

# 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<sub>1</sub>-T<sub>9</sub>) with different bio fertilizer combination of Azotobacter 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, Azotobacter, 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 ( $\text{NH}_4^+$ ) 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 follows T1 – 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<sup>-1</sup> 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 DISCUSSIONS

### 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. Azotobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azotobacter 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. Azotobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azotobacter 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 Azotobacter 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. Azotobacter and Azospirillum are free living bacteria and have specific role in fixing atmospheric nitrogen in soil which enhanced the soil fertility. Azotobacter 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. Azotobacter 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. Azotobacter 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 Azotobacter 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 Azotobacter 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.

## REFERENCES

- Ameta, G.S. and Dhakar, L.L. (2000). Response of winter maize to nitrogen levels in relation to varying population density and row spacing. *International J. Tropical Agric.* **18**(4) :395-98.
- Bashan, Y., Holguin, G and De-Bashan, L.E. (2004). Azospirillum plant relationships: physiological, Molecular, agricultural and environmental advances. *Canadian Journal of Microbiology.* 50:521-577.
- Bhagchand and Gautam, R.C. (2000). Effect of organic manure, bio fertilizers and inorganic fertilizers on growth, yield and quality of rainfed pearl millet. *Ann. Agric. Res.*, **21**(4) ; 459-464.
- Bhatnagar, S.K.; Yadav, O.P. and Gautam, R.C. (1998). Research achievements in pearl millet hybrid. *Indian J. Agric. Sci.* **68**(8): 423-430.
- Biari, A and Rahmani,, H.A. (2008). Growth promotion and enhances nutrient uptake of maize (*Zea mays* L.) by application of plant growth promoting rhizobacteria in arid region of Iran. *Journal of Biological Sciences.* **8**(6):1015 – 1020.
- Bouyoucos, G.J. (1927). The Hydrometer as a new method of the mechanical Analysis of soils. *Soil science*, **23**: 343-353.
- Chesnin, L., & Yien, C. H. (1950). *Turbidimetric Determination of Available Sulphates*. Soil Science Society of America Journal, **15**, 149-151.

- Chellamuthy, V. (2000). Effect of biofertilizers and inorganic fertilizers on the fodder yield of bajra. *Madras Agric. J.* **87**(4-6): 183-185.
- Choudhary, R.S. and Gautam, R.C. (2007). Effect of nutrient management practices of growth and yield of pearl millet. *Indian J. Agron.*, 52(1):64-66.
- Directorate of Millets Development, 2020; Project Coordinator Review, 2020.ICAR-AIRCP on pearl millet,Jodhpur-342,304,Rajasthan,India.
- Fisher, R.A. (1921). Statistical method for research works. Oliver and Boyd and Co. Inc. Endinburgh.
- Garg, B.K., Kathsy, S., Vyas, S.P., and Lahiri, A.N. (1993). Effect of plant density and soil fertility on pearl millet under drought and good rainfall situations. *Annals of arid zone*, **32**(1):13-20.
- Gholami, A., Shahsavani, S and Nezarat, S. (2009). The Effect of plant growth promoting rhizobacteria (PGPR) on germination, seedling growth and yields of maize. *World Academy of Science, Engineering and Technology*.**3**:01-06.
- Golada, S.L., Patel, B.J and Sharma, G.L. 2012. Effect of fym, nitrogen and Azospirillum inoculation of yield and quality of forage millet. *Agricultural Science Digest*.**32**(3):237-240.
- Gomez, K.A. and A.A. Gomez, (1984). Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork, 680p.
- Guggari, A.K., Kalaghatagi, S.B. (2005). Effect of fertilizer and biofertilizer on pearl millet and pigeonpea intercropping system under rainfed conditions. *Indian J. Agron.* **50**(1):24-26.
- Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Pvt Ltd, New Delhi. pp: 56.
- Kalaghatagi, S.b.; Itnal, C.J.; Jirali, D.I. and Nogad, M.S. (1996). Economising application of nitrogen and phosphorus through biofertilizers in pearl millet under dry land condition. *J. Maharastra agric. Univ.*, **21**(1); 28-30.
- Kaushik, M.K., and Shaktawat, M.S. (2005). Effect of row spacing, nitrogen and weed control on growth, yield and nutrient uptake of sorghum. *Indian J. Agron.* **50**(2):140.



- Kausik, S.K. and Gautam, R.C. (1991). Effect of dryland practices and plant population on the productivity and moisture use efficiency of pearl millet. *Indian J. Agron.* **36**(2):228-33.
- Khafi, H.R., Ramani, B.B., Mehta, A.C. and Pethani, K.V. (2000). Effect of different levels of nitrogen, phosphorus and spacing on yield and economics of hybrid bajara. *Crop Research, Hissar.* **20**(3): 411-414.
- Khanda, C.M., Mohapatra, A.K., Misra, P.K. (2001). Response of rice bean to row spacing and phosphorus under rainfed condition. *Ann. Agric. Res.*, **22**(4):481-484.
- Kumar, R., Bhatia, R., Kukreja, K., Behl, R., Dudeja, S.S., Narula, N. (2007). Establishment on plant roots. *Journal of Basic Microbiology.* **47**(5):436-9
- Kumar, N. and Gautam, R.C. (2004). Effect of moisture conservation and nutrient management practices on growth and yield of pearl millet (*Pennisetum glaucum*) under rainfed condition. *Indian J. Agron.*, **49**(3): 182-185.
- Lakum, Y.C., Patel, S.H and Mehta, P.V. 2011. Reducing fertilizer requirement with the use of biofertilizers in summer pearl millet (*Pennisetum glaucum* L.). *An Asian Journal of Soil Science.* **6**(1):50-53.
- Lindsay, W. L., and W. A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal* **42**: 421–28.
- Malik, K.A., Mirza, M.S., Hassan, U., Mehnaz, S., Rasul, G., Haurat, J., Bally, R and Normand, P. (2002). The role of plant associated beneficial bacteria in rice-wheat cropping system. In I.R. Kennedy and A.T.M.A Choudhury (eds.) *Biofertilizers in action*. Rural Industries Research and Development Corporation, Canberra. 73-83.
- Meena., Sanjak Kumar., Sutanu Maji., Devendra Kumar and Mnoj Kumar. (2014). Effect of organic manures and biofertilizers on growth, flowering, yield and quality of tomato. *International Journal of Agriculture Sciences.* **10**(1):329-332.
- Mishra, M.; Patjoshi, A.K. and Jena, D. (1998). Effect of biofertilization on production of maize. *Indian J. Agron.*, **43**:307-310.
- Naganagouda and Alagundagi, S.C. (2003). Effect on growth, fodder and grain yielding potentiality of sorghum genotypes mixed grown with cowpea as influenced by row spacing under fodder-food production system, *Andhra agric J.* **50**(3&4):188-193.

- Neelam, R., Singh, V.P and Anil kumar 2009. Biofertilizers: supplement to chemical fertilizers in pearl millet. *Research on Crops*. **12**: 701-703.
- Okon Y and Vanderleyden J 1997 Root-associated *Azospirillum* species can stimulate plants. *ASM News* **63**. 366–370.
- Olsen, S.H., Cole, V.V., Watenabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *United States Department of Agriculture, Circular* **93**(9): 1-9.
- Patil, R.K., Goyal, S.N., Vora, M.S. and Vaishnav, P.R. (2001). Response of *kharif* maize to inoculation with *Azotobacter* and *Azospirillum* at varying levels of nitrogen. *GAU. Res J.* **27**(1&2):13-17.
- Patra, A.K. and Nayak, B.C. (2001). Effect of spacing on rice varieties of various duration under irrigated condition. *Indian J. Agron*, **46**(3):449-452.
- Rajput, R.L. (1999). Effect of bio fertilizer application on yield of bajra. *Bhartiya Krishi Anusandhan Patrika*, **14**(3&4): 43-46.
- Rathore, S.S. and Gautam, R.C. (2003). Agro techniques to improve the productivity of pearl millet + cowpea intercropping system under dry land conditions. *Ann. Agric. Res.*, **24**: 971-975.
- Rathore, B.S.; Singh, V.P. and Hooda, R.S. (2004). Effect of mixed bio fertilizes in association with different levels of nitrogen application on nutrient content and uptake by pearl millet. *Crop Res.*, **28**(1,2 and 3): 39 - 41.
- Rathore, V.S.; Singh, P. and Gautam, R.C. (2006). Productivity and water – use efficiency of pearl millet as influenced by planting patterns and intergrated nutrient management. *Indian J. Agron.m* **51**(1): 46 – 48.
- Raul, O., Pedraza., Carlos, H and Bellone. 2009. *Azospirillum* inoculation and nitrogen fertilization effect of grain yield and on the diversity of endophytic bacteria in the phyllosphere of rice rainfed crop. *European Journal of Soil Biology*.**45**:36-43.
- Richards, L.A. 1954..Editor Soil and Water Conservation Research Branch Agricultural Research Service Agriculture Handbook No. 60 Issued February 1954 UNITED STATES DEPARTMENT OF AGRICULTURE.

- Salhia, B.M. (2005). The effect of *Azotobacter chroocum* as nitrogen biofertilizer on the growth and yield of *Cucumis sativus*. M.Sc. Thesis. The Islamic University – Gaza Deanery of Higher Education.
- Sarhan, T.Z., Mohammed, G.H and Teli, J.A. (2011). Effect of bio and organic fertilizers on growth yield and fruit quality of summer squash. *Sarhad Journal of Agriculture*. **27** (3): 377-383.
- Sarkar, R.K., Shit, D., Chakraborty A. (1996). Response of maize cultivars to row, spacing and manure and fertilizer application to rainfed upland of Bihar plateau. *Indian Agriculturist*, **40**(4):269-273.
- Satish Kumar, Kadian, V.S. and Singh, R.C. (2004). Response of pearl millet to row spacing and nitrogen application. *Ann. Agric. Res.* Vol. **25**(1):68-70.
- Satyajeet, R.K.; Nanwal and Yadav, V.K. (2007). Effect of integrated nutrient management of N,P and K concentration, uptake and productivity in pearl millet. *J. Maharashtra agric. Univ.*, **32**(2): 186-188.
- Shrivastava U.S.L., Paltoo-Ram, Om Prakesh, Ram, P., Prakesh O. (1996). Response of wheat to row spacing, seed rate and fertilizer. *Indian J. Agron.*, **41**(4):558-561.
- Siddiqui, M.R.H., Lakpale R., Tripathi P.S. (1999). Effect of spacing and fertilizer on medium duration rice varieties. *Indian J. Agron*, **44**(2):310-312.
- Singh, A.K., Singh, G.R., Dixit, R.S. (1997). Influence of plant population and moisture regimes on nutrient uptake and quality of winter maize. *Indian J. Agron.* **42**(1):107-111.
- Singh, Atul kumar (2002). Yield maximization by fertilizer FYM and plant population in pearl millet –wheat cropping system. *Ann. Agric. Res.*, **23**(1):22-25.
- Singh, Jagdev, Yadav, J.S., Virendra kumar, Yadav, B.D. (2000). Response of oat to *Azotobacter* at different nitrogen levels. *Indian J. Agron.*, **45**(2):433-436.
- Singh, R.; Singh, D.P. and Tyagi, P.K. (2003). Effect of *Azotobacter*, farm yard manures and nitrogen fertilization on productivity of pearl millet hybrids (*Pennisetum glaucum* L.) in semi arid tropical environment. *Archives of Agronomy and Soil Science*, **49**: 21-24.

- Sonawane, P.D.; Rodge, R.G. and Attarde, D.R. (2007). Effect of fertilizer, bio-fertilizer, inter-cropping system on pearl millet under rainfed conditions. *J. Maharashtra Agric. Univ.*, **32**(2): 176 – 178.
- Subba Rao, N.S. 1982. Biofertilizers in Agriculture. Oxford and IBH Pub. Co. New Delhi.
- Swedrzynska, D and Sawicka, A. 2000. Effect of Inoculation with *Azospirillum brasilense* on development and yielding of maize (*Zea mays* sp. *Saccharata* L.) under different cultivation conditions. *Polish Journal of Environmental Studies*. **9**(6):505-509.
- Thakur, D.P., Prakash O.M., Kharwara P.C., Bhalisa S.K. (1997). Effect of nitrogen and plant spacing on growth yield and economics of baby corn. *Indian J. Agron.*, **42**(3):479-487.
- Thilakarathna, M.S and Manish, N. (2015). A Review of nutrient management studies involving finger millet in the semi arid tropics of asia and Africa. **5**.262-290.
- Toth, S.J. and Prince, A.L. 1949. Estimation of cation-exchange capacity and exchangeable Ca, K and Na contents of soil by Flame Photometer techniques. *New Jersey Agricultural Experimental Station* **67**(6): 439-446.
- Verma, O.P.S. (1996) Integrated nutrient management in Pearlmillet under rainfed condition. *Indian J. Agron.* **41**(1):58-60.
- Yadav, R.D., Malik, C.V.S (2005). Effect of rhizobium inoculation and various sources of nitrogen on growth and yield of cowpea. *Legume Res.* **28**(1):38-41.

**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 <sup>-1</sup> )
1	T <sub>1</sub>	Azotobacter @ 25 g/kg + 30 cm × 15 cm	187.67	35.3	2.4	40.60
2	T <sub>2</sub>	Azospirillum @ 25g/kg + 30 cm ×15 cm	185.70	34.8	2.2	39.03
3	T <sub>3</sub>	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm	192.53	36.3	2.7	41.58
4	T <sub>4</sub>	Azotobacter @ 25 g/kg + 45 cm × 15 cm	195.90	37.0	2.8	42.91
5	T <sub>5</sub>	Azospirillum @ 25g/kg + 45 cm ×15 cm	189.97	35.9	2.6	40.95
6	T <sub>6</sub>	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm	205.17	39.1	3.2	46.96
7	T <sub>7</sub>	Azotobacter @ 25 g/kg + 60 cm × 15 cm	202.10	37.9	2.9	45.71
8	T <sub>8</sub>	Azospirillum @ 25g/kg + 60 cm ×15 cm	199.20	37.4	2.9	43.36
9	T <sub>9</sub>	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 <sup>-1</sup> )	Straw Yield (t ha <sup>-1</sup> )
1	T <sub>1</sub>	Azotobacter @ 25 g/kg + 30 cm × 15 cm	1.43	1795.00	2.44	3.60
2	T <sub>2</sub>	Azospirillum @ 25g/kg + 30 cm ×15 cm	1.20	1745.00	2.40	3.55
3	T <sub>3</sub>	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 30 cm ×15 cm	1.77	1875.00	2.52	3.65
4	T <sub>4</sub>	Azotobacter @ 25 g/kg + 45 cm × 15 cm	1.90	1914.00	2.56	3.69
5	T <sub>5</sub>	Azospirillum @ 25g/kg + 45 cm ×15 cm	1.67	1839.67	2.46	3.60
6	T <sub>6</sub>	Azotobacter @ 12.5g/kg +Azospirillum @ 12.5g/kg + 45 cm ×15 cm	2.33	2056.00	2.70	3.84
7	T <sub>7</sub>	Azotobacter @ 25 g/kg + 60 cm × 15 cm	2.23	1961.33	2.65	3.79
8	T <sub>8</sub>	Azospirillum @ 25g/kg + 60 cm ×15 cm	2.00	1928.67	2.61	3.74
9	T <sub>9</sub>	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 <sup>#</sup> (₹ ha <sup>-1</sup> )	Gross return (₹ ha <sup>-1</sup> )	Net return (₹ ha <sup>-1</sup> )	Benefit: Cost ratio
1	T <sub>1</sub>	Azotobacter @ 25 g/kg + 30 cm × 15 cm	38,395.00	1,07,697.00	69,302.00	1.80
2	T <sub>2</sub>	Azospirillum @ 25g/kg + 30 cm ×15 cm	38,365.00	1,08,060.00	69,695.00	1.82
3	T <sub>3</sub>	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 <sub>4</sub>	Azotobacter @ 25 g/kg + 45 cm × 15 cm	38,165.00	1,28,283.00	90,118.00	2.36
5	T <sub>5</sub>	Azospirillum @ 25g/kg + 45 cm ×15 cm	38,145.00	1,23,483.00	85,338.00	2.24
6	T <sub>6</sub>	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 <sub>7</sub>	Azotobacter @ 25 g/kg + 60 cm × 15 cm	37,993.00	1,32,867.00	94,874.00	2.50
8	T <sub>8</sub>	Azospirillum @ 25g/kg + 60 cm ×15 cm	37,980.00	1,30,550.00	92,570.00	2.44
9	T <sub>9</sub>	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.**