Studies on Growth, Yield and Economics of Pearl millet (*Pennisetum glaucum* L.) var. VARUN - 666 as influenced by Bio fertilizer and Spacing

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 with the objective to study the effect of bio fertilizer and spacing on growth, yield and economics of Pearl millet (*Pennisetum glaucum* L.) Var. VARUN - 666 under Randomized block design comprising of 9 treatments of which treatments (T_1-T_9) with different bio fertilizer combination of Azatobacter and Azospirillum along with spacing which are replicated thrice. The experimental results revealed that Application of Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm recorded significantly higher plant height (210.20 cm), Number of leaves/hill (40.3), Highest plant dry weight (49.49 gm), number of tillers/hill (3.3), number of ears/hill (2.43), number of grains/ear head (2097.33), grain yield (2.77 t/ha), straw yield (3.91 t/ha net return (Rs.1,03,453/ha), gross return (Rs.1,41,440/ha) and benefit: cost ratio (2.72).

Key words- Pearl millet, Azatobacter, Azospirillum, Spacing,Growth, Yield, Economics

INTRODUCTION

The millets are a group of highly variable small grained grasses, widely grown around the world as cereal crops. It is a dual purpose crop grown as grain for food and fodder for animals. Millets are important crop in the semi-arid tropics of Asia and Africa. In Asia, it is especially grown in the country like India and in African continent is grown in countries like Nigeria and Niger. Millets are favoured due to its productivity and short growing season under dry and high temperature conditions. Millets are indigenous to many parts of the world and had an evolutionary origin in tropical western Africa where the great number of both wild and cultivated form exists. Millets have been important food staples in human history, particularly in Asia and Africa and they have been in cultivation in East Asia for the last 10,000 years. India is the world's largest producer of millet.

Pearl millet (*Pennisetum glaucum* L.) is the most widely grown drought tolerant warm season coarse grain cereal grown on 26 million ha in some of the harshest semi-arid tropical environments of south Asia and sub-Sahara Africa. It is also consumed as feed and fodder for livestock. It is the sixth most important cereal crop in the world next to maize, rice, wheat, barley and sorghum. In India, pearl millet is the fourth most widely cultivated food crop after rice, wheat and maize. It occupies an area of 6.93 million ha with an average production of 8.61 million tones and productivity of 1243 kg/ha during 2018-19 (Directorate of Millets Development, 2020; Project Coordinator Review, 2020). It excels all other cereals due to its unique features - C4 plant with high photosynthetic efficiency, high dry matter production capacity and is grown under the most adverse agro-climatic conditions where other crops like sorghum and maize fail to produce economic yields.

Pearl millet is rightly termed as “nutricereal” as it is a good source of energy, carbohydrate, protein, fat, ash, dietary fiber, iron and zinc. Its grain is more nutritious and the protein content is not only high but it is also of good quality. The grain contains 11-19% protein, 60-78% carbohydrates and 3.0-4.6% fat and also has good amount of phosphorous and iron. 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. Pearl millet occupies fourth place in cereals and second place in coarse cereals and is the most widely cultivated millet next to jowar in India.

Bio-fertilizer is microbial inoculants of selective microorganisms like bacteria, fungi already existing in nature. The importance of bio-fertilizer is increasing day by day especially in view of the increasing price of the chemical fertilizer and effect on soil physical condition. It also improves physico-chemical properties of soil and enhances the efficiency of applied fertilizers.

Azotobacter is one of the most important non-symbiotic N-fixing microorganisms. A large number of experiments conducted have shown a positive response of Azotobacter application in wide range of crops like cereals, vegetables, cotton, sugarcane etc. 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 free-living nitrogen fixing bacteria which has been reported to fix about 20 kg N/ha in nonlegumes (Subba Rao, 1982). It fixes elemental nitrogen into ammonical form (NH_4^+) which is being utilized by the crop. In addition to this, the ability of Azotobacter to synthesize auxins, vitamins, growth substances and antifungal antibiotics confer it with supplementary advantage. The nitrogen which is being fixed by the Azotobacter in soil near root zone (Rhizosphere) was absorbed by the roots that might have improved the growth parameters of the crop (Rathore and Gautam, 2003; Kumar *et al*., 2012).

Azospirillum is benefit to plants by mechanisms related to enhancement of plant growth, increases the mineral uptake, increases the dry matter, improve the water absorption and improve the yield. The carrier based Azospirillum inoculant for non-leguminous crops are becoming increasingly popular in India in recent years. Azospirillum is a rhizosphere bacterium colonizing the roots of crop plants making use of root exudates and fixes substantial amount of atmospheric nitrogen. They exert beneficial effects on growth and yield of many economically important crops (Okon and Vanderleyden, 1997).

Out of various agronomical requirements to augment crop productivity, the optimum row spacing is one of the important factors determining crop production under dry as well as irrigated farming. It is well known that optimum plant spacing avoids undue competition for moisture, nutrients and light amongst the crop plants and ultimately results in to higher crop yields.

Plant population has great bearing on pearl millet production especially in dry land areas where crop is subjected to frequent mild to severe moisture stress. A row spacing of 45 cm is normally recommended, however, wider row spacing of 60. 75 and 90 cm have also been reported to give good yields of pearl millet, particularly under dry land conditions. In dry areas, greater number of plants in relation to available soil moisture may revert the efforts for obtaining higher production. Plant population should be reduced to the level where plant stand is consistent with moisture regime, so that soil moisture is not depleted before crop approaches maturity.

MATERIALS AND METHODS

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 which is located at 25° 24' 42" N latitude, 81° 50' 56" E longitude and 98 m altitude above the mean sea level (MSL). To assess the effect of biofertilizer and spacing 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 Potash through Muriate of Potash, in addition with Nitrogen through Urea and Phosphorus through DAP when applied in combinations as followsT1 – Azotobacter @ 25 g/kg + 30 cm × 15 cm, T2 – Azospirillum @ 25g/kg + 30 cm ×15 cm, T3 – Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm,T4 – Azotobacter @ 25 g/kg + 45 cm × 15 cm, T5 – Azospirillum @ 25g/kg + 45 cm ×15 cm, T6 – Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm, T7 – Azotobacter @ 25 g/kg + 60 cm × 15 cm, T8 - Azospirillum @ 25g/kg + 60 cm ×15 cm, T9 – Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The pearl millet crop was harvested treatment wise at harvesting maturity stage. Growth parameters viz. plant height (cm), number of leaves/plant, dry matter accumulation g plant^{-1} were recorded manually on five randomly selected representative plants from each plot of each replication separately and after harvesting, seeds were separated from each net plot and were dried under sun for three days. Later winnowed, cleaned and seed yield per ha was computed and expressed in tonnes per hectare. After complete drying under sun for 10 days stover yield from each net plot was recorded and expressed in tonnes per hectare. The data was computed and analysed by following statistical method of Gomez and Gomez (1984). The benefit: cost ratio was worked out after price value of seed with straw and total cost included in crop cultivation.

RESULTS AND DISSCUSIONS

Effect on growth parameters:

Plant height

It is evident from Table 1. that plant height measured increased with advancement in crop growth. At Harvest maximum plant height (210.20 cm) was recorded with treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. However, treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm, Azotobacter @ 25 g/kg + 60 cm × 15 cm are statistically at par to the treatment Azotobacter @ 12.5g/kg +Azospirillum

@ 12.5g/kg + 60 cm ×15 cm. The better plant growth attributes viz., plant height increased due to bio fertilizers as they improve the growth attributes due to production of various growth regulating substances such as indoles, gibberellins and cytokinins. Azatobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azatobacter and Azospirillum together supplied extra nutrients to the crop as compared to their individual inoculation and increased plant height. The decrease in plant population is due to wider row spacing having lower plants per unit area than closer row spacing. The increase in plant height under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Guggari and Kalaghatagi (2005), Rathore et al., (2006), Khanda et al., (2001), Satish kumar et al., (2004).

Number of leaves/plant

At harvest highest number of leaves (40.3) was recorded with treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. However, treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm was found to be statistically at par to the treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The better plant growth attributes viz., number of leaves/hill increased due to bio fertilizers as they improve the growth attributes due to production of various growth regulating substances such as indoles, gibberellins and cytokinins. Azatobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azatobacter and Azospirillum together supplied extra nutrients to the crop as compared to their individual inoculation and increased number of leaves/hill. The increase in number of leaves/hill under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Guggari and Kalaghatagi (2005), Rathore et al., (2006), Khanda et al., (2001), Satish kumar et al., (2004).

Number of tillers/plant

At Harvest maximum number of tillers (3.3) was recorded with treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. However, treatment Azotobacter @ 25 g/kg + 45 cm × 15 cm, Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm, Azotobacter @ 25 g/kg + 60 cm × 15 cm, Azospirillum @ 25g/kg + 60 cm ×15 cm are found to be statistically at par to the treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The increase in tillers due to Biofertilizer application might be due to Azatobacter and Azospirillum as their application led to higher availability of nitrogen and phosphorus that promoted growth and development and ultimately resulting in increasing number of tillers.The increase in number of tillers/hill under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Kumar and Gautam (2004), Guggari and Kalaghatagi (2005), Khanda et al., (2001), Satish kumar et al., (2004).

Dry matter accumulation

At Harvest maximum plant height was found in the treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm (49.49 g/hill). However, treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm was found to be statistically at par to the treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The better plant growth attributes viz., plant dry weight increased due to bio fertilizers as they improve the growth attributes due to production of various growth regulating substances such as indoles, gibberellins and cytokinins. Azatobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azatobacter and Azospirillum together supplied extra nutrients to the crop as compared to their individual inoculation and increased plant dry weight. Production of Phytohormone or growth regulators by these microbes might have had a greater effect on plant dry weight. The increase in plant height under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Guggari and Kalaghatagi (2005), Rathore et al., (2006), Khanda et al., (2001), Satish kumar et al., (2004).

Yield and Yield Attributes:

Number of ears/hill

Significant effect was observed by the statistical analysis of number of ears/hill. Treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm resulted in significantly higher number of ears/hill (2.43). However, Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm, Azotobacter @ 25 g/kg + 60 cm × 15 cm, Azospirillum @ 25g/kg + 60 cm ×15 cm were found to be statistically on par with Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. Azatobacter and Azospirillum are reported to fix atmospheric nitrogen, produce plant growth promoting substances like Indole Acetic Acid (IAA) and Indole Butyric Acid (IBA) and also increase the rate of mineral uptake by plant roots which in turn resulted in increase of number of ears/hill . The increase in number of ears/hill under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Kumar and Gautam (2004), Guggari and Kalaghatagi (2005), Khanda et al., (2001), Satish kumar et al., (2004).

Number of grains/ear head

Significant effect was observed by the statistical analysis of number of grains/ear. Treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm recorded significant and highest number of grains/ear (2097.33). However, Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm recorded statistical parity with Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. Azatobacter and Azospirillum are reported to fix atmospheric nitrogen, produce plant growth promoting substances like Indole Acetic Acid (IAA) and Indole Butyric Acid (IBA) and also increase the rate of mineral uptake by plant roots which in turn resulted in increase of number of grains/ear. The increase in number of grains/ear under wider row spacing might be attributed to less competition for resources and subsequently more availability of moisture, nutrients, light and space per plant for better development. These findings corroborate the results of Kumar and Gautam (2004), Guggari and Kalaghatagi (2005), Khanda et al., (2001), Satish kumar et al., (2004).

Grain yield

Grain yield was significantly influenced with different combinations of Biofertilizer and Spacing. Significant and highest grain yield (2773 kg/ha) was observed under Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. However, Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm was found to be statistically on par with Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The increase in grain yield might be due to fact that phytohormones produced by Azatobacter and Azospirillum stimulated root growth and induced changes in root morphology which in turn affected the assimilation of nutrients. The synergistic effect of biofertilizers which improved different growth parameters and several yield attributing characters in pearl millet and ultimately increased yield. The increase in grain yield at wider row spacing could be attributed to relatively less competition between the crop plants particularly for moisture and nutrients which resulted in better growth of plant. Greater availability of moisture and nutrients together with better exposure of plants to sun light enabled the plants to synthesise more carbohydrates and proteins which might have led to vigorous growth in terms of grain yield. The present findings are supported from the results of Kumar and Gautam (2004), Guggari and Kalaghatagi (2005), Rathore et al., (2006), Sonawane et al., (2007).

Straw yield

The straw yield of pearl millet was also influenced by the application of bio fertilizer and spacing. Highest straw yield (3911 kg/ha) was recorded with Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm, however, Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm and Azotobacter @ 25 g/kg + 60 cm × 15 cm were found to be statistically on par with Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm. The increase in straw yield might be due to fact that phytohormones produced by Azatobacter and Azospirillum stimulated root growth and induced changes in root morphology which in turn affected the assimilation of nutrients. The synergistic effect of biofertilizers which improved different growth parameters and several yield attributing characters in pearl millet and ultimately increased yield. The increase in straw yield at wider row spacing could be attributed to relatively less competition between the crop plants particularly for moisture and nutrients which resulted in better growth of plant. Greater availability of moisture and nutrients together with better exposure of plants to sun light enabled the plants to synthesise more carbohydrates and proteins which might have led to vigorous growth in terms of straw yield. The present findings are supported from the results of Kumar and Gautam (2004), Guggari and Kalaghatagi (2005), Rathore et al., (2006), Sonawane et al., (2007).

Economics:

Among the different combination of nutrient source Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm was recorded significantly higher net return (Rs.1,03,453/ha), gross return (Rs.1,41,440/ha) and benefit: cost ratio (2.72).

CONCLUSION

Treatment Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 60 cm ×15 cm was recorded significantly highest grain yield (2773 kg/ha), gross return (Rs.1,41,440 /ha), net return (Rs.1,03,453/ha) and benefit:cost ratio (2.72) which may be more preferable for farmers since it is economically more profitable and it can be recommended to the farmers.

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Table 1. Effect of Biofertilizer and Spacing on growth parameters of pearl millet at harvest

S.No	T.No.	Treatments	Plant height (cm)	Number of leaves/plant	Number of tillers/hill	Dry matter accumulation (g $plant^{-1}$)
1	T_1	Azotobacter @ 25 g/kg + 30 cm × 15 cm	187.67	35.3	2.4	40.60
2	T_2	Azospirillum @ 25g/kg + 30 cm ×15 cm	185.70	34.8	2.2	39.03
3	T_3	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm	192.53	36.3	2.7	41.58
4	T_4	Azotobacter @ 25 g/kg + 45 cm × 15 cm	195.90	37.0	2.8	42.91
5	T_5	Azospirillum @ 25g/kg + 45 cm ×15 cm	189.97	35.9	2.6	40.95
6	T_6	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm	205.17	39.1	3.2	46.96
7	T_7	Azotobacter @ 25 g/kg + 60 cm × 15 cm	202.10	37.9	2.9	45.71
8	T_8	Azospirillum @ 25g/kg + 60 cm ×15 cm	199.20	37.4	2.9	43.36
9	T_9	Azotobacter @ 25 g/kg + 30 cm × 15 cm	210.20	40.3	3.3	49.49
		SEm (±)	3.46	0.56	0.17	1.18
		CD (P 0.05)	10.27	1.62	0.51	3.49

Table 2. Effect of Biofertilizer and Spacing on yield and yield attributing characters of pearl millet

S. No	T. No	Treatments	No.of ears/hill	No. of grains/ear head	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
1	T_1	Azotobacter @ 25 g/kg + 30 cm × 15 cm	1.43	1795.00	2.44	3.60
2	T_2	Azospirillum @ 25g/kg + 30 cm ×15 cm	1.20	1745.00	2.40	3.55
3	T_3	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm	1.77	1875.00	2.52	3.65
4	T_4	Azotobacter @ 25 g/kg + 45 cm × 15 cm	1.90	1914.00	2.56	3.69
5	T_5	Azospirillum @ 25g/kg + 45 cm ×15 cm	1.67	1839.67	2.46	3.60
6	T_6	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm	2.33	2056.00	2.70	3.84
7	T_7	Azotobacter @ 25 g/kg + 60 cm × 15 cm	2.23	1961.33	2.65	3.79
8	T_8	Azospirillum @ 25g/kg + 60 cm ×15 cm	2.00	1928.67	2.61	3.74
9	T_9	Azotobacter @ 25 g/kg + 30 cm × 15 cm	2.43	2097.33	2.77	3.91
		SEm (±)	0.20	44.57	30.19	50.95
		CD (P 0.05)	0.62	132.44	89.71	151.37

Table 3. Effect of Biofertilizer and Spacing on economics of pearl millet

S.No	T.No.	Treatments	Cost of cultivation# (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit: Cost ratio
1	T_1	Azotobacter @ 25 g/kg + 30 cm × 15 cm	38,395.00	1,07,697.00	69,302.00	1.80
2	T_2	Azospirillum @ 25g/kg + 30 cm ×15 cm	38,365.00	1,08,060.00	69,695.00	1.82
3	T_3	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm	38,380.00	1,26,133.00	87,753.00	2.29
4	T_4	Azotobacter @ 25 g/kg + 45 cm × 15 cm	38,165.00	1,28,283.00	90,118.00	2.36
5	T_5	Azospirillum @ 25g/kg + 45 cm ×15 cm	38,145.00	1,23,483.00	85,338.00	2.24
6	T_6	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm	38,155.00	1,38,040.00	99,885.00	2.62
7	T_7	Azotobacter @ 25 g/kg + 60 cm × 15 cm	37,993.00	1,32,867.00	94,874.00	2.50
8	T_8	Azospirillum @ 25g/kg + 60 cm ×15 cm	37,980.00	1,30,550.00	92,570.00	2.44
9	T_9	Azotobacter @ 25 g/kg + 30 cm × 15 cm	37,987.00	1,41,440.00	1,03,453.00	2.72

#Data not subjected to statistical analysis.