International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 2034-2038

Received: 07-03-2018
Accepted: 09-04-2018

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Effect of organics on physical, chemical and biological properties of soil under fenugreek (*Trigonella foenum-graecum* L.) cultivation

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Abstract
A field experiment was conducted at the certified organic farm, Navsari Agricultural University, Navsari during *rabi* season of 2016-2017 to study the "Effect of organics on soil properties, growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.) grown under organic farming system". The treatment comprising three treatment of solid organics (S_0: Control, S_1: NADEP compost @ 5 t ha^{-1} and S_2: Vermicompost @ 2.5 t ha^{-1}) and four treatment of liquid organics (L_0: Control, L_1: *Panchagavya* @ 20 L ha^{-1}, L_2: *Jeevamruta* @ 200 L ha^{-1} and L_3: Enriched banana pseudostem sap @ 5 L ha^{-1}) were evaluated in Factorial Randomized Block Design with three replication on fenugreek variety "*GM-2*". The application of NADEP compost @ 5 t ha^{-1} recorded significantly higher soil organic carbon, available N, P_2O_5, K_2O, DTPA-extractable Fe, Mn and Zn content, higher total fungi, total bacteria, *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) and PSB (*Bacillus megaterium*) in soil and found statistically at par with treatment receiving vermicompost @ 2.5 t ha^{-1} except available N. However, significantly higher KMB (*Frateuria aurantia*) and free living N-Fixing Bacteria (Azotobacter croococum) with the application of vermicompost @ 2.5 t ha^{-1}. In liquid organics, the application of enriched banana pseudostem sap @ 5 L ha^{-1} recorded significantly higher organic carbon, available N, P_2O_5, K_2O and DTPA-extractable Fe and Mn content, higher total fungi, total bacteria, *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) and free living N-Fixing Bacteria (Azotobacter croococum) in soil after harvest of fenugreek and stood at par with treatment L_1 and L_2 in case of available P_2O_5 and K_2O and treatment L_1 in case of Mn content in soil. However, significantly higher KMB (*Frateuria aurantia*) and PSB (*Bacillus megaterium*) with the application of *Jeevamruta* @ 200 L ha^{-1}. The combined application of NADEP compost @ 5 t ha^{-1} and enriched banana pseudostem sap @ 5 L ha^{-1} (S_1L_3**)** gave significantly higher total fungi and *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) but total bacteria was higher with treatment combination S_1L_1, S_1L_2, S_1L_3 and S_2L_3, and PSB (*Bacillus megaterium*) higher with treatment combination S_1L_2 and S_1L_3. Similarly, combined application of all liquid organics with NADEP @ 5 t ha^{-1} or vermicompost @ 2.5 t ha^{-1} gave significantly higher KMB (*Frateuria aurantia*) and free living N-Fixing Bacteria (Azotobacter croococum).

Keywords: solid organics, liquid organics, physical properties, chemical property, biological property

Introduction
Fenugreek (*Trigonella foenum-graecum* L.), locally known as Methi, is a multipurpose crop grown in Northern Indian states like Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Haryana, Punjab, Uttar Pradesh and Andhra Pradesh, during winter season. Every part of this plant is utilized as leafy vegetable, fodder and condiments (Khiriya and Singh, 2006) [22]. Its seeds are a good source of protein, vitamins, alkaloid trigonellin and essential oil and have an immense medicinal value particularly against digestive disorders (Bhunia *et al.*, 2003) [2]. Seeds are used for the treatment of diabetes, dysentery, diarrhea and rickets. Diosgenin, which is extracted from the seeds is used in synthesis of sex hormones. Its roots are endowed with mini factory to synthesize nitrogen for plant. Thus, its cultivation enriches the soil in prilimary nutrient. Different organic sources also play an important strategy in order to improve the biological, chemical and physical conditions of the soil. Compost is rich source of plant nutrients and maintains a healthy soil environment for plant growth and development. Compost addition in soil not only increase crop yield, but also improve soil fertility in term of organic carbon, nitrogen content, permeability, plant available water capacity, soil aggregates and air filled porosity (Chatterjee and Bandyopadhyay, 2014) [4]. In this context use of solid and liquid organics gaining importance as the millions of microorganisms present are multiplied to billions during fermentation. The use of fermented organics may improve

nutrients status and biological activity. Chemical fertilizers play an important role to meet nutrient requirement of the crop but continuous use of these on lands will have deleterious effects on physical chemical and biological properties of soil, which in turn reflects on yield (Sarkar *et al*., 1997) [20]. Therefore, there is an urgent need to reduce the usage of chemical fertilizers and in turn increase the usage of organic manures which are known to improve soil properties of soil and supply the nutrients in available form to the plants. However, single organic source of nutrient supplementation may not cope up with the nutrient demand of crops. Combination of different solid and liquid organic sources or growth promoter help to solve dual problem of supplementation of sufficient nutrients besides synchronized nutrient availability as per crop demand associated with variable nutrient release pattern among different organic manures. In view of this background the present investigation to find out effect of solid and liquid organics on soil physical, chemical and biological properties under cultivation of fenugreek.

Materials and Methods

A field experiment on "Effect of organics on soil properties, growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.) grown under organic farming system" was carried out at Organic Farm (F block), Navsari Agricultural University, Navsari during *rabi* season of 2016-17. The soil had pH 7.78 and electrical conductivity 0.44 dSm-1. The soil was low in organic carbon (0.79) and available nitrogen (258.12 kg ha^{-1}), low in available P_2O_5 (45.58 kg ha^{-1}) and high in respect to available K_2O (273.52 kg ha^{-1}). The experiment was laid out in factorial randomized block design with three replications. There were twelve treatment combinations consisting of three levels of solid organics (S_0: Control, S_1: NADEP compost @ 5 t ha^{-1} and S_2: Vermicompost @ 2.5 t ha^{-1}) and four levels of liquid organics (L_0: Control, L_1: *Panchagavya* @ 20 L ha^{-1}, L_2: *Jeevamrut*a @ 200 L ha^{-1}, L_3: Banana pseudostem sap @ 5 L ha^{-1}). The solid organics were applied one day before sowing and liquid organics were incorporated in soil by drenching in the basal as per treatments. It was sown manually at 30 cm row to row spacing keeping seed rate of 20 kg ha^{-1}. The fenugreek variety Gujarat Methi-2 was sown in december during 2016-17. Standard agronomic practices were adopted for raising healthy crop. Data of growth and yield attributes were taken from 5 tagged plants. Biological and economic yields were taken from net plot

Chemical property

Effect of solid organics

The data revealed that solid organics were failed to exert any significant effect on soil pH and EC after harvest of fenugreek. The values of soil pH and EC varied from 7.53 to 7.74, 0.47 to 0.49 dS m^{-1}, respectively. A non significant of solid organics on soil reaction ($pH_{2.5}$) might be due to high buffering capacity of black soil. Similar finding of soil pH and electrical conductivity were reported by Ram lakshmi *et al.* (2011) [16, 17], Tharmaraj *et al.* (2011) [23] and Das and Singh (2014).

In case of soil organic carbon, significant effect of solid organics was obtained. Significantly higher organic carbon content (1.01%) was noted under treatment receiving NADEP compost @ 5 t ha^{-1} (S_1) and was statistically at par with treatment receiving vermicompost @ 2.5 t ha^{-1} (0.98%). However, lowest value of soil organic carbon (0.85%) was recorded with the treatment S_0 (Control). Singh and Kushwah (2006) [22] observed an increase in organic carbon content of soil due to continuous addition of FYM. These observations are in agreement with the findings of Rama Lakshmi *et al.* (2011) [16, 17], Laharia *et al.* (2012) [15] and Hasan and Ram (2015) [8].

Application of different solid organics didn't show significant effect on available Cu content in soil after harvest of fenugreek. Significantly higher available N (275.26 kg ha^{-1}), P (52.16 kg ha^{-1}), K_2O (295.68 kg ha^{-1}), DTPA-Fe (14.99 mg kg^{-1}), Mn (18.03 mg kg^{-1}) and Zn (0.70 mg kg^{-1}) were determined with the treatment S_1 and stood at par with treatment S_2. However, treatment S_0 (Control) registered significantly lowest content of available macro and minor nutrient in soil after harvest of fenugreek. Increase in available micronutrients status of soil in organically treated plot might be due to release of chelating agent from organic matter decomposition which might have prevented micronutrients from precipitation, oxidation and leaching. Laharia *et al.* (2013) [13] indicated that the organic manures and crop residues are organic in nature and during their decomposition in soil, release organic acid and help to improve chemical properties. Similar beneficial effect of organic manures on the available N, P_2O_5, K_2O and micro nutrient content of soil was reported earlier by Jat *et al.* (2012) [10], Ghosh *et al.* (2013) [6], Das and Singh (2014) [21], Hasan and Ram (2015) [15].

Effect of liquid organics

No significant impacts of liquid organics were found on pH and EC of the experimental soil after harvest of the fenugreek. The values of soil pH and EC varied from 7.56 to 7.72, 0.47 to 0.49 dS m^{-1}, respectively. In organic carbon content, Significantly higher organic carbon content (1.02%) was noted with treatment receiving enriched banana pseudostem sap @ 5 L ha^{-1} (L_3). However, significantly the lowest organic carbon content (0.89%) was noted with control (L_0). Similar results for soil chemical properties were reported by Salunkhe *et al*. (2013) [19], Jondhale *et al*. (2014) [11] and Boraiah *et al*. (2015) [3] with soil application of liquid organics.

Data indicated that available N, P_2O_5 and K_2O content in fenugreek harvested soil were influenced significantly with the application of liquid organics but not on available DTPA-Zn and Cu content of soil. However, higher available Zn (0.70 mg kg^{-1}) and Cu (4.43 mg kg^{-1}) was found in the treatment of L_3.The available N (278.00 kg ha^{-1}), P_2O_5 (52.67 kg ha^{-1}), K_2O (293.80 kg ha^{-1}), DTPA-Fe (18.87 mg kg^{-1}) and Mn (18.10 mg kg^{-1}) were found significantly higher in the treatment L_3 and it was found statistically at par with the treatment L_1 and L_2 in case of available P_2O_5 available K_2O and treatment L_1 in case of Mn. However, significantly the lowest available macro and micronutrient were noted with the treatment L_0 (Control). Solubilizing effect of liquid organics on fixed native forms of nutrients in soil and inclusion of liquid organics increased adsorptive power of soil for cations and anions and retard fixation. Similar finding were also reported by Salunkhe *et al.* (2013) [19], Jadhav *et al.* (2014) [9], Boraiah *et al*. (2015) [3] and Rao *et al.* (2015) [18].

Biological property

Effect of solid organics

The data revealed that application of solid organics significantly affected microbial population of soil after harvest of fenugreek. Among solid organics, application of NADEP compost @ 5 t ha^{-1} recorded significantly higher total

fungi (236.3 x10^6 cfu g^{-1}), total bacteria (299.42 x10^6 cfu g^{-1}), *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) 250.2 x 10^6 cfu g^{-1} and PSB (*Bacillus megaterium*) 257 x 10^6 cfu g^{-1}. Moreover, significantly higher KMB (*Frateuria aurantia*) 300.0 x 10^6 cfu g^{-1} and free living N-Fixing Bacteria (Azotobacter croococum) 291.6 x 10^6 cfu g^{-1} with vermicompost @ 2.5 t ha^{-1} and significantly lowest microbial population was recorded under control (S_0). Organic carbon is an important source for growth and development due to their heterotrophic nature. The solid organics contain higher amounts of organic nutrients, growth promoting substances, vitamins and enzymes and therefore, they increase the population of bacteria, fungi and actinomycete in rhizosphere region. The present results are therefore, in conformity with these earlier reports. Patil *et al.* (2012) [15], Gudadhe *et al*. (2015) [7] and Hasan and Ram (2015) [8].

Effect of liquid organics

The data revealed that application of solid organics significantly affect the microbial population in soil after harvest of fenugreek. Among liquid organics, application of enriched banana pseudostem sap @ 5 L ha^{-1} recorded significantly higher higher total fungi (260.2 x10^6 cfu g^{-1}), total bacteria (281.6 x10^6 cfu g^{-1}), *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) 255.3 x 10^6 cfu g^{-1} and free living N-Fixing Bacteria (Azotobacter croococum) 291.7 x 10^6 cfu g^{-1}. Moreover, significantly higher KMB (*Frateuria aurantia*) 284.1 x 10^6 cfu g^{-1} and PSB (*Bacillus megaterium*) 258.2 x 10^6 cfu g^{-1} with *Jeevamruta* @ 200 L ha^{-1}. However, significantly lowest microbial population was recorded with the control (L_0) treatment. Most of the bacteria, fungi and actinomycetes in soil are heterotrophic i.e. requiring organic carbon source for their growth. The liquid organics contain higher amount of organic nutrients, growth promoting substances, vitamins and enzymes and therefore, they increase the population of bacteria, fungi and actinomycete in rhizosphere region. The present results are therefore, in conformity with these earlier reports. Aulakh *et al.* (2013) [1], Jadhav *et al.* (2014) [9] and Shailaja *et al*. (2014) [21]

Physical property

Effect of solid organics

No major significant changes were observed for particle density, bulk density and porosity under the influence of solid organics. Although, the lowest particle density (2.60 Mg m^{-3}), bulk density (1.39 Mg m^{-3}) and higher porosity (46.44 %) were determined with the treatments S_1. Addition of organic manures improves the soil physical properties is a well-documented and scientifically proven fact but here such non-significant effect was quite acceptable as physical properties of soil remain unchanged in short course of time, hence non-significant result was anticipated. Similar results were reported by Martinez *et al*. (2013) [14], Vanlauwe *et al*. (2015) [24] and Gudadhe *et al*. (2015) [7].

Effect of liquid organics

Not significant effect of liquid organics was observed on physical properties of soil (particle density, bulk density and porosity). However, the lowest particle density (2.59 Mg m^{-3}), bulk density (1.39 Mg m^{-3}) and higher porosity (46.52 %) were determined with the treatments L_3 after harvest of fenugreek. Addition of organics improves the soil physical properties is a well-documented and scientifically proven fact but here such non-significant effect was quite acceptable as physical properties of soil remain unchanged in short course of time, hence non-significant result was anticipated. Similar results were reported by Boraiah *et al*. (2015) [3] and Gudadhe *et al*. (2015) [7]. Interaction of solid and liquid organics exert significant effect on total fungi and bacteria (Table 5). The combined application of NADEP compost @ 5 t ha^{-1} and enriched banana pseudo stem sap @ 5 L ha^{-1} (S_1L_3**)** gave significantly higher total fungi 300 x 10^6 cfu g^{-1}. In case of total bacteria, the combine application of S_1L_1, S_1L_2, S_1L_3 and S_2L_3 gave significantly higher total bacteria (300 x 10^6 cfu g^{-1}). However, significantly the lower total fungi (154.6 x 10^6 cfu g^{-1}**)** and total bacteria (183.33 x 10^6 cfu g^{-1}**)** were noted under treatment S_0L_0**.**

Interaction of solid and liquid organics exerts significant effect on KMB (*Frateuria aurantia*) and *Endophyte having PGPR activities* (*Pseudomonas fluorescens*) given in Table 5. The combined application of all liquid organics with NADEP compost @ 5 t ha^{-1} and vermicompost @ 2.5 t ha^{-1} gave significantly higher KMB (300 x 10^6 cfu g^{-1}). In case of *Pseudomonas fluorescens*, the combine application of S_1L_3 gave significantly higher *Pseudomonas fluorescens* (300 x 10^6 cfu g^{-1}). The significantly lower KMB (207.67 x 10^6 cfu g^{-1}) and *Pseudomonas fluorescens* (126.33 x 10^6 cfu g^{-1}) were noted under treatment S_0L_0.

Interaction of solid and liquid organics exerts significant effect on free living *N-Fixing Bacteria* (*Azotobacter croococum*) and PSB (*Bacillus megaterium*) (Table 5). The combined application of all liquid organics with NADEP compost @ 5 t ha^{-1} and vermicompost @ 2.5 t ha^{-1} gave significantly higher effect free living *N-Fixing Bacteria* 300 x 10^6 cfu g^{-1}. In case of PSB (*Bacillus megaterium*), the combine application of S_1L_2 and S_1L_3 gave significantly higher *PSB* (300 x 10^6 cfu g^{-1}). The significantly lower free living *N-Fixing Bacteria* (256.00 x 10^6 cfu g^{-1}) and PSB (125.0 x 10^6 cfu g^{-1}) were noted under treatment S_0L_0. The combined application of liquid organics in soil enhanced the microbial population in soil due to promoting effect of liquid and solid source of organics on availability of food in the soil for microbes. The presence of growth regulator, minerals and vitamins in organics promote the microbial growth in soil. Similar effect of liquid and solid organics are also reported by Rajanna *et al.* (2011) [16], Patil *et al.* (2012) [15] and Laharia *et al.* (2013) [13].

Conclusions

Based on the results of the experimentation, application of NADAP compost @ 5 t ha^{-1} or vermicompost @ 2.5 t ha^{-1} along with soil application of enriched banana pseudostem sap @ 5 L ha^{-1} improved soil properties by fenugreek as well as farmers economy grown under organic farming system in South Gujarat conditions

Table 1: Chemical compositions of solid organics

Manure	TOC	N	P	K	S	Fe	Mn	Zn	Cu
	(%)					(mg kg^{-1})			
NADEP compost	19.06	1.12	0.78	1.36	0.67	1188	96	42	25
Vermi- compost	20.1	1.09	0.65	1.4	0.55	1550	97	35	12

Table 2: Chemical compositions of liquid organics

Liquid organic	N	P	K	Fe	Mn	Zn	Cu
(mg L^{-1})							
Panchagavya	1000	175	194	29	0.87	0.68	0.05
Jeevamruta	770	166	53	79	4.00	2.60	1.30
Enriched banana pseudo stem sap	8570	175	1150	44	14.5	4.61	0.8

Table 3: Effect of solid and liquid organics on physical and chemical property of soil after harvest of fenugreek

Treatment	PD (Mg m^{-3})	BD (Mg m^{-3})	Porosity (%)	pH 1:2.5	EC 1:2.5 dS m^{-1}	Organic Carbon (%)	Available nutrients (kg ha^{-1})			DTPA- extractable micronutrients (mg kg^{-1})			
							N	P_2O_5	K_2O	Fe	Mn	Zn	Cu
Solid organics (S)													
S_0	2.61	1.40	46.03	7.74	0.49	0.85	259.79	48.77	278.90	13.70	16.89	0.64	4.09
S_1	2.60	1.39	46.44	7.53	0.47	1.01	275.26	52.16	295.68	14.99	18.03	0.70	4.35
S_2	2.60	1.40	46.38	7.57	0.47	0.98	271.26	51.97	292.97	14.81	17.78	0.68	4.26
S.Em. (±)	0.01	0.01	0.289	0.10	0.01	0.01	2.19	0.69	2.11	0.16	0.17	0.01	0.07
CD at 5%	NS	NS	NS	NS	NS	0.03	6.43	2.03	6.19	0.46	0.50	0.04	NS
Liquid organics (L)													
L_0	2.60	1.41	46.08	7.71	0.49	0.89	262.63	49.32	283.73	14.11	17.12	0.65	4.12
L_1	2.60	1.40	46.31	7.56	0.48	0.96	269.52	50.43	291.40	14.59	17.65	0.68	4.23
L_2	2.60	1.39	46.23	7.72	0.48	0.92	264.70	51.45	287.80	14.39	17.39	0.66	4.15
L_3	2.59	1.39	46.52	7.47	0.47	1.02	278.00	52.67	293.80	18.87	18.10	0.70	4.43
S.Em. (±)	0.01	0.01	0.334	0.12	0.01	0.01	2.53	0.80	2.44	0.18	0.20	0.01	0.08
CD at 5%	NS	NS	NS	NS	NS	0.04	7.42	2.35	7.15	0.53	0.58	NS	NS
Interaction (SXL)													
S.Em. (±)	0.01	0.01	0.578	0.20	0.01	0.02	4.38	1.39	4.22	0.31	0.34	0.03	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV %	1.46	1.46	2.16	4.62	5.29	4.25	2.83	4.71	2.53	3.72	3.39	6.57	6.00
Initial value	2.61	1.42	46.03	7.78	0.44	0.79	258.12	45.58	273.52	13.86	16.92	0.62	4.09

Table 4: Effect of solid and liquid organics on biological properties of soil after harvest of fenugree006B

Treatment	Microbial population (10^6 cfu g^{-1})					
	Total Fungi *(PDA)*	Total Bacteria *(NA)*	*Potash Mobalizing Bacteria (KMB)* *Frateuria aurantia (GYC)*	*Endophyte having PGPR activities* *Pseudomonas fluorescens (KING)*	*Free living N-Fixing Bacteria* *Azotobacter croococum (AMA)*	*Phosphate Solublizing Bacteria (PSB)* *Bacillus megaterium (PIKO-VSKAYA'S)*
Solid organics (S)						
S_0	200.2	231.1	238.7	202.6	266.6	197.8
S_1	236.3	299.4	275.8	250.2	278.7	257.0
S_2	198.6	273.9	300.0	225.3	291.6	237.9
S.Em. (±)	2.8	2.08	3.64	2.67	3.96	3.10
CD at 5%	8.3	6.09	10.68	7.83	11.60	9.09
Liquid organics (S)						
L_0	170.6	248.00	241.8	180.0	245.8	171.2
L_1	187.8	264.7	279.9	240.1	291.1	238.8
L_2	228.2	278.2	284.1	228.7	287.3	258.2
L_3	260.2	281.6	280.3	255.3	291.7	255.4
S. Em. (±)	3.3	2.40	4.20	3.08	4.57	3.58
CD at 5%	9.6	7.03	12.33	9.04	13.39	10.50
Interaction (S X L)						
S.Em. (±)	5.7	4.15	7.28	5.34	7.91	6.20
CD at 5%	16.6	12.18	21.36	15.66	23.90	18.19
CV %	4.64	2.68	4.65	4.09	4.91	4.65
Microbial count before sowing						
Intial	200.1	230.4	237.7	201.9	265.8	196.5

(Microbial population count may or may not be more then 300).

Table 5: Interaction effect of solid and liquid organics on microbial count of soil after harvest of fenugreek (10^6 cfu g^{-1}).

Solid organics	Total fungi			Total fungi			*Frateuria aurantia*			*Pseudomonas fluorescens*			*Azotobacter croococum*			*Bacillus megaterium*		
Liquid organics	S_0	S_0	S_0	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2	S_0	S_1	S_2
L_0	154.7	186.7	170.3	183.3	165.2	155.6	207.7	217.7	266.7	126.3	201.7	212.0	256.0	215.0	266.3	125.0	184.0	204.7
L_1	176.67	199.3	187.3	210.7	300.0	283.4	239.6	300.0	300.0	218.0	246.7	255.7	273.3	300.0	300.0	230.0	244.0	242.3
L_2	223.0	259.3	202.3	285.7	300.0	249.0	285.7	300.0	300.0	250.7	252.7	182.7	262.0	300.0	300.0	208.0	300.0	266.7
L_3	246.3	300.0	234.3	244.9	300.0	300.0	241.0	300.0	300.0	215.3	300.0	250.7	275.0	300.0	300.0	228.3	300.0	238.0
S.Em. (±)	5.7			4.15			7.28			5.34			7.91			6.20		
CD at 5%	16.6			12.18			21.36			15.66			23.20			18.19		
CV %	4.64			2.68			4.65			4.09			4.91			4.65		

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