator is mixed thoroughly with the substrates (Cuevas, 1997) [7]. The heap was covered over completely with white plastic sheets. Heat was maintained at 50°C or higher and the heap was turned over every 5-7 days for the first two weeks and thereafter once every two weeks. Turning over the pile provided adequate aeration and evened up the rate of decomposition throughout pile. By the end of the third month, the compost was ready for use. It was dark brown, crumbly and hard with earthy aroma.

Table 1: Physico-chemical characteristics of the experimental field before installation of experiment

Soil characteristics of the experimental field		
Properties	-	Value
A. Physical properties		
Coarse sand (%)	-	49.83
Silt (%)	-	18.20
Clay (%)	-	16.68
Textural class	-	Sandy loam
B. Chemical properties		
Electrical conductivity(dsm ⁻¹)	-	0.912
pH	-	7.82
Organic carbon (%)	-	0.40
Organic matter (%)	-	0.54
Available Nitrogen (Kg ha ⁻¹)	-	143.8
Available Phosphorus (Kg ha ⁻¹)	-	21.9
Available Potassium (Kg ha ⁻¹)	-	40
Available Zinc (Kg ha ⁻¹)	-	4.8

Table 2. Nutrient contents of different halophytic compost at maturity period (90 days)

Treatments	pH	C	N	C:N Ratio	P (%)	K (%)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Before Composting		After Composting		Percentage of reduction	
													Na	Cl	Na	Cl	Na	Cl
T1	7.2	49.21	1.85	26.20	0.73	1.54	1824	1430	8.30	10,197	31.80	177	21.0	15.2	8.5	7.3	40.5	48.0
T2	7.1	46.72	1.93	23.5	0.76	1.63	1962	1558	8.62	10,299	32.66	196	19.0	14.3	6.9	6.2	36.3	43.3
T3	6.9	44.59	2.75	15.30	1.33	2.05	3324	2730	10.77	10,619	34.94	406	.....	.....	.....	.....	.....	.....
T4	6.8	42.62	2.83	14.23	1.36	2.14	3462	2858	11.09	10,721	35.77	583	.....	.....	.....	.....	.....	.....
T5	6.7	39.95	2.81	13.27	1.34	2.08	3340	2740	11.80	10,630	35.34	429	.....	.....	.....	.....	.....	.....
T6	6.4	39.40	2.91	13.10	1.37	2.17	3476	2869	12.12	10,736	35.84	598	.....	.....	.....	.....	.....	.....

Treatments

Compost treatments and their concentrations

Table 3

Treatments	Compost application
T0	Control (Without compost)
T1	<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹
T2	<i>Suaeda maritima</i> compost @ 6.25 t ha ⁻¹
T3	<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹ + Farmyard manure @ 3.13 t h ⁻¹
T4	<i>Suaeda maritima</i> compost @ 6.25 t ha ⁻¹ + Farmyard manure @ 3.13 t h ⁻¹
T5	<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹ + Farmyard manure @ 3.13 th ⁻¹ + <i>Rhizobium</i> @ 2 kg ha ⁻¹
T6	<i>Suaeda maritima</i> compost @ 6.25 t ha ⁻¹ + Farmyard manure @ 3.13 th ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹

Table 4: Effect of different halophytic application on soil microbial population (Bacteria). Values shown are mean ± S.E. for three replicate experiments.

Treatment	Bacteria (cfu×10 ⁶ g ⁻¹ of dry soil)				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	21.0±1.15	23.0±1.15	27.0±1.15	30.0±1.15	27.0±1.73
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	23.0±1.73	27.0±1.73	34.0±1.73	39.0±1.73	31.0±1.15
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	25.0±2.30	30.0±2.30	39.0±2.88	46.0±2.30	34.0±1.73
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	28.0±1.15	34.0±1.73	45.0±2.30	54.0±1.15	38.0±1.73
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	32.0±1.73	39.0±2.88	52.0±1.73	63.0±1.73	43.0±1.15
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	37.0±2.88	45.0±1.73	60.0±1.73	73.0±2.30	50.0±1.73
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	43.0±2.30	52.0±2.30	69.0±1.15	84.0±1.73	59.0±1.73

Table-5: Effect of different halophytic application on soil microbial population (Fungi). Values shown are mean ± S.E. for three replicate experiments.

Treatment	Fungi (cfu×10 ⁴ g ⁻¹ of dry soil)				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	9.0±1.15	10.0±1.15	13.0±1.73	15.0±1.15	13.0 ±1.15
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	10.0±1.73	12.0±1.73	16.0±1.15	19.0±1.73	17.0 ± 2.30
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	11.0±1.15	13.0±1.15	17.0±1.15	20.0±2.30	18.0±2.30
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	12.0±1.73	15.0±1.73	19.0±1.73	23.0±1.73	20.0 ±1.73
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	13.0±1.15	16.0±1.54	22.0±2.30	27.0±1.15	23.0 ±1.15
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	14.0±1.15	17.0±1.15	25.0±1.73	31.0±1.73	26.0 ± 1.15
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	15.0±1.73	19.0±1.73	29.0±1.73	36.0±1.15	30.0±1.73

Table 6: Effect of different halophytic application on soil microbial population (Acitnomyces). Values shown are mean ± S.E. for three replicate experiments.

Treatment	Acitnomyces (cfu×10 ⁵ g ⁻¹ of dry soil)				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	12.0±1.73	15.0±1.15	20.0±1.73	24.0±1.73	22.0±1.73
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	13.0±1.15	17.0±1.73	23.0±1.15	28.0±1.73	25.0±1.15
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	14.0±1.15	19.0±1.15	25.0±1.73	31.0±1.73	27.0±1.73
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	15.0±1.73	21.0±1.15	28.0±1.73	35.0±2.30	30.0±1.15
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	17.0±2.30	24.0±1.73	32.0±2.30	40.0±1.73	34.0±1.73
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	18.0±1.73	27.0±1.15	37.0±1.73	46.0±2.30	39.0±2.30
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	20.0±2.30	31.0±1.15	43.0±2.30	54.0±1.73	45.0±2.30

Table 7: Effect of different halophytic application on soil microbial population (*Rhizobium*). Values shown are mean ± S.E. for three replicate experiments.

Treatment	<i>Rhizobium</i> (cfu×10 ³ g ⁻¹ of dry soil)				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	17.0±1.73	19.0±1.15	23.0±1.15	26.0±2.30	23.0±1.15
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	19.0±2.30	22.0±1.73	28.0±2.30	32.0±1.73	27.0±1.73
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	21.0±1.73	25.0±1.15	32.0±1.15	37.0±1.73	31.0±1.15
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	24.0±1.15	29.0±1.73	37.0±1.73	43.0±1.15	36.0±2.30
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	28.0±1.73	34.0±1.73	43.0±1.15	50.0±1.73	42.0±1.15
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	33.0±1.15	40.0±2.30	50.0±1.73	58.0±1.73	48.0±1.73

<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	39.0±1.73	47.0±2.30	58.0±2.30	67.0±1.73	54.0±1.73
---	-----------	-----------	-----------	-----------	-----------

Table 8: Yield and yield attributes of black gram as affected by application of different halophytic compost. Values shown are mean ± S.E. for three replicate experiments.

Treatment	Number of pods plant ⁻¹	Length of pod (cm)	Pod fresh weight (g)	Pod dry weight (g)	Number of seeds pod ⁻¹	Test Weight(g)
Untreated check; no organic input	9.0±1.15	3.9±0.17	6.63±0.034	2.11±0.017	3.33±0.33	3.49±0.028
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	13.0±1.73	4.5±0.37	8.98±0.023	2.75±0.023	4.33±0.33	4.28±0.017
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	16.0±1.15	4.8±0.26	9.98±0.011	3.04±0.023	4.66±0.33	4.63±0.034
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	22.0±1.73	5.2±6.23	11.84±0.02	3.62±0.017	5.0±0.57	4.99±0.011
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	27.0±1.73	5.5±0.15	12.98±0.028	3.97±0.023	5.6±0.33	5.35±0.023
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	33.0±1.73	5.9±0.47	15.55±0.023	4.78±0.023	6.3±0.33	5.71±0.017
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	40.0±1.15	6.3±0.28	17.01±0.017	5.22±0.017	7.0±0.57	6.36±0.320

Table-9: Yield and yield attributes of black gram as affected by application of different halophytic compost. Values shown are mean ± S.E. for three replicate experiments.

Treatment	Grain Yield (kg/ha)	Stover Yield (kg/ha)	Biological Yield (kg/ha)	Harvest Index
Untreated check; no organic input	532±2.30	1218±6.92	1750±14.43	30.47±0.191
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	632±1.73	1350±11.54	1982±23.09	31.88±0.282
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	669±5.19	1375±14.43	2044±17.32	32.72±0.023
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	729±6.35	1420±17.32	2149±14.43	33.91±0.066
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	799±10.96	1488±16.16	2287±25.98	34.43±0.080
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	894±13.85	1596±14.43	2490±23.09	35.89±0.22
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	993±8.66	1745±8.66	2738±23.09	36.26±0.011

Table 10: Effect of different halophytic application on soil pH. Values shown are mean ± S.E. for three replicate experiments.

Treatment	Soil pH				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	7.82±0.017	7.80±0.017	7.77±0.11	7.74±0.017	7.67±0.023
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	7.76±0.023	7.64±0.017	7.55±0.017	7.32±0.023	7.12±0.023
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	7.75±0.023	7.62±0.023	7.52±0.017	7.28±0.017	7.06±0.017
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	7.74±0.017	7.59±0.011	7.48±0.023	7.23±0.017	6.97±0.011
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	7.73±0.011	7.55±0.023	7.43±0.017	7.17±0.011	6.89±0.017
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	7.72±0.011	7.50±0.017	7.37±0.011	7.10±0.017	6.76±0.028
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	7.71±0.017	7.44±0.011	7.30±0.017	7.02±0.023	6.64±0.011

Table 11: Effect of different halophytic application on soil EC. Values shown are mean ± S.E. for three replicate experiments.

Treatment	Soil EC				
	15 th DAS	30 th DAS	45 th DAS	60 th DAS	HARVEST
Untreated check; no organic input	0.88±0.017	0.86±0.023	0.85±0.017	0.84±0.017	0.82±0.011
<i>Sesuvium portulacastrum</i> compost @ 6.25 t ha ⁻¹	0.87±0.011	0.84±0.011	0.82±0.011	0.80±0.011	0.77±0.011
<i>Suaeda maritima</i> compost@ 6.25 t ha ⁻¹	0.86±0.017	0.82±0.020	0.80±0.011	0.77±0.011	0.73±0.011
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	0.85±0.011	0.80±0.011	0.77±0.011	0.74±0.017	0.69±0.017
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @ 3.13 t ha ⁻¹	0.84±0.017	0.78±0.017	0.74±0.017	0.70±0.017	0.64±0.017
<i>Sesuvium portulacastrum</i> compost @ 3.13 t ha ⁻¹ + farmyard manure 3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	0.83±0.011	0.76±0.011	0.71±0.011	0.66±0.017	0.60±0.017
<i>Suaeda maritima</i> compost @ 3.13 t ha ⁻¹ + farmyard manure @3.13 t ha ⁻¹ + <i>Rhizobium</i> @ 2kg ha ⁻¹	0.84±0.011	0.74±0.017	0.68±0.017	0.62±0.017	0.56±0.011

Field Preparation

The land was prepared after ploughing twice with bullock drawn mould board followed harrowing by using cultivator-

tractor and the whole plot was levelled with leveler, individual plots were made manually as per experimental sketch. Channels were laid to facilitate irrigation to plots

individually. ADT 5 black gram variety was purchased from Rice research institute, Tamil Nadu Agricultural University, Aduthurai, Thanjavur District and was used for experimental study. The black gram seeds were sown by dibbling 3 to 5 seeds per hill at a depth of 3 to 5 cm and spacing of 30 x 10 cm. Plant samples were harvested for experimental purpose at an interval of 15, 30, 45, 60 days and harvest stage. The matured crop was harvested by leaving the border rows by hand pulling. Six treatments were used in randomized block. The amendment doses were determined totally based on the recommendation of Department of Agronomy, Tamil Nadu Agriculture University, Coimbatore, Tamil Nadu, India.

Growth analysis

Growth analysis such as shoot length, number of trifoliar leaves, number of branches, leaf area, total number of nodules, fresh weight of root nodules and fresh weight of plants were measured immediately after removing the plants from experimental plots. The dry weight of plants and root nodules were determined after they had been dried at 80°C for 24 hours.

Soil analysis

The pH of the soil was determined in the ratio 1:2:5 (soil and water suspension) by using pH meter. The electrical conductivity (EC) was measured in the ratio 1:2:5 (soil and water suspension) by using Elico-conductivity meter.

Statistical analysis

The results were analysed by using analysis of variance (ANOVA) and the group means were compared by Duncan's Multiple Range Test (Duncan, 1957). Values are considered statistically significant when $p < 0.05$.

Results and Discussion

Properties of the halophytic compost

Initially an experiment was carried out to find out whether the process of decomposition of halophytes reduces the NaCl concentration in the compost. From the results it was concluded that after 90 days completion of composite preparation, NaCl concentration in the composite was drastically reduced to 40.5% Na⁺ and 48.0% Cl⁻ in *Sesuvium portulacastrum* compost and 36.3% Na⁺ and 43.3% Cl⁻ in *Suaeda maritima* compost. It was also observed from the studies at the end of decomposition *Suaeda maritima* compost in combination with farmyard manure and *Rhizobium* gaining higher nutrient content value when compared to other halophytic composts. Nutrients such as N, P, K Ca, Mg and micronutrients were found higher in *Suaeda maritima* compost in combination with farmyard manure and *Rhizobium*. The reduction in pH and EC was also noticed in *Suaeda maritima* compost along with Farmyard manure and *Rhizobium* compost.

Impact of halophytic compost on soil microbial population in study site

From the results, it was observed that application of halophytic compost showed significant increase in soil microbial population such as bacteria, fungi, actinomycetes and *Rhizobium* and enhanced the yield of *Vigna mungo* L. when compared to unmanured soil. The experiment proved that soil microflora such as bacteria, fungi, actinomycetes and *Rhizobium* showed a significant increase in soil treated

with halophytic compost when compared to unmanured soil during first sixty days of cultivation period. Maximum soil microfloras were identified in *Suaeda* compost treatment in combination with farmyard manure and *Rhizobium* (T6). Generally, all the treatments were better than the unmanured soil. Nearly 64.28% increase in bacteria, 58.33% in fungi, 55.55% in actinomycetes and 61.19% in rhizobium (Table 4–7) were noticed in the soil treated with *Suaeda* compost along with farmyard manure and *Rhizobium* (T6). However, a reverse trend in microflora was observed after 60 days of treatment until the harvest stage, whereas a reduction of about 20% in bacteria, 20% in fungi, 21% in actinomycetes and 20% *Rhizobium* populations was recorded in *Suaeda* compost in combination with farmyard manure and *Rhizobium* (T6) when compared to the other treatments and unmanured soil. These results were in agreement with findings of Dar (1996)^[9]. and Marinari *et al.* (2000)^[23]. recorded an increased soil biological activity and soil microbial growth when vermicompost of sewage sludge was applied, which increased soil microflora by 8–28%. Nedunchezhiyan *et al.* (2013)^[26]. clearly revealed that organic material significantly increased the soil microbial population. Krishnakumar *et al.*, (2005)^[16]. indicated that application of organic compost would have resulted an increased micronutrients in the soil, which might have helped to enhance the soil microbial population. Prabhuraj *et al.* (2005)^[27]. reported that amalgamation of farmyard manure, sericulture waste compost, green manure and biofertilizers with NPK recorded highest phosphate solubilising microorganism and N-fixing bacteria. Meena *et al.* (2013)^[25]. Reported that application of concentrate manure and inorganic fertilizer increases the soil microbial population and enzyme activity in alluvium soil of Varanasi. Ambadi *et al.* (2018)^[4]. noticed that application of varied crop residues and green biomass compost to rabi sorghum growing soils enhanced uptake of nutrients, microbial biomass and fertility of soil. The use of organics plays an important role in maintaining soil fertility due to build-up of soil organic matter, which is productive for soil microbes (Kannan *et al.*, 2013)^[16].

Impact of halophytic compost on yield attributes of *Vigna mungo* L.

Results indicated that combined application of *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure 3.13 @ t h⁻¹ + *Rhizobium* @ 2kg t h⁻¹ recorded increase in number of pods plant⁻¹ (77.50%), pod length plant⁻¹ (38.09%), fresh weight of pod (61.02%), dry weight of pod (59.67%), number of seeds pod⁻¹ (52.42%) and 100 seed weight per gram (45.12%) over other treatments and unmanured soil (Table 8). Similarly highest grain (46.42%), Stover yield (30.20%), biological yield (36.08%) kg h⁻¹ harvest index (36.26%) respectively were recorded with the application of *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure 3.13 @ t h⁻¹ + *Rhizobium* @ 2kg t h⁻¹ over control. Other treatments were also significantly effective over control, however their level of effectiveness were less than treatment (T6) *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure 3.13 @ t h⁻¹ + *Rhizobium* @ 2kg t h⁻¹ (Table 9). Halophytic compost along with farmyard manure and *Rhizobium* may have increased nitrogen fixation and production of secondary metabolites resulting in enhanced availability and uptake of nitrogen, and this may be due to fast mineralization of halophytic compost along with

farmyard manure and *Rhizobium* have enhanced availability of nutrients to the plants thereby stimulating plant growth and development. In the present study optimization of *Suaeda maritima* compost along with farmyard manure and *Rhizobium* has enhanced the yield attributes of *Vigna mungo* L. These results are in conformity with the findings of Thiyageshwari *et al.* (2018) [35], who reported that application of rice husk compost as an alternate organic compost enhanced the production of *Vigna mungo* L and Hasan and Ram, (2015) [14]. Indicated that use of PGPR and organic manure significantly increased soil fertility, growth, nodulation and yield of *Vigna mungo* L. Malik *et al.* (2015) [22], showed that addition of *Rhizobium*, compost and nitrogen improved growth and yield of black gram and Rady *et al.* (2016) also reported that application of organic compost enhanced growth and yield of *Phaseolus vulgaris*. The use of integrated nutrient management enhanced growth and yield of *Vigna raidaita* L. (Gohain and Kikan, 2017; Meena *et al.* 2016) [24]. It has been reported that impact of biofertilizers increased plant growth and yield attributes of *Pisum sativum* L. (Insaf *et al.*, 2017) [15].

Impact of halophytic compost on soil properties

In the present study all the treatments reduced the soil pH than control. However the pH was reduced by (8.64%) in *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure 3.13 @ t h⁻¹ + *Rhizobium* @ 2kg t h⁻¹ when compared to other treatments and unmannered soil. Similar to pH, EC was also decreased in compost treated soil. The EC was decreased by (28.12%) in *Suaeda maritima* compost @ 6.25 t h⁻¹ + Farmyard manure 3.13 @ t h⁻¹ + *Rhizobium* @ 2kg t h⁻¹ when compared to other treatments and unmannered soil (Table10-11). In the present study application of *Suaeda maritima* compost in combination with farmyard manure and *Rhizobium* showed lower pH and EC in compost treated soil at harvest stage. This might may be due to the production of organic acids during decomposition of organic compost in soil (Das and Singh 2013) [10]. It has been indicated that soil pH and EC gradually decreased with the increase of incubation time in amended soils (Sanjy Roy and Abdul Kashem 2014) [31]. Similar results were also obtained by Ravindran *et al.* (2007) [30], who reported that impact of halophytic compost along with farmyard manure and Phospho solubilising bacteria reduces soil pH and EC.

Conclusion

Present results indicated that application of halophytic compost along with farmyard manure and *Rhizobium* had increased the soil microbial population and productivity of the black gram. The addition of various organics provides the substrate with carbon, which leads to an increase of the soil microflora during the first 60 days; after this period these activities decline since the available carbon content present in the soil is exhausted by soil microbes.

Acknowledgement

The Authors are very grateful to the university Grant Commission, New Delhi, India for providing the necessary facilities for undertaking this study under UGC—SAP.

References

1. Adesemoye AO, Kloepper JW. Plant–microbes interactions in enhanced fertilizer-use efficiency.

- Applied microbiology and biotechnology. 2009; 85(1):1-12.2.
- Ahmad R, Jilani G, Arshad M, Zahir ZA, Khalid A. Bio-conversion of organic wastes for their recycling in agriculture: an overview of perspectives and prospects. *Ann Microbiol.* 2007; 57:471-479
 - Ai C, Zhang S, Zhang X, Guo D, Zhou W, Huang S, *et al.* Distinct responses of soilbacterial and fungal communities to changes in fertilization regime and crop rotation. *Geoderma.* 2018; 319:156-166.
 - Ambadi A, Krishnamurty D, Rao S, Desai BK, Ravi M V, Shubha S, *et al.* Influence of varied crop residues and green biomass composts to rabi sorghum growing soils on uptake of major nutrients, microbial biomass and soil fertility status. *Journal of Applied and Natural Science.* 2018; 10(1):185-189.
 - Chaudhry AN, Jilani G, Khan MA, Iqbal T. Improved processing of poultry litter to reduce nitrate leaching and enhance its fertilizer quality. *Asian J Chem.* 2009; 21:4997-5003.
 - Chenu C, Angers DA, Barré P, Derrien D, Arrouays D, Balesdent J, *et al.* Increasing organic stocks in agricultural soils: knowledge gaps and potential innovations. *Soil Tillage Res.* 2019; 188:41-52.
 - Cuevas VC. Rapid composting technology in the Philippines: Its role in producing good-quality organic fertilizers. Food & Fertilizer Technology Center. 1997; 441:1-13
 - Da Costa PB, Beneduzi A, de Souza R, Schoenfeld R, Vargas LK, Passaglia LM, *et al.* The effects of different fertilization conditions on bacterial plant growth promoting traits: guidelines for directed bacterial prospection and testing. *Plant and soil.* 2013; 368(1-2):267-280.
 - Dar G. Effects of cadmium and sewage sludge on soil microbial biomass and enzymeactivities. *Bioresource Technology.* 2014; 56:141-145.
 - Das I, Singh AP. Effect of PGPR and organic manures on soil properties of organically cultivated mungbean. *The Bioscan.* 2013; 9(1):27-29.
 - Francis I, Holsters M, Vereecke D. The Gram-positive side of plant–microbe interactions. *Environ Microbiol.* 2010; 12:1-12.
 - Francioli D, Schulz E, Lentendu G, Wubet T, Buscot F, Reitz T, *et al.* Mineral vs. organic amendments: microbial community structure, activity and abundance of agriculturally relevant microbes are driven by long-term fertilization strategies. *Front. Microbiol.* 2016; 7:1446.
 - Gohain T, Kikon N. Optimization of organic nutrient sources for green gram (*Vigna radiata* L. Welczek) under rainfed conditions. *Indian Journal of Agricultural Research.* 2017; 51(5):443-447.
 - Hasan BK, Ram MR. Evaluation of PGPR and organic manure applications on soil fertility, growth, nodulation and yield of black gram (*Vigna mungo* L. Hepper). *International Journal of Agricultural Science and Research (IJASR).* 2015; 5(2):183-191
 - Insaf K, Devendra S, Jat BL. Effects of biofertilizers on plant growth and yield characters of *Pisum sativum* L. *Advance Research Journal of Crop Improvement.* 2017; 8(1):99-108.
 - Kannan RLM, Dhivya M, Abinaya D, Lekshmi Krishna R, Krishnakumar S. Effect of Integrated Nutrient

- Management on Soil Fertility and Productivity in Maize. *Bulletin of Environment, Pharmacology and Life Sciences*. 2013; 2(8):61-67
17. Kaur T, Brar B, Dhillon N. Soil organic matter dynamics as affected by long-term use of organic and inorganic fertilizers under maize-wheat cropping system. *NutrCycl Agroecosys*. 2008; 81:59-69.
 18. Krishnakumar SA, Saravanan SK, Natarajan V, Veerabadram S Mani. Microbial population and enzymatic activity as influenced by organic farming. *Research Journal of Agricultural and Biological Science*. 2005; 1:85-88.
 19. Legrand F, Picot A, Cobo-Díaz JF, Carof M, Chen W, Le Floch G. Effect of tillage and static abiotic soil properties on microbial diversity. *Appl. Soil Ecol*. 2018; 132:135-145.
 20. Leite LFC, Oliveira FC, Araújo ASF, Galvão SRS, Lemos JO. Soil organic carbon and biological indicators in an Acrisol under tillage systems an organic management in north-eastern Brazil. *Soil Res*. 2010; 48:258-265
 21. Lychuk TE, Moulin AP, Lemke RL, Izaurralde RC, Johnson EN, Olfert OO, *et al*. Climate change, agricultural inputs, cropping diversity, and environment affect soil carbon and respiration: a case study in Saskatchewan, Canada. *Geoderma*. 2019; 337:664-678
 22. Malik MMR, Akhtar MJ, Ahmad I, Khalid M. Synergistic use of rhizobium, compost and nitrogen to improve growth and yield of mungbean (*Vigna radiata*). *Pakistan J. Agric. Sci*. 2014; 51(1):383-388.
 23. Marinari SG, Masciandaro B Ceccanti, Grego S. Influence of organic and mineral fertilizers on soil biological and physiological properties. *Bioresource Technology*. 2000; 72:9-17.
 24. Meena S, Swaroop N, Dawson J. Effect of integrated nutrient management on growth and yield of green gram (*Vigna radiata* L.). *Agricultural Science Digest*. 2016; 36:63-65
 25. Meena VS, Maurya BR, Verma R, Meena RS, Jatav GK, Meena SK, *et al*. Soil microbial population and selected enzyme activities as influenced by concentrate manure and inorganic fertilizer in alluvium soil of Varanasi. *Bioscan*. 2013; 8(3):931-935.
 26. Nedunchezhiyan M, Byju G, Dash SN, Ranasingh N. Selected soil enzyme activities, soil microbial biomass carbon and root yield as influenced by organic production systems in sweet potato, *Communications in Soil Science and Plant Analysis*, 2013. DOI:10.1080/00103624.2012.756506
 27. Prabhuraj KUD, Bongale J, Sukumar H Sanaulla, Thimma Reddy H. Comparative study on the organic and integrated nutrient management in mulberry. *Progress of Research in Organic Sericulture and Seri-by-products Utilization*. Bangalore: Cole Publishing Company, 2005, 146-148
 28. Rady MM, Semida WM, Hemida KA, Abdelhamid MT. The effect of compost on growth and yield of *Phaseolus vulgaris* plants grown under saline soil. *International Journal of Recycling of Organic Waste in Agriculture*. 2005; 5(4):311-321
 29. Rajender, Tiwari AK. Pulses Revolution From Food to Nutritional Security. Crop Division, Govt. of India, Ministry of Agriculture and Farmers Welfare. Dept. of Agriculture Krishi Bhawan New Delhi, 2018.
 30. Ravindran KC, Venkatesan K, Balasubramanian T, Balakrishnan V. Effect of halophytic compost along with farmyard manure and phosphobacteria on growth characteristics of *Arachis hypogaea* Linn. *Science of the total environment*. 2007; 384(1-3):333-341.
 31. Roy S, Kashem MA. Effects of organic manures in changes of some soil properties at different incubation periods. *Open Journal of Soil Science*, 2014.
 32. Saikia SP, Jain V. Biological nitrogen fixation with non-legumes: an achievable target or a dogma. *Curr. Sci*. 2007; 92:317-322.
 33. Sharma SK, Ramesh A, Sharma MP, Joshi OP, Govaerts B, Steenwerth KL, *et al*. Microbial Community Structure and Diversity as Indicators for Evaluating Soil Quality, Biodiversity, Biofuels, Agroforestry and Conservation Agriculture. Springer, 2010, 317-358.
 34. She W, Bai Y, Zhang Y, Qin S, Feng W, Sun Y, *et al*. Resource availability drives responses of soil microbial communities to short-term precipitation and nitrogen addition in a desert shrubland. *Front. Microbiol*. 2018; 9:186.
 35. Thiyageshwari S, Gayathri P, Krishnamoorthy R, Anandham R, Paul D. Exploration of rice husk compost as an alternate organic manure to enhance the productivity of blackgram in Typic Haplustalf and Typic Rhodustalf. *International journal of environmental research and public health*. 2018; 15(2):358.
 36. Wang W, Niu J, Zhou X, Wang Y. Long-term change in land management from subtropical wetland to paddy field shifts soil microbial community structure as determined by PLFA and T-RFLP. *Pol J Eco*. 2011; 59:37-44.
 37. Watson ME. Testing compost. Extension Fact Sheet, School of Natural Resources, Columbus, OH, 2003, 1-4.