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Effect of Nitrogen Management on Microbial Population After Harvest of Maize (*Zea mays* L.) in typic haplustepts of Rajasthan

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***Abstract*— *The field experiment was conducted during the kharif season of 2018-19 at the Instructional Farm (Agronomy) of the Rajasthan College of Agriculture in Udaipur, situated at an altitude of 579.5 meters above sea level, with coordinates 24º34' latitude and 73º42' longitude. This region falls under agro-climatic zone IVa (Subhumid Southern Plain and Aravalli Hills) of Rajasthan. The results indicated that the highest populations of bacteria, fungi, and actinomycetes in the soil were observed under treatment T11, which involved 100% recommended dose of nitrogen from chemical fertilizers combined with 10 tons of FYM per hectare. This was followed by T3 (75% RDN from chemical fertilizers and 25% RDN from poultry manure), T2 (75% RDN from chemical fertilizers and 25% RDN from enriched compost), T4 (75% RDN from chemical fertilizers and 25% RDN from vermicompost), and T12 (100% RDN from chemical fertilizers), consistent across both years and in the pooled analysis.*

***Keywords*— Maize, Bactria, Fungi and Actinomycetes.**

I. INTRODUCTION

Maize has high production potential crop when compared to any other cereal crop. The productivity of maize is mainly dependent on its nutrient management. It is well known that maize is a heavy feeder of nutrients and because of its C_4 nature; it is very efficient in converting solar energy into production of dry matter. The crop has high genetic yield potential. Hence, it is called Miracle crop and "Queen of Cereals" (Durani et al., 2018). It has a fibrous root system that anchors the plant and allows for efficient nutrient and moisture uptake. The tall, erect stem can reach heights of 3 to 12 feet and consists of nodes, where leaves emerge, and internodes in between. Leaves are long, narrow and arranged alternately along the stem, playing a crucial role in photosynthesis. These morphological traits enable maize to thrive in various environments, making it a vital crop globally.

Improper farming techniques, such as excessive application of chemical inputs and frequent changes in land use, contribute to variability in soil microbial communities, adversely affecting soil fertility and productivity (Onet *et al.,* 2016). Conversely, organic farming methods that utilize eco-friendly fertilizers, such as compost, manure and microbial amendments, can mitigate some of the harmful effects associated with synthetic fertilizers (Aurelia Onet *et al.,* 2019). Moreover, studies indicate that prolonged monocultures without the incorporation of organic fertilizers or crop rotation, combined with continuous mineral fertilizer application, lead to a significant decrease in soil organic matter (Luo *et al*., 2015). Mineral fertilization has also been linked to reduced soil porosity and nutrient availability (Song *et al.*, 2015). The use of synthetic fertilizers disrupts the biological interactions within the soil ecosystem, negatively impacting both soil microorganisms and the overall health of agricultural systems, thereby exacerbating the environmental consequences of farming (Lucian Constantin Dincă *et al.,* 2022).

Applying herbicides to soil microorganisms can inhibit, activate, or have no effect at all. Bezuglova *et al.* (2019) showed that foliar application of sulfonylurea herbicide decreased the abundance of bacteria, especially for the quickly growing ones on winter wheat soil. Jie chen *et al.* (2021) reported that sterane first decreased soil bacterial diversity and abundance in maize fields 10 days after sowing but increased them 60 days after application. Herbicides changed the population and diversity of the cultivatable soil bacteria, actinomycetes and fungi, according to research done by Borowik *et al.* (2017) after applying a mixture of herbicide consisting of terbuthylazine, S-metolachlor, and mesotrioneto pot culture maize soil (Bezug *et al*., 2017). According to Borowik (2017), the spray of sulfonylurea herbicide on winter wheat soil caused stress on the soil, which in turn affected the plants and soil bacteria.

Additionally, a study by Borowik *et al.* (2017) reported that a combination of herbicides—specifically terbuthylazine, S-metolachlor, and mesotrione altered the populations and diversity of cultivatable soil bacteria, actinomycetes, and fungi in maize pot cultures. Borowik (2017) also noted that the use of sulfonylurea herbicides imposed stress on the soil environment, which subsequently impacted both plant health and soil microbial communities. Herbicides may influence soil microbial diversity by affecting root growth and altering the secretion of root exudates, which are known to play a critical role in regulating microbial communities in the soil.

Majorly poor management of N fertilizer has key role to play in obtaining low yield productivity, so in order to achieve optimum crop productivity management of nutrients through judicious application of inorganic sources, organic sources, bio-fertilizers and micro-nutrients are required (Gu and Yang *et al*., 2022). Improving N management is required to understand the contribution of a farmer's behavior to current N application practical problems, such as N use efficiency (NUE) of the main cereal production system (McAllister *et al*., 2012).The use of appropriate and conjunctive use of application of suitable nutrients through organic and inorganic solely or in combination can provide the solutions to the problems such as increase in the price of inorganic fertilizers and deterioration effect of soil fertility and productivity.

II. MATERIAL AND METHODS

The field experiment was carried out during the kharif season of 2018-19 at the Instructional Farm (Agronomy) of the Rajasthan College of Agriculture in Udaipur, located at an altitude of 579.5 meters above mean sea level, with coordinates at 24º34' latitude and 73º42' longitude. This area is classified under agro-climatic zone IV-a (Subhumid Southern Plain and Aravalli Hills) of Rajasthan. In 2018, the mean maximum and minimum temperatures were 34.40°C and 13.70°C, while in 2019, they were 33.60°C and 13.20°C, respectively. The soil used for the experiment was clay loam in texture, exhibiting a bulk density of 1.55 and 1.56 Mg m^{-3}, a particle density of 2.65 and 2.66 Mg m^{-3}, porosity of 41.46% and 41.35%, and water holding capacity of 38.91% and 39.00% for the years 2018 and 2019. The soil's pH levels were 8.27 and 8.28, electrical conductivity (EC) was 0.85 and 0.86 dS m^{-1}, organic carbon content was 0.50% and 0.52%, and cation exchange capacity was 9.03 and 9.20 Cmol (P^{+}) kg^{-1}. The available nitrogen ranged from 265 to 278 kg ha^{-1}, while available phosphorus was 16.27 and 17.13 kg ha^{-1}, and available potassium was 430 and 442 kg ha^{-1} during 2018 and 2019, respectively.

Application of organic manure and nitrogen fertilization

The organic nutrient sources used in the experiment included farmyard manure, enriched compost, poultry manure, and vermicompost. These organic manures were applied to the field according to specific treatments and thoroughly mixed in one month prior to sowing, while chemical fertilizers were applied at the time of planting. The nutrient contents of the organic manures were as follows: farmyard manure (FYM) had 0.49% nitrogen, 0.25% P_2O_5, and 0.48% K_2O; enriched compost contained 1.2% nitrogen, 2.1% P_2O_5, and 0.9% K_2O; poultry manure had 1.4% nitrogen, 1.0% P_2O_5, and 1.1% K_2O; and vermicompost contained 1.6% nitrogen, 1.3% P_2O_5, and 1.2% K_2O. The recommended application rates for nitrogen, phosphorus, and potassium were 120:60:30 kg ha^{-1}. Nitrogen was supplied through urea in two equal applications: half as a basal dose and the remaining half as top dressing at the knee-high stage of growth.

Experimental design and treatments

The experiment was designed using a Randomized Block Design with three replications and thirteen treatments. These treatments included various combinations of organic manure and chemical nitrogen fertilizers viz., T_0 : Control T_1 : 75% Recommended N through CF + 25% Recommended N through FYM, T_2 : 75% Recommended N through CF + 25% Recommended N through Enriched Compost, T_3 : 75% Recommended N through CF + 25% Recommended N through Poultry Manure, T_4 : 75% Recommended N through CF + 25% Recommended N through Vermicompost; T_5 : 50% Recommended N through CF + 25% Recommended N through FYM + 25%

Recommended N through Enriched Compost, T_6 : 50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure, T_7 : 50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost, T_8 : 50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure, T_9 : 50% Re commended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost, T_{10} : 50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure, T_{11} : 100% Recommended N through CF + FYM (10 t ha^{-1}) and T_{12} : 100% Recommended N through CF. Maize variety Pusa Early Hybrid Maize-2 (PEHM-2) was sown at the seed rate of 25 kg ha^{-1} at inter row of 60 and plant to plant spacing of 20 cm.

Statistical analysis

The data collected for various parameters were analyzed using the analysis of variance (ANOVA) technique as described by Panse and Sukhatme (1985) for a factorial randomized block design. The results are reported at a 5% significance level (P = 0.05).

III. RESULT AND DISCUSSION

An assessment of data shows that bacteria, fungi & actinomycetes population in post harvested soil increased due to integrated use of organic and inorganic nitrogen source during both the years and in pooled mean. The data shown in Table 1 and Figure 1 reveal that the highest bacterial population in the soil, measured at 41.25, 41.75, and 41.50 cfu $g^{-1,}$ was found under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}). This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer), across both years and in the pooled mean. In contrast, the lowest bacterial population of 12.68, 13.11, and 12.89 cfu g^{-1} was observed under T_0 (control) during both years and in the pooled mean. The data presented in Table 2 and Figure 2 indicate that the highest fungal population in the soil was observed under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}), with values of 18.27, 18.67, and 18.47 cfu g^{-1}. This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer) across both years and in the pooled mean. Conversely, the lowest fungal population was recorded under T_0 (control), with values of 6.88, 7.30, and 7.09 cfu g-1 during both years and in the pooled mean. The data presented (Table 3 and figure 3) shows that highest actinomycetes (26.00, 26.72 and 26.36 cfu g^{-1}) population in soil was recorded under T_{11} (100 % RDN through chemical fertilizer +FYM @10t ha^{-1}) followed by T_3 (75 % RDN through chemical fertilizer +25% RDN through poultry manure), T_2 (75 % RDN through chemical fertilizer + 25% RDN through enriched compost), T_4 (75 % RDN through chemical fertilizer + 25% RDN through vermicompost) and T_{12} (100 % RDN through chemical fertilizer) during both years and in pooled mean, respectively. The lowest actinomycetes (8.87, 9.27 and 9.07 cfu g^{-1}) population in soil was recorded under T_0 (control) during both years and in pooled mean, respectively and the increase in bacteria, fungi and actinomycetes population in soil was obtained to the extent of 221.83, 194.73, 192.40, 182.32 &165.26; 160.56, 148.99 , 137.71, 129.33 and 124.02 and 190.60, 165.26, 156.00, 153.58 & 142.55 per cent in pooled analysis with the application of T_{11}, T_3, T_2, T_4 & T_{12} as compared to control (T_0), respectively. All the treatments combination of organic and inorganic source of nitrogen significantly improved the soil microbial population (bacteria, fungi and actinomycetes) during 2018, 2019 and on pooled analysis. The application of 100% RDN through chemical fertilizer plus 10t ha^{-1} farmyard manure reported highest soil microbial population (bacteria, fungi and actinomycetes) in soil during during 2018, 2019 and on pooled analysis. The use of organic manure (FYM/ enriched compost/ and poultry manure) along with chemical fertilizer led to higher microbial population in soil and increase microbial respiration than use of chemical fertilizer alone. Organic manure is a rich source of organic matter and an important source of nutrients for plants and microorganisms in soil. The incorporation of organic manure in soil promoted microbial activities and improved chemical fertilizer use efficiency. The lowest microbial activity was noticed in control and the plots receiving nutrients through chemical fertilizers alone, which might be due to more acidification of soil and mining of the macronutrients. The cumulative effect of organic and inorganic fertilization in increasing organic carbon content of soil which acted as carbon and energy source for microbes and their quick build up in the soil (Sun *et al*., 2015). The present study showed higher microbial population in FYM treated plot along with chemical fertilizers because FYM is a source of nutrient and also as substrate for decomposition and mineralization of nutrients, thereby creating a favourable condition for the proliferation of the microbes in the soil. Among the microbes, bacterial population was maximum followed by actinomycetes and fungi, which may be due to their higher multiplication rates (Dincă *et al*., 2022). The organic-inorganic fertilizers may improve nutrient cycling which increased the nutrients status of soil and higher nutrient status accelerated the microbial activity in soil and these results were supported by Zhang *et al.* (2021).

IV. CONCLUSION

On the basis of above experiment it is concluded that the highest bacteria, fungi and actinomycetes population in the soil was found under treatment T_{11} (100% RDN from chemical fertilizer + FYM at 10 t ha^{-1}). This was followed by T_3 (75% RDN from chemical fertilizer + 25% RDN from poultry manure), T_2 (75% RDN from chemical fertilizer + 25% RDN from enriched compost), T_4 (75% RDN from chemical fertilizer + 25% RDN from vermicompost), and T_{12} (100% RDN from chemical fertilizer), across both years and in the pooled mean.

Table 1: Effect of nitrogen management on bacteria population in soil after harvest of maize crop

Symbol	Treatments	Bacteria (10^7cfu g^{-1} of soil)		
		2018	**2019**	**Pooled**
T_0	Control	12.68	13.11	12.89
T_1	75% Recommended N through CF + 25% Recommended N through FYM	33.68	34.09	33.88
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	37.50	37.91	37.70
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	37.80	38.21	38.00
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	36.20	36.61	36.40
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	32.00	32.41	32.20
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	32.24	32.65	32.44
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	30.58	30.99	30.78
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	33.36	33.77	33.56
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	32.45	32.86	32.65
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	32.68	33.09	32.88
T_{11}	100% Recommended N + FYM (10 t/ha)	41.25	41.75	41.50
T_{12}	100 % Recommended N through CF	34.00	34.41	34.20
	SEm±	0.56	0.71	0.45
	CD (P=0.05)	1.63	2.06	1.28

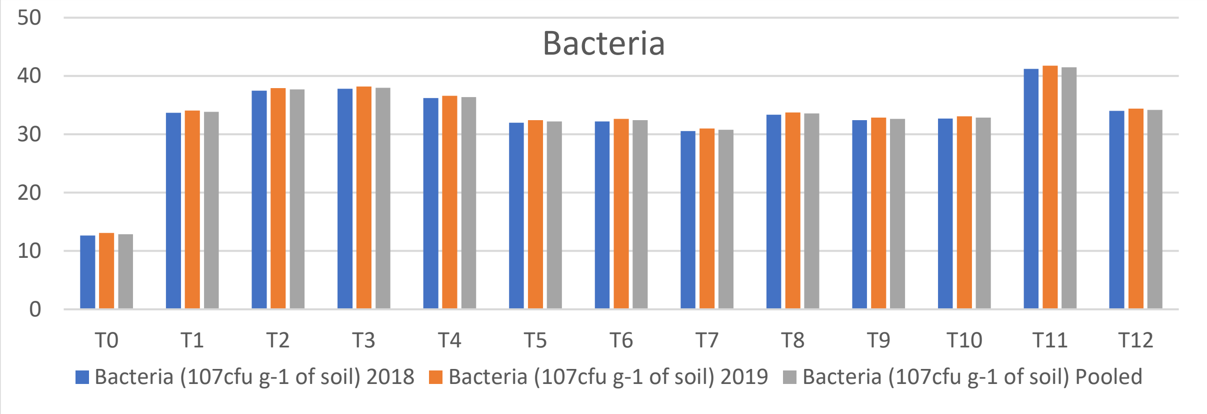

Fig.1: Effect of nitrogen management on bacteria population in soil after harvest of maize crop

Table 2: Effect of nitrogen management on Fungi population in soil after harvest of maize crop

Symbol	Treatments	Fungi (10^5 cfu g^{-1} of soil)		
		2018	**2019**	**Pooled**
T_0	Control	6.88	7.3	7.09
T_1	75% Recommended N through CF + 25% Recommended N through FYM	15.5	15.9	15.7
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	16.65	17.05	16.85
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	17.45	17.85	17.65
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	16.06	16.46	16.26
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	14.01	14.41	14.21
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	14.26	14.66	14.46
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	12.88	13.28	13.08
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	15.32	15.72	15.52
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	14.68	15.08	14.88
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	15.02	15.42	15.22
T_{11}	100% Recommended N + FYM (10 t/ha)	18.27	18.67	18.47
T_{12}	100 % Recommended N through CF	15.68	16.08	15.88
	SEm±	0.27	0.27	0.19
	CD (P=0.05)	0.79	0.8	0.55

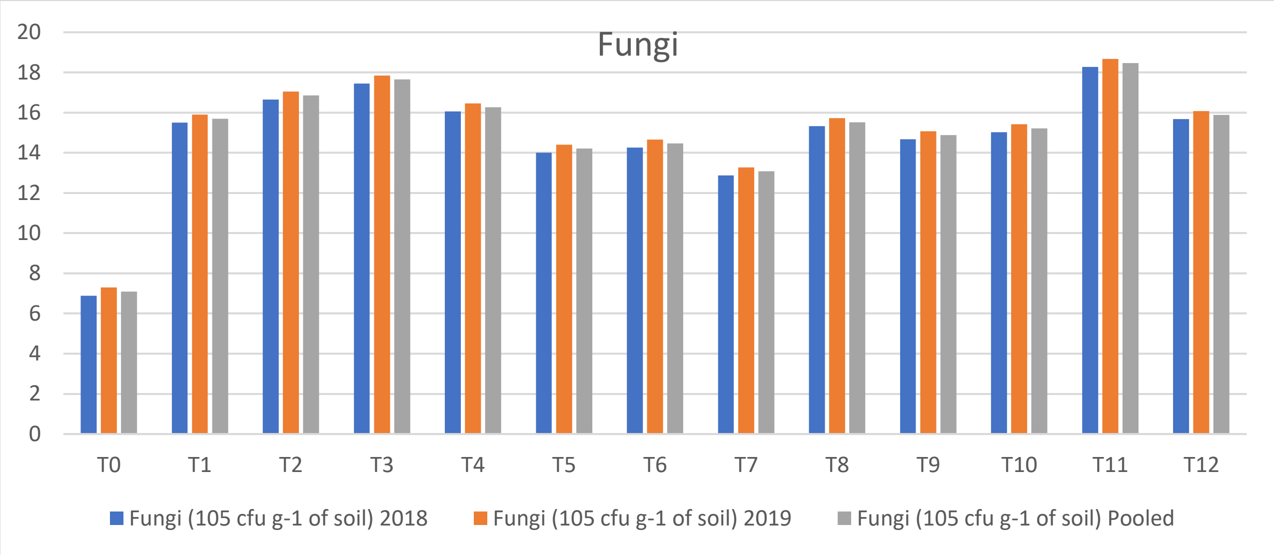

Fig.2: Effect of nitrogen management on fungi population in soil after harvest of maize crop

Table 3: Effect of nitrogen management on actinomycetes population in soil after harvest of maize crop

Symbol	**Treatments**	**Actinomycetes (10^6 cfu g^{-1} of soil)**		
		2018	**2019**	**Pooled**
T_0	Control	8.87	9.27	9.07
T_1	75% Recommended N through CF + 25% Recommended N through FYM	21.23	21.63	21.43
T_2	75% Recommended N through CF + 25% Recommended N through Enriched Compost	23.02	23.43	23.22
T_3	75% Recommended N through CF + 25% Recommended N through Poultry Manure	23.86	24.27	24.06
T_4	75% Recommended N through CF+ 25% Recommended N through Vermicompost	22.80	23.21	23.00
T_5	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Enriched Compost	18.02	18.42	18.22
T_6	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Poultry Manure	18.65	19.05	18.85
T_7	50% Recommended N through CF + 25% Recommended N through FYM + 25% Recommended N through Vermicompost	18.00	18.40	18.20
T_8	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Poultry Manure	21.12	21.52	21.32
T_9	50% Recommended N through CF + 25% Recommended N through Enriched Compost + 25% Recommended N through Vermicompost	19.20	19.60	19.40
T_{10}	50% Recommended N through CF + 25% Recommended N through Vermicompost + 25% Recommended N through Poultry Manure	19.88	20.28	20.08
T_{11}	100% Recommended N + FYM (10 t/ha)	26.00	26.72	26.36
T_{12}	100 % Recommended N through CF	21.80	22.21	22.00
	SEm±	0.43	0.42	0.30
	CD (P=0.05)	1.25	1.24	0.86

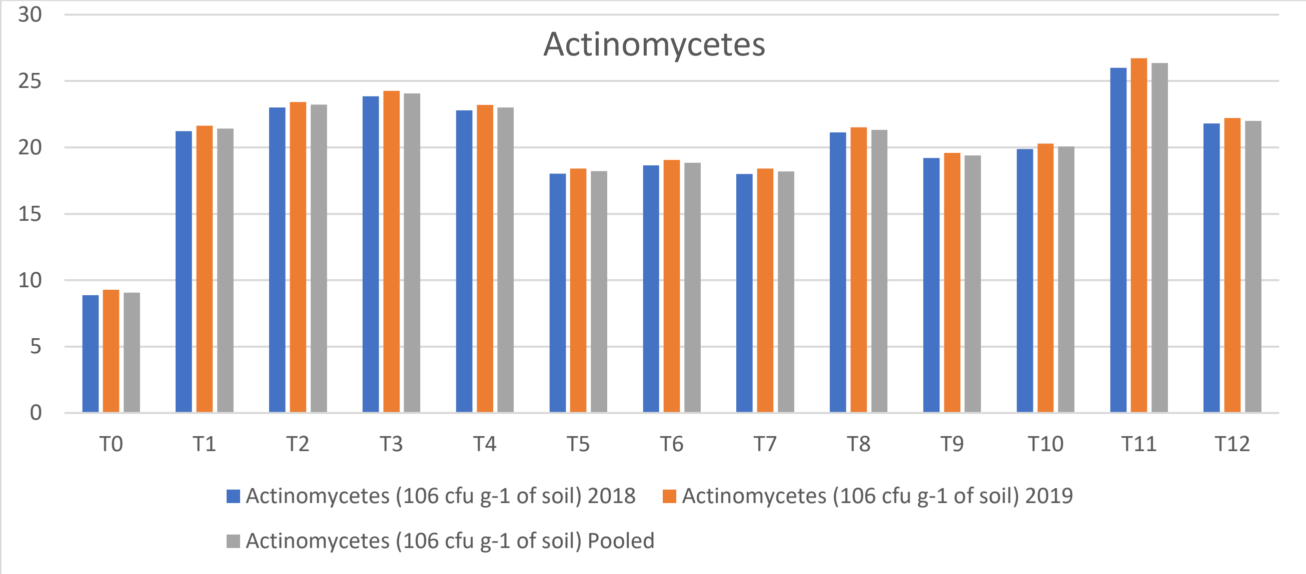

Fig.3: Effect of nitrogen management on actinomycetes population in soil after harvest of maize crop

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