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Kuruva Mounika
M.Sc., Department of Soil Science and Agricultural Chemistry, Acharya N. G. Ranga Agricultural University, Agricultural College, Bapatla, Andhra Pradesh, India

Dr. A Lalitha Kumari
M.Sc., Department of Soil Science and Agricultural Chemistry, Acharya N. G. Ranga Agricultural University, Agricultural College, Bapatla, Andhra Pradesh, India

Dr. CH Sujani Rao
M.Sc., Department of Soil Science and Agricultural Chemistry, Acharya N. G. Ranga Agricultural University, Agricultural College, Bapatla, Andhra Pradesh, India

Dr. M Martin Luther
M.Sc., Department of Soil Science and Agricultural Chemistry, Acharya N. G. Ranga Agricultural University, Agricultural College, Bapatla, Andhra Pradesh, India

Corresponding Author:
Kuruva Mounika
M.Sc., Department of Soil Science and Agricultural Chemistry, Acharya N. G. Ranga Agricultural University, Agricultural College, Bapatla, Andhra Pradesh, India

Soil biological properties influenced by organics and biofertilizers in *Rabi* sorghum

Kuruva Mounika, Dr. A Lalitha Kumari, Dr. CH Sujani Rao and Dr. M Martin Luther

Abstract
A field experiment was conducted during 2020 at Agricultural College Farm, Bapatla to study the effect of organics and biofertilizers on soil biological properties by *rabi* sorghum. Significantly highest enzyme activity (dehydrogenase and urease) and microbial population (bacteria, fungi and actinomycetes) were recorded in the treatment received 100% RDF + FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_2) at blooming and harvest stage and it was on par with treatments 100% RDF + Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_3) and 100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} (T_4). The lowest was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage in soil.

Keywords: Organic manures, Biofertilizers, Enzyme activity, Microbial population

Introduction
Sorghum (*Sorghum bicolor*) *is* one of the important cereal crops of the world which is commonly called as jowar, great millet and camel crop. It is widely grown in the semi-arid tropics where water availability is limited and tolerance to drought is highly required. In India, area under sorghum crop is 5.62 m ha, production is 4.57 m t and productivity is 812 kg ha^{-1}.
Incorporation of organic manures is known to influence favorably the physical, chemical and biological properties of soil and thus enhance crop productivity by means of maintaining soil health. They also supply secondary and micro nutrients in available form while chemical fertilizers might supply one or two nutrients only. Manures play a key role to maintain soil pH and also increase soil organic carbon, total nitrogen, stable aggregates, structure, porosity, water holding capacity and soil biota.
Use of biofertilizers like *Azospirillum* & PSB in sorghum crop not only fixes the atmospheric nitrogen but also solubilizes the insoluble form of nutrients in soil. Thus improves the fertilizer use efficiency and improves germination, vigour in seedling and yield in sorghum crop. Integrated and balanced use of nutrients through inorganic and organic sources and bio-fertilizers is a pre-requisite to sustain soil health and to produce maximum yield.

Materials and Methods
A field experiment entitled "Effect of organics and biofertilizers on soil properties and performance of *rabi* sorghum" was conducted at Agricultural College Farm, Bapatla during *rabi* season, 2020-21 in randomized block design. The experiment comprised of eight treatments *viz.*, 100% RDF (T_1); 100% RDF+FYM @ 10 t ha^{-1}+ *Azospirillum* @ 5kg ha^{-1} + PSB @ 5kg ha^{-1} (T_2); 100% RDF + Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} (T_3); 100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} (T_4); 125% RDF (T_5); 75% RDF+FYM @10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB@ 5kg ha^{-1} (T_6); 75% RDF+ Vermi-compost @3t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1}+ PSB @ 5kg ha^{-1} (T_7); 75% RDF+ Neem cake @ 500 kg ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} (T_8) in three replications.
The experimental soil was neutral in reaction with a pH of 7.6 and non-saline with an EC value of 0.45 d S m^{-1}. The soil was clay in texture, medium in organic carbon (0.54%), medium in available nitrogen (315 kg ha^{-1}), high in available phosphorus (49.5 kg P_2O_5 ha^{-1}) and available potassium (365 kg K_2O ha^{-1}). The soil was sufficient in zinc (1.38 mg kg^{-1}), copper (3.40 mg kg^{-1}), manganese (6.03 mg kg^{-1}) and iron (9.45 mg kg^{-1}).

Biofertilizers (*Azospirillum* @ 5kg ha^{-1} + PSB @ 5kg ha^{-1}) were mixed with FYM, vermicompost, neem cake separately and applied to the field according to the treatments two weeks before sowing. Inorganic nitrogen (urea) was applied at different levels as per the treatments in three splits (as basal dose, 30 DAS and at 60 DAS). The phosphorus and potassium were applied to all the plots in the form of SSP (basal) and MOP (two equal splits). Bacteria, fungi and actinomycetes were estimated as per the procedures outlined by Kapoor and Paroda (2007) [4]. Dehydrogenase activity was estimated by using Klein *et al*. (1971) [71] and urease activity was estimated by using Kapoor and Paroda (2007) [4].

Results and Discussions

Dehydrogenase activity

The dehydrogenase activity in soil was influenced by the addition of organics and biofertilizers (Table.1 and Fig.1) indicated that there was significant difference among the treatments. The dehydrogenase activity in soil decreased from blooming to harvest stage. Significantly highest dehydrogenase activity (87.01 and 68.01 µg TPF g^{-1} 24 h^{-1}) was observed in treatment T_2 (100% RDF + FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1}+PSB @ 5 kg ha^{-1} and this was on par with T_3 (100% RDF +Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} -85.14 and 66.14 µg TPF g^{-1} 24 h^{-1}) and T_4 (100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5ha^{-1} -79.90 and 59.90 µg TPF g^{-1} 24 h^{-1}) at blooming and harvest stage respectively. The lowest (40.50 and 30.57 µg TPF g^{-1} 24 h^{-1}) was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage in soil.

Dehydrogenase activity was recorded highest in the treatments which received organics and biofertilizers this might be due to the enhanced level of soil enzyme activity due to addition of organic manures promotes the recycling of nutrients in the soil ecosystem (Ramesh *et al*. 2006). Increase in dehydrogenase activity in FYM treated plots was due to manure promoted biological and microbial activities and accelerated the breakdown of organic substances in the added manure (Lalfakzuala *et al*., 2008) [6].

Urease activity: The urease activity in soil was influenced by the addition of organics and biofertilizers (Table.1 and Fig.2) indicated that there was significant difference among the treatments. The dehydrogenase activity in soil decreased from blooming to harvest stage. Significantly highest urease activity (26.10 and 19.88 µg NH_4^+ - N g^{-1} soil h^{-1}) was observed in treatment T_2 (100% RDF + FYM @ 10 t ha^{-1} +*Azospirillum* @ 5 kg ha^{-1}+PSB @ 5 kg ha^{-1}) which was on par with T_3 (100% RDF +Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1}-23.80 and 17.90 µg NH_4^+-N g^{-1} soil h^{-1}) and T_4 (100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5ha^{-1} -23.30 and 16.90 µg NH_4^+ -N g^{-1} soil h^{-1}) at blooming and harvest stage respectively . The lowest (12.50 and 10.23 µg NH_4^+ - N g^{-1} soil h^{-1}) was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage in soil.

Enhancement of urease activity with increased rate of nitrogen application along with FYM to soil might be due to added organic manures which acted as sole source of carbon and energy for microbes by which their population increased resulting in increased enzymatic activity (Selvi *et al.,* 2004 and Qureshi *et al.,* 2005) [12]. Higher urease activity on FYM addition might be due to more organic matter content, enhanced hydrolysis of urea (Siva Devika *et al.,* 2018) [14].

Microbial Populations

Bacteria (×10^6 CFU g^{-1} soil): Data pertaining to the bacterial populations present in soil was presented in Table.2 and Fig.3 indicated that there was significant difference among treatments at blooming and harvest stage of crop. Significantly highest bacterial populations (29.87 and 25.90 ×10^6 CFU g^{-1}) was observed in treatment T_2 (100% RDF + FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1}+PSB @ 5 kg ha^{-1}) at blooming and harvest stage and this was on par with T_3 (100% RDF +Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1}-28.02 and 24.39 CFU g^{-1} soil) and T_4 (100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5ha^{-1}-27.59 and 23.66 CFU g^{-1} soil). The lowest (14.05 and 13.00 CFU g^{-1} soil) was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage. Increase in bacterial population on FYM addition was due to increased supply of nutrients and more organic matter content (Lalfakzuala *et al*., 2008) [6]. Similar findings reported by Ramalakshmi *et al.* (2008) [9] and Mahanta *et al.* (2013).

Fungi (×10^4 CFU g^{-1} soil)

Data pertaining to the bacterial populations present in soil was presented in Table. 2 and Fig.4 indicated that there was significant difference among treatments at blooming and harvest stage of crop. Significantly highest fungal populations (9.63 and 6.86 ×10^3 CFU g^{-1}) was observed in treatment T_2 (100% RDF + FYM @ 10 t ha^{-1} +*Azospirillum* @ 5 kg ha^{-1}+PSB @ 5 kg ha^{-1} at blooming and harvest stage and this was on par with T_3 (100% RDF +Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} -9.20 and 6.50 CFU g^{-1} soil) and T_4 (100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5ha^{-1}-8.83 and 5.99 CFU g^{-1} soil). The lowest (3.55 and 2.00 CFU g^{-1} soil) was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage.

Significant influence of fungal population with the FYM and biofertilizer application was due to availability of sufficient food and energy source in the form of organic carbon (Zhang *et al*., 2018) [16]. Similar findings reported by Selvi *et al.* (2003) [13] and Ravishankar *et al*. (2008) [11].

Actinomycetes (×10^5 CFU g^{-1} soil)

Data pertaining to the actinomycetes populations present in soil was presented in Table. 3 and Fig.5 indicated that there was significant difference among treatments at blooming and harvest stage of crop. Significantly highest actinomycetes populations (20.20 and 16.07 ×10^4 CFU g^{-1}) was observed in treatment T_2 (100% RDF + FYM @ 10 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1}+PSB @ 5 kg ha^{-1} at blooming and harvest stage and this was on par with T_3 (100% RDF +Vermicompost @ 3 t ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5kg ha^{-1} – 19.90 and 15.78 CFU g^{-1} soil) and T_4 (100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5ha^{-1} – 18.60 and 14.63 CFU g^{-1} soil). The lowest (7.15 and 6.20 CFU g^{-1} soil) was observed with the treatment receiving 100% RDF (T_1) at blooming and harvest stage.

Ramalakshmi *et al*. (2008) [9] observed the highest actinomycetes populations were found in the soils treated with FYM @ 10 t ha^{-1} along with mineral fertilizer as compared to inorganic fertilizer due to direct supply of organic matter content. Similar findings reported by Ravishankar *et al*. (2008) [11] and Mahanta *et al.* (2013).

Table 1: Effect of organic manures and biofertilizers on dehydrogenase (µg TPF g^{-1} 24 h^{-1}) and urease activity (µg NH_4^+ - N g^{-1} soil h^{-1}) in soil

Treatments	Dehydrogenase Activity		Urease Activity	
	Blooming	Harvest	Blooming	Harvest
T_1: 100% RDF	40.50	30.57	12.50	10.23
T_2: 100% RDF+FYM @ 10 t ha^{-1}+ *Azospirillum* + PSB	87.01	68.01	26.10	19.88
T_3: 100% RDF + Vermicompost@ 3 t ha^{-1}+ *Azospirillum*+PSB	85.14	66.14	23.80	17.90
T_4:100% RDF+ Neem cake @ 500 kg ha^{-1}+ *Azospirillum* +PSB	79.90	59.90	23.30	16.90
T_5: 125% RDF	41.18	32.15	13.90	11.10
T $_6$: 75% RDF+FYM @ 10 t ha^{-1} + *Azospirillum* + PSB	72.10	49.90	21.20	15.70
T_7: 75% RDF+ Vermicompost @ 3 t ha^{-1}+ *Azospirillum* + PSB	65.70	46.70	20.50	15.40
T_8: 75% RDF+ Neem cake @ 500 kg ha^{-1} + *Azospirillum* + PSB	64.40	43.60	19.80	14.80
S.Em±	4.80	3.57	1.41	1.00
CD (0.05%)	14.40	10.71	4.23	3.00
CV (%)	7.95	7.30	8.23	7.74

Note:

- *Azospirillum* @ 5 kg ha^{-1}; PSB @ 5 kg ha^{-1}
- 100% RDF- 80 N: 40 P_2O_5: 40 K_2O kg ha^{-1}

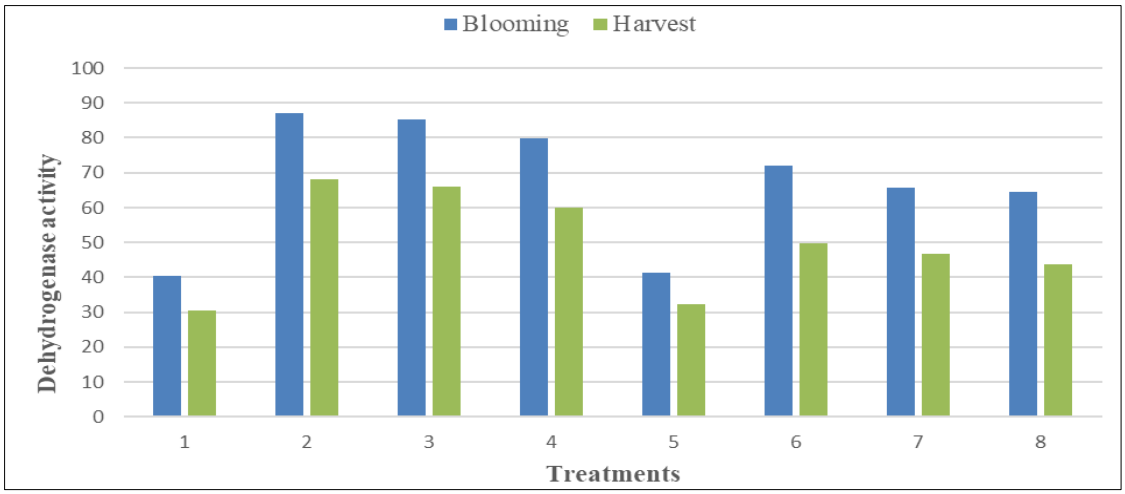

Fig 1: Effect of organic manures and biofertilizers on dehydrogenase (µgTPFg^{-1} 24h^{-1}) in soil

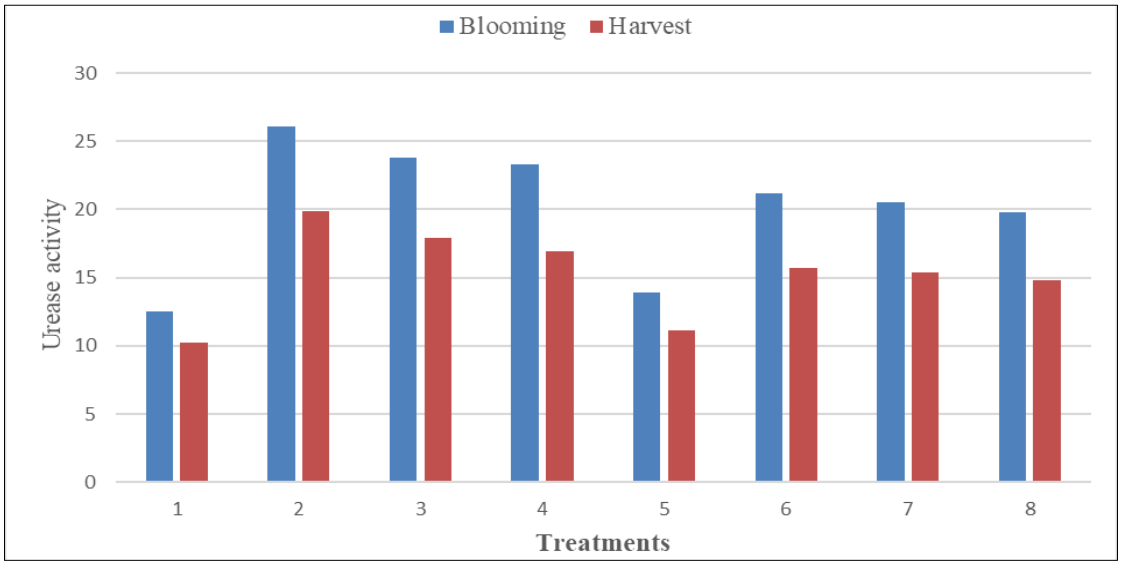

Fig 2: Effect of organic manures and biofertilizers on urease activity (µg NH_4^+-Ng^{-1} soil h^{-1}) in soil

Table 2: Effect of organic manures and biofertilizers on bacterial and fungal population (CFU g^{-1}) in soil

Treatments	Bacteria ($X10^6$)		Fungi ($X10^3$)	
	Blooming	Harvest	Blooming	Harvest
T_1: 100% RDF	14.05	13.00	3.55	2.00
T_2: 100% RDF+FYM @ 10 t ha^{-1}+ *Azospirillum* + PSB	29.87	25.90	9.63	6.86
T_3:100% RDF + Vermicompost @ 3 t ha^{-1}+ *Azospirillum*+PSB	28.02	24.39	9.20	6.50
T_4:100% RDF+ Neem cake @ 500 kg ha^{-1}+ *Azospirillum*+ PSB	27.59	23.66	8.83	5.99

T_5: 125% RDF	14.57	13.39	3.58	2.42
T_6: 75% RDF+FYM @ 10 t ha^{-1} + *Azospirillum* + PSB	25.00	20.98	7.40	5.71
T_7: 75% RDF+ Vermicompost @ 3 t ha^{-1}+ *Azospirillum* + PSB	24.22	20.53	6.97	4.98
T_8: 75% RDF+ Neem cake @ 500 kg ha^{-1} + *Azospirillum* + PSB	23.55	19.76	6.77	4.23
S.Em±	1.59	1.42	0.42	0.36
CD (0.05%)	4.77	4.26	1.26	1.08
CV (%)	10.96	9.35	9.05	8.00

Note:

- *Azospirillum* @ 5 kg ha^{-1}; PSB @ 5 kg ha^{-1}
- 100% RDF- 80 N: 40 P_2O_5: 40 K_2O kg ha^{-1}

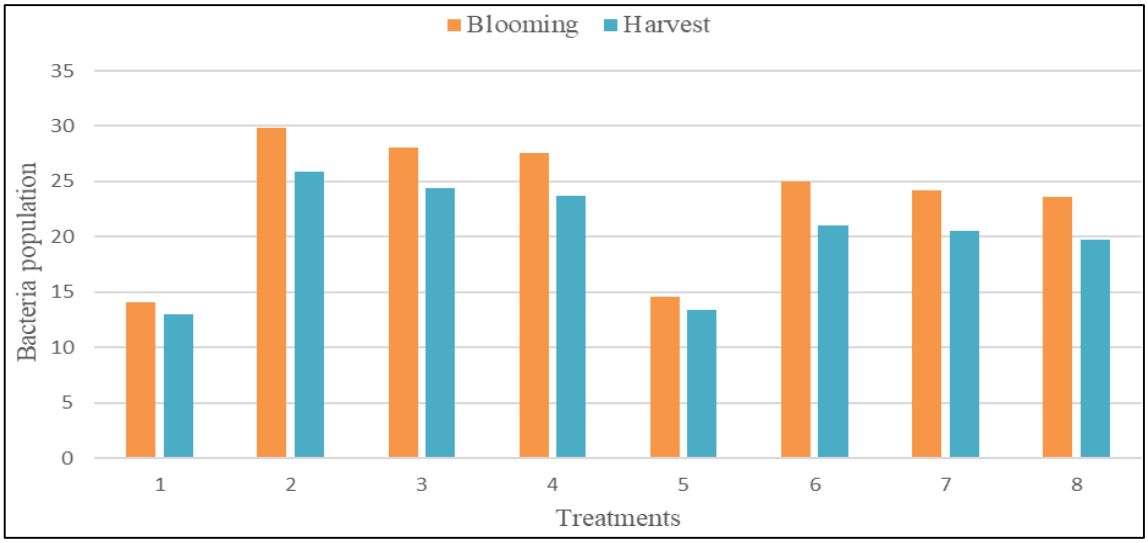

Fig 3: Effect of organic manures and biofertilizers on bacterial population (CFU g^{-1}) in soil

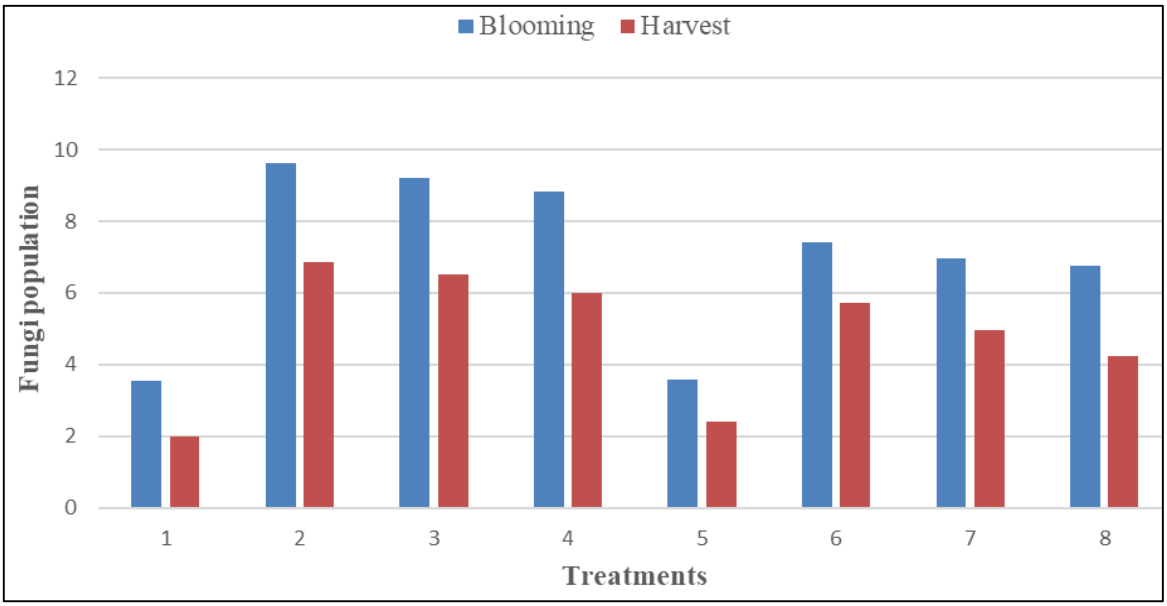

Fig 4: Effect of organic manures and biofertilizers on fungal population (CFU g^{-1}) in soil

Table 3: Effect of organic manures and biofertilizers on actinomycetes population (CFU g^{-1}) in soil

Treatments	Actinomycetes ($X10^4$)	
	Blooming	Harvest
T_1: 100% RDF	7.15	6.20
T_2: 100% RDF+FYM @ 10 t ha^{-1}+ *Azospirillum* + PSB	20.20	16.07
T_3: 100% RDF + Vermicompost @ 3 t ha^{-1}+ *Azospirillum* + PSB	19.90	15.78
T_4: 100% RDF + Neem cake @ 500 kg ha^{-1}+ *Azospirillum* + PSB	18.60	14.63
T_5: 125% RDF	7.21	6.75
T_6: 75% RDF+FYM @ 10 t ha^{-1} + *Azospirillum* + PSB	15.68	12.30
T_7: 75% RDF+ Vermicompost @ 3 t ha^{-1}+ *Azospirillum* + PSB	14.90	10.57
T_8: 75% RDF+ Neem cake @ 500 kg ha^{-1} + *Azospirillum* + PSB	14.40	10.01
S.Em±	1.11	0.85

CD (0.05%)	3.33	2.55
CV (%)	9.93	8.72

Note:

- *Azospirillum* @ 5 kg ha^{-1}; PSB @ 5 kg ha^{-1}
- 100% RDF- 80 N: 40 P_2O_5: 40 K_2O kg ha^{-1}

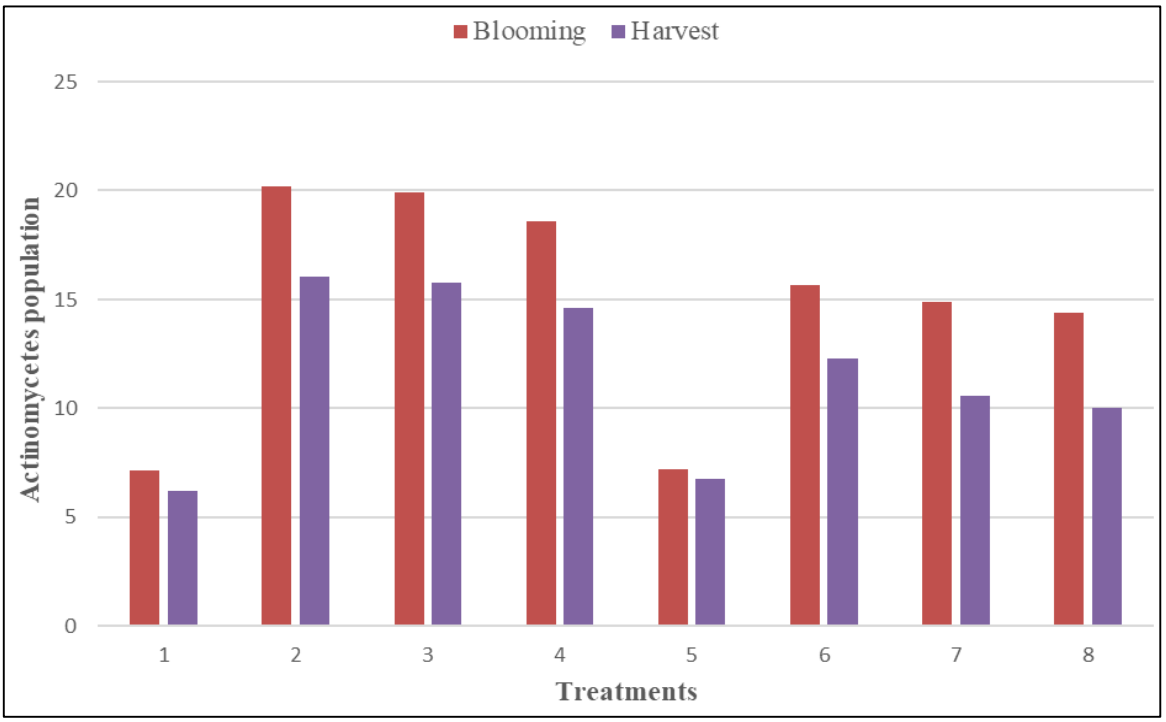

Fig 5: Effect of organic manures and biofertilizers on actinomycetes population (CFU g^{-1}) in soil

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