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Influence of Organic Nutrient Management on Soil Properties, Growth, Yield and Economics of Garlic (*Allium sativum* L.) in Coastal Salt Affected Soil of Gujarat

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A field experiment was conducted at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti-Umbharat, Navsari, Gujarat during *rabi* seasons of 2012-13, 2013-14 and 2014-15 to study the effect of organic manures and bio-fertilizer on growth and productivity of garlic. In total six treatment combinations comprising of three treatments of organics which were applied on nitrogen equivalent basis *i.e.*, O_1: 50% N through FYM as basal + 50% N through castor cake at 40 DAS, O_2: 50% N through biocompost as basal + 50% N through castor cake at 40 DAS, O_3: 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS and two treatments of biofertilizer *i.e.*, B_1: with biofertilizer (PSB and *Azotobacter*) and B_2: without biofertilizer were evaluated in factorial randomized block design with four replications. Application of recommended dose of N @ 100 kg ha^{-1} of which 50% N through bio-compost as basal and remaining 50% N through castor cake at 40 DAS recorded significantly higher average bulb weight (11.98 g), bulb yield (7.9 t ha^{-1}) and lower weight loss after six months of storage (18.14%). Cloves inoculation with biofertilizers resulted in significantly higher plant height (59.07 cm) and average bulb weight (12.29 g). In case of interaction effect, application of recommended dose of N @ 100 kg/ha of which 50% N through bio-compost as basal and remaining 50% N through castor cake at 40 DAS along with bio-fertilizers recorded higher bulb yield (9.2 t ha^{-1}), gross return (₹ 3,66,174 ha^{-1}), net return (₹ 2,63,039ha^{-1}) and BC ratio (2.55) followed by 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS with bio-fertilizer.

(***Key words:*** *Biofertilizer, Coastal salt affected soil, Garlic yield, Organic manures*)

Garlic (*Allium sativum* L.) is the second most important bulb crop after onion belonging to family Alliaceae. In India, garlic growing area is 274 thousand hectares with a production of 1271 thousand MT in 2016-17 (Anonymous, 2017). In Gujarat, garlic is grown on 10.10 thousand hectares with production of 79.20 thousand MT (Anonymous, 2017). It is used practically all over the world for flavouring and seasoning various vegetables and meat dishes. Garlic is rich in proteins, minerals like phosphorus, calcium, magnesium and carbohydrates. It also contains fat, vitamin C and sulphur. It is already being used in several food preparations, notably in chutneys, pickles, curry powders, curried vegetables, meat preparations, tomato ketchup. Besides, garlic also has some antifungal, antimicrobial, insecticidal and other medicinal properties. It has hypoglycemic (capable of lowering blood sugar) properties and garlic therapy has also been suggested in flatulence, constipation, faulty digestion, inadequate food intake, chronic coughs, leprosy and many other diseases (Adegoke *et al*., 1998). Supplementation with garlic extract has been reported to inhibit vascular calcification in human patients with high blood cholesterol (Durak *et al*., 2004).

In Gujarat, the coastal salt affected soils occupy an area of 4.62 lakh ha. In coastal area, excessive amounts of salt have adverse effects on the physical and chemical properties of soil as well as plant growth. Organic materials such as farmyard manure, biocompost, vermicompost, castor cake, plant residues and manures are currently used to ameliorate the salt affected soil. The application of organic materials to salt affected soils can improve surface soil fertility, soil structure and permeability thus, enhancing salt leaching, reducing surface evaporation, inhibiting salt accumulation in surface soils. The biofertilizers *viz*., *Azotobacter* and phosphate solubilising bacteria (PSB) help in increasing the availability of nutrients to plant, which results in to better growth of plant. Use of organic manures with bio-fertilizer improves the soil physical and chemical properties and increases in garlic yield was reported

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by Gowda *et al*. (2007) and Singh *et al*. (2015). In view of this background, the present investigation was undertaken to find out the ideal combination of organic manures with biofertilizer that would improve the yield of garlic in a salt affected soil of coastal Gujarat.

MATERIALS AND METHODS

A field experiment was conducted during the *rabi* seasons of 2012-13, 2013-14 and 2014-15 at the Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti-Umbharat in the South Gujarat near the Arabian Sea. Geographically, Danti-Umbharat is situated at 20° 83′ N latitude and 72° 50′ E longitude at an elevation of 2.5 m above mean sea level on the western coastal belt of India. The climate of this region is characterized by fairly hot summer, moderately cold winter, humid and warm monsoon. The area receives an annual average rainfall of 1100 mm, most of which occurs from the second week of June to last week of September. The mean minimum and maximum temperatures vary from 11.1 to 23.3°C and 24.4 to 39.1 °C, respectively. The soil (0-15 cm) of the experiment plot was clayey in texture, having pH_2 (9.08), electrical conductivity (EC_2 - 0.41 dS m^{-1}), organic carbon (0.58 %) low in available N (278 kg ha^{-1}), medium in available P_2O_5 (45.56 kg ha^{-1}) and high in available K_2O (1172 kg ha^{-1}).

The field experiment was laid out in factorial randomized block design with four replications, comprising of three treatments of organics which were applied on nitrogen equivalent basis (Table 1) *i.e*., O_1: 50% N through FYM as basal + 50% N through castor cake at 40 DAS, O_2: 50% N through biocompost as basal + 50% N through castor cake at 40 DAS, O_3: 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS and two treatments of biofertilizer *i.e*., B_1: with biofertilizer (PSB and *Azotobacter*) and B_2: without biofertilizer. Local variety of *dhaincha* was broadcasted in experimental site for green manuring with seed rate of 40 kg ha^{-1} before sowing of garlic crop. *Dhaincha* was grown upto 45 days after sowing (DAS) and incorporated into the soil. Garlic variety 'Gujarat Garlic-1' was used for the experimentation. Garlic seed was used @ 400-500 kg ha^{-1} cloves for the experiment. After preparing the experimental plots, cloves of garlic were sown in rows in the field. Nitrogen content was estimated in organics sources on dry weight basis and their quantities required for a specific amount of N as per treatment were calculated (Table 1). Farmyard manure, biocompost and vermicompost were applied 2 week before sowing and incorporated in soil, while castor cake was applied at 40 DAS as per treatments. Cloves were treated with biofertilizers (PSB and *Azotobacter*) as per treatments at the time of sowing. Pest management was

Table 1. *Moisture and nitrogen content of organic manures as well as quantity of organic manures used in the experiment*

Organics	N content (%) (Dry basis)	Moisture content (%)	Quantity of organics for getting 50 kg N ha^{-1} on N equivalent basis (t ha^{-1})
Year 2012-13			
FYM	0.49	34	12.65
Biocompost	0.92	31	6.58
Vermicompost	1.35	45	5.00
Castor cake	4.2	7	1.20
Year 2013-14			
FYM	0.53	29	11.23
Biocompost	0.92	31	6.58
Vermicompost	1.27	42	5.20
Castor cake	4.4	7	1.14
Year 2014-15			
FYM	0.51	32	11.96
Biocompost	0.94	34	6.60
Vermicompost	1.29	43	5.16
Castor cake	4.2	9	1.21

done based on cultural and biological methods. After harvesting, random samples (each of 3 kg) were taken from every treatment, stored at normal room conditions and weight losses percentage of bulb was estimated after 6 months of storage.

After harvest of garlic crop, surface soil samples (0-15 cm) were collected treatment-wise from all replications during all the individual years. Soil pH and EC were determined in soil water suspension (1:2 soil: water ratio) using pH and EC meter as described by Jackson (1973). Organic carbon content of soil samples were determined by the method given by Walkley and Black (1934). Available nitrogen in soil was determined by alkaline potassium permanganate method of Subbiah and Asija (1956). Available P_2O_5 content was extracted by using colorimeter as per Olsen *et al*. (1954). Available K_2O was measured using a flame photometer as described by Jackson (1973). Analysis of variance (ANOVA) technique for a factorial randomised block design was performed by using WINDOSTAT software version-7. Critical difference (CD) at a 0.05 level of probability was used to compare differences among treatment means.

Economics of garlic cultivation, as influenced by organic manures and biofertilizer, were calculated by considering the prevailing market price of garlic (₹ 40/-kg^{-1}). A premium price ranging from 0 to 100% higher than that for conventional produce is already being realized in many organically produced crops in India (Chadha and Choudhary, 2007). Therefore, economic evaluation of organic garlic cultivation was also done by assuming ₹ 10 price premium for the produce to assess whether garlic can be profitably grown under organic farming conditions.

RESULTS AND DISCUSSIONS

Growth and yield attributing characters

The results of growth and yield attributes such as plant height, average bulb weight and bulb diameter as well as weight loss after six months of garlic affected by different treatments are given in Table 2. Average bulb weight and weight loss after six month affected significantly due to application of organic manures. Application of 50% N through biocompost as basal + 50% N through castor cake at 40 DAS (O_2) and 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS (O_3) remained at par with each other and both recorded significantly higher values of average bulb weight (11.91 and 11.88 g, respectively) as compare to application of 50% N through FYM as basal + 50% N through castor cake at 40 DAS (O_1) (10.53 g). The weight loss during storage after six months was recorded significantly lower in the treatment (O_3) with application of 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS than rest of the treatments. However, no significant difference in the plant height and bulb diameter was observed among the different treatments. The results obtained in the present study are supported by similar findings as reported by Kore *et al*. (2006) in garlic. Zaki *et al*. (2014) referred that the decreasing bulb weight loss during storage might be due to improved uptake of both macro and micro nutrient elements that led to proper nutrient balance in the bulb tissues.

The growth and yield attributes such as plant height and average bulb weight varied significantly with the biofertilizer treatments (*Azotobacter* and PSB). Biofertilizer treatment significantly increased the plant height (59.07 cm) and average bulb weight (12.29 g) as compare to without biofertilizer treatment (56.33 cm and 10.59 g, respectively). In case of interaction effect of organic manures and bio-fertilizer, all the growth and yield parameters ware found non-significant. Biofertilizers and organic manures are responsible for adequate and steady supply of all essential nutrients; improve the soil physical and chemical properties; are associated with vigorous vegetative growth and more efficient use of available inputs, leading to higher productivity. Talware *et al*. (2012) also reported similar beneficial effect of organic manures and biofertilizers on growth and yield attributes of garlic.

Bulb yield

The results pertaining to bulb yield of garlic affected by different treatments are presented in Table 2. Bulb yield of garlic was significantly affected due to organics and their interactive effect with bio-fertilizer. Application of 50% N through bio-compost as basal + 50% N through castor cake at 40 DAS and 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS remained at par with each other and both were recorded significantly higher bulb yield (7.85 and 7.70 t ha^{-1}, respectively) as compared to 50% N through FYM as basal + 50% N through castor cake at 40 DAS (6.53 t ha^{-1}). In case of bio-fertilizer,

Table 2. *Effect of different treatments on growth and yield attributes as well as bulb yield of garlic (Pooled over 3 years)*

Treatments	Plant height (cm)	Bulb weight (g)	Bulb diameter (cm)	Weight loss after six months (%)	Bulb yield (t ha^{-1})
Organics					
O_1: 50% N through FYM as basal + 50% N through castor cake at 40 DAS	56.27	10.53	4.57	18.56	6.53
O_2:50% N through biocompost as basal + 50% N through castor cake at 40 DAS	58.50	11.91	4.86	18.14	7.85
O_3:50% N through vermicompost as basal + 50% N through castor cake at 40 DAS	58.34	11.88	4.85	16.98	7.70
S. Em±	0.89	0.28	0.10	0.30	0.217
CD (P=0.05)	NS	0.79	NS	0.86	0.619
Biofertilizer					
B_1: With biofertilizer (PSB and *Azotobacter*)	59.07	12.29	4.83	18.00	8.129
B_2: Without biofertilizer	56.33	10.59	4.68	17.73	6.593
S. Em±	0.73	0.23	0.08	0.25	0.44
CD (P=0.05)	2.07	0.64	NS	NS	NS
Interaction effect (O x B)	NS	NS	NS	NS	S

Table 3. *Effect of different treatments on soil chemical properties after three years*

Treatment	pH_2		EC_2 (dS m^{-1})		OC (%)		Av. N (kg ha^{-1})		Av. P_2O_5 (kg ha^{-1})		Av. K_2O (kg ha^{-1})	
	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)
Initial	9.08	8.96	0.41	0.49	0.58	0.42	278	262	45.56	42.82	1172	1155
Organics												
O_1	8.25	8.34	0.21	0.21	0.82	0.75	252	247	53.39	47.72	1232	1190
O_2	8.28	8.32	0.24	0.26	0.87	0.85	277	267	55.17	51.52	1268	1247
O_3	8.28	8.30	0.24	0.25	0.81	0.72	246	241	54.39	51.24	1258	1219
S. Em±	0.04	0.03	0.01	0.02	0.03	0.06	9	9	0.93	0.66	48	37
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.99	NS	NS
Biofertilizer												
B_1	8.27	8.31	0.22	0.23	0.85	0.71	259	257	58.05	50.97	1257	1222
B_2	8.27	8.32	0.24	0.25	0.82	0.73	257	246	50.58	49.34	1248	1216
S. Em±	0.03	0.03	0.01	0.01	0.03	0.05	7	7	0.76	0.54	39	30
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	2.30	1.62	NS	NS

bulb yield of garlic was found to be non-significant. The interaction effect of 50% N through bio-compost as basal + 50% N through castor cake at 40 DAS and bio-fertilizer (*Azotobacter* and PSB) (O_2B_1) recorded significantly higher bulb yield (9.15 t ha^{-1}) than rest of the treatment combinations but it was at par with treatment combination O_3B_1 consisting of 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS with bio-fertilizer (8.53 t ha^{-1}) (Table 4). The results obtained in the present study confirm the hypothesis that the combination of biofertilizers and organic manures increases the soil macro and micronutrients and promotes microbial population, which ultimately promotes the plant growth and production at a sustainable basis. This might be due to the fact that organic manure supplied to balanced nutrition to the crop, improved soil properties and thereby resulting in better crop growth and development leading to higher yield. Bhandari *et al*. (2012) also reported that the use of biofertilizers along with organic manures performed better than use of only chemical fertilizers. Jawadagi *et al*. (2012) also reported that the bulb yield, net returns and B:C ratio of onion were maximum in the crop nourished with 50% FYM + 50% vermicompost + biofertilizers (*Azospirillum* and phosphate solubilising bacteria). Similar results have also been reported by Gowda *et al*. (2007) and Singh *et al*. (2015).

Soil properties

The different combination levels of organics did not significantly affect the pH_2, EC_2, organic carbon content, available N, P_2O_5 and K_2O contents of the soil at both the depths except the available P_2O_5 content in subsurface layer (Table 3). However, the values of these properties at both the depths were improved considerably in all the treatments from their initial value. While, the available P_2O_5 content in subsurface layer significantly increased due to application of 50% N through biocompost as basal + 50% N through castor cake at 40 DAS (O_2) as compared to 50% N through FYM as basal + 50% N through castor cake at 40 DAS (O_1)but it remained at par with 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS (O_3). In case of biofertilizers, the pH_2, EC_2, organic carbon, available N and K_2O content of soil at both the depths were not significantly affected. Only available P_2O_5 content of soil at both the depths was significantly increased in bio-fertilizer treatment (B_1- 58.05 and 50.97 kg ha^{-1}, respectively) as compared to without bio-fertilizer treatment (B_2- 50.97 and 49.34 kg ha^{-1}, respectively). The PSB may have solubilized the unavailable phosphorus in the soil thereby increasing its availability. The beneficial effects of application of organics in soil physical, chemical and biological properties have been reported by many workers (Appireddy *et al*., 2008; Appireddy and Mina, 2011; Kaur *et al*., 2005; Zhao *et al*., 2009). Application of organic manures is reported to ameliorate the salt affected soils by improving its properties (Chavan *et al*., 1991; Leogrande and Vitti, 2019).

Economics

In general, the cost of garlic cultivation was higher with the use of different organic manures (Table 4). This was mainly due to higher costs of organic manures and more manual labour involved in transportation, spreading and incorporation of organic manures. As the interaction effect of organics and biofertilizers was found to be significant, economics was computed for different treatment combinations. Application of 50% N through biocompost as basal + 50% N through castor cake at 40 DAS along with bio-fertilizer (treatment O_2B_1) gave highest gross return(₹ 3,66,174 ha^{-1}), net return (₹ 2,63,039 ha^{-1}) and BC ratio (2.55) followed by 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS with biofertilizers.

As the organically grown garlic fetches higher prices as compared to conventionally grown garlic, the economics parameters were calculated considering the ₹10 premium price of organically grown garlic (Table 4). It indicated that the highest gross return (₹ 4,57,718 ha^{-1}), net return (₹ 3,54,582 ha^{-1}) and BC ratio (3.44) followed by 50% N through vermicompost as basal + 50% N through castor cake at 40 DAS with biofertilizers (O_3B_1).

From the results of the study, it can be concluded that in order to achieve the maximum yield and net return from organically grown garlic under coastal salt affected soils of south Gujarat, garlic can be grown as rabi crop with application 50% N through bio-compost as basal and remaining 50% N through castor cake at 40 DAS along with bio-fertilizers (PSB and *Azotobacter*). Application of organics also decreased the soil salinity and improved organic carbon status of the soil.

Table 4. *Effect of different treatments on cost of cultivation and economic returns*

Treatments	Bulb yield (Pooled) (t ha^{-1})	Cost of cultivation (₹ ha^{-1})	Regular selling price @ ₹ 40 kg^{-1}			Premium selling price @ ₹ 50 kg^{-1}		
			Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	BCR	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	BCR
O_1B_1	6.70	108500	268102	159602	1.47	335128	226628	2.09
O_1B_2	6.36	107950	254326	146376	1.35	317907	209958	1.94
O_2B_1	9.15	103136	366174	263039	2.55	457718	354582	3.44
O_2B_2	6.55	102586	262091	159505	1.55	327614	225028	2.19
O_3B_1	8.53	122139	341150	219012	1.79	426438	304299	2.49
O_3B_2	6.87	121589	274763	153174	1.26	343454	221865	1.82
S. Em±	0.31	-	-	-	-	-	-	-
CD (P=0.05)	0.88	-	-	-	-	-	-	-

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