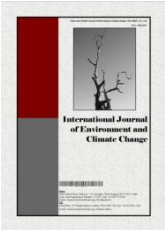

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Effect of Biofertilizer and Organic Manure on Growth and Yield of Pearl Millet (*Pennisetum glaucum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Kharif season* of 2021, at crop research farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj in North Eastern plains of Eastern Uttar Pradesh. The objective of the research study was to determine the effect of Bio fertilizer and Organic manure on growth and yield of Pearl millet under Randomized block design comprising of 9 treatments of which treatments with different combination of *Rhizobium* and *VAM* along with Organic manure like FYM and Vermicompost which were replicated thrice. The experimental results revealed that plant height (201.20 cm) and plant dry weight (50.05 g) were recorded significantly (P<0.05) highest in treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. The highest number of ears/hill (2.43), number of grains/ear head (2157.33), grain yield (1973.00 Kg/ha), straw yield (3920 kg/ha) and harvest index (41.32%) were recorded with treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha.

Keywords: Growth; economics; FYM; pearl millet; rhizobium; VAM; vermicompost; yield.

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1. INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) is the warm season and most broadly grown drought tolerant crop. It is the coarse cereal grown nearly in 25 M ha and also in some of the harsh semi-arid tropical environments of sub-Sahara and South Asia. It is the 6th most important cereal crop grown next to maize, rice, wheat, barley and sorghum in the world and also consumed as feed and fodder for livestock. It is the fourth most extensively grown food crop after paddy, wheat and maize. It occupies an area of 6.93 M ha with an average production of 8.61 M ha tones and 1243 kg/ha of productivity during 2018-19 [1]. It outperforms all other cereals due to its unique characteristics: a C4 plant with high photosynthetic efficiency, high dry matter production capacity, and the ability to grow in the harshest agro-climatic conditions, where other crops such as sorghum and maize fail to produce economically viable yields.

Pearl millet is a good source of calories, carbohydrate, protein, fat, ash, dietary fibre, iron, and zinc, and is appropriately referred to as a "nutricereal." Its grain is more nutritious, and its protein level is not only high, but also of high quality. The grain is high in phosphorus and iron, and includes 11-19 per cent protein, 60-78 per cent carbohydrates, and 3.0-4.6 per cent fat. It is fairly rich in fat content as compared to the other cereals. It has the maximum potential of all the millets and is mainly grown in drought prone areas and marginal soils. India is one of the largest producers of coarse cereals with as many as 10 predominantly rained crops, grown in diverse soils, climate and harsh environments. It occupies fourth place in cereals and second place in coarse cereals and is the maximum widely cultivated millet next to Jowar in India.

One of the most important non-symbiotic N-fixing microbes is Azotobacter. A vast number of trials have indicated that Azotobacter application has a beneficial response in a wide range of crops, including cereals, vegetables, cotton, and sugarcane. The benefits are due to its N-fixing capacity, ability to produce growth promoting substances and antifungal antibiotics, which inhibit the growth of root pathogens. Azotobacter is a nitrogen-fixing bacteria that may fix up to 20 kg of nitrogen per hectare in nonlegumes [2]. It converts elemental nitrogen into the ammonical form (NH4+), which the crop can use. In addition, Azotobacter's ability to manufacture auxins, vitamins, growth factors, and antifungal medicines gives it a competitive advantage. The roots absorbed the nitrogen fixed by Azotobacter in the soil near the root zone (Rhizosphere), which may have boosted the crop's growth qualities [3].

Azospirillum benefits plants through mechanisms that improve plant development, increase mineral uptake, increase dry matter, increase water absorption, and increase yield. In recent years, carrier-based Azospirillum inoculants for non-leguminous crops have grown in popularity in India. Azospirillum is a Rhizosphere bacterium that colonizes the roots of crop plants and fixes a significant quantity of atmospheric nitrogen using root exudates. They have a positive impact on the growth and yield of a variety of commercially significant crops [4].

In tropical nations like India, maintaining soil organic matter is a challenge, hence applying organic wastes is critical for maintaining fertility levels. Soil organic matter is crucial for ecosystem services and agronomic yields [5, 6]. Despite the fact that the world is facing climate change due to rapidly increasing CO2 levels in the atmosphere, soil organic matter accumulation and thus C sequestration [7] have received attention as a climate change mitigation option at global [8] and regional scales since the 1990s. Indeed, soil carbon sequestration is an essential alternative for not just mitigating climate change but also improving soil fertility and overall agro-ecosystem production [9, 10].

In field crops, FYM is a significant source of organic manure. However, the manure's limited availability is a major stumbling block to its utilisation as a fertiliser source. The decomposing mixture of farm animal excrement and urine, as well as litter and leftover material from roughages or fodder fed to cattle, is referred to as farm yard manure. FYM is a good source of plant nutrients and is high in organic matter. Because of the poor nutrient economy of light textured soil, FYM must be used to complement fertiliser. Organic matter increases the capacity of the soil to store water. Improvement in physical properties of soil, organic carbon and available nitrogen, phosphorus and potassium due to long term application of FYM and fertilizer has been documented by [11]. It is a storehouse of key plant nutrients, has an impact on the physical, chemical, and biological aspects of soil, gives energy to soil organisms, and is critical for long-term crop productivity. Between the ground surface and the atmosphere, it also acts as a sink for greenhouse gases.

Vermicompost has been promoted as a good organic manure for use in field crops as part of integrated nutrient management methods. Vermicompost is becoming increasingly popular as a substitute for other organic manures due to its higher nutritional concentration and faster release of nutrients, which are largely available to the current crop. It also contributes to the improvement of the soil's physical condition. Vermicomposting is a cost-effective and environmentally beneficial approach to recycle agricultural and household waste. It's also known as biological manure, and its use not only supplies plant nutrients and growth regulators to the soil, but it also improves water retention, nutrient content, and organic carbon content.

1.1 Objective

To study of effect of Bio fertilizer and Organic manure levels on growth and yield of pearl millet.

2. MATERIALS AND METHODS

2.1 Site Selection

During the kharif season of 2021, a field experiment was conducted at the Crop Research Farm of the Department of Agronomy at Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj, which is located at 25o 24' 42" N latitude, 81o 50' 56" E longitude, and 98 m above mean sea level (MSL). To determine the impact of Bio fertilizer and Organic manure on growth and yield of Pearl millet (*Pennisetum glaucum* L.). The experiment was laid out in Randomized Block Design comprising of 9 treatments which are replicated thrice. Each treatment net plot size is 3m × 3m. The treatment are categorized as with recommended dose of nitrogen through urea and potash through Muriate of Potash, in addition with Phosphorus and zinc when applied in combinations as follows, T1 – *Rhizobium* @ 10 g/kg + FYM @ 5 t/ha, T2 – *Rhizobium* @ 10 g/kg + Vermicompost @ 5 t/ha, T3 – *Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, T4 – *VAM* @ 10 g/kg + FYM @ 5 t/ha, T5 – *VAM* @ 10 g/kg + Vermicompost @ 5 t/ha, T6 – *VAM* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, T7 – *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 5 t/ha, T8 - *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha, T9 – *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha.

2.2 Data Collection

At harvesting maturity, the pearl millet crop was harvested treatment by treatment. Plant height (cm) and dry matter accumulation g plant-1 were manually recorded on five randomly selected representative plants from each plot of each replication individually, and seeds were isolated from each net plot and dried in the sun for three days after harvesting. After that, the grain was winnowed, cleaned, and the yield per hectare was calculated and expressed in tonnes per hectare. After a 10-day sun drying period, the stover production from each net plot was measured and expressed in kilogrammes per hectare.

2.3 Data Analysis

The data was generated and analysed using the Gomez and Gomez statistical approach [12].

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

It is evident from Table-1 that plant height measured increased with advancement in crop growth. At harvest significantly ($P<0.05$) maximum plant height 201.20 cm was recorded with treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. However, treatment *Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha are statistically at par to the treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. *Rhizobium* inoculation significantly enhanced the plant height, which could be attributed to increase in uptake of nutrients more specifically nitrogen. Availability of N increased the vegetative growth due to rapid cell multiplication. *VAM* has been related to increased uptake of nutrients, especially Phosphorus leading to increase in plant height. Increased availability of nutrients through vermicompost and FYM in the soil through mineralization of organic sources could have triggered cell elongation and multiplication resulting in higher growth rate of shoots in turn plant height of pearl millet in organic. Combinations of organics and inorganics ensured ready availability of nutrients at initial stages of crop due to improved soil properties and prolonged nutrient availability through

organics also helped increase plant height. Similar findings were also reported by Narolia et al., [13], Sharma et al., [14].

3.2 Dry Matter Accumulation

At Harvest plant dry weight (50.05 g/hill) was found to be significantly (P<0.05) maximum in the treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha (49.49 g/hill). However, treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha was found to be statistically at par to the *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. *Rhizobium* and *VAM* significantly enhanced the plant dry weight, which could be attributed to increase in uptake of nutrients more specifically nitrogen. Availability of N increased the vegetative growth due to rapid cell multiplication, while phosphorus fertilization through *VAM* improved the root system which in turn helped more assimilation of nutrients resulting in increased plant dry weight. The improved physico -chemical properties due to Vermicompost and FYM increased availability of nutrients at a slow rate for a longer period with the use of organics might be responsible for more tillers, maximum leaf area and increased photosynthesis leading to accumulation of significantly higher dry matter. Similar findings were also reported by Narolia et al., [13], Sharma et al., [14], Aravind et al*.* [15]**.**

3.3 Yield and Yield Attributes

3.3.1 Number of ears/hill

Significant effect was observed by the statistical analysis of ear head length. Treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha resulted in significantly (P<0.05) higher number of ears/hill (2.43). However, *Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, *VAM* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 5 t/ha, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha were found to be statistically on par with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. Increase in number of ears/hill was due to *Rhizobium* and *VAM* may be attributed to reason that *Rhizobium* enhanced nitrogen utilization efficiency along with enzymatic attributes, while *VAM* enhanced efficiency of nutrients absorption and release of growth substances which increased Number of ears/hill and Number of grains/ear.

Table 1. Effect of Bio fertilizer and Organic manure on growth parameters of pearl millet

S.No	Treatments	Plant height (cm)	Dry matter accumulation (g plant^{-1})
1.	*Rhizobium* @ 10 g/kg + FYM @ 5 t/ha	178.67	39.83
2.	*Rhizobium* @ 10 g/kg + Vermicompost @ 5 t/ha	183.57	40.93
3.	*Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	193.10	43.81
4.	*VAM* @ 10 g/kg + FYM @ 5 t/ha	176.70	38.14
5.	*VAM* @ 10 g/kg + Vermicompost @ 5 t/ha	180.63	41.55
6.	*VAM* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	190.20	42.86
7.	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 5 t/ha	186.90	41.95
8.	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha	196.17	46.93
9.	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	201.20	50.05
	S.Em (±)	3.45	1.29
	CD (P 0.05)	10.33	3.86

Vermicompost and FYM are the cumulative effects of plant growth and vigour, which result in a larger supply of metabolites that have a substantial impact on growth character and yield qualities, as well as a higher rate of photosynthesis and higher photosynthate translocation from source to sink for development. Similar results were also reported by Choudhary and Gautam [16], Kumar et al., [17], Fazily et al. [18].

3.3.2 Number of grains/ear head

Significant effect was observed by the statistical analysis of number of grains/ear. Treatment *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha recorded significant ($P<0.05$) and highest number of grains/ear (2157.33). However, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha recorded statistical parity with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. Increase in number of grains per ear was due to *Rhizobium* and *VAM* may be attributed to reason that *Rhizobium* enhanced nitrogen utilization efficiency along with enzymatic attributes, while *VAM* enhanced efficiency of nutrients absorption and release of growth substances which increased Number of grains/ear. Vermicompost and FYM are cumulative effect of growth and vigour of plants which leads to increased supply of metabolites which have significant effect on growth character and yield attributes and also higher rate of photosynthesis as well as higher translocation of photosynthates from source to sink for the development. Similar results were also reported by Choudhary and Gautam [16], Kumar et al., [17], Anil kumar et al., [19].

3.4 Grain Yield

The grain yield showed increasing trend with the application of Bio fertilizer and Organic manure in pearl millet. Significant and highest ($P<0.05$) grain yield (1973 kg/ha) was observed under *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. However, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha was found to be statistically on par with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. Application of Bio fertilizers like *Rhizobium* and *VAM* along with Organic manures like FYM and Vermicompost increased the soil fertility and availability of nutrients which might have resulted in increased translocation and production of photosynthates at the source. This production of photosynthates might have been utilized by the plants to increase yield. The increase amount of nutrients uptake might have promoted root enabling them to absorb more nutrients, thereby enhancing grain yield. Application of FYM and vermicompost released the macro and micro nutrient during the course of microbial decomposition. The increased yield in organic treatment through vermicompost can be attributed improved physical conditions of the soil apart from during the entire crop growing phase, nutrients are slowly released. During the growth and development of plants, the progressive release and consistent supply of nutrients from vermicompost could have kept photosynthetic efficiency and metabolite production at a greater level, as well as the translocation of photosynthates to various sinks, resulting in increased grain yield. A similar set of findings was also published by Basavaraju *et al*., [20] and Panchal *et al.,* [21].

3.5 Stover Yield

The straw yield of pearl millet was also influenced by the application of Bio fertilizer and Organic manure. Highest ($P<0.05$) straw yield (3920 kg/ha) was recorded with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, however, *Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha, *VAM* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha and *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha were found to be statistically on par with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha. Application of Bio fertilizers like *Rhizobium* and *VAM* along with Organic manures like FYM and Vermicompost increased the soil fertility and availability of nutrients which might have resulted in increased translocation and production of photosynthates at the source. This production of photosynthates might have been utilized by the plants to increase yield. The increase amount of nutrients uptake might have promoted root enabling them to absorb more nutrients, thereby enhancing straw yield. Application of FYM and vermicompost released the macro and micro nutrient during the course of microbial decomposition. The increased yield in organic treatment through vermicompost can be attributed improved physical conditions of the soil

Table 2. Effect of Bio fertilizer and Organic manure on yield and yield attributing characters of pearl millet

S. No	Treatments	Ear head length (cm)	No. of grains/ear head	Grain Yield (Kg ha^{-1})	Stover Yield (Kg ha^{-1})
1	*Rhizobium* @ 10 g/kg + FYM @ 5 t/ha	1.43	1848.00	1543.33	3530
2	*Rhizobium* @ 10 g/kg + Vermicompost @ 5 t/ha	1.77	1929.33	1669.67	3575
3	*Rhizobium* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	2.23	2019.33	1796.67	3761
4	*VAM* @ 10 g/kg + FYM @ 5 t/ha	1.20	1797.00	1505.00	3474
5	*VAM* @ 10 g/kg + Vermicompost @ 5 t/ha	1.67	1893.67	1633.33	3550
6	*VAM* @ 10 g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	2.00	1985.33	1746.33	3726
7	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 5 t/ha	1.90	1970.00	1700.67	3629
8	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + Vermicompost @ 5 t/ha	2.33	2115.00	1817.00	3850
9	*Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha	2.43	2157.33	1973.00	3920
	S.Em (±)	0.21	44.59	16.58	68.71
	CD (P 0.05)	0.63	133.68	49.71	205.98

apart from slow release of nutrients during entire crop growth period. During the growth and development of plants, the progressive release and consistent supply of nutrients from vermicompost could have kept photosynthetic efficiency and metabolite production at a greater level, as well as the transfer of photosynthates to various sinks, resulting in increased straw yield. A similar set of findings was also published by Upendranaik et al. [22] and Singh et al. [23].

4. CONCLUSION

Based on the findings of the investigation it may be concluded that treatment with *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha 25 kg N/ha + 50 kg P/ha performed exceptionally in all growth and yield parameters and in obtaining maximum grain yield of pearl millet. Hence, *Rhizobium* @ 5 g/kg + *VAM* @ 5g/kg + FYM @ 2.5 t/ha + Vermicompost @ 2.5 t/ha 25 kg N/ha + 50 kg P/ha may be more preferable and can be recommended to the farmers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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