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Influence of green manuring and organic formulations on the biological properties of soil at different growth stages

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Abstract
The field experiment conducted at AICRP on IFSRP, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India) was carried out during the year 2018-19 and 2019-20 to evaluate the effect of green manuring and organic formulations on soil biological properties at different growth stages. The experiment was laid out in split plot design with three replication. There were nine treatment combinations. The three main plot treatments of *kharif* green mauring crop (*viz*., G_0- no green manure crop (Cultivated fallow), G_1- sunnhemp and G_2- dhaincha), 3 sub plot treatments of *rabi* crops (*viz*., C_1- wheat, C_2- chickpea and C_3- onion) and 3 sub-sub plot treatments of organic formulation (*viz*., O_1- jeevamrut, O_2- em solution and O_3- vermiwash). The results showed that The residual effect of Dhaincha (G_2) recorded significantly maximum soil microbial population of fungi (23.92 and 26.45 cfu x 10^{-5} g^{-1} soil) and (29.63 and 35.19 cfu x 10^{-5} g^{-1} soil), bacteria (57.29 and 60.69 cfu x 10^{-7} g^{-1} soil) and (47.69 and 50.44 cfu s 10^{-7} g^{-1} soil), actinomycetes (44.66 and 47.49 cfu x 10^{-4} g^{-1} soil) and (41.51 and 43.28 cfu x 10^{-4} g^{-1} soil) at flowering and at harvest stage respectively, than rest of the green manuring crop treatments during both the years of investigation. While the application of Jeevamrut @ 500 lit ha^{-1} recorded significantly maximum soil microbial population of fungi (24.17 and 26.58 cfu x 10^{-5} g^{-1} soil) and (30.12 and 35.25 cfu x 10^{-5} g^{-1} soil), bacteria (57.90 and 61.05 cfu x 10^{-7} g^{-1} soil) and (47.68 and 50.23 cfu x 10^{-7} g^{-1} soil), actinomycetes (45.12 and 48.14 cfu x 10^{-4} g^{-1} soil) and (41.86 and 44.17 cfu x 10^{-4} g^{-1} soil) at flowering and at harvest stage respectively, than rest of the organic formulation treatments during both the years of investigation.

Keywords: Organic formulation, green mauring crop, fungi, bacteria, actinomycetes

Introduction
The rapid growth of population and reduction in productive agricultural lands are causing widespread soil degradation. In this regard, systematic soil incorporation of N_2-fixing legume crops as a green manure could be an important agronomic approach in order to reduce the need for costly external inputs and improve internal resources for sustainable production. Green manure is a promising, at least partial, substitution for chemical fertilizer in agriculture, especially for nitrogen (N), which in soil can be radically changed by exogenous input. Green manuring with legumes greatly improves soil fertility by increasing SOC and nitrogen due to biological fixation of atmospheric nitrogen. Thus green manuring with legumes may reduce the required amount of nitrogen fertilizer by 100-200 kg N ha^{-1} drastically reducing production costs.

Organic manures such as FYM, compost, different oil cakes etc. are maintain soil health but they are bulky in nature and also release nutrients slowly and due to that limit the availability immediately to growing crop. In other hand liquid organics called bio-inoculants viz., Jeevamrut, Cow urine, EM solution, Liquid biofertilizer, humic acid which contain microbial count and plant growth promoting substances (PGPR) stimulate growth, yield and quality of crops (Desai *et al*. 2014) [3]. Therefore, the nutrient application through organic fertilizers, if supplemented with low cost organic liquid bio-inoculants sources, will not only economize the nutrient use but also improve the soil health and factor productivity on sustainable basis (Basavaraj *et al*. 2015) [2].

Materials and Methods
A field experiment was carried out during 2018-19 and 2019- 20 at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar Maharashtra (India) at fixed site between 19°23'and 19°38' N and between 74°39' and 74°65'E, 511 m above sea level, with the average annual rainfall of 520 mm.

The weather situation during experimentation indicated that, the total rainfall received during the crop growing season (June 2018 to March 2019) was 257 mm in 15 rainy days, it was 49.42 per cent less than the average annual rainfall (521 mm) while during second year total rainfall received during the crop growing season (June 2019 to March 2020) was 715 mm in 45 rainy days; it was 37.23 per cent more than the average annual rainfall (521 mm). The maximum and minimum temperature was ranged between 26.50C to 41.30C and 7.40C to 25.00C, while during second year maximum and minimum temperature was ranged between 25.10C to 39.200C and 11.90C to 26.100C respectively. The mean weekly morning relative humidity was ranged between 30 to 81 % while evening relative humidity was ranged from 11 to 73 % while during second year mean weekly morning relative humidity was ranged between 51 to 88 % while evening relative humidity was ranged from 17 to 79 %. The mean number of bright sunshine hours ranged between 0.2 to 11.6 hrs during first year while during second year mean number of bright sunshine hours ranged between 0.2 to 10.8 hrs. The wind velocity ranged between 0.3-10 km hr^{-1} during first year while during second year the wind velocity ranged between 0.2 - 8.30 km hr-1 during crop growth period. In general, weather parameter during both year of experiment period was favorable for growth and development for *kharif* green manuring crops and *rabi* wheat chickpea and onion crop.

The experimental soil was clay loam in texture, alkaline in reaction (pH 8.06), low in organic carbon (0.49 %) with electrical conductivity (0.28 dSm^{-1}). The soil was low in available nitrogen (182.17 kg ha^{-1}), medium in available phosphorus (15.53 kg ha^{-1}) and very high in available potassium (401.56 kg ha^{-1}), respectively. The bulk density, field capacity, permanent wilting point and porosity of the soil were 1.31 g m^{-3}, 33.73, 16.43 and 49.34 per cent respectively. The DTPA micronutrient status indicates that the soil was sufficient in respect of Fe (4.53 mg kg^{-1}), Mn (2.46 mg kg^{-1}) and Cu (0.36 mg kg^{-1}) and deficient in Zn (0.55 mg kg^{-1}).The total count of soil microbes viz., fungi (18.31 x 10^{-5} g^{-1} of soil), bacteria (42.17 x 10^{-7} g^{-1} of soil) and actinomycetes (36.15 x 10^{-4} g^{-1} of soil), were observed at optimum level before starting of experiment. In general soil was suitable for growing of the wheat, chickpea and onion crop.

The experiment consists of 3 main plot treatments of *kharif* green mauring crop (viz., G_0 - No green manure crop (Cultivated fallow), G_1 - Sunnhemp and G_2 - Dhaincha), 3 sub plot treatments of cropping system (viz., C_1 - Wheat, C_2 - Chickpea and C_3 - Onion) and 3 sub-sub plot treatments of organic formulation (viz., O_1 - Jeevamrut, O_2 - Em solution and O_3 - Vermiwash). The experiment was laid out in split plot design and replicated three times.

The soil was brought to fine tilth and during *kharif* season for sowing of green manuring crops field was divided into 9 plots with 3 replications where gross plot size 9.0 x 8.10 m each. While only rotavator used to obtain required tilth in *rabi* season. The leveled field was then divided in required number of sub plots in split plot design during *rabi* with 3 replications (Fig. 3). The gross plot size for wheat, chickpea and onion was 3.00 m x 2.70 m and net plot size was 2.80 m x 2.25 m, 2.80 m x 2.10 m and 2.80 m x 2.40 m respectively. Organic formulations in which jeevamrut, EM and vermiwash were used in the present study. The all organic formulations were prepared on farm and applied in two equal split through surface irrigation method with second and third irrigation.

Results and Discussion

Soil Biological Properties

The soil microbial population as influenced by different organic treatments was determined at flowering and at harvest stage of first and second trial during both the years of experiment and are presented in Table 1 and 2.

Fungi (cfu x 10^{-5})

The soil fungi population as influenced by different organic treatments was determined at flowering and at harvest stage of first and second trial during both the years of experiment and are presented in Table 1 and 2.

The mean fungi population at flowering stage was (22.92 and 24.96 cfu x 10^{-5}), whereas at harvest stage it was (28.70 and 34.42 cfu x 10^{-5}), during both the years of investigation.

Effect of green manuring crops

Data presented in Table 1 and 2 revealed that fungi population was influenced significantly due to residual effect of green manuring treatments during both the years. The residual effect of dhaincha recorded significantly higher fungi population at flowering and at harvest stage than rest of the green manuring crop treatments during both the years. However, it was at par with residual effect of sunnhemp at flowering and at harvest stage during both the years. Significantly minimum fungi population was recorded in no green manuring crop treatments at flowering and at harvest stage of observation during both years of experimentation.

Effect of organic formulations

Data presented in Table 1 and 2 illustrated that fungi population was influenced significantly due to application of different organic formulation treatments through surface irrigation during both the years. The application of jeevamrut @ 500 lit ha^{-1} recorded significantly higher fungi population at flowering and at harvest stage than rest of the organic formulation treatments during both the years. However, it was at par with application of vermiwash @ 500 lit ha^{-1} at flowering and at harvest stage during both the years. Application of EM solution @ 500 lit ha^{-1} through surface irrigation noticed significantly minimum fungi population at flowering and at harvest stage during both the years of experimentation.

Interaction

The interaction effect between green manuring crop and organic formulation treatments was not influenced significantly in respect of fungi population at flowering and at harvest stage during both the years of experimentation.

Bacteria (cfu x 10^{-7})

The soil bacterial population as influenced by different organic treatments was determined at flowering and at harvest stage of first and second trial during both the years of experiment and are presented in Table 1 and 2.

The mean bacteria population at flowering stage was (56.25 and 58.99 cfu x 10^{-7}), whereas at harvest stage it was (46.62 and 49.39 cfu x 10^{-7}), during both the years of investigation.

Effect of green manuring crops

Data presented in Table 1 and 2 revealed that bacterial population was influenced significantly due to residual effect of green manuring treatments during both the years. The

residual effect of dhaincha recorded significantly higher bacterial population at flowering and at harvest stage than rest of the green manuring crop treatments during both the years. However, it was at par with residual effect of sunnhemp at flowering and at harvest stage during both the years. Significantly minimum bacterial population was recorded in no green manuring crop treatments at flowering and at harvest stage of observation during both years of experimentation.

Table 1: Soil microbial population as influenced by different organic treatment at flowering stage of first and second cycle

Treatment		Soil microbial population					
		Fungi (cfu x 10^{-5} g^{-1} soil)		Bacteria (cfu x 10^{-7} g^{-1} soil)		Actinomycetes (cfu x 10^{-4} g^{-1} soil)	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
A.	**Effect of green manuring crops (*Kharif* Season) – G**						
G_0:	No green manure crop	21.86	23.12	54.74	57.22	41.91	45.57
G_1:	Sunnhemp	22.99	25.31	56.71	59.06	43.44	46.45
G_2:	Dhaincha	23.92	26.45	57.29	60.69	44.66	47.49
	S.Em. ±	0.38	0.44	0.47	0.49	0.45	0.29
	C.D. at 5 %	1.47	1.72	1.85	1.91	1.78	1.96
B.	**Effect of organic formulations (*Rabi* Season) - O**						
O_0 :	Jeevamrut @ 500 lit ha^{-1}	24.17	26.58	57.90	61.05	45.12	48.14
O_1 :	EM solution @ 500 lit ha^{-1}	21.83	23.03	54.31	56.68	41.78	44.67
O_2 :	Vermiwash @ 500 lit ha^{-1}	22.77	25.28	56.54	59.24	43.10	46.70
	S.Em. ±	0.48	0.90	0.82	1.05	0.68	0.64
	C.D. at 5 %	1.48	2.77	2.51	3.25	2.10	2.43
	Interaction (G x O)						
	Between two sub plot means at same level of main plot means						
	S.Em. ±	0.83	1.55	1.41	1.83	1.18	1.24
	C.D. at 5 %	NS	NS	NS	NS	NS	NS
	Between two main plot means at same level of sub plot means						
	S.Em. ±	0.78	1.34	1.25	1.57	1.07	1.39
	C.D. at 5 %	NS	NS	NS	NS	NS	NS
	General mean	22.92	24.96	56.25	58.99	43.33	46.50
	Initial	18.31		42.17		38.79	

Table 2: Soil microbial population as influenced by different organic treatment at harvest stage of first and second cycle

Treatment		Soil microbial population					
		Fungi (cfu x 10^{-5} g^{-1} soil)		Bacteria (cfu x 10^{-7} g^{-1} soil)		Actinomycetes (cfu x 10^{-4} g^{-1} soil)	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
A.	**Effect of green manuring crops (*Kharif* Season) – G**						
G_0 :	No green manure crop	27.98	33.72	45.44	48.36	38.44	40.10
G_1 :	Sunnhemp	28.49	34.36	46.75	49.37	39.52	41.90
G_2 :	Dhaincha	29.63	35.19	47.69	50.44	41.51	43.28
	S.Em. ±	0.32	0.39	0.33	0.34	0.58	0.63
	C.D. at 5 %	1.25	1.33	1.28	1.35	2.29	2.55
B.	**Effect of organic formulations (*Rabi* Season) - O**						
O_0 :	Jeevamrut @ 500 lit ha^{-1}	30.12	35.25	47.68	50.23	41.86	44.17
O_1 :	EM solution @ 500 lit ha^{-1}	27.36	33.57	45.93	48.44	37.92	39.14
O_2 :	Vermiwash @ 500 lit ha^{-1}	28.62	34.44	46.27	49.50	39.68	41.98
	S.Em. ±	0.59	0.63	0.47	0.85	0.81	0.99
	C.D. at 5 %	1.82	2.16	1.45	1.68	2.49	3.05
	Interaction (G x O)						
	Between two sub plot means at same level of main plot means						
	S.Em. ±	1.02	1.19	0.82	1.47	1.40	1.71
	C.D. at 5 %	NS	NS	NS	NS	NS	NS
	Between two main plot means at same level of sub plot means						
	S.Em. ±	0.89	0.61	0.74	1.25	1.28	1.45
	C.D. at 5 %	NS	NS	NS	NS	NS	NS
	General mean	28.70	34.42	46.62	49.39	39.82	41.76
	Initial	18.31		42.17		38.79	

Effect of organic formulations

Data presented in Table 1 and 2 illustrated that bacterial population was influenced significantly due to application of different organic formulation treatments through surface irrigation during both the years. The application of jeevamrut @ 500 lit ha^{-1} recorded significantly higher bacterial population at flowering and at harvest stage than rest of the organic formulation treatments during both the years. However, it was at par with application of vermiwash @ 500 lit ha^{-1} at flowering and at harvest stage during both the years. Application of EM solution @ 500 lit ha^{-1} through surface irrigation noticed significantly minimum bacterial population at flowering and at harvest stage during both the years of experimentation.

Interaction
The interaction effect between green manuring crop and organic formulation treatments was not influenced significantly in respect of bacterial population at flowering and at harvest stage during both the years of experimentation.

Actinomycetes (cfu x 10^{-4})
The soil actinomycetes population as influenced by different organic treatments was determined at flowering and at harvest stage of first and second trial during both the years of experiment and are presented in Table 1 and 2.
The mean actinomycetes population at flowering stage was (43.33 and 46.50 cfu x 10^{-4}), whereas at harvest stage it was (39.82 and 41.76 cfu x 10^{-5}), during both the years of investigation.

Effect of green manuring crops
Data presented in Table 1 and 2 revealed that actinomycetes population was influenced significantly due to residual effect of green manuring treatments during both the years. The residual effect of dhaincha recorded significantly higher actinomycetes population at flowering and at harvest stage than rest of the green manuring crop treatments during both the years. However, it was at par with residual effect of sunnhemp at flowering and at harvest stage during both the years. Significantly minimum actinomycetes population was recorded in no green manuring crop treatments at flowering and at harvest stage of observation during both years of experimentation. This might be due to incorporation of green manuring crop in soil activate the microbial population in soil which start the decomposition of organic matter rapidly. Green manure is good source of carbon, which is food for microbes, which helps to multiplies bacteria, fungi and actinomycetes populations in soil. These results are in agreement with those reported.

Effect of organic formulations
Data presented in Table 1 and 2 illustrated that actinomycetes population was influenced significantly due to application of different organic formulation treatments through surface irrigation during both the years. The application of jeevamrut @ 500 lit ha^{-1} recorded significantly higher actinomycetes population at flowering and at harvest stage than rest of the organic formulation treatments during both the years. However, it was at par with application of vermiwash @ 500 lit ha^{-1} at flowering and at harvest stage during both the years. Application of EM solution @ 500 lit ha^{-1} through surface irrigation noticed significantly minimum actinomycetes population at flowering and at harvest stage during both the years of experimentation. Significantly higher bacteria, fungi, *actinomycetes*, over other bioinoculants application. This might be due to jeevamrut contains enormous amount of microbial load which multiplies in the soil and acts as a tonic to enhance the microbial activity in the soil. Also jeevamrut is good source of carbon, which is food for microbes. Palekar (2006) [6]; Vasanthkumar (2006) [11]; Sreenivas *et al*. (2011) [9] also reported that liquid manures contain micronutrients in addition to different microflora especially nitrogen fixers and phosphate solubilizers. Similar observations were made by Swaminathan (2005) [10] who reported that presence of naturally occurring beneficial microorganisms predominantly bacteria, yeast, actinomycetes, photosynthetic bacteria and certain fungi were detected in organic liquid manures. Devakumar *et al*. (2014) [4] reported that the use of handful of soil for jeevamrut preparation served as source of initial inoculum of bacteria, fungi, *actinomycetes*, N-fixers and P-solubilizers. Hence, more number of beneficial microorganisms was found in bioinoculants treated soil. These observations are in conformity with Papen *et al*. (2002) [7], Rajanna *et al*. (2011) [8] Aulakh *et al*. (2013) [1] and Lavanya *et al*. (2016) [5].

Interaction
The interaction effect between green manuring crop and organic formulation treatments was not influenced significantly in respect of actinomycetes population at flowering and at harvest stage during both the years of experimentation.

Conclusion
From the above study it could be concluded that, incorporation of dhaincha (G_2) as green manuring crop during *kharif* season, followed by application of jeevamrut @ 500 lit ha^{-1} during *rabi* season improve the soil biological properties (fungi, bacteria and actinomycetes) at flowering and at harvest stage during both the years of investigation.

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