Agropedology 2020, 30 (01), 55-62
doi.org/10.47114/j.agroped.2020.jun8

Effect of FYM and Fermented Liquid Manures on Some Physico-Chemical and Biological Properties of Soil and Nutrients Status at Harvest of Chilli (*Capsicum annuum* L.)

M. Chandrakala[1*] and N. S. Hebsur[2]

[1]*National Bureau of Soil Survey and Land Use planning, Hebbal Bangalore-560024, Karnataka, India*
[2]*Department of Soil Science and Agricultural Chemistry, UAS, Dharwad, Karnataka, India*

Abstract: A field experiment was carried out on Vertisols to evaluate the effect of FYM and fermented liquid manures on nutrient status and biologic activity of soil at harvest of chilli at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka during *kharif* 2007-08. Treatments consisted of three different levels of manures *viz.* M_1 – FYM equivalent to RDN; M_2 – Recommended dose of fertilizer (100:50:50 kg N, P_2O_5, K_2O ha^{-1}); M_3 – FYM equivalent to RDN + RDFYM @ 25 t ha^{-1} and liquid manures as L_1 – Beejamrut + Jeevamrut; L_2 – Panchagavya; L_3 – Beejamrut + Jeevamrut + Panchagavya; L_4 – Control (no liquid manures). Results revealed that bulk density, pH and EC did not differed significantly. The application of FYM equivalent to RDN + RDFYM recorded significantly higher organic carbon (7.6 g kg^{-1}) and available NPK (381.17, 12.76, 319.14 kg ha^{-1} NPK, respectively) and micronutrients *viz.* Zn, Fe, Cu and Mn (0.56, 3.40, 0.68 and 31.5 mg kg^{-1}, respectively) followed by application of FYM equivalent RDN over RDF. Irrespective of liquid manures, FYM equivalent to RDN + RDFYM (M_3) and FYM equivalent to RDN (M_1) recorded significantly higher dehydrogenase activity (27.68 and 22.50 g TPF g $soil^{-1}$-day^{-1} at 160 DAT, respectively) over RDF (M_2). However, application of Beejamrut + Jeevamrut recorded significantly higher available phosphorus (12.31 kg ha^{-1}). The combined application of Beejamrut + Jeevamrut + Panchagavya (L_3) had significantly higher dehydrogenase activity (22.24 g TPF g $soil^{-1}$-day^{-1} at 160 DAT) compared to Panchagavya (L_2) and control (L_4).

Keywords: *Beejamrut, Jeevamrut, Panchagavya, FYM, soil available nutrients, dehydrogenase activity*

Introduction

The current global scenario emphasizes the need to adopt eco-friendly agricultural practices for sustainable agriculture. Inorganic agriculture not only adversely affects the soil health but also negatively influences on beneficial soil microbial community. Indiscriminate use of chemical fertilizers and pesticides led to several harmful effects on soil, water and environment causing their pollution and decline in the productivity of the soil. In order to detoxify the agriculture lands, it's necessary to switch over eco-friendly and cost effective organic agriculture (Sarkar *et al*. 2014). Supply of nutrients through organic manures alone has failed to maintain satisfactory yield level in a short period. The combined application of organics such as FYM, compost, green leaf manure, vermicompost *etc*

*Corresponding author : (Email: chandra.ssac@gmail.com)

and liquid organics *viz.*, Jeevamrut, Beejamrut, Panchagavya, Gomutra, Angara and Vermiwash *etc* which contain substantial microbial count and plant growth promoting substances stimulate growth, yield and quality of crops as well as improves soil health (Somasundaram 2003, Chandrakala *et al.* 2011a and Chandrakala *et al*. 2011b) and also increases soil nutrients uptake (Chandrakala *et al.* 2007). Among different organic manures, application of FYM increased the availability of nitrogen, phosphorus and potassium in soil (Bonde and Rao 2004). Since, chilli is a long duration and exhaustive crop application of organics is essential to maintain nutrient supplying capacity of the soil (Chandrakala *et al*. 2007). The present study was taken with the objective is to study the effect of FYM and fermented liquid manures such as Panchagavya Beejamruth, Jeevamruth on some soil physico-chemical and biological properties and soil available nutrients status at harvest of chilli.

Materials and Methods

The experiment was laid out in Factorial Randomized Block Design with three replications. There were 12 treatments involving three different levels of manures *viz.,* FYM equivalent RDN (M_1), RDF (M_2) and FYM equivalent to RDN + RDFYM (M_3) and four levels of liquid manures as Beejamrut + Jeevamrut (L_1), Panchagavya (L_2), Beejamrut + Jeevmarut + Panchagavya (L_3) and control (L_4) at the Main Agricultural Research Station, College of Agriculture, Dharwad, Karnataka on Vertisols during *kharif* 2007-08. The experimental soil had bulk density 1.31 Mg m^{-3}, pH 7.53, soluble salt content 0.38 dS m^{-1}, organic carbon 5.8 g kg^{-1} with available N, P, K to the tune of 303.0, 22.0, 401.0 kg ha^{-1}, respectively. Available Fe, Mn, Cu and Zn contents in soils were 3.0, 2.3, 0.62, and 0.49 mg kg^{-1}, respectively (Table 1).

Table 1. Physico-chemical properties of experimental soil

Sr. No.	Particulars	Value
1	Physical properties	
i	Particle size distribution (%)	
	Coarse sand	7.2
	Fine sand	12.2
	Silt	28.7
	Clay	51.8
ii	Textural class	Clay
iii	Bulk density (Mg m^{-3})	1.31
2	Chemical properties	
i	pH (1:2.5)	7.53
ii	EC (1:2.5) dS m^{-1}	0.38
iii	Organic carbon (g kg^{-1})	5.8
iv	Available nitrogen (kg ha^{-1})	303
v	Available phosphorus (kg ha^{-1})	22
vi	Available potassium (kg ha^{-1})	401
vii	Available micronutriments (mg kg^{-1})	
	Iron	3.00
	Zinc	0.49
	Copper	0.62
	Manganese	2.30

Five weeks old chilli (Byadgi dabbi) seedlings were transplanted with a spacing of 75 x 75 cm. Calculated amount of FYM was applied 3 weeks prior to transplanting. Recommended dose of N was applied partly urea and DAP while the entire dose of phosphorous and potash were applied through DAP and muriate of potash, respectively. Beejamrut was applied through seedling dip while Jeevamrut @ 250 l $acre^{-1}$ through direct soil application (uniformly pouring to soil) was given twice once at transplanting and another at 30 days after transplanting. Panchagavya @ 3 per cent foliar spray was given twice once at 50 per cent flowering and another at 15 days after first spray. Neem seed kernel extract @ 5 per cent was sprayed to crop at second and fourth week after transplanting to control pest and diseases. Representative soil samples (0-20 cm depth) were drawn from each plot after harvest (140 Days After Transplanting) of chilli for chemical analysis. The soil samples were air-dried at 25 °C until the water content was approximately two-thirds of the field capacity (~ 0.26 g g^{-1} soil). Soil was then sieved through a 2-mm mesh sieve to remove stones and homogenize the sample.

The soil samples were analyzed for particle size analysis by international pipette method (Piper 2002), bulk density by core sampler method (Dastane 1967), pH (1: 2.5) using pH meter (Systronics model 331), electrical conductivity (1: 2.5 soil : water extract) using conductivity bridge (Systronics model 304), organic carbon by Walkley and Black's wet oxidation method, available phosphorus by Olsen's method, available potassium by flame photometer method as outlined by Sparks *et al.* (1996), available nitrogen using alkaline potassium permanganate method by Subbiah and Asija (1956), DTPA extractable Cu, Fe, Mn and Zn by Lindsay and Norvell (1978). Data were analyzed statistically using Duncan's Multiple Range Test (DMRT).

Soil samples were taken from a depth 0–20 cm. 10 g of homogenized freshly collected soil was used to estimate the dehydrogenase activity. The dehydrogenase assay involves calorimetric determination of 2, 3, 5 triphenyl formazone (TPF) produced by the reduction of 2, 3, 5 triphenyl tetrazolium chloride (TTC) by soil microorganisms. The reduced product of TPF was extracted by methanol and its concentration was measured in a spectrophotometer at 530 nm wave length. The enzyme activity was expressed as g of TPF produced per gram of soil incubated at 37°C for 24 hours (Casida *et al.* 1964).

Results and Discussion

The physico-chemical properties of post harvest soil did not differ significantly (Table 2 and 3) by the application of manures and liquid manures. In general, application of manures decreased the bulk density but increased the organic carbon content of soil. Among manures, irrespective of liquid organic manures, the lower bulk density (1.20 Mg m^{-3}) and the higher organic carbon content (7.60 g kg^{-1}) was recorded with FYM equivalent to RDN + RDFYM (M_3) followed by FYM equivalent to RDN (M_1) and RDF (M_2). The highest bulk density (1.33 Mg m^{-3}) and the lowest organic carbon (6.54 g kg^{-1}) were observed with RDF (M_2). The lower bulk density might be due to reduction in soil compaction. Williams *et al.* (2017) opined that organic farming reduces the soil's susceptibility to compaction. Application of liquid manures also lowered the bulk density and increased the organic carbon content. The application of Beejamrut + Jeevamrut + Panchagavya (L_3) had the lowest bulk density (1.23 Mg m^{-3}) and highest organic carbon content (7.44 g kg^{-1}) followed by Beejamrut + Jeevamrut (L_1), Panchagavya (L_2). The highest bulk density (1.28 Mg m^{-3}) and the lowest organic carbon content (7.07 g kg^{-1}) were observed with control (L_4).

Application of manures and liquid manures did not differ significantly (Table 2) with respect to soil reaction and electrical conductivity. Among manures, irrespective of liquid manures, lower pH (7.39) and higher EC (0.42 dS m^{-1}) was recorded with FYM equivalent to RDN+RDFYM (M_3) followed by FYM equivalent to RDN (M_1) and the highest pH (7.47) and lowest EC (0.42 dS m^{-1}) was recorded with RDF (M_2). The combined application of Beejamrut + Jeevamrut + Panchagavya (L_3) and the treatment receiving Beejamrut + Jeevamrut (L_1) recorded the lowest pH (7.40 and 7.40,

Table 2. Influence of manures and liquid manures on bulk density, soil reaction and electrical conductivity of soil at harvest of chilli

Manures / Liquid manures	Bulk density (Mg m^{-3})					pH (1:2.5)					EC (1:2.5) (dS m^{-1})				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
M_1	1.21^{a}	1.24^{a}	1.22^{a}	1.25^{a}	1.23^{a}	7.40^{a}	7.41^{a}	7.40^{a}	7.42^{a}	7.41^{a}	0.38^{a}	0.37^{a}	0.38^{a}	0.38^{a}	0.38^{a}
M_2	1.32^{a}	1.33^{a}	1.30^{a}	1.37^{a}	1.33^{a}	7.42^{a}	7.49^{a}	7.46^{a}	7.52^{a}	7.47^{a}	0.37^{a}	0.37^{a}	0.36^{a}	0.38^{a}	0.37^{a}
M_3	1.19^{a}	1.22^{a}	1.18^{a}	1.22^{a}	1.20^{a}	7.39^{a}	7.41^{a}	7.35^{a}	7.40^{a}	7.39^{a}	0.41^{a}	0.43^{a}	0.42^{a}	0.42^{a}	0.42^{a}
Mean	1.24^{a}	1.26^{a}	1.23^{a}	1.28^{a}	1.25	7.40^{a}	7.44^{a}	7.40^{a}	7.45^{a}	7.42	0.38^{a}	0.39^{a}	0.38^{a}	0.39^{a}	0.38
	[illegible]		LSD value			S. Em.±			LSD value		S. Em.±			LSD value	
Manures (M)	0.06		0.17			0.28			0.83		0.02			0.06	
Liquid manures (L)	0.07		0.21			0.33			0.97		0.02			0.06	
M x L	0.12		0.35			0.56			1.65		0.03			0.08	

Table 3. Influence of manures and liquid manures on soil organic carbon and dehydrogenase activity at harvest of chilli

Manures / Liquid manures	Organic carbon (g kg^{-1})					Dehydrogenase activity (µg TPF (g soil)$^{-1}$ day^{-1} at 160 DAT				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
M_1	7.40^{a}	7.43^{a}	7.80^{a}	7.37^{a}	7.50^{a}	19.34^{cd}	18.50^{cd}	23.18^{ab}	17.45^{de}	19.62^{b}
M_2	6.53^{a}	6.44^{a}	6.87^{a}	6.30^{a}	6.54^{a}	16.83^{def}	14.40^{ef}	17.87^{de}	13.41^{f}	15.63^{c}
M_3	7.58^{a}	7.63^{a}	7.67^{a}	7.53^{a}	7.60^{a}	22.11^{abc}	21.73^{bc}	25.67^{a}	20.50^{bcd}	22.50^{a}
Mean	7.17^{a}	7.17^{a}	7.44^{a}	7.07^{a}	7.21	19.43^{b}	18.21^{bc}	22.24^{a}	17.12^{c}	19.72
	S. Em.±		LSD value			S. Em.±			LSD value	
Manures (M)	1.34		3.95			0.58			1.72	
Liquid manures (L)	1.54		4.54			0.68			1.99	
M x L	2.66		7.85			1.17			3.45	

DAT – Days after transplanting

respectively) and the lowest EC (0.38 dS m^{-1}). However, the highest pH (7.45) and EC (0.37 dS m^{-1}) was recorded with control (L_4).

The treatment FYM equivalent to RDN + RD FYM recorded significantly higher available NPK (381.17, 12.76, 319.14 kg ha^{-1}, respectively) and Zn, Fe, Cu and Mn as 0.56, 3.40, 0.68 and 3.15 mg kg^{-1}, respectively followed by FYM equivalent to RDN (Table 4 and 5). It seems that the available nutrient status of soil is increased considerably due to solubilization of native nutrients in soil due to organic acids produced during decomposition of manures as well as its own nutrient contents (Yadav and Chhipa 2007). The significant increase in available N content of soil with FYM equivalent to RDN + RD FYM was closely followed by M_1 (381.17 and 380.25 kg ha^{-1}, respectively) over M_2 (357.31 kg ha^{-1}). The organic carbon, available N, P and K were improved with the conjunctive use of NPK and panchagavya and biofertilizers in ashwagandha grown soils (Vajantha *et al*. 2011).

The increase in available P content of soil with M_3 (12.76 kg ha^{-1}) followed by M_1 (12.11 kg ha^{-1}) appears to be due to greater decomposition of native soil P by organic acids released during the decomposition of FYM by root proliferation and organic manure mediated complexation of cations responsible for fixation of P in soil (Sushma *et al*. 2007). The increase in available K content in soil with M_3 (319.14 kg ha^{-1}) followed by M_1 (313.07 kg ha^{-1}) and M_2 (298.23 kg ha^{-1}) might be due to decomposing products of FYM which contained various organic acids that released non-exchangeable K to the available forms (Chitra and Janaki 1999).

The increased availability of Zn with M_3 (0.56 mg kg^{-1}) was followed by M_1 (0.52 mg kg^{-1}) and M_2 (0.43 mg kg^{-1}). Zinc forms relatively stable chelates with organic ligands which decreased the susceptibility of zinc to adsorption, fixation/ precipitation. The increase in available Fe with M_3 (3.40 mg kg^{-1}) followed by M_1 (3.24 mg kg^{-1}) and M_2 (2.89 mg kg^{-1}) might be due to enhanced microbial activity and chemical reduction of Fe^{+++} to Fe^{++} leading to formation of stable complexes that decreased the susceptibility of Fe to adsorption/ fixation or precipitation. The increase in available Cu and Mn in soil with the application of FYM might be due to mineralization and release of native Cu and Mn from soil. Sushma *et al.* (2007) also observed higher available micronutrient contents with the application of FYM along with RDF over RDF alone.

The treatments L_3 (Beejamrut + Jeevamrut) and L_2 (Panchagavya) had significantly lower available phosphorus in soil compared to control which might be due uptake by plants. The treatment of M_3L_4 recorded significantly higher available P in soil (14.12 kg ha^{-1}) owing to production of organic acids from decomposed of FYM leading to solubilization of P bearing minerals. The treatment M_3 with liquid manures recorded significantly higher available Fe, Cu and Mn followed by M_2 (RDF) with liquid manures, which could be due to release of micronutrients present in FYM *via* mineralization by microbes load present in liquid manures. Hangarge *et al.* (2002) reported that the application of RDF or organic sources alone was not beneficial but the combined effects of different sources of nutrients proved to be better. The liquid organic manures in the form of Panchagavya and Kunapajala have improved the physical, chemical and biological properties of soil. Jat *et al.* (2018) reported increased soil organic carbon and soil nutrients status with the application of organic manures *viz.*, FYM, vermicompost and Panchagavya.

The dehydrogenase activity was significantly influenced by the application of manures and liquid manures (Table 3) at 160 DAT. Among the manures, irrespective of liquid manures, FYM equivalent to RDN + RDFYM (M_3) and FYM equivalent to RDN (M_1) recorded significantly higher dehydrogenase activity to the magnitude of 27.68 and 22.50 g TPF g $soil^{-1}$-day^{-1} at 160 DAT, respectively over RDF (M_2). This could be attributed to favorable effects of manures in proliferating microbial population by providing carbon as source of energy for microflora and also protection to the enzyme fraction upon increase in the soil humus content (Martens *et al.* 1992). The lowest dehydrogenase activity of 15.63 g TPF g $soil^{-1}$-day^{-1} at 160 DAT was recorded with RDF (M_2). Rajeshwari (2005) reported significantly higher

Table 4. Influence of manures and liquid manures on available macronutrients status of soil at harvest of chilli

Manures / Liquid manures	Available N (kg ha^{-1})					Available P (kg ha^{-1})					Available K (kg ha^{-1})				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
M_1	387.25^{a}	373.65^{a}	368.49^{a}	391.61^{a}	380.25^{a}	12.51^{abcd}	11.76^{abcd}	10.78^{cd}	13.39^{ab}	12.11^{ab}	314.70^{a}	311.06^{a}	310.51^{a}	316.02^{a}	313.07^{ab}
M_2	359.42^{a}	352.30^{a}	350.87^{a}	366.62^{a}	357.31^{b}	11.37^{bcd}	11.10^{bcd}	10.42^{d}	11.94^{abcd}	11.21^{b}	301.02^{a}	294.63^{a}	293.25^{a}	304.03^{a}	298.23^{b}
M_3	393.76^{a}	378.78^{a}	356.63^{a}	395.52^{a}	381.17^{a}	13.06^{abc}	12.23^{abcd}	11.62^{bcd}	14.12^{a}	12.76^{a}	319.73^{a}	315.33^{a}	315.65^{a}	325.86^{a}	319.14^{a}
Mean	380.14^{a}	368.24^{a}	358.67^{a}	384.58^{a}	372.91	12.31^{ab}	11.70^{a}	10.94^{c}	13.51^{a}	12.03	311.82^{a}	307.01^{a}	306.46^{a}	315.30^{a}	310.15
	S. Em.±		LSD value			S. Em.±		LSD value			S. Em.±		LSD value		
Manures (M)	7.09		20.81			0.37		1.09			5.55		16.30		
Liquid manures (L)	8.19		24.16			0.42		1.25			6.42		18.94		
M x L	14.18		41.83			0.74		2.18			11.11		32.77		

Table 5. Influence of manures and liquid manures on available micronutrients status of soil at harvest of chilli

Manures / Liquid manures	Zn (mg kg^{-1})					Fe (mg kg^{-1})					Cu (mg kg^{-1})					Mn (mg kg^{-1})				
	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean	L_1	L_2	L_3	L_4	Mean
M_1	0.52^{a}	0.52^{a}	0.53^{a}	0.51^{a}	0.52^{b}	3.25^{abc}	3.20^{abcd}	3.27^{ab}	3.20^{abcd}	3.23^{b}	0.65^{a}	0.66^{a}	0.67^{a}	0.64^{a}	0.65^{b}	2.97^{a}	3.00^{a}	3.03^{a}	2.93^{a}	2.98^{b}
M_2	0.43^{a}	0.42^{a}	0.44^{a}	0.43^{a}	0.43^{c}	2.88^{cd}	2.90^{bcd}	2.93^{bcd}	2.85^{bcd}	2.89^{c}	0.48^{b}	0.48^{b}	0.49^{b}	0.47^{b}	0.48^{c}	2.55^{b}	2.57^{b}	2.60^{b}	2.52^{b}	2.56^{c}
M_3	0.55^{a}	0.55^{a}	0.57^{a}	0.55^{a}	0.56^{a}	3.40^{a}	3.42^{a}	3.43^{a}	3.37^{a}	3.40^{a}	0.68^{a}	0.68^{a}	0.69^{a}	0.67^{a}	0.68^{a}	3.13^{a}	3.17^{a}	3.20^{a}	3.10^{a}	3.15^{a}
Mean	0.50^{a}	0.50^{a}	0.51^{a}	0.49^{a}	0.50	3.18^{a}	3.17^{a}	3.21^{a}	3.14^{a}	3.18	0.60^{a}	0.61^{a}	0.62^{a}	0.59^{a}	0.60	2.88^{a}	2.91^{a}	2.94^{a}	2.85^{a}	2.90
	S. Em.±		LSD value			S. Em.±		LSD value			S. Em.±		LSD value			S. Em.±		LSD value		
Manures (M)	0.01		0.03			0.05		0.16			0.009		0.02			0.05		0.16		
Liquid manures (L)	0.01		0.03			0.06		0.17			0.01		0.03			0.06		0.17		
M x L	0.2		0.05			0.11		0.33			0.01		0.03			0.11		0.33		

dehydrogenase activity (16.40 g TPF g soil^{-1}-day^{-1}) with the application of RDN through FYM over RDN through fertilizer (12.18 g TPF g soil^{-1}-day^{-1}).

Among liquid manures, the treatment receiving Beejamrut + Jeevamrut + Panchagavya (L_3) realized significantly higher dehydrogenase activity (22.24 g TPF g soil^{-1} day^{-1} at 160 DAT) compared to Panchagavya (L_2) and control (L_4). However, the control (L_4) recorded significantly lower dehydrogenase activity (17.12 g TPF g soil^{-1} day^{-1} at 160 DAT). Similar to Panchagavya, Jeevamrut also contains enormous amount of microbial load which multiplies in the soil and acts as a tonic to enhance microbial activity in soil (Palekar 2006). Interaction effect of manures and liquid manures did not show significant difference. Upadhyay *et al*. (2019) reported that application of Panchagavya as seedling root dip + one spray at 30 DAT @ 6%+ application through irrigation water at 60 DAT had highest activity of dehydrogenase at 30, 60 DAT and harvesting stage in rice-lentil system.

Conclusion

Application of FYM equivalent to RDN + RDFYM and FYM equivalent to RDN alongwith liquid manures decreased the bulk density but increased the organic carbon content, dehydrogenate activity, available micro and macro nutrients status of soil at harvest of chilli. Interaction effect was non-significant. It is concluded that, application of organic manure and liquid organic manures improved the physico-chemical, fertility and biological properties of the soil.

References

Bonde, D. and Rao, R.K. (2004). B-glycosidase and alkaline phosphatase activity as affected by organic and modern method of cotton cultivation of the rainfed Vertisols. *Indian Journal of Agriculture Sciences* **74,** 276-278.

Casida, L.E., Klein, D.A. and Santoro, T. (1964). Soil dehydrogenase activity. *Soil Science* **98**, 371-376.

Chandrakala, M., Hebsur, N.S. and Nalina, C.N. (2011b). Effect of FYM and fermented liquid manures on yield and economics of chilli (*Capsicum annum* L.). *Research Journal of Agricultural Sciences* **2**, 722-724.

Chandrakala, M., Hebsur, N.S. and Mahendra Kumar, M.B. (2011a). Effect of FYM and fermented liquid manures on quality of chilli (*Capsicum annuum* L.). *Research Journal of Agricultural Sciences* **2,** 761-763.

Chandrakala, M., Hebsur, N.S., Bidari, B.I. and Radder, B.M. (2007). Effect of FYM and fermented liquid manures on nutrients uptake by chilli (*Capsicum annuum* L.) and soil nutrient status at harvest. *Journal of Asian Horticulture* **4,** 19-24.

Chitra, L. and Janaki, P. (1999). Impact of various organic sources on K uptake and yield of rice in Thambirabarani river tract of Tamil Nadu. *The Madras Agriculture Journal* **86**, 46-48.

Dastane, N.G. (1967). A practical manual for water use research, Navbharat Prakashan Publications, Poona. pp.2-3.

Hangarge, D.S., Raut, R.S., Malewar, G.V., More, S.D. and Keshbhat, S.S. (2002). Yield attributes and nutrients uptake by chilli due to organics and inorganics on Vertisols. *Journal of Maharashtra Agricultural Universities* **27,** 109-110.

Jat, N.K., Yadav, R.S. and Kumar, S. (2018). Agronomic evaluation of biodynamic preparations and *Panchagavya* for organic cultivation in North Western Indo-Gangetic Plains, India. *Annals of Plant and Soil Research* **20**, 384-390.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. *Journal of American Society of Soil Science* **42**, 421-428.

Martens, D.A., Johanson, J.B. and Frankenberger, W.T. (1992). Production and persistence of soil enzymes with repeated addition of organic residues. *Soil Science* **153**, 53-61.

Palekar, S. (2006). Text book on Shoonya Bandovalada naisargika Krushi, published by Swamy Anand, Agri Prakashana, Bangalore.

Piper, C.S. (2002). Soil and Plant Analysis, Surabhi Publication, New Delhi.

Rajeshwari, R.S. (2005). Integrated nitrogen management on growth and yield of maize (*Zea mays* L.). M.Sc. (Agri.) Thesis submitted to University of Agricultural Sciences, Dharwad. (unpublished)

Sarkar, S., Kundu and S.S., Ghorai, D. (2014). Validation of ancient liquid organics- Panchagavya and Kunapajala as plant growth promoters. *Indian Journal of Traditional Knowledge* **13,** 398-403.

Somasundaram, E. (2003). Evaluation of organic sources of nutrients and panchagavya spray on the growth and productivity of maize – sunflower – greengram system. Ph.D. Thesis submitted to Tamil Nadu Agricultural University Coimbatore. (published)

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M. (1996). Methods of soil analysis. Part 3. Chemical Methods American Society of Agronomy. Soil Science Society of America Madison, Wisconsin, USA.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soil. *Current Science* **25**, 259-260.

Sushma, A.R., Basavaraja, P.K., Badrinath, M.S. and Sridhara, S. (2007). Residual effect of integrated nutrient management with coir pith compost and other organics on subsequent ragi crop yield and chemical properties of Vertisols. *Journal of Indian Society of Soil Science* **55,** 500-504.

Upadhyay, P. K., Sen, A., Rathore, S.S., Kumar, B., Singh, R.K., Prasad, S.K., Sankar, A. (2019). Scientific validation of indigenous organic formulation-panchagavya for sustaining rice productivity and residual effect in rice-lentil system under hot semi-arid eco-region of middle Indo-Gangetic plains *Indian Journal of Traditional Knowledge* **18**, 104-113.

Vajantha, B., Umadevi M., Patnaik, M.C. and Rajkumar, M. (2011). Effect of INM and Panchagavya on soil fetility status of Ashwagandha (*Withania somnifera* L.). *An Asian Journal of Soil Science* **6,** 88-96.

Williams, Dallas M., Blanco‐Canqui, H., Francis, C.A. and Galusha, T.D. (2017). Organic farming and soil physical properties: An assessment after 40 years. *Agronomy Journal* **109**, 600-609.

Yadav, K.K. and Chhipa, B.R. (2007). Effect of FYM, gypsum and iron pyrites on fertility status of soil and yield of wheat irrigated with high RSC water. *Journal of the Indian Society of Soil Science* **55,** 324-329.

Received: November, 2020 *Accepted: May, 2021*