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Influence of maize based vegetable cropping sequences on soil available nutrients and microbial populations

A.K.Kolage[1], N.J.Danawale[2], D.P.Pacharane[3] and D.W.Thawal[4]
Department of Agronomy, Mahatma Phule Krushi Vidyapeeth,
[1, 2] and [3] Assistant Professor of Agronomy, [4] Ex-Professor of Agronomy
Rahuri-413722, Dist. Ahmednagar (Maharashtra)
***Corresponding Author:** avikolage@gmail.com

ABSTRACT
The field experiment was conducted at Instructional Farm of Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri on clay soil during kharif and rabi seasons of 2014-15 and 2015-16. The objective was to study the soil available nutrients and microbial populations at harvest as influenced by maize based vegetable cropping sequences. The experimental results indicated that, at the end of two years of cropping sequences, application of fertilizer as per soil test crop response equation + FYM to kharif maize followed by 125 per cent general recommended dose of fertilizer to succeeding crops viz., onion, garlic and potato during rabi season found most suitable nutrient management in maize based vegetable cropping sequences for improving in soil available nutrients (N, P, K). Amongst the cropping sequences, maize-garlic cropping sequence found superior in improving the soil available nutrients. Regarding soil microbial populations, application of fertilizer as per soil test crop response equation + FYM to kharif maize followed by 75 per cent general recommended dose of fertilizer to succeeding crops viz., onion, garlic and potato during rabi season found most suitable nutrient management in maize based vegetable cropping sequences for improving in soil fungi, bacteria and actinomycetes. Whereas, maize-onion, maize-garlic and maize-potato cropping sequences showed highest populations in fungi, bacteria and actinomycetes, respectively.
Keywords: *Nutrient management, cropping sequences, soil available nutrients, soil fungi, bacteria and actinomycetes.*

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INTRODUCTION

One of the most promising avenues of boosting crop production is to increase the intensity of cropping. Sequence cropping is gaining importance in Indian agriculture. Rotation and sequence cropping plays an important role in cropping system research. The effects of modern agriculture on soil microbial communities are very complex; yet understanding them is important for the effective and sustainable management of agricultural ecosystems [12]. The soil microbial community is an important biological component valued for its role in improving soil health, nutrient availability, and crop productivity. Soils containing a high microbial diversity are characteristic of a healthy soil-plant relationship, whereas those with low microbial diversity are characterized as an unhealthy soil than often hardly responds to environmental changes [13].The microbial population dynamics is governed by interaction between plant type, climate and management practices. The microbiological and biochemical conditions of soil can serve as a marker of the soil status and is closely linked to its natural soil fertility. The objective of this experimental study was to evaluate the microbial dynamics and soil available nutrients as influenced by maize based vegetable cropping sequences.

MATERIAL AND METHODS

The field experiment was conducted during 2014-15 and 2015-16 at Post Graduate Research Farm, Department of Agronomy, MPKV., Rahuri (19° 48' N and 19° 57' N latitude, 74° 32' E and 74° 19' E longitude and 495 to 569 m above MSL). The experiment was carried out on clay type of soil with low in available nitrogen (156.80 kg ha-1), medium in available phosphorus (17.09 kg ha-1) and high in available potassium (492.80 kg ha-1). The soil was moderately alkaline in reaction (pH 8.02). The electrical conductivity and organic carbon were 0.35 dSm^{-1} and 0.56, respectively.

Experimental design and treatments

The experiment was laid out in randomized block design in *kharif* season in nine replications and strip plot design in *rabi* season with three replications. The treatment consisted of three cropping sequences *viz.,* C_1:maize-onion, C_2:maize-garlic and C_3:maize-potato with four nutrient management treatments *viz.,* T_1-general recommended dose of fertilizer (GRDF), T_2-fertilizer dose as per soil test (AST), T_3- Fertilizer dose as per Soil Test Crop Response yield equation for 100 q ha^{-1} targeted yield without FYM and T_4-Fertilizer dose as per Soil Test Crop Response yield equation for 100 q ha^{-1} targeted yield with FYM whereas three fertilizer levels to rabi crops *viz.,* F_1-75 % GRDF, F_2-100 % GRDF and F_3- 125 % GRDF as sub plot treatments. Maize- NK 6240, onion- N 2-4-1, garlic- Phule Baswant and potato-*Kufri Jyoti* cultivars were used during *kharif* and *rabi* seasons, respectively. Both the years of crop seasons were favourable to grow the *kharif* and *rabi* crops. The recommended package of practices were adopted to grow the crops and fertilizers were applied as per treatment.

Soil sampling

Initial soil samples were collected in June-2014 prior to the start of the experiment and after harvest of each crop during *kharif* and *rabi* seasons. Soil samples were taken as per treatment wise from the surface layer (0-30 cm) of with three replications for soil chemical analysis during 2014-15 and 2015-16. For soil microbial analysis initial soil sample was collected from the surface layer (0-30 cm) before maize (*kharif*) at harvest onion, garlic and potato (rabi crops) during both the years. These soil samples were kept at 4.0°C in plastic bags for a few days to stabilize the microbiological activity disturbed during soil sampling and handling and then analysed. Total fungi, bacteria and actinomycetes were estimated by the standard procedure of Serial Dilution Plate Technique [4]

RESULT AND DISCUSSION

A. Soil available nutrients

1. Maize-onion cropping sequence :

In residual effect of *kharif* maize, application of fertilizer dose as per STCR equation with FYM registered significantly maximum available nitrogen (194.03 and 195.52 kg ha^{-1}), phosphorus (28.49 and 29.73 kg ha^{-1}) and potassium (524.65 and 533.82 kg ha^{-1}) than rest of the treatments during both the years. However, it was at par with the treatment as per general recommended dose of fertilizer in case of phosphorus during first year of the experiment. Regarding potassium, it was at par with the treatment as per general recommended dose of fertilizer and the treatment STCR equation without FYM during first year. Maximum soil available nutrients were observed in fertilizer dose as per STCR equation with FYM because of higher addition of nutrients in soil. Similar findings were reported by[8], [14] and [10].

In fertilizer levels to *rabi* onion, application of 125 per cent general recommended dose of fertilizer to *rabi* onion registered significantly maximum soil available nitrogen, phosphorus and potassium than rest of the treatments. These results are in accordance with [11][15]. The interaction effect between residual effect of *kharif* maize and fertilizer levels to *rabi* onion was found significant in respect of soil available phosphorus during first year and in case of nitrogen during first year of the experiment. The higher soil available nitrogen, phosphorus and potassium was might be because of nutrients added to succeeding crops was sufficient to harvest yield potential of crops in cropping system. Similar findings were reported by [7] [3].

2. Maize-garlic cropping sequence : In residual effect of *kharif* maize, application of fertilizer dose as per STCR equation with FYM registered significantly maximum available nitrogen (196.52 and 199.18 kg ha^{-1}), phosphorus (28.06 and 31.00 kg ha^{-1}) and potassium (532.35 and 535.00 kg ha^{-1}) than rest of the treatments during both the years. However, it was at par with the treatment as per general recommended dose of fertilizer in case of potassium during first year of the experiment. The higher soil available nitrogen, phosphorus and potassium was might be because of the nutrients added to succeeding crops was sufficient to harvest yield potential of crops in cropping sequences. Similar findings were reported [15][3].

In fertilizer levels to garlic, application of 125 per cent general recommended dose of fertilizer to garlic registered significantly higher soil available nitrogen, phosphorus and potassium than rest of the treatments. Similar findings postulated by [7] and [1].Interaction effect between residual effect of *kharif* maize and fertilizer levels to garlic was found non significant.

3. Maize-potato cropping sequence :

In residual effect of *kharif* maize,application of fertilizer dose as per STCR equation with FYM registered significantly maximum available nitrogen (191.15 and 192.58 kg ha^{-1}), phosphorus (30.27 and 30.94 kg ha^{-1}) and potassium (529.12 and 533.17 kg ha^{-1}) than rest of the treatments during both the years. However, it was at par with the treatment as per general recommended dose of fertilizer in case of

available phosphorus and potassium during first year and under available phosphorus during second year of the experiment.

In fertilizer levels to potato, application of 125 per cent general recommended dose of fertilizer to potato registered significantly higher soil available nitrogen, phosphorus and potassium than rest of the treatments. However, it was at par with application of 100 per cent general recommended dose of fertilizer to potato, under available nitrogen during first year. Interaction effect between residual effect of *kharif* maize and fertilizer levels to potato was found non significant in respect of soil available nitrogen, phosphorus and potassium during both years of the experiment.

B. Soil microbial populations

1. Maize-onion cropping sequence : In residual effect of *kharif* maize, application of fertilizer dose as per STCR equation with FYM registered significantly higher populations of fungi (9.67 and 9.89 cfu X 10^4 g^{-1} of soil), bacteria (13.89 and 14.00 cfu X 10^5 g^{-1} of soil) and *actinomycetes* (6.00 and 6.11 cfu X 10^6 g^{-1} of soil) than rest of the treatments during both the years of the experiment except in case of *actinomycetes* during second year, it was found non significant. However, it was at par with the treatment as per general recommended dose of fertilizer in respect to fungi, bacteria during both years and *actinomycetes* during first year.

In fertilizer levels to *rabi* onion, application of 75 per cent general recommended dose of fertilizer to *rabi* onion recorded significantly maximum number of fungi (9.83 and 9.92 cfu x 10^4 g^{-1} of soil), bacteria (12.89 and 12.92 cfu x 10^5 g^{-1} of soil) and *actinomycetes* (5.92 and 6.00 cfu x 10^6 g^{-1} of soil) than rest of the treatments during both the years of the experiment except in case of *actinomycetes* during second year, it was found non significant. However, it was at par with application of 100 per cent general recommended dose of fertilizer in respect to fungi, bacteria and *actinomycetes* during first years, while in case of fungi and bacteria during second year of the experiment. The interaction effect between residual effect of *kharif* maize and fertilizer levels to *rabi* onion were found non significant in respect of fungi, bacteria and *actinomycetes* during both the years. On an average the growth was more during second year as compared to first year but more as compared to initial. These results are in agreement with those reported [8] and [9].

2. Maize-garlic cropping sequence :

In residual effect of *kharif* maize, application of fertilizer dose as per STCR equation with FYM registered significantly higher population of fungi (8.89 and 10.00 cfu x 10^4 g^{-1} of soil), bacteria (14.00 and 15.11 cfu x 10^5 g^{-1} of soil) and *actinomycetes* (5.02 and 5.13 cfu x 10^6 g^{-1} of soil) than rest of the treatments except in case of *actinomycetes*, it was found non significant during both the years of the experiment. However, it was at par with the treatment as per general recommended dose of fertilizer in respect to bacteria during both years.

In fertilizer levels to garlic, application of 75 per cent general recommended dose of fertilizer to garlic recorded significantly maximum number of fungi (8.67 and 9.75 cfu x 10^4 g^{-1} of soil), bacteria (13.75 and 14.67 cfu x 10^5 g^{-1} of soil) and *actinomycetes* (5.27 and 5.25 cfu x 10^6 g^{-1} of soil) than rest of the treatments during both the years of the experiment. However, it was at par with the treatment, application of 100 per cent general recommended dose of fertilizer in respect to *actinomycetes* during first year, while in case of fungi, bacteria and *actinomycetes* during second year of the experiment. The interaction effect between residual effect of *kharif* maize and fertilizer levels to garlic was found non significant in respect of fungi. Soil microbial mass is the index of soil fertility which depends upon nutrient fluxes. Similar findings were postulated by [10] ,[2] .

3. Maize-potato cropping sequence :

In residual effect of *kharif* maize, application of fertilizer dose as per STCR equation with FYM registered significantly higher population of fungi (8.56 and 9.33 cfu x 10^4 g^{-1} of soil), bacteria (13.56 and 13.91 cfu x 10^5 g^{-1} of soil) and *actinomycetes* (7.00 and 7.22 cfu x 10^6 g^{-1} of soil) than rest of the treatments during both the years of the experiment except in case of *actinomycetes*, it was found non significant during first year. However, it was at par with the treatment as per general recommended dose of fertilizer in respect to fungi, bacteria during both years and *actinomycetes* during first year. Similar findings were reported by [5] [9][12].

In fertilizer levels to potato, application of 75 per cent general recommended dose of fertilizer to potato recorded significantly maximum number of fungi (8.33 cfu x 10^4 g^{-1} of soil) during first year and *actinomycetes* (7.17 and 7.25 cfu x 10^6 g^{-1} of soil) during first and second year, respectively than rest of the treatments However, it was at par with the treatment, application of 100 per cent general recommended dose of fertilizer in respect to fungi and *actinomycetes* during first year, while in case of *actinomycetes* during second year of the experiment. The interaction effect between residual effect of *kharif* maize and fertilizer levels to potato were found non significant in respect of fungi, bacteria and *actinomycetes* during both the years.

CONCLUSION

On the basis of two years of experiment, it could be concluded that, application of fertilizer as per soil test crop response equation + FYM to *kharif* maize followed by 125 per cent general recommended dose of fertilizer to succeeding crops viz., onion, garlic and potato during *rabi* season found most suitable nutrient management in maize based vegetable cropping sequences for improving in soil available nutrients (N, P, K) and 75 per cent general recommended dose of fertilizer to succeeding crops viz., onion, garlic and potato during *rabi* season showed maximum soil microbial populations (fungi, bacteria and *actinomycetes*). Amongst the cropping sequences, maize-garlic cropping sequence found superior in improving the soil available nutrients whereas, maize-onion, maize-garlic and maize-potato cropping sequences showed highest populations in fungi, bacteria and *actinomycetes,* respectively.

Table No.1 Soil available nutrients as influenced by different treatments after harvest of cropping sequences.

Treatments	Maize-onion						Maize-garlic						Maize-potato					
	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
A. Nutrient management (*Kharif* maize)																		
T_1:GRDF	184.08	187.31	27.55	27.79	518.47	522.23	185.39	190.39	26.99	29.43	519.35	523.76	178.46	184.10	28.83	29.50	512.95	518.76
T_2:AST	166.98	174.87	23.11	24.81	477.60	481.91	174.59	183.85	26.87	28.02	492.38	496.14	150.19	157.91	21.60	22.38	462.80	465.35
T_3:STCR eq^{n}	179.09	183.19	24.90	26.63	507.66	512.84	184.30	187.46	26.97	29.20	508.43	514.37	177.52	178.27	22.83	24.11	504.38	509.06
T_4:STCR eq^{n} + FYM	194.03	195.52	28.49	29.73	524.65	533.82	196.52	199.18	28.06	31.00	532.35	535.00	191.15	192.58	30.27	30.94	529.12	533.17
S.Em. ±	2.19	2.23	0.54	0.50	6.44	3.07	2.00	1.72	0.18	0.26	6.70	1.71	2.02	2.37	0.57	0.47	7.48	2.37
C.D.at 5%	7.59	7.73	1.85	1.72	22.29	10.63	6.91	5.95	0.61	0.90	23.18	5.91	7.00	8.19	1.96	1.64	25.88	8.21
B. Fertilizer levels (*Rabi* crops)																		

F1: 75 % GRDF	F2:100 % GRDF	F3:125 % GRDF	S.Em. ±	C.D.at 5%	C. Interaction (AxB)		Initial soil status
468.17	506.48	545.11	2.08	6.23		NS	**492.80**
463.19	502.14	541.61	7.29	21.86		NS	**492.80**
22.07	26.20	31.92	0.31	0.93		NS	**17.09**
21.57	25.81	30.26	0.65	1.93		NS	**17.09**
162.15	179.80	192.69	2.79	8.38		NS	**156.8**
159.63	177.16	186.20	3.60	10.80		NS	**156.8**
490.68	517.79	543.48	3.43	10.29		NS	**492.80**
488.59	509.28	541.51	6.72	20.14		NS	**492.80**
25.35	29.70	33.19	0.23	0.70		NS	**17.09**
23.85	27.15	30.66	0.16	0.48		NS	**17.09**
175.12	190.96	204.58	1.67	5.01		NS	**156.8**
170.99	187.41	197.21	1.37	4.11		NS	**156.8**
484.29	508.10	545.71	2.10	6.31		NS	**492.8**
480.83	502.94	537.51	5.03	15.07		NS	**492.80**
20.98	26.49	34.24	0.54	1.62		NS	**17.09**
20.80	24.90	32.34	0.27	0.81		Sig*	**17.09**
171.17	184.18	200.31	1.68	5.04		Sig	**156.8**
168.71	179.46	194.97	2.05	6.15		NS	**156.8**

Table No.2 Soil microbial populations as influenced by different treatments after harvest of cropping sequences.

Treatments			A. Nutrient management (*Kharif* maize) T1 GRDF	T2 AST
Maize-potato	**Actino--mycetes** (cfuX10^6 g^{-1} of soil)	2015-16	6.89	6.44
		2014-15	6.56	6.22
	Bacteria (cfuX10^5 g^{-1} of soil)	2015-16	13.17	10.88
		2014-15	13.11	10.56
	Fungi (cfuX10^4 g^{-1} of soil)	2015-16	8.44	7.89
		2014-15	8.33	7.78
Maize-garlic	**Actino--mycetes** (cfuX10^6 g^{-1} of soil)	2015-16	4.56	4.71
		2014-15	4.60	4.56
	Bacteria (cfuX10^5 g^{-1} of soil)	2015-16	14.22	13.78
		2014-15	13.44	12.89
	Fungi (cfuX10^4 g^{-1} of soil)	2015-16	9.22	9.11
		2014-15	8.22	8.00
Maize-onion	**Actino--mycetes** (cfuX10^6 g^{-1} of soil)	2015-16	5.67	5.44
		2014-15	5.56	5.33
	Bacteria (cfuX10^5 g^{-1} of soil)	2015-16	13.44	10.89
		2014-15	13.56	11.00
	Fungi (cfuX10^4 g^{-1} of soil)	2015-16	9.67	9.11
		2014-15	9.56	9.22

T_3	STCR eq^n	8.78	8.89	10.78	11.00	5.11	5.22	7.78	8.89	11.67	12.67	4.40	4.38	8.11	8.00	11.22	11.23	6.22	6.67
T_4	STCR eq^n + FYM	9.67	9.89	13.89	14.00	6.00	6.11	8.89	10.00	14.00	15.11	5.02	5.13	8.56	9.33	13.56	13.91	7.00	7.22
S.Em. ±		0.14	0.17	0.21	0.24	0.14	0.19	0.18	0.14	0.22	0.34	0.19	0.18	0.09	0.29	0.33	0.31	0.17	0.18
C.D.at 5%		0.50	0.60	0.74	0.83	0.50	NS	0.63	0.50	0.76	1.18	NS	NS	0.31	0.99	1.14	1.08	0.58	NS
B. Fertilizer levels (*Rabi* crops)																			
F_1	75 % GRDF	9.83	9.92	12.83	12.92	5.92	6.00	8.67	9.75	13.75	14.67	5.27	5.25	8.33	8.75	12.25	12.55	7.17	7.25
F_2	100 % GRDF	9.50	9.50	12.42	12.33	5.58	5.67	8.42	9.25	13.00	14.00	4.77	4.85	8.50	8.33	12.08	12.50	6.67	7.08
F_3	125 % GRDF	8.58	8.75	11.67	11.75	5.00	5.17	7.58	8.92	12.25	13.17	3.90	3.98	7.25	8.17	12.00	11.85	5.67	6.08
S.Em. ±		0.17	0.25	0.19	0.27	0.24	0.28	0.20	0.21	0.18	0.24	0.17	0.19	0.25	0.50	0.37	0.46	0.19	0.32
C.D.at 5%		0.50	0.75	0.56	0.82	0.71	NS	0.59	0.64	0.54	0.71	0.51	0.57	0.75	NS	NS	NS	0.56	0.95
C. Interaction (AxB)																			
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial soil status		**7.95**	**7.95**	**9.81**	**9.81**	**5.31**	**5.31**	**7.95**	**7.95**	**9.81**	**9.81**	**5.31**	**5.31**	**7.95**	**7.95**	**9.81**	**9.81**	**5.31**	**5.31**

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