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Influence of organic sources and organic formulations on the biological properties of soil in soybean-onion cropping sequence

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Abstract
The field experiment conducted at Instructional Farm, Department of Agronomy, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India) during the year 2019-20 and 2020-21 to evaluate the effect of organic sources and organic formulations on the biological properties of soil in soybean-onion cropping sequence. The experiment was laid out in split plot design with three replications. There were 16 treatment combinations formed with four main plot treatments of organic sources *viz.*, S_0 - Control, S_1 - FYM @ 5 t ha^{-1}, S_2 - vermicompost @ 2.5 t ha^{-1}, S_3 - FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} and four subplot treatments of organic formulations *viz.*, F_0 -Control, F_1 - *jeevamrut* @ 500 lit ha^{-1}, F_2 - EM solution @ 100 lit ha^{-1}, F_3 - *jeevamrut* @ 250 lit ha^{-1} + @ 50 lit ha^{-1} EM solution. The results showed that the application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} 15 days before sowing/transplanting recorded significantly maximum soil microbial population of soil *viz.*, bacteria, fungi and actinomycetes than rest of the organic source treatments during both the years of experiment. While the application of organic formulation *jeevamrut* @ 500 lit ha^{-1} twice through irrigation at 30 and 60 DAS/DAT recorded significantly maximum soil microbial population of soil *viz.*, bacteria, fungi and actinomycetes than rest of the organic formulation treatments during both the years of experiment.

Keywords: FYM, vermicompost, organic formulation, fungi, bacteria, actinomycetes

Introduction
Increasing agricultural land productivity is necessary to meet the rising population's needs for food, fuel, fiber, and other resources without compromising the health of the soil. Without organic additions, fertilizers used to boost crop productivity seriously deteriorate the qualities of the soil and pollute the surrounding ecosystem. In addition to being highly costly, the chemical fertilizer lowers the microbial population in soil and presents health risks, raising the expense of production. The physical, chemical, and biological conditions of the soil are improved by application of FYM to promote favorable crop development and yield. Application of vermicompost in the field improves the quality of soil by increasing microbial biomass and microbial activity, which are important components in cycling of nutrients, production of plant growth regulators and protecting the plants from soil-borne diseases and insectpests (Pooja *et al.*, 2022) [7].

Ecologically safe liquid organic formulation made from cow products is *jeevamrut.* The positive effects of *jeevamrut* were linked to increased microbial load and growth hormones, which may have improved soil biomass and maintained the availability and uptake of both native and applied soil nutrients, ultimately leading to improved crop growth and yield. *Jeevamrut* also contains enormous amount of microbial load which multiply and enhance N fixation and nutrient mobilization and utilization increase the soil fertility (Palekar, 2006) [6]. Prof. Dr. Teruo Higa first proposed the idea of Effective Microorganisms (EM) in the 1980s. As a result, a collection of advantageous microorganisms were cultivated and applied to enhance soil properties, increase organic matter productivity, and enhance crop nutrient uptake. The primary product, EM•1 Microbial Inoculant, is currently manufactured in more than 70 nations.

Materials and Methods

A field experiment was carried out during 2019-20 and 2020- 21 at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar Maharashtra (India), is situated between 19° 48' and 19° 57' North latitude and 74° 52' and 74° 19' East longitude, 511 m above sea level. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.87) with low available nitrogen (192.7 kg ha^{-1}), medium available phosphorus (17.81 kg ha^{-1}), high available potassium (387.16 kg ha^{-1}), and low in organic carbon (0.48 per cent) with normal electrical conductivity (0.27 dSm^{-1}). The corresponding numerical values for bulk density, porosity, field capacity and permanent wilting point were 1.35 g cm^{-3}, 49.06 per cent, 33.14 and 16.33 per cent, respectively. Soil biological properties were determined by serial dilution technique. The bacteria, fungi and actinomyecetes were serially diluted and the count of colony forming units were 34 cfu x 10^6 g^{-1}, 19 cfu x 10^5 g^{-1} and 22 cfu x 10^4 g^{-1}, respectively.

The experiment was laid out in split plot design with three replications. There were 16 treatment combinations formed with four main plot treatments of organic sources *viz.*, S_0 - Control, S_1 - FYM @ 5 t ha^{-1}, S_2 - vermicompost @ 2.5 t ha^{-1}, S_3 - FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} and four subplot treatments of organic formulations *viz.*, F_0 -Control, F_1 - *jeevamrut* @ 500 lit ha^{-1}, F_2 - EM solution @ 100 lit ha^{-1}, F_3 - *jeevamrut* @ 250 lit ha^{-1} + @ 50 lit ha^{-1} EM solution.

In *kharif* soybean variety Phule sangam was sown at spacing 30 cm x 10 cm while in *rabi* transplanting of seedlings of onion variety N - 2 - 4 - 1 were done by maintaining 15 cm x 10 cm spacing during both the years. Treatment wise organic sources such as FYM and vermicompost were applied 15 days before sowing or transplanting of the crops during both the years of experimentation. Organic formulations in which *jeevamrut*, E M solution and their combinations were prepared on farm. The all organic formulations were applied two times through surface irrigation at 30 and 60 DAS/TAS in each crop during both the years.

The microbial count was taken by using the method suggested by Halvorsun and Zeigber, 1993 [4]. Microbial populations of fungi, bacteria and actinomycetes in rhizosphere soil was enumerated by using standard microbiological methods carried out initially before sowing of crops, at flowering stage and at harvest stage of soybean crop and at harvest stage of onion crop in both years of experiment.

Results and Discussion

Biological properties of soil

The soil microbial population was determined at flowering stage and at harvest stage of soybean and at harvest stage of onion during both the years of experiment. The population of fungi, bacteria and actinomycetes in soil as influenced by different treatment are presented in Table 1 and Table 2.

Fungi

The population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion as influenced by different treatment is presented in Table 1 and Table 2. The mean population of fungi at flowering stage and at harvest stage of soybean was 32.35 and 29.92 cfu x10^5 g^{-1} of soil during first year and 38.79 and 34.73 cfu x10^5 g^{-1} of soil during second year respectively. The mean population of fungi at harvest stage of onion is 35.63 cfu x10^5 g^{-1} during first year and 37.93 cfu x10^5 g^{-1} of soil during second year respectively.

Effect of organic sources

Data presented in Table 1 and Table 2 revealed that the population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly due to effect of application of different organic sources during both the years. Data presented in Table 1 and Table 2 indicated that application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} (S_3) recorded maximum population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments. However, minimum population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (S_0) of organic sources during both the years. These results are close conformity to Gorde *et al.* (2022) [3].

Effect of organic formulations

The population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly during both the years due to effect of application of different organic formulations. Data presented in Table 1 and Table 2 revealed that application of *jeevamrut* @ 500 lit ha^{-1} at 30 and 60 DAS/DAT (F_1) recorded maximum population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments during both the years. Minimum population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (F_0) of organic formulations during both the years. Raut *et al.* (2022) [9] showed that application of *jeevamrut* @ 500 lit ha^{-1} recorded significantly maximum population of fungi than rest of the organic formulation treatments.

Interaction

The interaction effect between organic sources and organic formulations in respect of population of fungi in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was found non-significant during both the years.

Bacteria

The population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion as influenced by different treatment is presented in Table 1 and Table 2. The mean population of bacteria at flowering stage and at harvest stage of soybean was 46.86 and 42.72 cfu x10^6 g^{-1} of soil during first year and 52.30 and 48.31 cfu x10^6 g^{-1} of soil during second year respectively. The mean population of bacteria at harvest stage of onion was 47.89 cfu x10^6 g^{-1} of soil during first year and 51.96 cfu x10^6 g^{-1} of soil during second year respectively.

Effect of organic sources

Data presented in Table 1 and Table 2 revealed that the population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly due to effect of application of different organic sources during both the years. Data presented in Table 1 and Table 2 indicated that application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} (S_3) recorded maximum population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments. However, minimum population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (S_0) of organic

sources during both the years. Gorde *et al*. (2022) [3] also found similar results.

Effect of organic formulations

The population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly during both the years due to effect of application of different organic formulations. Data presented in Table 1 and Table 2 revealed that application of *jeevamrut* @ 500 lit ha^{-1} at 30 and 60 DAS/DAT (F_1) recorded maximum population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments during both the years. Minimum population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (F_0) of organic formulations during both the years. Raut *et al.* (2022) [9] also confirmed that application of *jeevamrut* @ 500 lit ha^{-1} recorded significantly maximum population of bacteria than rest of the organic formulation treatments.

Interaction

The interaction effect between organic sources and organic formulations in respect of population of bacteria in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was found non-significant during both the years.

Actinomycetes

The population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion as influenced by different treatment is presented in Table 1 and Table 2. The mean population of actinomycetes at flowering stage and at harvest stage of soybean was 35.13 and 32.40 cfu x10^4 g^{-1} of soil during first year and 39.80 and 35.90 cfu x10^4 g^{-1} of soil during second year respectively. The mean population of actinomycetes at harvest stage of onion was 37.39 cfu x10^4 g^{-1} of soil during first year and 39.30 cfu x10^4 g^{-1} of soil during second year respectively.

Effect of organic sources

Data presented in Table 1 and Table 2 revealed that the population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly due to effect of application of different organic sources during both the years. Data presented in Table 1 and Table 2 indicated that application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} (S_3) recorded maximum population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments. However, minimum population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (S_0) of organic sources during both the years. The finding conforms the results of Gorde *et al*. (2022) [3].

Effect of organic formulations

The population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was influenced significantly during both the years due to effect of application of different organic formulations. Data presented in Table 1 and Table 2 revealed that application of *jeevamrut* @ 500 lit ha^{-1} at 30 and 60 DAS/DAT (F_1) recorded maximum population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion than rest of the treatments during both the years. Minimum population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was observed under the control treatment (F_0) of organic formulations during both the years. Raut *et al.* (2022) [9] reported that application of *jeevamrut* @ 500 lit ha^{-1} recorded significantly maximum population of actinomycetes than rest of the organic formulation treatments.

Table 1: Mean microbial population in soil as influenced by different treatments at flowering and at harvest of soybean crop

Treatments	Fungi (cfu x 10^5 g^{-1} of soil)				Bacteria (cfu x 10^6 g^{-1} of soil)				Actinomycetes (cfu x 10^4 g^{-1} of soil)			
	2019		2020		2019		2020		2019		2020	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
Organic sources (S)												
S_0 - Control	29.75	27.35	35.98	32.57	44.08	40.02	49.51	45.47	32.20	29.77	37.15	33.80
S_1 - FYM @ 5 t ha^{-1}	32.56	30.09	39.02	34.80	47.05	42.80	52.50	48.52	35.41	32.52	39.98	35.95
S_2 - V C@ 2.5 t ha^{-1}	32.85	30.49	39.38	35.09	47.45	43.20	52.90	48.92	35.80	33.03	40.28	36.21
S_3 - FYM @ 2.5 t ha^{-1} + VC @ 1.25 t ha^{-1}	34.23	31.76	40.77	36.47	48.84	44.85	54.29	50.32	37.10	34.27	41.77	37.65
S. Em (±)	0.37	0.35	0.36	0.35	0.37	0.36	0.36	0.36	0.36	0.35	0.36	0.38
C. D. at 5 %	1.29	1.20	1.24	1.22	1.27	1.24	1.23	1.26	1.23	1.20	1.26	1.30
Organic formulations (F)												
F_0 – Control	27.69	25.27	34.08	30.10	42.17	38.08	47.67	43.78	30.80	27.79	35.21	31.28
F_1 - *Jeevamrut* @ 500 lit ha^{-1}	35.62	33.13	41.94	37.92	50.02	45.96	55.46	51.43	38.12	35.61	42.89	39.11
F_2 - E M solution @ 100 lit ha^{-1}	32.30	29.93	38.89	34.71	46.92	42.72	52.37	48.35	35.10	32.38	39.85	35.86
F_3 - *Jeevamrut* @ 250 lit ha^{-1} + E M solution @ 50 lit ha^{-1}	33.79	31.37	40.24	36.21	48.31	44.11	53.70	49.67	36.48	33.82	41.24	37.36
S. Em (±)	0.48	0.48	0.48	0.47	0.49	0.48	0.48	0.48	0.46	0.50	0.49	0.48
C. D. at 5 %	1.41	1.40	1.41	1.38	1.44	1.40	1.39	1.42	1.36	1.45	1.43	1.39
Interactions (SxF)												
Between two sub plots at same level of main plot means												
S. Em (±)	0.96	0.96	0.97	0.94	0.98	0.96	0.95	0.97	0.93	0.99	0.98	0.95
C. D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Between two main plots at same level of sub plot means												
S. Em (±)	0.91	0.90	0.91	0.89	0.93	0.91	0.90	0.92	0.88	0.93	0.92	0.91
C. D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	32.35	29.92	38.79	34.73	46.86	42.72	52.30	48.31	35.13	32.40	39.80	35.90

Table 2: Mean microbial population in soil as influenced by different treatments after harvest of onion crop

Treatments	Fungi (cfu x 10^5 g^{-1} of soil)		Bacteria (cfu x 10^6 g^{-1} of soil)		Actinomycetes (cfu x 10^4 g^{-1} of soil)	
	2020	2021	2020	2021	2020	2021
Organic sources (S)						
S_0 - Control	33.72	35.26	45.13	49.16	34.72	36.66
S_1 - FYM @ 5 t ha^{-1}	35.50	38.09	48.06	52.16	37.50	39.49
S_2 - V C@ 2.5 t ha^{-1}	35.90	38.49	48.46	52.56	37.90	39.85
S_3 - FYM @ 2.5 t ha^{-1} + VC @ 1.25 t ha^{-1}	37.40	39.88	49.92	53.95	39.45	41.19
S. Em (±)	0.39	0.36	0.33	0.37	0.39	0.37
C. D. at 5 %	1.34	1.24	1.16	1.28	1.34	1.28
Organic formulations (F)						
F_0 – Control	31.02	33.32	43.29	47.26	32.78	34.71
F_1 - *Jeevamrut* @ 500 lit ha^{-1}	38.80	41.10	51.09	55.13	40.56	42.40
F_2 - E M solution @ 100 lit ha^{-1}	35.66	37.96	47.93	52.03	37.42	39.35
F_3 - *Jeevamrut* @ 250 lit ha^{-1} + E M solution @ 50 lit ha^{-1}	37.05	39.35	49.26	53.42	38.81	40.74
S. Em (±)	0.49	0.50	0.47	0.49	0.49	0.47
C. D. at 5 %	1.44	1.45	1.38	1.43	1.44	1.38
Interactions (SxF)						
Between two sub plots at same level of main plot means						
S. Em (±)	0.99	0.99	0.94	0.98	0.99	0.94
C. D. at 5 %	NS	NS	NS	NS	NS	NS
Between two main plots at same level of sub plot means						
S. Em (±)	0.94	0.93	0.88	0.93	0.94	0.90
C. D. at 5 %	NS	NS	NS	NS	NS	NS
General mean	35.63	37.93	47.89	51.96	37.39	39.30

Interaction

The interaction effect between organic sources and organic formulations in respect of population of actinomycetes in soil at flowering stage and at harvest stage of soybean and at harvest stage of onion was found non-significant during both the years.

Among the different organic treatment, application of *jeevamrut* @ 500 lit ha^{-1} at 30 and 60 DAS/DAT (F_1) recorded significantly higher bacteria, fungi, actinomycetes, over other treatments. 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. *Jeevamrut* is good source of carbon, which is food for microbes. Palekar, (2006) [6]; Vasanthkumar, (2006) [12]; Sreenivasa *et al.*, (2011) [10] also reported that liquid manures contain micronutrients in addition to different microflora especially nitrogen fixer and phosphate solubilizer. Similar observations were recorded by Swaminathan (2005) [11] who showed 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) [2] 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 Rajanna *et al.*, (2011) [8] Aulakh *et al.*, (2013) [1] and Lavanya *et al.*, (2016) [5].

Conclusion

The maximum microbial population of soil *viz*., bacteria, fungi and actinomycetes were recorded in application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} 15 days before sowing/transplanting and application of organic formulation *jeevamrut* @ 500 lit ha^{-1} twice through irrigation at 30 and 60 DAS/DAT.

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