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Original Research Article

Appraisal of Soil Microbial Status under Rabi Safflower Using Soil Test Crop Response Approach

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Keywords

SSNM, STCR, RDF, Safflower, Farmyard manure, and Microbial population

A B S T R A C T

The field experiment was conducted at research farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season 2017-18 and 2018-19, to find out the appraisal of soil microbial status under *rabi* safflower using soil test crop response approach. Soil microbial population was estimated at flowering and at harvest of safflower. The total count of fungi, bacteria and actinomycetes were increased at flowering and gradually decreased towards harvest of crop but values were higher than initial population during both the years of experimentation. The results revealed that, soil microbial population was influenced significantly by manure application and site specific nutrient management practices treatments during both the years of investigation. Among the manure treatments, application of 5 t FYM ha^{-1} had recorded significantly higher population of bacteria (64.82, 57.17 cfu x 10^6 g^{-1} soil), (72.82, 63.39 cfu x 10^6 g^{-1} soil), actinomycetes (31.67, 24.81 cfu x 10^4 g^{-1} soil), (35.10, 27.35 cfu x 10^4 g^{-1} soil) and fungi (24.42, 15.68 cfu x 10^4 g^{-1} soil), (26.01, 20.34 cfu x 10^4 g^{-1} soil) at flowering and at harvest of safflower during the year of 2017-18 and 2018-19, respectively. The minimum population of bacteria, actinomycetes and fungi were recorded in the treatment receiving no manure at flowering and at harvest of crop during both the years. Among the site specific nutrient management practices, the total soil microbial population i.e. bacteria (59.32, 52.97 cfu x 10^6 g^{-1} soil), (73.89, 59.13 cfu x 10^6 g^{-1} soil), actinomycetes (32.83, 26.08 cfu x 10^4 g^{-1} soil), (36.40, 30.03 cfu x 10^4 g^{-1} soil) and fungi (25.05, 16.38 cfu x 10^4 g^{-1} soil), (28.34, 21.68 cfu x 10^4 g^{-1} soil) were higher with the treatment of SSNM (STCR eqaution) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1}) at flowering and at harvest of safflower during both the years of study, respectively. Lowest count of bacteria, actinomycetes and fungi population was observed under the treatment of no fertilizer at flowering and at harvest of safflower during both the years of experimentation.

Introduction

Safflower (*Carthamus tinctorius* L.) is an oldest oilseed crop cultivated in India, mainly for cooking oil and dyes. Besides, safflower is a multipurpose crop species used in preparation of medicines, cosmetics, salads and margarine production (Balasubramanian and Palaniappan, 2005). Safflower seed contains 28-34% of oil, flavourless and colourless, and nutritionally similar to sunflower oil, having enough amount of linoleic acid (78%), which is very useful for reducing blood cholesterol content (Kadu and

Ismail 2008). Soil microbial biomass is an important ecological indicator and acts as a source and sink of available nutrient for plant growth. It is supposed to be an integral part of decomposer subsystem. Soil microorganisms play a crucial role in ecosystem functions such as organic matter decomposition, nutrient cycling, transformation, mineralization etc. Organic source as FYM enrich soil organic matter and inorganic fertilizer have priming effect on native soil organic matter (Marinari *et al.*, 2000), thus both have role in increasing soil biological activity. Plassart *et al.*, (2008) microbial activities depend upon the substrate availability in soil. An organic source like FYM is the source of energy to the soil microflora and organic carbon content is considered to be an index of the soil health (Chand, 2006).

The Long Term Fertilizer Experiments have indicated very clearly that the response to the fertilizers could be raised significantly with balanced application of fertilizer nutrients along with organic manures. Integrated nutrient management (INM) encourages conjunctive use of chemical fertilizers including secondary and micronutrients, organic manures, farm yard manure, bio fertilizers and green manures on a large scale. It is a tool which can offer good options and economic choices to supply plants with sufficient amounts of most macro and micronutrients and also can reduce the dose of chemical fertilizers, create favourable soil physiochemical conditions and healthy environment, eliminate the constraints, safeguard the soil nutrient balance in the long run to an optimum level for sustaining the desired crop productivity (Anonymous, 2019).

Fertilizer recommendation based on soil test crop response correlation (STCR) concept is more quantitative, precise and meaningful because the combined use of soil and plant analysis is involved in it. While developing the STCR targeted yield equation contribution of nutrients from soil, fertilizer and organics are taken in to consideration. Similarly, by taking these into consideration, nutrient requirement (NR) to produce a quintal of grain or any economic produce are considered. It gives a real balance between applied nutrients and the available nutrients already present in the soil. This approach facilitates the farmers to apply only required amount of nutrient fertilizer matching with crop needs and fertility status of soil to realize the yield targets and sustain the soil fertility (Sachidanand *et al.*, 2007 and Regar and Singh, 2014). Therefore, under taken with a view of evolving soil test and targeted yield based fertilizer recommendation for safflower and test their adoptability under *rainfed* condition. Keeping above facts in mind present study was carried out at PDKV, Akola with the key objective of evaluating the performance of *rabi* safflower under STCR approach on microbial studies with integration of organic manures in *rainfed* condition.

Materials and Methods

A field experiment was conducted at research farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS), during *rabi* season of 2017-18 and 2018-19. The experimental soil was medium deep black, alkaline reaction pH (8.0), EC (0.30 dSm^{-1}), low in available nitrogen (194.0 kg ha^{-1}), medium in available phosphorus (26.10 kg ha^{-1}) and slightly high in available potassium (327 kg ha^{-1}). The status of organic carbon content (0.59) which was medium in category. Fertilizers were applied to the crop based on uptake pattern, target yield and fertility status. Initial value of available nitrogen, phosphorus and potassium were considered to calculate the fertilizer requirement for targeted yields of safflower. Fertilizer adjustment equation employed for calculation of nutrient requirement for safflower crop and major nutrients applied on the basis of soil test values under different treatments i.e. F.N = 9.11 x T – 0.45 x S.N; F. P_2O_5: 6.27 x T – 2.19 x S. P; F. K_2O: 9.27 x T – 0.38 x S. K and target yield was taken 15 q/ha. Where: F N, F P_2O_5 & F K_2O = Nutrient (N, P_2O_5 & K_2O) applied through fertilizer (kg ha^{-1}) SN, SP & SK= Available nutrient (N, P & K) in soil (kg ha^{-1}) T = Targeted yield (q ha^{-1}). The experiment was laid out in FRBD with fifteen treatments combination *viz.*, Factor A consisting three treatments M_0 **-** No manure, M_1**-** 5 t FYM ha^{-1} and M_2 - Greengram residue incorporation likewise Factor B consist of five nutrient management treatments i.e. F_0- control (no fertilizer), F_1- Recommended NPK, F_2- SSNM (STCR equation), F_3- SSNM (STCR equation) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1} and F_4 - SSNM (NPK) (deficient + 25% rec.; medium: rec.; high: - 25 % rec.). This treatments combination replicated four times. The fertilizers used were urea, Di-ammonium phosphate and muriate of potash. Sulphur was supplied through single super phosphate@10 kg ha^{-1}. Zinc was applied through zinc sulphate @25 ha^{-1}. The variety of safflower was AKS-207 on 6^{th} October 2017-18 and 24^{th} September 2018-19 by keeping 45 cm x 20 cm spacing during both the years. FYM @ 5 t/ha^{-1} and greengram residue incorporation @ 2 t ha^{-1} content 0.46%, 0.17%, 0.48% and 1.61%, 0.22%, 0.55% NPK, respectively. FYM incorporated in soil 14 days before sowing. The amount of rainfall received during crop growing seasons was 66.1 mm and 175.3 mm in 2017-18 and 2018-19, respectively. Soil microbial counts (bacteria, actinomycetes and fungi) were estimated using serial dilution method (Dhingra and Sinclair, 1993). The experimental data of microorganisms were statistically analysed to draw conclusion of significance by using the methods described by (Gomez and Gomez, 1984). Initial microbial counts observed in the soil were as follows

Total Bacterial count = 11.7 x 10^6

Total Fungal count = 8.4 x 10^4

Total Actinomyteces count = 9.6 x 10^4

Results and Discussion

Bacterial population of safflower

Effect of manure application

Data presented in Table 1 revealed that bacteria population in soil were influenced by manure application practice during both the years of study. At flowering and at harvest of safflower the bacterial count was found significantly higher in treatment receiving application of 5 t FYM ha^{-1} (64.82, 57.17 cfu x 10^6 g^{-1} soil), (72.82, 63.39 cfu x 10^6 g^{-1} soil), respectively and which was superior over treatments of no manure and greengram residue incorporation during both the years of investigation. The lowest bacterial count (46.72, 37.16 cfu x 10^6 g^{-1} soil), (57.66, 41.40 cfu x 10^6 g^{-1} soil) registered with treatment of no manure i.e. control at flowering and at harvest during 2017-18 and 2018-19, respectively.

The bacterial population also differed with the stage of crop growth as well. Generally higher bacterial population was observed at flowering stage than at harvesting stage. This could be attributed to higher degree of plant metabolism activities at flowering stage, thereby, secreting higher amount of root exudates which acts as substrates to microbial population. Hence, in general, higher degree of bacterial population was observed at flowering stage than that at harvesting stage.

Decreased bacterial population towards crop at harvest might be due to less content of organic matter left after decomposition which might have affected the bacterial population in the soil. It is axiomatic that soil organic matter is the food for microbes so the decrease in organic matter content after the harvest of safflower crop may be one reason for the decreased bacterial population. Moisture content in the soil also one of the very important criteria for the survival of microbes which decreased at the time of safflower harvesting as no irrigation was given and there was no rain further.

Manna and Hazra (1996) reported that FYM application @ 4 t ha^{-1} increased microbial biomass in soybean -wheat cropping system. They also found that higher size of microbial biomass and soil respiration were recorded in the treatment 5 t ha^{-1} cow dung slurry +50 kg P_2O_5+*Azotobacter chrococcum*. Thakur *et al.*,(1998) reported that the microbial population in the soil *viz.*, bacteria, fungi, actinomycetes etc. were found maximum with the combined use of chemical fertilizer and organic manure (5 t FYM ha^{-1}) and Shendria Sanjivani (37 kg ha^{-1}) in cotton. Manna and Ganguly (2001) also reported that incorporation of FYM increased the soil microbial biomass than other organic manures.

Effect of nutrient management

The data on bacterial population as influenced by different site specific nutrient management practices during 2017-18 and 2018-19 at flowering and harvest are given in Table 1. Bacterial population under different treatments of nutrient management was in the range between 54.32 to 46.73 cfu × 10^6 g^{-1} soil and 65.81 to 51.46 cfu × 10^6 g^{-1} soil at flowering up to harvest of crop during both the years, respectively. At flowering and at harvest stage, the treatment receiving SSNM (STCR equation) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1}) recorded the maximum bacterial population (59.32 cfu × 10^6 g^{-1} soil, 52.97 cfu × 10^6 g^{-1} soil) and (73.89 cfu × 10^6 g^{-1} soil, 59.13 cfu × 10^6 g^{-1} soil), respectively which was on par with the treatment receiving SSNM (STCR equation) and superior over rest of nutrient management treatments during 2017-18 and 2018-19. Whereas, lowest value of bacterial population was noted in treatment no fertilizer (44.25 cfu × 10^6 g^{-1} soil, 35.88 cfu × 10^6 g^{-1} soil) and (55.18 cfu × 10^6 g^{-1} soil, 39.13 cfu × 10^6 g^{-1} soil) at flowering and at harvest stage during both the years, respectively. The rise in the bacterial populations at flowering stage could be attributed to favourable environment and the availability of food sources at that stage due to the residual organic materials and balanced dose of fertilizers especially N and K along with FYM, which has resulted in more organic carbon accumulation and lead to more microbial activity. The results are in line with the earlier findings of Salinas-Garcia *et al.*, 2002 and Sharma *et al.*, (1998) reported that the microbial population was almost doubled with the balanced and integrated use of chemical fertilizers and organics than with imbalanced use of chemical fertilizers and treatments involving the use of 100 per cent NPK.

Actinomycetes population of safflower

Effect of manure application

The data regarding actinomycetes population in soil safflower crop influenced significantly due to manure application treatments at flowering and at harvest during 2017-18 and 2018-19 are presented in Table 2. Data revealed that, higher actinomycetes population in soil was observed with treatment of application 5 t FYM ha^{-1} (31.67 cfu x 10^4 g^{-1} soil, 24.81 cfu x 10^4 g^{-1} soil), (35.10 cfu x 10^4 g^{-1} soil, 27.35 cfu x 10^4 g^{-1}

soil) which was significantly superior over treatments of no manure (26.30 cfu x 10^4 g^{-1} soil, 18.80 cfu x 10^4 g^{-1} soil), (28.09 cfu x 10^4 g^{-1} soil, 20.30 cfu x 10^4 g^{-1} soil) and greengram residue incorporation (29.23 cfu x 10^4 g^{-1} soil, 20.46 cfu x 10^4 g^{-1} soil), (32.00 cfu x 10^4 g^{-1} soil, 23.69 cfu x 10^4 g^{-1} soil) at flowering and at harvest of safflower during 2017-18 and 2018-19, respectively.

The Lower actinomycetes population was recorded with no manure treatment application at flowering and at harvest stage of safflower during both the years of study.

This might be due to relatively higher rate of multiplication of microbes associated with organic manures, which act as a substrate for stimulation and rapid multiplication of microorganisms.

Further, increase in microbial population could be the result of enhancement of soil organic matter in the soil as indicated by positive correlation of enzyme activities with soil organic carbon. This can be ascribed to the decomposed food material available from organic sources.

The similar results were reported by Vineela *et al.,* (2008), Nath *et al.,* (2015) and Mishra *et al.,* (1991) also found that microbial population increased with increasing application of FYM upto 20 t ha^{-1} and biomass was more in treatment receiving FYM, which serves as sources of carbon and nutrients.

Selvi *et al.,* (2004) reported that amongst the microbes, bacterial population was the highest as compared to fungi and actinomycetes in soil after all crops of cropping sequence. The control showed significantly lower value of microbial count. The higher level of N as well as use of FYM produced favourable influences on soil bacteria.

Effect of nutrient management

The data revealed that site specific nutrient management treatments have significant influence on actinomycetes population at flowering and harvest during both the years of study (Table 2). Among various nutrient management treatments, fertilizer applied through SSNM (STCR equation) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1}) showed significantly higher actinomycetes population (32.83 cfu x 10^4 g^{-1} soil, 26.08 cfu x 10^4 g^{-1} soil), (36.40 cfu x 10^4 g^{-1} soil, 30.03 cfu x 10^4 g^{-1} soil) than the rest of the treatments at flowering and at harvest during 2017-18 and 2018-19, respectively.

Likewise, lower value with concern to actinomycetes population obtained in treatment of no fertilizer i.e. control (24.75 cfu x 10^4 g^{-1} soil, 16.65 cfu x 10^4 g^{-1} soil), (26.88 cfu x 10^4 g^{-1} soil, 18.78 cfu x 10^4 g^{-1} soil) at flowering and at harvest during both the years, respectively.

This might be due to the positive influence of N and K from inorganic source at initial stages by masking the initial inhibitory effect of organic acids produced during decomposition which promoted the rapid multiplication of microflora in the soil. The present study findings were in agreement with those of Raghavendra *et al.,* (2018).

Fungal population of safflower

Effect of manure application

The data pertaining to the effect of different manure treatments on fungai population of safflower at flowering and at harvest during 2017-18 and 2018-19 are given in Table 3.

Table.1 Bacterial population (cfu x 10^6 g^{-1} soil) at flowering and at harvest of safflower as influenced by different treatments during the year 2017-18 and 2018-19

Treatments	2017-18		2018-19	
	At flowering	At harvest	At flowering	At harvest
A) Manure application				
M_0: No Manure	46.72	37.16	57.66	41.40
M_1: 5 t FYM ha^{-1}	64.82	57.17	72.82	63.39
M_2: Greengram (residue incorporation)	53.95	45.85	66.82	51.70
SE m±	1.08	1.14	1.28	1.02
CD @ 5%	3.09	3.27	3.66	2.90
B) Site specific nutrient management				
F_0: Control (No fertilizer)	44.25	35.88	55.18	39.13
F_1: Recommended NPK kg ha^{-1}	52.33	45.73	62.59	47.97
F_2: SSNM (STCR equation)	57.21	50.17	70.09	56.05
F_3: F_2 + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	59.32	52.97	73.89	59.13
F_4: SSNM (NPK) (deficient: +25% rec, medium: rec, high: - 25%)	56.00	48.88	67.28	52.88
SE m±	1.40	1.48	1.66	1.31
CD @ 5%	3.99	4.22	4.73	3.75
Interaction (M x F)				
SE m±	2.42	2.56	2.87	2.27
CD at 5%	NS	NS	NS	NS
GM	54.32	46.73	65.81	51.46

Table.2 Actinomycetes population (cfu x 10^4 g^{-1} soil) at flowering and at harvest of safflower as influenced by different treatments during the year 2017-18 and 2018-19

Treatments	2017-18		2018-19	
	At flowering	At harvest	At flowering	At harvest
A) Manure application				
M_0: No Manure	26.30	18.80	28.09	20.30
M_1: 5 t FYM ha^{-1}	31.67	24.81	35.10	27.35
M_2: Greengram (residue incorporation)	29.23	20.46	32.00	23.69
SE m±	0.53	0.59	0.64	0.75
CD @ 5%	1.52	1.67	1.83	2.15
B) Site specific nutrient management				
F_0: Control (No fertilizer)	24.75	16.65	26.88	18.78
F_1: Recommended NPK kg ha^{-1}	27.50	19.57	31.48	22.12
F_2: SSNM (STCR equation)	30.75	23.07	34.32	28.07
F_3: F_2 + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	32.83	26.08	36.40	30.03
F_4: SSNM (NPK) (deficient: +25% rec, medium: rec, high: - 25%)	29.50	21.42	32.73	25.07
SE m±	0.69	0.76	0.83	0.97
CD @ 5%	1.96	2.16	2.36	2.78
Interaction (M x F)				
SE m±	1.19	1.31	1.43	1.69
CD at 5%	NS	NS	NS	NS
GM	29.07	21.36	32.16	24.43

Table.3 Fungi population (cfu x 10^4 g^{-1} soil) at flowering and at harvest of safflower as influenced by different treatments during the year 2017-18 and 2018-19

Treatments	**2017-18**		**2018-19**	
	At flowering	**At harvest**	**At flowering**	**At harvest**
A) Manure application				
M_0: No Manure	18.65	10.80	20.90	14.03
M_1: 5 t FYM ha^{-1}	24.42	15.68	26.01	20.34
M_2: Greengram (residue incorporation)	21.50	13.41	24.30	18.44
SE m±	0.55	0.67	0.67	0.58
CD @ 5%	1.56	1.90	1.91	1.65
B) Site specific nutrient management				
F_0: Control (No fertilizer)	16.67	9.38	18.32	12.07
F_1: Recommended NPK kg ha^{-1}	19.47	11.30	21.70	15.52
F_2: SSNM (STCR equation)	23.55	15.13	26.28	20.57
F_3: F_2 + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	25.05	16.38	28.34	21.68
F_4: SSNM (NPK) (deficient: +25% rec, medium: rec, high: - 25%)	22.88	14.30	24.03	18.18
SE m±	0.71	0.86	0.87	0.75
CD @ 5%	2.02	2.46	2.47	2.13
Interaction (M x F)				
SE m±	1.22	1.49	1.50	1.29
CD at 5%	NS	NS	NS	NS
GM	21.52	13.30	23.74	17.60

During the year 2017-18 and 2018-19, among the manure application treatments, significantly highest fungai population (24.42 cfu x 10^4 g^{-1} soil, 15.68 cfu x 10^4 g^{-1} soil) and (26.01 cfu x 10^4 g^{-1} soil, 20.34 cfu x 10^4 g^{-1} soil) was observed with treatment of application 5 t FYM ha^{-1} followed by greengram residue incorporation (21.50 cfu x 10^4 g^{-1} soil, 13.41 cfu x 10^4 g^{-1} soil) and (24.30 cfu x 10^4 g^{-1} soil, 18.44 cfu x 10^4 g^{-1} soil) and no manure (18.65 cfu x 10^4 g^{-1} soil, 10.80 cfu x 10^4 g^{-1} soil) and (20.90 cfu x 10^4 g^{-1} soil, 14.03 cfu x 10^4 g^{-1} soil) at flowering and at harvest stage, respectively. Lowest fungal population in control plots was due to the without addition of any external input at flowering and at harvest during both the years of study. FYM is one of the suitable medium in which microbial inoculants grow to a reasonably higher number with long shelf life. The performances of FYM which stimulates fungal growth were of higher order, which is mainly attributed to dead food material available from FYM. Addition of organic manure like FYM, which might have regulated soil temperature and available soil moisture and the humus content of soil which have created favourable soil environment for sustenance, rapid multiplication and their activity on nutrient availability. Fungai population reduced at harvest this might be due to soil moisture content was very less at the time of harvest and undecomposed material left in soil had also decreased. The results are akin to those reported by Schenck (2003), Meena and Ghasolia *et al.,* (2013), Mairan and Dhawan (2016) and Badole and More (2000) reported that application of FYM resulted in the higher fungal population than the other organic source in cotton-groundnut cropping system.

Effect of nutrient management

Data regarding fungai population significantly influenced by site specific nutrient management treatments at flowering and at harvest stage during both the years of study are represented in Table 3.

During both the years of investigation, fungal population in soil was noticed highest with treatment application of fertilizer through SSNM (STCR equation) + ($ZnSO_4$@ 25 kg ha^{-1} + S @ 10 kg ha^{-1}) (25.05 cfu x 10^4 g^{-1} soil, 16.38 cfu x 10^4 g^{-1} soil), (28.34 cfu x 10^4 g^{-1} soil, 21.68 cfu x 10^4 g^{-1} soil) and found significantly superior over remaining site specific nutrient management treatments, which was being statistically identical with treatment of SSNM (STCR equation) (23.55 cfu x 10^4 g^{-1} soil, 15.13 cfu x 10^4 g^{-1} soil), (26.28 cfu x 10^4 g^{-1} soil, 20.57 cfu x 10^4 g^{-1} soil) at flowering and at harvest of safflower during 2017-18 and 2018-19, respectively.

The soil test based fertilizers application significantly enhanced the fungal population in soil as compared to control. The fungal population registered lowest in treatment of no fertilizer i.e. control at both stage of safflower during 2017-18 and 2018-19.

This might be due to increase in fungal population due to use of inorganic fertilizers in balanced form so create more acidification than pure due to nutrient response. Microbial oxidation of ammonium salts present in inorganic fertilizers leads to formation of nitric acid and decreased soil pH, a predisposing condition for fungal proliferation to take place. The results were in conformity with the findings of Raghavendra *et al.*, (2018).

From the above enumeration, it can be concluded that application of 5 t FYM ha^{-1} registered significantly highest values with respect to microbial population in soil i.e. bacteria, actinomyteces and fungi of *rabi* safflower under *rainfed* condition. Similarly, among nutrient management practices, application of fertilizer through SSNM (STCR equation) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @10 kg ha^{-1}) recorded maximum soil microbial population viz. bacterial, actinomyteces and fungi in safflower. Hence, it is advisable in Vidarbha region, that in *rabi* safflower, for higher productivity and remunerative crop, balanced amount of fertilizer through STCR integrated with organic manure should be applied for sustainable development of soil fertility and soil health.

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