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Impact of nutrients, nitrogen fixers and phosphate solubilizers on microbiological properties of soil and yield in sesamum-pea cropping sequence

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Abstract
This study was conducted at the Soil Microbiology section of Department of Soil Science, College of Agriculture, CSK HPKV, Palampur in pea-sesamum cropping sequence during *Rabi*, 2008 and *kharif*, 2009. There were eight treatments with randomized block design (RBD). The soil was silty clay loam in texture, pH 5.2, cation exchange capacity 10.3 c mol (p^+) kg^{-1}, organic carbon 9.5 g kg^{-1}, available N and P (267.1 kg ha^{-1} and 10.2 kg ha^{-1}) during this study. After the harvest of crop, representative soil samples from each plot were taken from the depths of 0-0.15 m and 0.15-0.30 m and were analyzed for microbiological properties of soil. The results revealed that highest total microbial count, microbial biomass carbon, dehydrogenase, phosphatase and urease activity was recorded where organics, inorganic and biofertilizers were applied conjunctively. The yield of pea and sesamum crop were recorded highest where organic sources (FYM), inorganic sources (Half N and P and full K (RDF) and biofertilzers (Nitrogen Fixer (B) + Phosphate Solubilizers) were applied.

Keywords: Balanced fertilization, state level recommendations

Introduction
The dawn of 21^{st} century poses very tough challenges to the agriculture with slogan to produce more food to nourish the increasing human population from shrinking land for sustainable agriculture. It will be challenging task for agricultural scientists in already shrunken arable land and only alternative is the vertical growth in agriculture production through increased production per unit area per unit time (Bedi *et al.* 2009) [1]. Fertilizers are the essential among different factors contributing towards agricultural production. The benefits of increased use of fertilizers in achieving targets of food grain production are well established. However, practicing farming with high yielding crop varieties under present fertilizers constraints due to the ever increasing prices, a viable proposition would be the adoption of economic and judicious use of fertilizers and management practices so that the higher investment on fertilizers is reaped adequately. Further, chemical fertilizers alone are unable to maintain the long-term soil health and sustain crop productivity as they are unable to supply all the essential nutrients, particularly the trace elements (Subba Rao and Srivastava 1998) [2].
On the other hand, organic manures improved soil physical, chemical and biological properties and thus, resulting in enhanced crop productivity along with maintaining soil health. Although, the organic manures contain plant nutrients in small quantities as compared to the chemical fertilizers, the presence of growth hormones and enzymes, besides plant nutrients make them essential for improving soil fertility, productivity and soil health (Bhuma 2001) [3]. In addition to this, the organic manures help in improving the use efficiency of inorganic fertilizers (Singh and Biswas 2000) [4]. Organic manures also help in plant metabolic activities through supply of important micronutrients in early vigorous growth of the plant (Anburani and Manivannan 2002) [5]. Legumes-cereal cropping system is most common in our country because of the residual nitrogen from symbiosis benefits to the subsequent cereal crops (Tilak 1993) [6]. But the legume - oilseed cropping system is very uncommon. The present research proposal was formulated with the objective to study different microbiological properties of soil and yield of pea – sesamum cropping sequence.

Material and Methods
In order to find out the objectives of this study a field experiment was conducted in pea-sesamum cropping sequence during *rabi*, 2008 and *kharif*, 2009 at the Soil Microbiology section of Department of Soil Science, College of Agriculture, CSK HPKV, Palampur.

There were eight treatments which were replicated thrice in a randomized block design. The treatments were; (T_1): 10 t FYM ha $^{-1}$ + NF (A) + PSB + CCR, (T_2): 10 t FYM ha $^{-1}$ + NF (A) + PSB + CCR, (T_3): 5 t FYM ha $^{-1}$ + NF (A) + P and K (RDF), (T_4): 5 t FYM ha $^{-1}$ + NF (A) + PSB + Half N and P (RDF) + K (RDF), (T_5): 5 t FYM ha $^{-1}$ + NF (B) + P and K (RDF), (T_6): 5 t FYM ha $^{-1}$ + NF (B) + PSB + Half N and P (RDF) + K (RDF), (T_7): N, P and K (RDF), (T_8) Control. Recommended dose of fertilizer (RDF) rate corresponds to the state level recommendations for respective nutrients. FYM application was made @ 10 t ha^{-1} on fresh weight basis for both crops, which corresponds to the practice being followed by the farmers of the region. The FYM applied contained 60 per cent moisture; and its average nutrient content during the period of experimentation on dry weight basis was 1.01, 0.26 and 0.40 per cent of N, P and K, respectively.

All the micrbiological properties were studied from surface (0-15 cm) and subsurface (15-30 cm) soil samples**;** enumeration of microbial population was done by plate count technique of (Wollum 1982) [7] through serial dilution using a variety of media; microbial biomass carbon was determined by fumigation-extraction method of Vance *et.al.* (1987) [8]; dehrdrogenase activity was determined by the method as described by Casida *et al.* (1964) [9]; phophatase activity was determined by the method as described by Tabatabai and Bremmer (1969) [10]; urease activity was determined by the method as described by Tabatabai and Bremmer (1972) [11].

In pea, green pod yield was recorded at every picking from each treatment and total yield of green pods were worked out by adding the yield obtained at every picking. After harvesting vines were kept for sun drying for 2-3 days and the vine yield was recorded by worked out their weight from every treatment plots. In sesamum, the grains were extracted from the capsules and grain yield was recorded by worked out their weight from every treatment plots. After harvesting stover was left in plots kept for sun drying for 2-3 days and stover yield was calculated their weight from every treatment plots.

Results and Discussions

Microbiological properties of soil.

Microbial population: The significant effect of organic, inorganic and integrated sources of nutrients on total microbial population was recorded in both surface (0-15 cm) and subsurface (15-30 cm) soils. Total microbial population in integrated use of nutrients was found better than use of organic as well as inorganic practices. Between organics treatments T_2 was found to be significantly superior to T_1. Total microbial population was the maximum in T_6 whereas, control depicted the lowest. Amongst integrated nutrient management, T_6 have shown 7.87 and 8.7 per cent increase over T_5 and T_4 respectively. It might be due fact that proper and continuous mineralization of nutrients from organic to inorganic pool resulted in maintaining the continuous supply of food as well as energy for the growth of microorganisms. Results are corroborated with finding of Bedi (2004) [12]. Treatment T_5 significantly gave more total microbial population to treatment T_3. Similar to total microbial population, individual organisms *i.e.* bacteria, fungi and actinomycetes follow the same trend. Individual microorganisms were significantly higher in integrated nutrient management practices followed by organic practices, inorganic practices and control respectively. The bacterial population was more than the fungi and actinomycetes population in all the treatments at surface soil samples.

Table 1: Effect of organic and inorganic sources of nutrients on microbial population

Treatments	Bacterial popula-tion (cfu g^{-1} X 10^7)	Fungal popula-tion (cfu g^{-1} X10^6)	Actino-mycetes population (cfu g^{-1} X 10^5)	Total popula-tion	Bacterial popula-tion (cfu g^{-1} X 10^7)	Fungal popula-tion (cfu g^{-1} X 10^6)	Actino-mycetes population (cfu g^{-1}X 10^5)	Total population
	Depth (m)							
	0-0.15					0.15-0.30		
T_1	41	35	25	101	39	33	23	95
T_2	45	39	27	111	42	35	25	102
T_3	46	41	31	118	43	39	30	112
T_4	48	43	35	126	45	40	34	122
T_5	49	43	35	127	44	45	33	119
T_6	50	48	39	137	48	48	29	125
T_7	40	33	25	98	42	35	26	103
T_8	39	30	24	93	38	31	22	91
CD (P= 0.05)	4.19	6.57	4.82	2.98	NS	5.25	7.82	4.51

In general total microbial population as well as individual microbial population of microorganisms was less in sub-surface soil as compared to surface soil. Total microbial population differed significantly amongst different treatments. Integrated nutrient management practices registered significantly higher total microbial population than inorganic practices and organic practices. The treatment T_6 has shown 2.45 and 5.04 per cent increase over T_4 and T_5. Akin to surface soil the bacterial population was more than the fungi and actinomycetes population in all the treatments at surface soil samples. In general the total as well as individual population was higher at surface soil in comparison to subsurface soil because more accumulation of organic matter in surface than subsurface. Results are corroborated with finding of Bedi (2004) [12].

Microbial biomass carbon: Biomass carbon was higher in surface samples than subsurface sample. Microbial biomass carbon was observed maximum in treatment T_6 and the minimum in control. All the treatment differed significantly with each other. Amongst all the treatments, integrated use of organic and inorganic sources improves the microbial biomass carbon content of soil. Applications of organics were found superior than inorganic. Treatment T_6 gave 35.15 per cent increase over T_4. All the treatments were found statistically superior than control. In subsurface soil the microbial biomass carbon content of soil decreased as compared to surface soil. A significant increase was observed in all treatments. Treatments T6 have highest available microbial biomass carbon and lowest in control. Applications of organics were found superior than inorganic. Treatment T_6 recorded 15.6 per cent increase over T_4 (5 tonnes FYM ha^{-1} + Nitrogen fixer (A) + Phosphate Solubilizer + Half of Recommended N and P + Recommended K).

Table 2: Effect of organic and inorganic sources of nutrients on microbial biomass carbon and dehydrogenase activity

Treatments	Microbial biomass carbon (µg g^{-1})		Dehydrogenase activity (µg TPF g^{-1} hr^{-1})	
	Depth(cm)		Depth(cm)	
	(0-15)	(15 -30)	(0-15)	(15-30)
T_1	69.6	58.6	3.6	3.1
T_2	74.4	66.4	3.9	2.7
T_3	54.6	50.2	3.5	2.5
T_4	91.3	88.7	5.2	3.2
T_5	68.4	67.5	4.1	3.9
T_6	123.4	102.6	5.8	4.1
T_7	58.6	52.0	3.2	2.7
T_8	40.2	38.3	2.2	1.9
CD (P= 0.05)	4.9	3.9	0.4	0.3

Biomass carbon in integrated nutrient management was higher than the other treatments might be due to more microbial population and organic carbon in the integrated nutrient management which resulted in more biomass carbon due to increased in chemical nitrogen with more organic material application. Results are corroborated with the finding of Santhy *et al*. (2004) [13].

Dehydrogenase activity: The data pertaining to the effect of organic, inorganic and integrated sources of nutrients on dehydrogenase activity on surface (0-15 cm) and subsurface (15-30 cm) soil have been indicated that the effect of organic, inorganic and integrated sources of nutrients was found significant in all treatments. Amongst all the treatments, use of integrated sources of nutrients was found superior over organic and inorganic sources of nutrients. Organic sources were found better than inorganic sources of nutrients. Treatment T_2 was superior to T_1. The treatment T_6 has shown 16.3 per cent increase over T_5. Dehydrogenase activity was higher in integrated use of nutrients than organic and inorganic treatments might be higher organic matter and fast rate of decomposition due to proper C: N/C: P and C: P ratio. The results are similar with findings of Bedi and Dubey (2009)[14]. In the subsurface soil, treatment T_6 has shown 5.1 per cent increase over T_5. In general dehydrogenase activity was lower in subsurface sample as compared to surface sample might be due less organic matter (Bedi 2004) [12].

Phosphatase activity: An inquisition of data indicated that effect of organic, inorganic and integrated sources of nutrients was found significant in all treatments. Amongst all the treatments, use of integrated sources of nutrients was found superior over organic and inorganic sources of nutrients. Organic sources were found better than inorganic sources of nutrients. The treatment T_6 have shown 1.88 per cent increase over T_5.The treatments which received the combined application of organic and inorganic together might be due to fact that the addition of organic sources maintain the continuity of addition of nutrients from organic to inorganic form so the substrate of phosphorus *i.e.* monoesters and di-esters are continuously available and cause the phosphatase activity. Similar results were obtained by Bedi *et al*. (2009) [1]. In the subsurface soil, treatment T_6 showed maximum (5.1 µg g^{-1} hr^{-1}) and minimum of enzymatic activity. Treatment T_6 have shown 4.08 per cent increase over T_5.

Table 3: Effect of organic and inorganic sources of nutrients on phosphatase and urease activity

Treatments	Phosphtase activity (µg g^{-1} hr^{-1})		Urease activity (µg g^{-1} min^{-1})	
	Depth (m)		Depth (m)	
	(0-0.15)	(0.15-0.30)	(0-0.15)	(0.15-0.30)
T_1	2.3	1.9	3.0	2.7
T_2	3.2	2.9	2.4	2.2
T_3	3.6	3.2	3.9	3.4
T_4	5.3	4.9	4.4	4.1
T_5	4.1	3.6	3.6	3.3
T_6	5.4	5.1	5.2	4.9
T_7	3.4	2.9	4.8	4.7
T_8	1.8	1.5	1.7	1.6
CD (P= 0.05)	0.2	0.2	0.3	0.2

Urease activity: An inquisition of data indicated that effect of organic, inorganic and integrated sources of nutrients was found significant in all treatments. Amongst all the treatments, use of integrated sources of nutrients was found superior over organic and inorganic sources of nutrients. Inorganic sources were found better than organic sources of nutrients. The treatment T_6 showed maximum urease activity and minimum in control. The maximum urease activity received in the combined application of organics and inorganics together than organics and inorganics alone, might be due to the application of organic source and inorganic source together maintain the continuity of conversion of nutrients from organic to inorganic form because it act on C-N bonds other than peptide bonds in linear amides and thus belongs to a group of enzymes that include glutaminase and amidase. The results are corroborated with the findings of Jaun *et al*. (2008) [15].

In the subsurface soil, treatment T_6 showed maximum and minimum of enzymatic activity in control. The treatment T_6 have shown 4.25 per cent increase over T_7 (Recommended dose of NPK).

Yield of pea

Green pod yield: Green pod yield under the different sources of nutrients differed significantly. The highest green pod yield was recorded in the treatment T_6 and the lowest green pod yield was recorded in the treatment T_8. Between the organic sources, treatment T_2 gave significantly higher green pod yield than T_1. Organics were found significantly superior to inorganic sources of nutrient. Among all the treatments, treatments T_2 and T_1 registered 37.2 per cent and 24.4 per cent higher yield than treatment T_7 (inorganic sources of nutrients). Amongst integrated sources of nutrients, 50 percent substitution of nitrogen and phosphorus from

Table 4: Effect of organic and inorganic sources of nutrients on green pod yield and vine yield of pea

Treatments	Green Pod yield (q ha^{-1})	Vine yield (q ha^{-1})
T_1:10 t FYM ha^{-1} + NF (A) + PSB + CCR	80.5	15.3
T_2:10 t FYM ha^{-1} + NF (A) + PSB + CCR	88.8	15.5
T_3:5 t FYM ha^{-1} + NF (A) + P and K (RDF)	95.2	15.7
T_4: 5 t FYM ha^{-1} + NF (A) + PSB + Half N and P (RDF) + K (RDF)	102.5	18.8
T_5: 5 t FYM ha^{-1} + NF (B) + P and K (RDF)	80.8	18.2
T_6: 5 t FYM ha^{-1} + NF (B) + PSB + Half N and P (RDF) + K (RDF)	108.6	19.2
T_7: N, P and K (RDF),	64.7	17.6
T_8: Control	41.5	13.2
CD (P= 0.05)	1.80	0.27

(*NF: Nitrogen Fixer, *PSB: Phosphate solubilizers, *CCR: Chopped Cropped Residue, *RDF: Recommended Dose of Fertilizers)

Organic and bio fertilizers found to be significantly superior to substitution of 50 per cent nitrogen alone. Substitution of 50 per cent nitrogen and phosphorus from organic and bio fertilizers found to be significantly superior to T_7 and organic sources of nutrients. Similar results were reported by Patel *et al.* (1998) [16] that the application of *Rhizobium* and Phosphate solubilizing bacteria substitute 50 per cent N and P and significantly improve green pod yield of pea. Results are corroborated with the findings Singh *et al.* (2006) [17].

Vine yield: The maximum vine yield was recorded in treatment T_6 followed by T_4, T_5, T_7, T_3, T_2 and T_1, respectively. Between organic treatments, T_2 gave numerically higher yield than T_1. Difference between treatment T_2 and T_1 is statistically at par. Treatment T_6 recorded 45.4 per cent higher vine yield than the control. Under integrated nutrient management treatments, substitution of 50 per cent nitrogen and phosphorus through organic and bio fertilizers found to be better than the substitution of 50 percent nitrogen with nitrogen fixing bio fertilizers alone, along with recommended dose of phosphorus. T_6 gave 2.12 per cent increase over T_4 All the treatments were significantly superior to control. Results are corroborated with findings of Rather *et al.* (2010) [18] who reported that application of bio fertilizers increased the vine yield of pea.

Yield of sesamum

Seed yield: Seed yield under the different sources of nutrients differed significantly. The highest seed yield was recorded in the treatment T_6 and the lowest seed yield was recorded in control. Inorganic treatment found to be significantly superior to organic sources of nutrient. Treatments T_2 and T_1 registered 2.43 and 10.5 per cent lower yield than treatment T_7 (inorganic sources of nutrients). It might be due to that the application of nutrients through chemical sources provided the readymade sources of nutrients which caused immediate availability of nutrients to crop, whereas the organic sources of nutrient supply less and continuous nutrient which may not fulfill the nutrients requirement of crops at particular stage and latter on it may be lost owing to continuous mineralization of nutrients. Results are corroborated with the findings of Ashfaq-Ahmad *et al.* (2001) [19]. Among all the treatments, treatments T_6 and T_4 were found statistically at par with each other. Results are corroborated with the findings of Attia (2001) [20] and Habbasha *et al*. (2007) [21].

Stover yield: The effect of organic, inorganic and integrated sources of nutrients on stover yield was differed significantly. The maximum stover yield was recorded in T_6 and minimum in T_8. The treatment T_6 recorded 49.01 per cent higher stover yield than the control. Between organic treatments, T_2 gave higher stover yield than T_1. Under integrated nutrient management treatments, substitution of 50 per cent nitrogen and phosphorus through organic

Table 5: Effect of organic and inorganic sources of nutrients on seed yield, stover yield of sesamum

Treatments	Seed yield (q ha $^{-1}$)	Stover yield (q ha^{-1})
T_1:10 t FYM ha $^{-1}$ + NF (A) + PSB + CCR	3.8	5.7
T_2:10 t FYM ha $^{-1}$ + NF (A) + PSB + CCR	4.1	6.1
T_3:5 t FYM ha $^{-1}$ + NF (A) + P and K (RDF)	4.3	6.4
T_4: 5 t FYM ha $^{-1}$ + NF (A) + PSB + Half N and P (RDF) + K (RDF)	4.8	7.2
T_5: 5 t FYM ha $^{-1}$ + NF (B) + P and K (RDF)	4.6	6.9
T_6: 5 t FYM ha $^{-1}$ + NF (B) + PSB + Half N and P (RDF) + K (RDF)	5.1	7.6
T_7: N, P and K (RDF),	4.2	6.1
T_8: Control	3.4	5.1
CD (P= 0.05)	0.34	0.38

(*NF: Nitrogen Fixer, *PSB: Phosphate solubilizers, *CCR: Chopped Cropped Residue, *RDF: Recommended Dose of Fertilizers)

And biofertilizers found to be better than the substitution of 50 per cent nitrogen with nitrogen fixing biofertilizers alone, along with recommended dose of phosphorus. The treatment T_6 gave 5.5 per cent increase over T_4. Similar results were reported by Habbasha *et al.* (2007) [21] that cumulative effect of organic and inorganic sources of nutrients increased straw and biological yield of sesamum. All the treatments were found significantly superior to control.

Conclusion

- The maximum values total microbial count, microbial biomass carbon, dehydrogenase, phosphatase and urease activity was recorded where organic sources (FYM), inorganic sources (Half N and P and full K (RDF) and biofertilzers (Nitrogen Fixer (B) + Phosphate Solubilizers) were applied.
- The yield of pea and sesamum crop were recorded highest where organics, inorganic and biofertilizers were applied conjunctively.

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