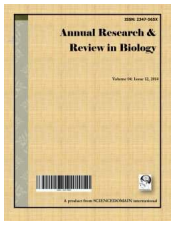

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Synergistic Effect of Organic, Inorganic and Biofertilizers on Soil Microbial Activities in Rhizospheric Soil of Green Pea

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Authors' contributions

This work was carried out in collaboration between all authors. Author HK performed the experiments. Authors SKG and SSW designed the study, wrote the protocol and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

To study the effect of incorporation of organic, inorganic and biofertilizers on rhizospheric microbial population and enzyme activities at various time intervals in pea crop, the experiment was laid in randomized blocked design in triplicate with plot size of 7 ×2.5 m^2 using Punjab-88 variety. Study was conducted during winter season of 2015-16 in field of Department of Agronomy, Punjab Agricultural University, Ludhiana, India. Enumeration of bacteria, fungi, actinomycetes, diazotrophs, PGPR and PSB was done on Nutrient Agar medium, Glucose Yeast Extract medium, Kenknight's medium, Jensen's medium, King's B medium and NBRIP medium respectively, using serial dilution spread plate technique. Activities of soil enzymes (Alkaline phosphatase, Urease and Dehydrogenase) were studied. Significantly higher total bacterial population (150 ×10^7 CFU g^{-1} of soil) and PGPR (218 ×10^5 CFU g^{-1} of soil) population was observed in treatments when there was combination of organic, inorganic and consortium biofertilizer. Actinomycetes remained unaffected with different fertilizers. Biofertilizer used in combination with FYM resulted in significantly higher

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population of fungi (20 $\times 10^3$ CFU g^{-1} of soil), diazotrophs (140 $\times 10^5$ CFU g^{-1} of soil) and PSB (80 $\times 10^4$ CFU g^{-1} of soil). Among rhizospheric soil enzyme activities, alkaline phosphatase activity was significantly higher in treatment with FYM +consortium biofertilizer while dehydrogenase activity was higher in treatment with inorganic fertilizer +FYM +consortium biofertilizer. Urease activity showed a variable pattern during different time intervals. Microbial activities were also affected by different stages of plant growth. Total bacterial population showed positive correlation with enzyme activities during initial stages of plant growth but showed negative correlation with urease activity during late stages of plant growth. Combined application of organic and inorganic fertilizers resulted in improved soil microflora leading to significantly higher enzyme activities which were further enhanced by inoculation of biofertilizers.

Keywords: Consortium; enzyme; microflora; plant growth and soil.

1. INTRODUCTION

In Indian agriculture system, increasing crop production is the major need of the hour in order to sustain the increasing human population. Adequate soil fertility ensures appropriate nutrient availability to the plant thereby ensuring enhanced crop growth and increased yield [1]. However, excessive use of chemical fertilizer in order to boost crop production may not prove propitious on soil health. The term soil health characterizes the soil as a dynamic system comprised of living microorganisms which embody the soil ecosystem. Soil microflora constitutes the biological parameters of soil which are considered to play a vital role in maintaining soil health, productivity, and sustainability [2]. Chemical fertilizers not only leave toxic elements; although in trace amounts in soil; but also alter the microbial dynamics thereby interfering with soil fertility levels.

In a soil-plant system, the rhizosphere determines the overall interactions (soil and plant health) therefore any change in fertility management will strongly influence the soil-plant interactions. In context of soil fertility management, addition of biofertilizers is emerging as an economically attractive and ecologically sound means of fertilization [3]. Microbial inoculants constitute an important part of integrated nutrient management that leads to sustainable agriculture. Biofertilizer are the microbial inoculants which contains living micro organisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant [4]. They improve soil structure and add organic matter to the soil. Besides improving soil health they also reduce the application of chemical fertilizers thereby lowering their toxic effect.

Organic manures can be used as adjuncts to promote population of beneficial microorganisms in the soil. A prudent use of organic manures and biofertilizers may be fruitful in not only maintaining sustainable crop production and soil health but also supplement chemical fertilization of the crop [5]. Pea is used in human diet throughout the world and it is rich in protein (21-25%), carbohydrates, vitamins A and C, calcium and phosphorous and has high levels of amino acids lysin and tryptophan [6]. The green pea (*Pisum sativum* L.) of the family Papilionoideae is a cool season nutritive and pod shaped vegetable crop. It is commonly green in color and can be occasionally purple or golden yellow. So keeping all the points in concern, the study was proposed to evaluate the effect of combined effect of organic, inorganic and biofertilizers on microbial dynamics of rhizospheric soil of green pea.

2. MATERIALS AND METHODS

2.1 Experimental Design and Treatments

A field experiment was conducted during winter season of 2015-16 in field of Department of Agronomy, Punjab Agricultural University, Ludhiana, India. The geographical location of the area is 30.9010^{o}N and 75.8573^{o}E (about 262 m above sea level). The experiment was laid in randomized blocked design in triplicate with plot size of 7 ×2.5 m using Punjab-88 variety. A total of 10 different fertilizer combinations were made which are listed in Table 1.

The experiment was conducted by following package and practices of PAU. All the treatments were inoculated with *Rhizobium* culture. The inorganic fertilizer viz. urea was applied @ 50 kg per acre, diammonium phosphate @ 80 kg per acre and organic fertilizer in the form of farm yard manure (FYM) @ 100 kg per acre. Consortium

biofertilizer (Phosphate Solubilizing Bacteria (PSB) + Plant Growth Promoting Rhizobacteria (PGPR)) were used in different combinations with organic and inorganic fertilizers.

Table 1. Details of treatments used in experiment

Treatments	Fertilizer
T1	Without NPK
T2	N(100%) + P(100% of recommended dose)
T3	NP 50% from organic + 50% from inorganic
T4	NP 25% from organic + 75% from inorganic
T5	NP 100% from organic
T6	T1+ consortium biofertilizer
T7	T2+ consortium biofertilizer
T8	T3+ consortium biofertilizer
T9	T4+ consortium biofertilizer
T10	T5+ consortium biofertilizer

2.2 Soil Sampling and Analysis

Soil samples were collected with auger from rhizospheric soil (0-15 cm) of pea crop grown at the research field at different time intervals- 0, 30, 60 and 90 DAS (Days After Sowing) and at harvest. Enumeration of bacteria, fungi, actinomycetes, diazotrophs, PGPR (Plant Growth Promoting Rhizobacteia) and PSB (Phosphorous solubilizing bacteria) was done on Nutrient Agar medium, Glucose Yeast Extract medium, Kenknight's medium, Jensen's medium, King's B medium and NBRIP medium respectively, using serial dilution spread plate technique. Activities of soil enzymes as: alkaline phosphatase by the method of Tabatabai and Bremner 1969 [7], urease by the method of Douglas and Bremner 1971 [8] and dehydrogenase by the method of Tabatabai 1982 [9] were studied. The soil samples were dried, crushed and sieved to perform the enzyme activities assay.

2.3 Statistical Analysis

A two-factor analysis of variance (ANOVA) was performed to determine the effect of different fertilizer treatments, stages of plant growth and their interaction on soil microbial population and enzyme activities. Correlation among different microbial population and enzyme activities was executed to observe the synergistic and/or antagonist effect among various parameters. For statistical analysis of data, CPCS1 and SPSS 16.0 software were used. The level of significance referred in the results is $P< 0.05$.

3. RESULTS AND DISCUSSION

The results obtained indicated that microbial population and soil enzyme activities were significantly affected by biofertilizer inoculation and the stages of plant growth. The initial soil bacterial count was found to be 51 $\times 10^7$ CFU g^{-1} of soil, fungal count was observed to be 7 $\times 10^3$ CFU g^{-1} of soil, actinomycetes count was 21 $\times 10^4$ CFU g^{-1} of soil, diazotrophs count 13 $\times 10^5$ CFU g^{-1} of soil, PSB count was 8 $\times 10^4$ CFU g^{-1} of soil and PGPR count was 42 $\times 10^5$ CFU g^{-1} of soil. Microbial population increased from 0 days indicating the establishment of inoculated biofertilizer.

3.1 Bacterial Population

The total bacterial count was found maximum (150 $\times 10^7$ CFU g^{-1} of soil) at 60 days time interval in treatment with inorganic fertilizer +FYM +consortium biofertilizer, which was statistically higher than control and all other fertilization treatments. It may be due to the fact that solid manure introduces a high amount of beneficial microflora and phytohormones in the soil which increases the organic matter content and water-air relationships in the soil. These results were in accordance with works of Mandal et al. [1] and Zhong et al. [10]. The increase in bacterial population with biofertilization may be attributed to supplementation of soil with beneficial bacteria through biofertilizer inoculation which supported bacterial growth due to their role in phytohormone production, detoxification of soils contaminated with heavy metals and high salt levels, extracellular polysaccharide synthesis and other processes. The increase in bacterial population from 30 DAS to 60 DAS is due to establishment of bacterial population with increased rhizodeposits and availability of nutrients [11].

3.2 Fungal Population

The maximum count of fungal population (20 $\times 10^3$ CFU g^{-1} of soil) was observed in soil samples treated with FYM +consortium biofertilizer at 90 days after sowing. However, the interaction of treatments with stages of plant growth exhibited a non significant effect on fungal population in rhizospheric soil.

Table 2. Microbial population in different treatments at different time intervals in rhizospheric soil of pea

Days after sowing	Treatments	Bacteria ($\times10^7$ CFU g^{-1} soil)	Fungi ($\times10^3$ CFU g^{-1} soil)	Actinomycetes ($\times10^4$ CFU g^{-1} soil)	Diazotrophs ($\times10^5$ CFU g^{-1} soil)	PSB ($\times10^4$ CFU g^{-1} soil)	PGPR ($\times10^5$ CFU g^{-1} soil)
3	T1	63 ± 2	7 ± 0	**62** ± 2.64	32 ± 2	10 ± 1	54 ± 3
0	T2	78 ± 3	8 ± 1	31 ± 1.73	52 ± 3	15 ± 2	77 ± 2
	T3	95 ± 3.6	10 ± 2	48 ± 3.6	59 ± 3	19 ± 3	88 ± 4.0 4
D	T4	89 ± 1.73	9 ± 0	37 ± 2.64	54 ± 2.64	17 ± 2	98 ± 3
A	T5	86 ± 2.64	13 ± 1.73	57 ± 3.61	92 ± 3.61	22 ± 3	9 0 ± 2
Y	T6	84 ± 2	9 ± 1	55 ± 2	76 ± 2	40 ± 3	76 ± 3
S	T7	98 ± 3	11 ± 1.73	27 ± 1.73	89 ± 3.61	49 ± 3.61	1 04 ± 3.6
	T8	**114** ± 4.3	12 ± 1	31 ± 3	101 ± 3.61	68 ± 2.64	**164** ± 4.4
	T9	110 ± 2.6	10 ± 2.64	29 ± 2	98 ± 3	57 ± 3	140 ± 3
	T10	102 ± 3	**15** ± 1	42 ± 2	**120** ± 4.36	**72** ± 2.64	138 ± 2.6
6	T1	86 ± 3	9 ± 1	**51** ± 2.64	52 ± 2	21 ± 2	84 ± 2
0	T2	94 ± 2.64	10 ± 1.73	26 ± 2	68 ± 3	34 ± 2	96 ± 3
	T3	108 ± 3	13 ± 1	39 ± 2.52	76 ± 2.64	44 ± 2	114 ± 3
D	T4	101 ± 2.5	11 ± 1.73	32 ± 2.64	71 ± 1	40 ± 1.73	1 36 ± 3.6
A	T5	98 ± 3.61	14 ± 2	49 ± 3.61	110 ± 2.08	46 ± 2.64	124 ± 3.4
Y	T6	118 ± 3	11 ± 1	42 ± 2	89 ± 2	55 ± 2.64	108 ± 3
S	T7	126 ± 3.6	13 ± 1.7	21 ± 2	96 ± 3	62 ± 2.64	143 ± 3
	T8	**150** ± 3	14 ± 2	26 ± 2	117 ± 2.64	78 ± 2.64	**198** ± 4.3
	T9	142 ± 1	12 ± 1	19 ± 2.31	106 ± 4.58	73 ± 2.64	16 5 ± 3
	T10	137 ± 2.6	**18** ± 1.7	27 ± 3	**140** ± 5.29	**80** ± 2	159 ± 2
9	T1	82 ± 3	10 ± 1.73	**43** ± 2	49 ± 3.6	22 ± 2	98 ± 3
0	T2	89 ± 3.6	12 ± 1	17 ± 1	61 ± 3	28 ± 3	115 ± 2.5
	T3	94 ± 3	15 ± 2	25 ± 3	69 ± 3	32 ± 2.64	138 ± 3.6
D	T4	96 ± 3.46	14 ± 2.64	23 ± 0	65 ± 2.1	35 ± 2.61	15 7 ± 5.3
A	T5	90 ± 2	17 ± 2	33 ± 1.73	102 ± 3.61	39 ± 3	149 ± 2.6
Y	T6	114 ± 3	13 ± 1.73	36 ± 2.65	82 ± 2	42 ± 1	126 ± 3
S	T7	119 ± 2	14 ± 1	13 ± 1	91 ± 3.60	57 ± 2	167 ± 4.3
	T8	**138** ± 1	16 ± 2.46	16 ± 2	104 ± 3	67 ± 3	**218** ± 3
	T9	130 ± 3	13 ± 1	14 ± 1	86 ± 2.64	63 ± 2.65	186 ± 5.5
	T10	121 ± 2.6	**20** ± 2	23 ± 0	**112** ± 2	**78** ± 3	172 ± 3
1	T1	79 ± 2.51	8 ± 0	**29** ± 3	34 ± 2	13 ± 2	78 ± 3
2	T2	86 ± 2	11 ± 1	10 ± 1	50 ± 2	20 ± 1	98 ± 3.05
0	T3	90 ± 3	14 ± 2	14 ± 2	56 ± 2	28 ± 2	105 ± 2
	T4	89 ± 3.46	13 ± 1.73	12 ± 2	52 ± 3	24 ± 3	135 ± 3
D	T5	87 ± 3	15 ± 3	25 ± 3	96 ± 4	31 ± 4	129 ± 3
A	T6	107 ± 2.6	10 ± 1	22 ± 2	78 ± 3	34 ± 2	110 ± 2
Y	T7	110 ± 2	12 ± 2.64	8 ± 0	86 ± 2	42 ± 3	127 ± 3.5
S	T8	118 ± 2.6	13 ± 2.64	10 ± 1	98 ± 1	52 ± 1	**132** ± 3.4
	T9	**124** ± 4.6	9 ± 1	9 ± 1.73	84 ± 2.64	50 ± 1.73	126 ± 3
	T10	112 ± 2.6	**19** ± 3.6	12 ± 2	**106** ± 2	**61** ± 2.52	118 ± 2
CD @5%							
Environment		**1.24**	**0.77**	**0.92**	**1.43**	**0.99**	**1.42**
Treatment		**1.96**	**1.22**	**1.46**	**2.26**	**1.58**	**2.24**
Interaction		**3.92**	**NS**	**2.91**	**4.52**	**3.16**	**4.48**

All values are mean of three replications

Although, the interaction of various treatments with different time intervals showed statistically non significant effect of fungal population, addition of FYM significantly increased the fungal population. However, inorganic fertilizers seemed to have retrogressive effect on growth of fungal strains which can be related to production of toxic metabolites from mineral nitrogen [12].

3.3 Actinomycetes Population

The application of different fertilization systems had significant effect on growth of actinomycetes. Highest population of actinomycetes (62 $\times 10^4$ CFU g^{-1} of soil) was observed in uninoculated treatment i.e without any fertilization at 30 days time interval. The adversary effect of microbial inoculants on actinomycetes growth may be attributed to secretion of antibiotics by inoculated PGPR strain, such as 2,4-diacetylphloroglucinol which exhibits antifungal properties. The decrease in actinomycetes population over period of plant growth is due to progressive increase in PGPR population. Significantly higher actinomycetes population in treatment without any fertilization can be supported by the fact that they are efficient decomposers of nutrient poor carbon sources and exhibit high activity in nitrogen limited soils [13,14].

3.4 Diazotroph Population

FYM and consortium biofertilizer had stimulating effect on rhizospheric diazotroph population. Maximum population (140 $\times 10^5$ CFU g^{-1} of soil) was observed at 60 days time interval. The reason behind high population in treatment with FYM +consortium biofertilizer may be that FYM supplements the soil with high amount of organic matter leading to increased carbon and energy sources for rapid diazotroph growth. Addition of biofertilizers which act as supplementation to the soil nitrogen assimilates thereby inducing the growth of oligonitrophilic bacteria and *Azotobacter*. Similar results were reported by Park et al. [15], Biari et al [16] and Emtsev et al. [17] who studied the positive effects of biofertilizers on soil biological parameters.

3.5 PSB Population

The results indicated increase in PSB population with biofertilizer inoculation (Table 2). Maximum PSB population (80 $\times 10^4$ CFU g^{-1} of soil) was observed in treatment with FYM +consortium biofertilizer at 60 days time interval. The PSB population in treatments with biofertilizer inoculation was significantly higher than treatments without biofertilizer inoculation. This may be attributed to the supplementation of PSB to the soil by the addition of consortium biofertilizer. Treatments containing inorganic sources of phosphorus had significantly lower PSB population than organically treated treatments because of the inhibitory effect of inorganic phosphate applied via chemical fertilizer on the growth of PSB. Maximum population was observed at 60 DAS time interval owing to establishment of the microflora whereas decrease from 60 DAS to 90 DAS and finally to harvest may be attributed to decrease in optimum temperature during winter season.

3.6 PGPR Population

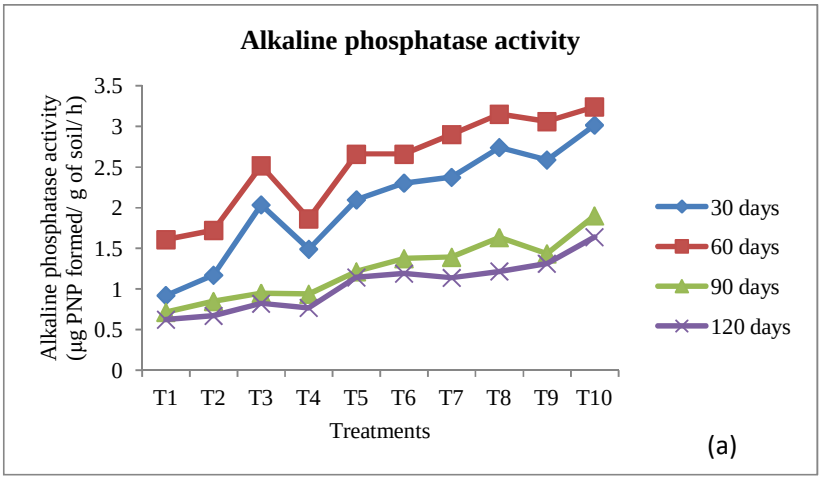
Significantly higher PGPR population (218 $\times 10^5$ CFU g^{-1} of soil) was observed in treatments with biofertilizer inoculation in comparison with treatments without biofertilizer inoculation (Table 2). This may be due to various activities associated with microbial inoculants such as regulation of soil nitrogen regime, phytohormone production, detoxification of soils contaminated with heavy metals and high salt levels, extracellular polysaccharide synthesis and other processes [15,16,17]. Higher PGPR population in treatments having combination of both organic and inorganic can be due to the fact that bacteria are the most sensitive group of microorganisms and they can react faster to the environmental changes than other groups of microorganisms. Addition of FYM introduces readily available organic compounds thus inducing the growth of PGPR.

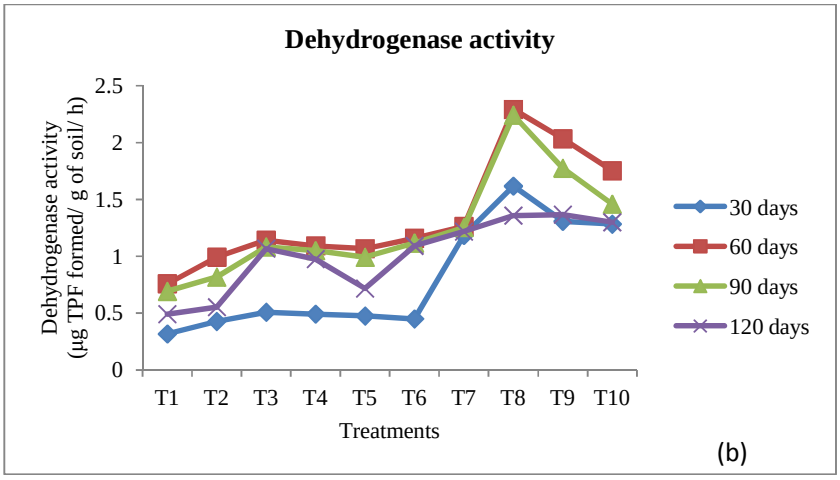
3.7 Enzyme Activities

Soil enzymes produced by the soil inhabitants are continuously playing an important role in maintaining soil ecology, physical and chemical properties, fertility and soil health. The effect of different fertilizer management systems was studied in which different treatments, days and their interactions had significant relation with enzyme activities.

3.7.1 Alkaline phosphatase

The results indicated that alkaline phosphatase activity was significantly higher in treatments having biofertilizers inoculations as compared to uninoculated treatments (Fig. 1(a). Moreover, treatments having combined application of organic and inorganic fertilizers had higher alkaline phosphatase activity as compared to





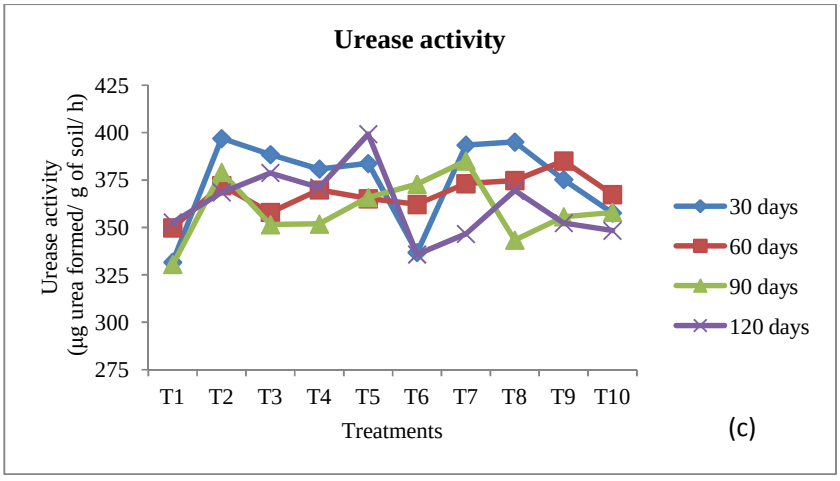


Fig. 1 (a-c). Enzyme activities in different treatments at different time intervals

treatments with inorganic fertilizers alone. Maximum activity of alkaline phosphatase was observed in treatment with FYM +consortium biofertilizer at 30 DAS time interval. The results were in accordance with Balakrishnan et al. [18] who ascertain that the application of compost in

combination with PSB significantly increased soil microflora such as bacteria, fungi and actinomycetes and soil enzyme activities such as dehydrogenase and phosphatase. Phosphatase activity is highly correlated with soil microbial biomass and in turn, the provision of organic carbon and stimulation of microbial growth under the combined treatments (organic + inorganic) could have eleveated the synthesis of phosphatase enzymes thereby contributing to the soil phosphatase pool. Therefore, the application of organic fertilizers increased nutrient turnover through both increased microbial biomass and activity [19,20].

3.7.2 Dehydrogenase

The combined application of inorganic, organic and biofertilizers had a noticeable effect on soil dehydrogenase activity. The results indicated that dehydrogenase activity was higher in treatments having high bacterial population (Fig. 1(b), the reason being that dehydrogenase activity is only present in viable cells and it is considered to reflect the total range of oxidative activity of soil microflora. Moreover, the enzyme activities in the soil are closely related to the organic matter content. The application of balanced amounts of nutrients and manures through inorganic and organic fertilizers improved the organic matter of soil, which corresponded with higher enzyme activity. Similar trend of results was observed by Garcia-Gil et al. [21] who mentioned that dehydrogenase activity was higher in organic manure treatments, indicating an increase in the microbial metabolism in soil as a result of mineralization of biodegradable carbon compounds.

3.7.3 Urease

The effect of biofertilizers and organic fertilizers on enzyme activity indicated that the urease activity showed variable pattern during the crop developmental stages as shown in Fig. 1(c). Urease activity is dependent on soil organic matter content as well as nitrogen levels. All the treatments had 100% nitrogen levels either from inorganic sources or from organic sources or from both combined [19,22,23]. This may be due to high levels of inorganic nitrogen provided via inorganic fertilizers whose effect was comparable with the urease activity shown by microorganisms present in FYM and biofertilizers. However, the results at 60 days time interval showed that effect of application of biofertilizers, organic fertilizers and inorganic fertilizers had non-significant effect on soil urease activity however there was a significant increase in urease activity over uninoculated control.

3.8 Correlation between Microbial Population and Enzyme Activities

At 30 days time interval, bacterial population was highly correlated to phosphatase (r=0.819), urease (r=0.466) and dehydrogenase (r=0.874) activities at 0.01 level of significance (Table 3(a). Fungal population was positively correlated with phosphatase (r=0.664) and dehydrogenase (r=0.512) activities at 0.01 level of significance. Actinomycetes population was negatively correlated with alkaline phosphatase (r=-0.363), urease (r=-0.678) and dehydrogenase (r=-0.642) activities at 0.01 level of significance. At 60 days time interval, correlation between microbial population and enzyme activities shows that bacteria, PSB and PGPR populations were strongly correlated with all the three enzyme activities viz., alkaline phosphatase, urease and dehydrogenase (Table 3 (b). However, actinomycetes population showed negative correlation with enzyme activities after 60 days time interval similar to 30 days time interval. After 90 days time interval, the correlation between microbial population and enzyme activities showed a changing pattern. Bacterial population was negatively correlated with urease activity (r=-0.058) while it was posivitely correlated with alkaline phosphatase (r=0.849) and urease (r=0.914) activities (Table 3(c). PGPR activity was also negatively correlated with urease activity but was positively correlated with alkaline phosphatase and dehydrogenase activity. At harvest, bacterial population was negatively correlated with urease activity (r=-0.459) at 0.05 level of significance (Table 3 (d).

Fungal population was positively correlated with alkaline phosphatase (r=0.382) and urease (r=0.587) activities at 0.05 and 0.01 level of significance respectively. At harvest, actinomycetes population was positively correlated with urease activity (r=0.109) unlike at other intervals. Diazotroph and PSB population were negatively correlated with urease activity and had strong positive correlation with alkaline phosphatase and dehydrogenase activity.

Table 3. Correlation between microbial population and enzyme activities at (a) 30 days (b) 60 days (c) 90 days (d) harvest

(a)	Bac	Fungi	Actino	Diazo	PSB	PGPR	Phos	Urease	Deh
Bac	1	0.576**	-0.629**	0.792**	0.812**	0.925**	0.845**	0.479**	0.866**
Fungi		1	-0.070	0.803**	0.622**	0.605**	0.681**	0.198	0.539**
Actino			1	-0.341	-0.457*	-0.603**	-0.363*	-0.678**	-0.642**
Diazo				1	0.891**	0.808**	0.870**	0.188	0.790**
PSB					1	0.865**	0.823**	0.055	0.918**
PGPR						1	0.757**	0.384*	0.932**
Phos							1	0.283	0.734**
Urease								1	0.308
Deh									1
(b)	**Bac**	**Fungi**	**Actino**	**Diazo**	**PSB**	**PGPR**	**Phos**	**Urease**	**Deh**
Bac	1	0.551**	-0.657**	0.776**	0.965**	0.892**	0.839**	0.654**	0.936**
Fungi		1	-0.240	0.806**	0.663**	0.550**	0.712**	0.209	0.486**
Actino			1	-0.379*	-0.630**	-0.620**	-0.430*	-0.834**	-0.626**
Diazo				1	0.883**	0.760**	0.900**	0.467**	0.738**
PSB					1	0.875**	0.942**	0.643**	0.884**
PGPR						1	0.782**	0.692**	0.932**
Phos							1	0.391*	0.791**
Urease								1	0.687**
Deh									1
(c)	**Bac**	**Fungi**	**Actino**	**Diazo**	**PSB**	**PGPR**	**Phos**	**Urease**	**Deh**
Bac	1	0.347	-0.567**	0.690**	0.908**	0.843**	0.849**	-0.058	0.914**
Fungi		1	-0.189	0.759**	0.520**	0.503**	0.636**	0.132	0.387*
Actino			1	-0.328	-0.471**	-0.675**	-0.381*	-0.123	-0.571**
Diazo				1	0.826**	0.742**	0.912**	0.095	0.660**
PSB					1	0.754**	0.960**	0.007	0.755**
PGPR						1	0.747**	-0.098	0.924**
Phos							1	0.065	0.750**
Urease								1	-0.124
Deh									1

(d)	Bac	Fungi	Actino	Diazo	PSB	PGPR	Phos	Urease	Deh
Bac	1	-0.077	-0.530**	0.717**	0.720*	0.452*	0.793**	-0.459*	0.894**
Fungi		1	0.163	0.539**	0.200	0.422*	0.382*	0.587**	-0.009
Actino			1	-0.297	-0.387*	-0.487**	-0.265	0.109	-0.609**
Diazo				1	0.723**	0.554**	0.920**	-0.018	0.673**
PSB					1	0.451*	0.837**	-0.365*	0.714**
PGPR						1	0.432*	0.360	0.674**
Phos							1	-0.287	0.756**
Urease								1	-0.334
Deh									1

***. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at 0.05 level (2-tailed)*

***Bac: Bacterial population; Actino: Actinomycetes population; Diazo: Diazotrophic population; PSB: Phosphate Solublising Bacteria; PGPR: Plant Growth Promoting Rhizobacteria; Phos: Alkaline Phosphatase activity; Deh: Dehydrogenase

4. CONCLUSION

It was concluded that microbial inoculants had significant effect on dynamics of rhizospheric soil across-the-board. Addition of consortium biofertilizer increased the total bacterial population, fungal population, diazotrophic population, PSB population and PGPR population while actinomycetes population remained unaffected. The improvement in soil enzyme activities was also observed in soil samples treated with biofertilizers. The correlation analysis demonstrated that bacterial population was highly correlated with enzyme activities during initial stages of plant growth but was negatively correlated with urease activity during later stages of plant growth. Further, combined application of organic and inorganic fertilizers improves the soil biological and biochemical properties in comparison to their individual applications. This portrays the synergistic effect of inorganic and organic fertilizers. Therefore, the combined application of inorganic, organic and biofertilizers helps in elevating the soil health leading to increased soil fertility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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