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Nutrients Uptake and the Yield of Okra and Carrot in Response to Bioslurry and Inorganic N Fertilizers

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Authors' contributions

This work was carried out in collaboration between all authors. Author Atif designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AM, AN and SJ managed the analyses of the study. Authors SSHS and AHS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Bioslurry can be used as soil amendment to improve soil fertility in sustainable ways. The experiments to investigate the effect of bioslurry and inorganic fertilizers on nutrient uptake and yield of carrot and okra were conducted from 2011 to 2012 at Institute of Soil Chemistry and Environmental Sciences, Ayub Agriculture Research Institute Faisalabad. Both experiments were set up as randomized complete block design (RCBD) and provided with three replications, consisted of seven treatments (100 kg N inorganic fertilizer (IF), 100 kg N-fresh slurry (FS), 100 kg N-dried slurry (DS), 100 kg N-farm manure (FM), 50 kg N-FS and 50 kg N-IF, 50 kg N-DS and 50 kg N-IF, 50 kg N-FS and 50 kg N-IF for carrot, and 90 kg N inorganic fertilizer (IF), 90 kg N-fresh slurry (FS), 90 kg N-dried slurry (DS), 90 kg N-farm manure (FM), 45 kg N-FS and 45 kg N-IF, 45 kg N-DS and 45 kg N-IF, 45 kg N-FM and 45 kg N-IF for okra). Experimental results revealed maximum carrot (43.2 t ha^{-1}) and okra (6.58 t ha^{-1}) yield with the application of recommended dose of inorganic fertilizers and it was statistically at par with treatment containing integration of fresh

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slurry and inorganic fertilizers. The uptake of nutrients by vegetables, and economics was also improved with the integration of organic and inorganic fertilizers. Resultantly, the combination of FS and IF was found best in improving the yield of carrot and okra on sustained basis and it also proved to be cost effective and economical.

Keywords: Bioslurry; dried slurry; farm manure; carrot; okra; yield.

1. INTRODUCTION

Organic manures play a vital role in retaining soil fertility and crop production on sustainable ways. The application of organic sources alone to fulfill the nutrients requirements is facing problems due to its low nutrient contents and high dosage of its application. Consequently, application of organic manures in combination with inorganic fertilizers can be helpful in obtaining the sustainability of vegetable production [1]. Bioslurry is one of the organic sources which is obtained as by product after the generation of biogas from biogas fermenters. It is environment friendly, inexpensive, and renewable source of nutrients for plants [2]. Soil properties like soil structure, aeration, water-holding capacity and nutrients for sustainable crop productivity improve by the application of bioslurry [3,4]. Bioslurry has shown positive effects on restoring soil fertility and on the mobilization and recycling of soil nutrients, which are at alarmingly low levels in Pakistan [5]. Therefore it can be a potential source for improving crop production in combination with chemical fertilizers.

Carrot (*Daucus carota* L.) is an essential root vegetable and best source of carotene; a precursor of vitamin A [6]. It contains ample quantities of minerals and nutrients [7,8]. Carrot is steamed or boiled in vegetables, consumed uncooked in salads and may also be prepared with other vegetables in the preparation of soups and stews [9].

Okra (*Hibiscus esculentus* L.) is the vegetable grown throughout the tropical and subtropical parts of the world [10]. It is grown for its immature pod that can be used as a boiled or fried vegetable [11]. Okra provides proteins, carbohydrates, fats, vitamins and minerals [12]. Despite the high nutritive value of okra, optimum yields and quality have not been attained because of a continued decline in soil fertility and a decreased use of organic amendments [13].

The focus of this study was to investigate the effect of bioslurry in combination with inorganic fertilizers on yield of carrot and okra.

2. MATERIALS AND METHODS

The field trials to investigate the effect of bioslurry and inorganic fertilizers on nutrient uptake and yield of carrot and okra have been conducted from 2011 to 2012 at Institute of Soil Chemistry and Environmental Sciences, Ayub Agriculture Research Institute Faisalabad. The used soil was sandy clay loam, free from salinity and sodicity but low in organic matter content. However it was marginal in phosphorus while potassium contents were sufficient (Table 2). Each experiment was set up as randomized complete block design (RCBD) and provided with three replications. Recommended dose of phosphorus and potassium (65 kg P_2O_5 + 65 kg K_2O and 75 kg P_2O_5 + 60 kg K_2O for carrot and okra respectively) were used in each treatment. Following seven treatments were used in the experiment (Table 1).

Table 1. Treatment plan

Treatments	Carrot	Okra
T1	100 kg N inorganic fertilizers (IF)	90 kg N inorganic fertilizers (IF)
T2	100 kg N-fresh slurry (FS)	90 kg N-fresh slurry (FS)
T3	100 kg N-dried slurry (DS)	90 kg N-dried slurry (DS)
T4	100 kg N-farm manure (FM)	90 kg N-farm manure (FM)
T5	50 kg N-fresh slurry (FS) and 50 kg N-IF	45 kg N-fresh slurry (FS) and 45 kg N-IF
T6	50 kg N-dried slurry (FS) and 50 kg N-IF	45 kg N-dried slurry (FS) and 45 kg N-IF
T7	50 kg N-farm manure (FS) and 50 kg N-IF	45 kg N-farm manure (FS) and 45 kg N-IF

Table 2. Basic soil analysis

Depth	pH	ECe	O.M	N	P	K	Sand	Silt	Clay	Texture
cm	-	dS m^{-1}	-%-		mg kg^{-1}			-%-		
0-15	8.23	1.85	0.78	0.039	9.14	200	52.8	21.7	25.5	Sandy
15-30	8.15	1.78	0.69	0.035	8.68	180				clay loam

The fresh and dried slurry used in the experiments had higher contents of N, P and K as compared to farm manure (Table 3). On the basis of N, the calculated amounts of fresh slurry, dried slurry and farm manure were used in each experiment.

Table 3. Chemical composition of bio- slurry and farm manure

Organic material	N	P	K
	-%-		
Fresh slurry	0.94	0.48	0.88
Dried slurry	0.96	0.50	0.90
Farm manure	0.64	0.36	0.58

The calculated amounts of amendments (dried slurry and farm manure) were well mixed in the soil at the time of land preparation while fresh slurry was applied through fertigation with first irrigation after sowing of each vegetable. Carrot seeds (cv. T-29) were sown on ridges in winter 2011. The distance between rows was 75 cm while plant to plant distance was maintained at 8 cm. The seeds of okra (cv. Subzpari) were dibbled on both sides of ridges in summer 2012. The distance between two rows was 75 cm. Thinning was done 15 days after sowing, to maintain the plant to plant distance of 20 cm. The crop was irrigated at 10-15 days interval. All the recommended management practices were performed throughout the growth period of tested vegetables in the permanent layout. The vegetables yield data of whole experimental plot (3.0 m × 5.0 m) was recorded and converted into standard unit i.e. t ha^{-1}.

2.1 Soil Sampling and Analysis

Before the start of experiment, five representative soil samples from the site were taken following diagonal technique from two depths (0-15 and 15-30 cm). The samples of each depth were mixed separately to form composite samples in order to investigate the initial fertility status of the soil. After one year of experimentation on two vegetables (carrot & okra), soil samples were collected from each experimental plot for estimation of improved fertility status of the soil by the applied organic amendments. The collected soil samples were air dried, crushed and sieved through a 2 mm stainless steel sieve for physicochemical characteristics. Hydrometer method [14] was used for the measurement of soil particle distribution. For the determination of soil pHs 250 g soil was saturated with distilled water and paste was allowed to stand for one hour. After that pH was recorded by pH meter (Jenway-3510) with glass electrodes using buffer of pH 4.0 and 9.0 as standard [15]. Vacuum pump was used for the extraction of soil paste extract and EC_e was measured with conductivity meter (Jenway-4510). Method described by Ryan et al. [16] was used for the estimation of soil organic carbon (SOC) content. Olsen's method [17] was used for available phosphorus determination and ammonium acetate (1 N of pH 7.0) extractable potassium [18] was estimated by flame photometer (PFP-7 Jenway).

2.2 Plant Sampling and Analysis

The carrot root samples were taken at the time of harvesting while okra fruit samples were taken at first picking. In laboratory the samples were washed to remove soil particles, sun dried, crushed and oven dried. Then 0.5 g ground sample was taken for the analysis of N, P and K contents using the standard procedures given in Muhmood et al. [19]. The uptake of nutrients by carrot and okra was determined on dry weight basis using the relationship given in Majeed et al. [20]:

$$\text{Nutrient uptake kg ha}^{-1} = \frac{\text{nutrient contents (\%) in plant part} \times \text{Yield}}{100}$$

The data collected from the experiments regarding different parameters was subjected to analysis of variance to test the significance of treatments and treatment means were compared using least significant difference (LSD) [21]. A benefit-cost analysis was conducted to estimate the economic feasibility of different organic amendments to increase vegetable production and net economic returns as described by CIMMYT [22].

2.3 Analysis of Organic Materials

Fresh and dried slurry was taken from biogas plant at Chak No. 254 RB Faisalabad, Pakistan. Fresh slurry, dried slurry and farm manure samples were analyzed for their chemical constituents using standard methods described by Nelson and Sommers [23].

3. RESULTS AND DISCUSSION

3.1 Vegetable Yield (t/ha)

The results regarding effect of bioslurry alone and in combination with inorganic fertilizers on carrot and okra yield are presented in Table 4 and Table 5 respectively. The obtained results depicted that maximum carrot yield (43.2 t/ha) was in treatment where recommended dose of inorganic fertilizer was applied and the yield in this treatment was statistically non-significant (Appendix, Table 1) with the carrot yield (42.9 t/ha) in treatment containing integration of fresh bioslurry and inorganic fertilizers. Comparative analysis of treatments with organic materials alone showed that the carrot yield in case of all organic materials was statistically at par with each other (Appendix Table 1); however, maximum yield was obtained where bioslurry alone was used. In case of okra, the highest okra fruit yield (6.58 t/ha) was in treatment receiving recommended dose of inorganic fertilizers and it was at par with the treatment where fresh slurry was integrated with inorganic fertilizers.

Table 4. Effect of bioslurry and inorganic fertilizers on carrot yield (t ha^{-1})

Treatments	Carrot yield
	-t ha^{-1}-
100 kg N inorganic fertilizers (IF)	43.2 a
100 kg N-fresh slurry (FS)	29.9 cd
100 kg N-dried slurry (DS)	30.9 cd
100 kg N-farm manure (FM)	29.7 d
50 kg N-fresh slurry (FS) and 50 kg N-IF	42.9 a
50 kg N-dried slurry (FS) and 50 kg N-IF	37.9 ab
50 kg N-farm manure (FS) and 50 kg N-IF	36.0 bc
LSD	2.85

Similar trend in okra yield was obtained in case of organic materials containing treatments as was seen in carrot yield. In the present study the maximum vegetables yield with the application of inorganic fertilizer was due to the fact that inorganic fertilizers release and supply nutrients rapidly which accelerated plant growth resulting in higher yield. Integration of fresh slurry and inorganic fertilizers gave statistically similar yield of carrot and okra as obtained with the application of inorganic fertilizer. This is due to synergistic effect of organic and inorganic fertilizers on crop performance. Mahmoud et al. [24] found similar results in cucumber as obtained in the present study. Ullah et al. [25] conducted a study regarding effect of organic manures and chemical fertilizers on the yield of brinjal and soil properties and they found results which were in line with the results of this study.

Table 5. Effect of bioslurry and inorganic fertilizers on okra yield (t ha^{-1})

Treatments	Okra yield
	-t ha^{-1}-
90 kg N inorganic fertilizers (IF)	6.58 a
90 kg N-fresh slurry (FS)	3.90 d
90 kg N-dried slurry (DS)	3.85 d
90 kg N-farm manure (FM)	3.83 d
45 kg N-fresh slurry (FS) and 45 kg N-IF	6.52 a
45 kg N-dried slurry (FS) and 45 kg N-IF	5.72 bc
45 kg N-farm manure (FS) and 45 kg N-IF	5.64 c
LSD	0.37

3.2 Macronutrient Uptake

The data regarding macronutrient uptake by vegetables (carrot & okra) is presented in Tables 6 and 7. The maximum macronutrient uptake by carrot was observed in treatment where inorganic fertilizer was applied alone. The macronutrient uptake in treatment where 50% nitrogen from fresh slurry and 50% nitrogen from inorganic fertilizer was applied varied non significantly (Appendix Tables 3-8) with inorganic fertilizer containing treatment. The comparative analysis of organic materials alone and their combination with inorganic fertilizer regarding macronutrient uptake showed that all of them were at par with each other. Highest macronutrients uptake by both vegetables was obtained with the application of inorganic fertilizers because they supply nutrients rapidly and in readily available form, which resulted in a greater uptake of nutrients from the soil. The uptake of macronutrients by both vegetables improved with the integration of organic and inorganic fertilizers. The reason of a high uptake of nutrients by applied bioslurry along with

inorganic fertilizers was that it beside improving soil quality also supplied micro, macro nutrient to soil, increase uptake of nutrients to plant that flourish the plant growth. Comparative analysis of bioslurry and farm manure regarding nutrient availabilty showed that bioslurry gives better results than farm manure due to narrow C:N ratio of bioslurry. Sarwar et al. [5] also found similar results. Jeptoo et al. [26] conducted a study about the effect of bioslurry manure on carrot and found results which were in accordance with the results of the present study.

3.3 Chemical Soil Properties

Soil analysis (Table 8) after harvest of vegetables showed that pH and ECe of soil does not change to much extent before and after the experiment. In case of organic matter a definite trend was observed in the soil after the crop. The organic matter content was 0.78% before the start of experiment which reached to 0.89% after experiment. Available potassium contents improve to some extent by the application of organic materials alone and in combination with mineral fertilizers; however, no definite sequence in available phosphorus was observed. The results regarding effect of bioslurry and inorganic fertilizers on soil properties depicted that pH and ECe of the soil shows no definite trend and very little change was found in this study, this might be due to greater buffering capacity of the soil. The results are supported by Yadav [27]. In the presnt study soil organic matter was decreased by inorganic fertilizer application but was increased with all types of organic manure application and that was recorded the highest with combined application. The result is supported by Wells et al. [28]. Application of bioslurry and farm yard manure alone and in combination with inorganic fetilizers showed positive contribution on potassium availability; however, no definite trend was found for phosphorus. This might be due to alkaline soil pH property because soil phosphorus in high soil pH environment becomes deficit even if it is present in plentiful amount. Ullah et al. [25] conducted a study to inestigate the effect of biolurry on soil properties and their results were in line with the results of the present study.

3.4 Economics Analyses of Vegetable Production

The economic analysis (Table 9) depicted that maximum benefit (Rs. 5.14 and 5.10) after consuming one rupee for carrot and okra respectively was observed in treatment where fresh bioslurry was integrated with inorganic fertilizers. The minimum benefit was obtained with the application of organic materials alone.

Table 6. Effect of bioslurry and inorganic fertilizers on nutrient uptake by carrot (kg ha^{-1})

Treatments	N	P	K
		-kg ha^{-1}-	
100 kg N inorganic fertilizers (IF)	52.7 a	4.46 a	56.0 a
100 kg N-fresh slurry (FS)	38.7 cd	3.27 b	39.7 de
100 kg N-dried slurry (DS)	37.3 cd	3.19 bc	38.3 de
100 kg N-farm manure (FM)	33.3 d	2.71 c	34.7 d
50 kg N-fresh slurry (FS) and 50 kg N-IF	49.7 ab	4.30 a	53.3 ab
50 kg N-dried slurry (FS) and 50 kg N-IF	44.0 abc	3.64 b	47.3 bc
50 kg N-farm manure (FS) and 50 kg N-IF	42.0 bcd	3.50 b	45.3 cd
LSD	8.80	0.51	7.30

Table 7. Effect of bioslurry and inorganic fertilizers on nutrient uptake by okra (kg ha^{-1})

Treatments	N	P	K
		-kg ha^{-1}-	
90 kg N inorganic fertilizers (IF)	32.5 a	4.87 a	20.2 a
90 kg N-fresh slurry (FS)	20.7 cd	3.63 bc	12.0 bc
90 kg N-dried slurry (DS)	20.1 cd	3.28 c	11.6 bc
90 kg N-farm manure (FM)	19.2 d	3.27 c	11.1 c
45 kg N-fresh slurry (FS) and 45 kg N-IF	30.8 ab	4.56 ab	19.1 a
45 kg N-dried slurry (FS) and 45 kg N-IF	25.3 bc	4.37 b	14.7 b
45 kg N-farm manure (FS) and 45 kg N-IF	24.0 cd	4.32 b	13.8 bc
LSD	5.28	0.48	3.30

Table 8. Post harvest soil analysis

Treatments	pH	ECe	O.M	P	K
		dS m^{-1}	%	mg kg^{-1}	
RD of N	8.19 **NS**	1.83**NS**	0.74 d	9.38 **NS**	208 d
FS on the basis of RD of N	8.20	1.80	0.83 bc	9.63	210 bcd
DS on the basis of RD of N	8.18	1.81	0.82 c	9.43	210 bcd
FM on the basis of RD of N	8.17	1.79	0.81c	9.51	208 cd
Half N from FS and half N from IF	8.16	1.78	0.89 a	9.58	216 ab
Half N from DS and half N from IF	8.14	1.82	0.87 ab	9.45	218 a
Half N from FM and half N from IF	8.16	1.80	0.84 bc	9.44	214 abc
LSD	0.27	0.23	0.04	0.68	6.08

RD = recommended dose, FS = fresh slurry, DS = dried slurry, FM = farm manure, IF = inorganic fertilizer

Table 9. Economical analysis of the experiment

Treatments	Carrot	Okra
	Cost benefit ratio (CBR)	
RD of NPK	4.63	4.52
FS on the basis of RD of N	3.49	2.68
DS on the basis of RD of N	3.61	2.64
FM on the basis of RD of N	3.47	2.63
Half N from FS and half N from IF	5.14	5.10
Half N from DS and half N from IF	4.44	4.36
Half N from FM and half N from IF	4.21	4.30

RD = recommended dose, FS = fresh slurry, DS = dried slurry, FM = farm manure, IF = inorganic fertilizer

4. CONCLUSION

The carrot and okra vegetables in terms of yield and nutrients uptake depicted significant differences in response to different combinations of organic and inorganic amendments. However, the best combination was fresh bioslurry along with inorganic fertilizers. It not only caused a significant increase in nutrient uptake and yield of both vegetables but also proved to be cost effective and economical.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 1. Carrot yield

Source	DF	SS	MS	F	P
Replication	2	11.646	5.823		
Treatments	6	619.407	103.235	8.45	0.0010
Error	12	146.564	12.214		
Total	20	777.617			

CV = 9.77%

Table 2. Okra yield

Source	DF	SS	MS	F	P
Replication	2	0.9017	0.45087		
Treatments	6	28.4987	4.74979	22.59	0.0000
Error	12	2.5234	0.21028		
Total	20	31.9239			

CV = 8.91%

Table 3. Carrot nitrogen uptake

Source	DF	SS	MS	F	P
Replication	2	64.10	32.048		
Treatments	6	847.90	141.317	5.67	0.0053
Error	12	299.24	24.937		
Total	20	1211.24			

CV = 11.74%

Table 4. Carrot phosphorus uptake

Source	DF	SS	MS	F	P
Replication	2	0.15272	0.07636		
Treatments	6	6.91396	1.15233	14.10	0.0001
Error	12	0.98041	0.08170		
Total	20	8.04710			

CV = 7.98%

Table 5. Carrot potassium uptake

Source	DF	SS	MS	F	P
Replication	2	94.10	47.048		
Treatments	6	1126.95	187.825	11.16	0.0003
Error	12	201.90	16.825		
Total	20	1422.95			

CV = 9.12%

Table 6. Okra nitrogen uptake

Source	DF	SS	MS	F	P
Replication	2	39. 310	19.6548		
Treatments	6	466.339	77.7232	8.84	0.0008
Error	12	105.544	8.7953		
Total	20	611.192			

CV = 12.10%

Table 7. Okra phosphorus uptake

Source	DF	SS	MS	F	P
Replication	2	0.1465	0.07323		
Treatments	6	17.4776	2.91293	35.28	0.0000
Error	12	0.9909	0.08257		
Total	20	18.6149			

CV = 8.75%

Table 8. Okra potassium uptake

Source	DF	SS	MS	F	P
Replication	2	12.301	6.1505		
Treatments	6	239.012	39.8354	11.56	0.0002
Error	12	41.339	3.4449		
Total	20	292.652			

CV = 12.67%

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