Plant Archives Vol. 25, No. 1, 2025 pp. 1297-1303 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.193

RESPONSE OF BIO-FERTILIZERS AND ZINC LEVELS ON GROWTH, YIELD ATTRIBUTES AND ECONOMICS OF PEARL MILLET (*PENNISETUM GLAUCUM* L.)

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(Date of Receiving-20-12-2024; Date of Acceptance-24-02-2025)

ABSTRACT

The field experiment was conducted in Crop Research Farm (CRF) in Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) during *Zaid* season 2023-24 on Pearl millet crop**.** The treatment consisted of Potassium (30, 40 and 50 Kg/ha) and Zinc (15,20 and 25 kg/ha) and a control. The experiment was laid out with a Randomize Block Design (RBD) with ten treatments which are replicated thrice as T_1 - Pseudomonas 5 g/kg seed + Zinc 5 kg/ha, T_2 - Pseudomonas 15 g/kg seed + Zinc 15 kg/ha, T_3 - Pseudomonas 15 g/kg seed + Zinc 25 kg/ha T_4 - Azotobacter 15 g/kg seed + Zinc 5 kg/ha, T_5 - Azotobacter 15 g/kg seed + Zinc 15 kg/ha, T_6 - Azotobacter 15 g/kg seed + Zinc 25 kg/ha, T_7 - Trichoderma 5 g/kg seed + Zinc 5 kg/ha T_8 - Trichoderma 5 g/kg seed + Zinc 15 kg/ha, T_9 - Trichoderma 5 g/kg seed + Zinc 25 kg/ha and T_{10} Control – 60:40;40 kg/ha. The soil of experiment plot was sandy loamy in texture, nearly neutral in soil reaction (pH 6.6), low in organic carbon (0.47 %), available N (235.42 kg/ha), available P (36.2 kg/ha) and available K (220.7 kg/ha). Application of Trichoderma 5 g/kg seed + Zinc 25 kg/ha was recorded with the results which revealed that significantly highest growth attributes of Pearl millet at 80 DAS viz., Plant height (203.24 cm), dry weight (144.17 g), Ear head length (30.23 cm), grains/head (1848.78) and yield attributes such as Grain yield (4530.43 kg/ha), Stover yield (7246.59 kg/ha) and cost of cultivation (INR 38,144.00), Gross return (INR 1,09,857.70), Net return (INR 71,713.74) and Benefit cost ratio (1.88) were found higher with application of Trichoderma 5 g/kg seed + Zinc 25 kg/ha.

***Key words*: ** Bio-fertilizers, Pearl millet, Zinc, yield attributes.

Introduction

Pearl millet (*Pennisetum glaucum* L.) is commonly known in India as Bajra or Bajri also known as 'cattail' and 'bullrush millet'. It is originated from tropical western Africa. It belongs to the family *Gramineae* (*Poaceae*). The cultivated species are *Pennisetum glaucum* L. (2n=14) used for grain and Pennisetum purpureum (2n=28) used for green and dry fodder. Pearl millet is the fifth most important cereal crop globally after rice, wheat, maize, and sorghum. It is used as a staple food for human consumption and fodder for livestock sector. It is a good source of energy (360 calories) and carbohydrates (67 g) and consist of 12 g protein, 5 g fat and 2 g minerals in 100 gm of bajra seeds (Directorate of Millets Development, 2021-22; Project Coordinator Review, 2022). It is considered as poor man's food. It is critically important for food and nutritional security as it possess several advantages such as early maturing, drought tolerance, require minimal purchase of inputs and is mostly free from biotic and abiotic stresses. Pearl millet

(*Pennisetum glaucum* L.) is most widely grown as staple food by small and marginal farmers in Asia and Africa. It is a C4 plant having high photosynthetic efficiency, more dry matter productivity and survives under adverse Agro-climatic conditions with lesser inputs and more economic returns. The crop is critically important for food and nutritional security of humans and animals in arid and semi-arid regions as Pearl millet is early maturing, drought tolerant, and has inherent ability to endure high temperatures up to 42°C during reproductive phase enabling it for cultivation in adverse conditions, thus making it a climate resilient crop. Due to its excellent nutritional properties, pearl millet is designated as nutri-cereal (Gazette of India, No.133 dated 13th April, 2018) for production, consumption, trade and was included in Public Distribution System (PDS).

Biofertilizers deficiency is usually the most important single factor which is responsible for poor yield of pulses on all soils. It is a major constituent of proteins and nucleic acids. The cost of nitrogenous and phosphatic fertilizers are increasing day by day hence, it is required to use some cheaper source of fertilizers like Azotobacter, Rhizobium and phosphatic solubilizing bacteria, Trichoderma, Pseudomonas fluorescens etc. Bio fertilizers are commonly called microbial inoculants which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by the crop plants through their biological processes. Azotobacter is a beneficial free living (no symbiosis) nitrogen fixing bacteria which is reported to fix 20-60 kg/ha nitrogen in soil annually. (Forlain *et al*., 1998). “Bio - fertilizers”, are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed treatments and soil application designed to improve soil fertility and to help plant growth by increasing the number and biological activity of desired microorganisms in the root environment (Smitha, 2005). Azotobacter is a genus of usually motile, oval or spherical bacteria that form thick-walled cysts (and also has hard crust) and may produce large quantities of capsular slime. They are aerobic, free-living soil microbes that play an important role in the nitrogen cycle in nature, binding atmospheric nitrogen, which is inaccessible to plants, and releasing it in the form of ammonium ions into the soil (nitrogen fixation). In addition to being a model organism for studying diazotrophs, it is used by humans for the production of biofertilizers, food additives, and some biopolymers.

Trichoderma is a genus of fungi that is present in most types of soils, where they are the most prevalent culturable fungi. *Trichoderma* spp. frequently are isolated from forest or agricultural soils and from wood. Some also have been found growing on other fungi. There are around 90 species in the Trichoderma genus. Trichoderma strains are considered to be among the most useful fungi in industrial enzymes production, agriculture and bioremediation.

Pseudomonas fluorescens associated secondary control activity like ACC deaminase, IAA synthesis, siderophores production, and antifungal compounds synthesis regulates the PGPR. Pseudomonas spp. and PGPR mixture in an inoculum shows coupled activity and forms a mutualistic association aiming to increase plant growth.

Micronutrients are important for maintaining soil health and also increasing productivity of crops. Micronutrients are important for plant growth, as plants require a proper balance of all the essential nutrients for normal growth and optimum yield. These are needed in very small amounts. Zinc is a key component of enzymes that are required for growth hormones and other metabolic processes in plants. It’s also a key component in the production of proteins and chlorophyll. Zinc is especially for regular healthy growth and reproduction of plants (Marschner, 1995). In plants, zinc plays a key role as a structural constitute or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways.

Materials and Methods

This experiment was laid out during the *Zaid* season of 2021-22 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The crop research farm is situated at 25^0 39" 42" N latitude, 81^0 67" 56" E longitude and at an altitude of 98 m above mean sea level. The experiment was layout in Randomized Block Design (RBD) with ten treatment and three replicated. The treatment details are as follows T_1 - Pseudomonas 5 g/kg seed + Zinc 5 kg/ha, T_2 - Pseudomonas 15 g/kg seed + Zinc 15 kg/ha, T_3 - Pseudomonas 15 g/kg seed + Zinc 25 kg/ha T_4 - Azotobacter 15 g/kg seed + Zinc 5 kg/ha, T_5 - Azotobacter 15 g/kg seed + Zinc 15 kg/ha, T_6 - Azotobacter 15 g/kg seed + Zinc 25 kg/ha, T_7 - Trichoderma 5 g/kg seed + Zinc 5 kg/ha T_8 - Trichoderma 5 g/kg seed + Zinc 15 kg/ ha, T_9 - Trichoderma 5 g/kg seed + Zinc 25 kg/ha and T_{10} Control – 60:40;40 kg/ha. Optimum plant population was maintained by thinning and gap filling. Thinning operation was done after 10 days after sowing. The Biometric observations were recorded at various stages of crop growth on different parameters *viz.*, Plant height, Dry weight, Crop Growth Rate, Relative Growth Rate

Table 1: Effect of Biofertilizers and Zinc levels on growth attributes of Pearl millet.

S.N.	Treatments	Growth Attributes			
		Plant height (cm) 80 DAS	Dry weight (g) 80 DAS	CGR ($g/m^2/day$) 60 DAS	RGR (g/g/day) 60 DAS
1.	Pseudomonas 15 g/kg seed + Zinc 5 kg/ha	176.70	131.93	42.57	0.028
2.	Pseudomonas 15 g/kg seed + Zinc 15 kg/ha	177.83	133.17	42.29	0.028
3.	Pseudomonas 15 g/kg seed + Zinc 25 kg/ha	181.80	135.87	43.07	0.028
4.	Azotobacter 15 g/kg seed + Zinc 5 kg/ha	185.11	136.74	42.26	0.027
5.	Azotobacter 15 g/kg seed + Zinc 15 kg/ha	187.17	137.93	41.76	0.026
6.	Azotobacter 15 g/kg seed + Zinc 25 kg/ha	191.67	139.82	42.32	0.026
7.	Trichoderma 5 g/kg seed + Zinc 5 kg/ha	195.68	141.90	42.34	0.026
8.	Trichoderma 5 g/kg seed + Zinc 15 kg/ha	198.92	143.10	41.41	0.025
9.	Trichoderma 5 g/kg seed + Zinc 25 kg/ha	203.24	144.17	39.47	0.022
10.	Control (RDF: - 60:40:40 NPK kg/ha)	168.85	118.62	33.42	0.024
	F test	S	S	S	NS
	SEm±	3.70	2.17	1.74	0.0010
	CD (P=0.05)	11.01	6.45	5.18	-

on five plants randomly selected from each net plot. Post -harvest Observations include Length of Head, Number of grains per Head, Test weight, Garin yield, stover yield and Harvest Index. The experimental crop was harvested in month of 21st November 2022. The produce from net plots were harvested in one lot and tied in bundles and allowed to complete dried material was passes through threshing operation. After threshing and winnowing the clean seeds from each plot were weighed and the weight was recorded grain yield in kg/plot.

Results and Discussions

Growth Parameter

Plant height (cm)

At 80 DAS maximum plant height of (203.24 cm) was recorded with treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha).), whereas treatment 7 and 8 (Trichoderma 5 g/kg seed + Zinc 5 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha,) were statistically at par with treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha).

The plant height of Pearl millet increased significantly due to application of different Bio-fertilizers and Zinc. The probable reason for increase in plant height due to application of bio fertilizer and Zinc were bio fertilizer play crucial role in a free-living nitrogen-fixing bacterium termed *Azotobacter* has been reported to fix about 20 kg/ha of nitrogen in non- legumes. The results were found in accordance with Ramdev *et al.,* (2017). The significant increase in the height may be due to inoculation of bacterial preparation accelerate plant growth provide biologically fixed nitrogen to the inoculated plant and also stimulate plant growth by excreting plant growth promoting substances like auxins, kinetins, vitamins and gibberellins as similarly observed by Patidar and Mali (2004).

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Plant dry weight (g/plant)

At 80 DAS highest plant dry weight (144.17 g) was found in treatment 9 Trichoderma 5 g/kg seed + Zinc 25 kg/ha).). However, treatment 5, 6, 7 and 8 (Azotobacter 15 g/kg seed + Zinc 15 kg/ha, Azotobacter 15 g/kg seed + Zinc 25 kg/ha, Trichoderma 5 g/kg seed + Zinc 5 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha,) were statistically at par with the treatment 9 (Trichoderma 5 g/ kg seed + Zinc 25 kg/ha).

The dry weight of Pearl millet increased significantly due to application of Biofertilizers. As biofertilizers might have provided congenial nutritional environment to the plants, which helps in attributing to its pivotal role in several physiological and biochemical processes which are of vital importance for growth and development of plant in terms of dry weight. The increase in dry weight may be attributed to role of Zinc as a catalyst or stimulant in most of the physiological and metabolic processes and metal activator or enzymes resulting in increased growth and development of plant. Similar results were also reported by Reddy *et al.,* (2021) and Vinod Kumar *et al.,* (2018).

Table 2: Effect of Biofertilizers and Zinc levels on yield and yield attributes of Pearl millet.

S.N.	Treatments	Yield and Yield attributes				
		Ear head length (cm)	No. of grains/ear head	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
1.	Pseudomonas 15 g/kg seed + Zinc 5 kg/ha	22.77	1279.65	5.80	3359.37	6391.84
2.	Pseudomonas 15 g/kg seed + Zinc 15 kg/ha	23.21	1308.55	5.93	3490.14	6473.69
3.	Pseudomonas 15 g/kg seed + Zinc 25 kg/ha	23.63	1339.06	6.31	3573.38	6585.61
4.	Azotobacter 15 g/kg seed + Zinc 5 kg/ha	24.87	1409.91	6.76	3718.26	6660.26
5.	Azotobacter 15 g/kg seed + Zinc 15 kg/ha	25.28	1516.07	6.94	3854.11	6751.13
6.	Azotobacter 15 g/kg seed + Zinc 25 kg/ha	26.04	1610.44	7.55	3964.08	6958.59
7.	Trichoderma 5 g/kg seed + Zinc 5 kg/ha	28.82	1629.51	7.66	4171.65	7085.82
8.	Trichoderma 5 g/kg seed + Zinc 15 kg/ha	29.04	1715.03	7.92	4340.04	7176.40
9.	Trichoderma 5 g/kg seed + Zinc 25 kg/ha	30.23	1848.75	8.22	4530.43	7246.59
10.	Control (RDF: - 60:40:40 NPK kg/ha)	21.43	1215.07	5.71	3076.06	5689.70
	F test	S	S	NS	S	S
	SEm±	1.17	80.20	0.40	113.02	165.13
	CD (P=0.05)	3.48	338.30	1.197	335.81	490.63

Relative growth rate (g/g/day)

During the growth interval of 60 - 80 DAS interval highest RGR value (0.028 g/g/day) was recorded with treatment 1, 2 and 3 (Pseudomonas 5 g/kg seed + Zinc 5 kg/ha, Pseudomonas 15 g/kg seed + Zinc 15 kg/ha, Pseudomonas 15 g/kg seed + Zinc 25 kg/ha).

Yield attributes and Yield Parameter

Ear head length (cm)

A significant impact was experiential by the statistical analysis of ear head length. Treatment with Trichoderma 5 g/kg seed + Zinc 25 kg/ha was recorded highest ear head length (30.23). However, treatment 7 and 8 (Trichoderma 5 g/kg seed + Zinc 5 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha) were found statistically at par with treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). Whereas, biofertilizers application can be attributed to a general development in plant growth as replicated by increased dry matter accumulation, which may be due to an increased availability of nutrients to plants at the flowering stage, which might take greater effective tiller formation and ultimately increased ear head length. The increase in ear head length (cm) may be attributed to physiological and metabolic processes rely on Zinc, as well as tryptophan synthesis. Zinc is a vital component of several proteins that produce growth hormones (auxins) such as IAA. In two separate studies, Sharma *et al.*, (2012) and Sharma *et al.*, (2008) came to the same result.

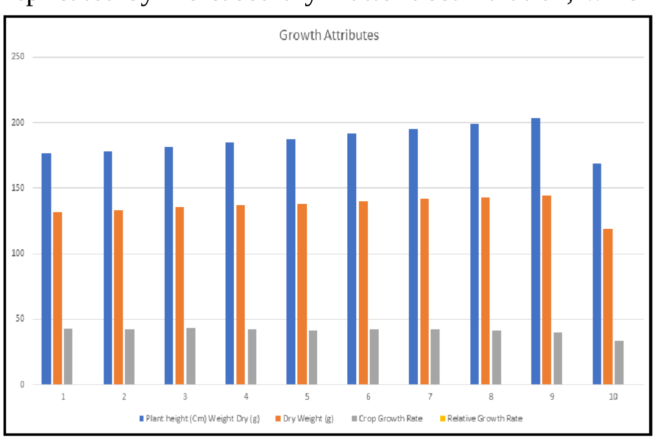

Fig. 1: Effect of Biofertilizers and Zinc levels on growth attributes of Pearl millet on clustered column graph.

Number of grains/ear head

Significant effect was observed by the statistical analysis of number of grains/ear head. Treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). recorded significant and highest number of grains/ear head (1848.75). However, treatment 5, 6, 7 and 8 (Azotobacter 15 g/kg seed + Zinc 25 kg/ha, Azotobacter 15 g/kg seed

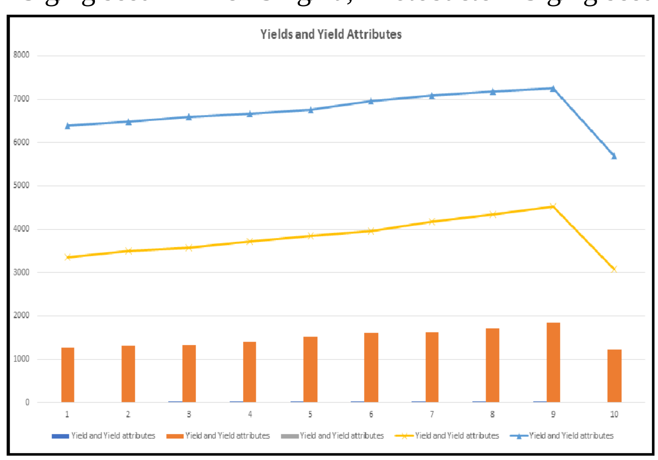

Fig. 2: Effect of Biofertilizers and Zinc levels on yields and yield attributes of Pearl millet on clustered column line graph.

Table 3: Effect of Biofertilizers and Zinc levels on economics of production of Pearl millet.

S.N.	Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	Benefit cost ration
1.	Pseudomonas 15 g/kg seed + Zinc 5 kg/ha	36,544.00	84,006.92	47,462.92	1.30
2.	Pseudomonas 15 g/kg seed + Zinc 15 kg/ha	37,044.00	86,859.62	49,815.62	1.34
3.	Pseudomonas 15 g/kg seed + Zinc 25 kg/ha	37,544.00	88,824.91	51,280.91	1.37
4.	Azotobacter 15 g/kg seed + Zinc 5 kg/ha	36,844.00	91,945.48	55,101.48	1.50
5.	Azotobacter 15 g/kg seed + Zinc 15 kg/ha	37,344.00	94,923.62	57,579.62	1.54
6.	Azotobacter 15 g/kg seed + Zinc 25 kg/ha	37,844.00	97,669.17	59,825.17	1.58
7.	Trichoderma 5 g/kg seed + Zinc 5 kg/ha	37,144.00	1,02,190.40	65,046.39	1.75
8.	Trichoderma 5 g/kg seed + Zinc 15 kg/ha	37,644.00	1,05,826.80	68,182.80	1.81
9.	Trichoderma 5 g/kg seed + Zinc 25 kg/ha	38,144.00	1,09,857.70	71,713.74	1.88
10.	Control (RDF: - 60:40:40 NPK kg/ha)	34,144.00	76,514.40	42,370.47	1.24

*Data was not subjected to statistical analysis

+ Zinc 25 kg/ha, Potassium 50 kg/ha along with Zinc 15 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha) were statistically at par with the treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). Biofertilizers could be attributed to overall improvement in plant growth and increased availability of nutrients to plants at the flower primordial initiation stage which might have helped in greater effective tillers formation and ultimately increased number of grains/ear head and ear head length Marngar and Dawson (2017). It may be attributed to the role of Zinc as a catalyst or stimulant in most of physiological and metabolic process a component of some protein and a compound needed for production of growth hormones (auxins) like Indole Acetic Acid. Similar results were also reported by Reddy *et al.,* (2021), Vinod Kumar *et al.,* (2018) and Chouhan *et al.,* (2015).

Yield attributes and Yield Parameter

Ear head length (cm)

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Number of grains/ear head

Significant effect was observed by the statistical analysis of number of grains/ear head. Treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). recorded significant and highest number of grains/ear head (1848.75). However, treatment 5, 6, 7 and 8 (Azotobacter 15 g/kg seed + Zinc 25 kg/ha, Azotobacter 15 g/kg seed + Zinc 25 kg/ha, Potassium 50 kg/ha along with Zinc 15 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha) were statistically at par with the treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). Biofertilizers could be attributed to overall improvement in plant growth and increased availability of nutrients to plants at the flower primordial initiation stage which might have helped in greater effective tillers formation and ultimately increased number of grains/ear head and ear head length Marngar and Dawson (2017). It may be attributed to the role of Zinc as a catalyst or stimulant in most of physiological and metabolic process a component of some protein and a compound needed for production of growth hormones (auxins) like Indole Acetic Acid. Similar results were also

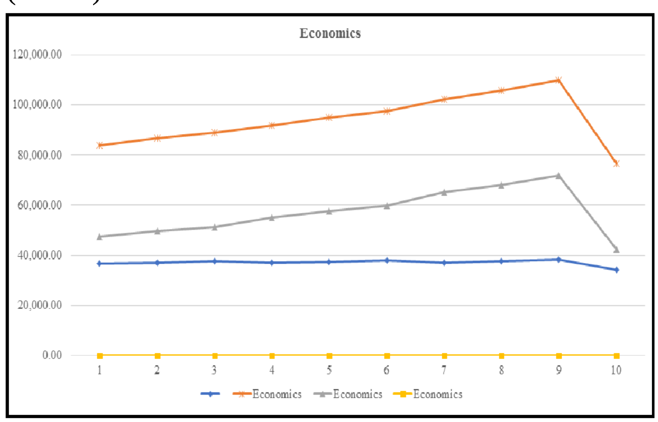

Fig. 3: Effect of Biofertilizers and Zinc levels on Economics of Pearl millet on line graph.

reported by Reddy *et al.,* (2021), Vinod Kumar *et al.,* (2018) and Chouhan *et al.,* (2015).

Test weight (g)

The statistical analysis on test weight was found to be non-significant. However, highest test Trichoderma 5 g/kg seed + Zinc 25 kg/ha) and lowest test weight (5.71 g) was recorded in control. Significant increase in number of grains /ear head is due to increase in the availability of Nitrogen through bio fertilizer inoculation by which more ear heads are produced due to increased rates of spikelet's primordial production, similar results were found Marngar and Dawson (2017).

Grain yield (kg/ha)

Increased grain yield was obtained due to Biofertilizers and Zinc and RDF treatment combinations. The highest grain yield (4530.43 kg/ha) was obtained in treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha) whereas, treatment 8 (Trichoderma 5 g/kg seed + Zinc 15 kg/ha) were statistically at par with treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). Applying Biofertilizers might be applied to improve vegetative development, probably uptake and utilization of other elements fascinated by its wide root system developed by biofertilizers imitation was reported by Muraleedharan, (2010). Zinc's role as a "catalyst" in the synthesis of tryptophan, as well as the growth and development of the plant, may be ascribed to the increase in grain yield. Similar findings were previously published by Sharma *et al*., (2012) and Singh *et al*., (2016).

Stover yield (kg/ha)

Application of Biofertilizers and Zinc has significantly impact on stover production of the Pearl millet. At Trichoderma 5 g/kg seed + Zinc 25 kg/ha, the highest stover yield (7246.59 kg/ha) was obtained whereas, treatments 6, 7 and 8 (Azotobacter 15 g/kg seed + Zinc 25 kg/ha, Trichoderma 5 g/kg seed + Zinc 5 kg/ha and Trichoderma 5 g/kg seed + Zinc 15 kg/ha) were obtained statistically at par with the treatment 9 (Trichoderma 5 g/kg seed + Zinc 25 kg/ha). Applying Biofertilizers might be ascribed to improve vegetative development, probably uptake and utilizations of other elements fascinated by its wide root system developed under Trichoderma was reported by Nelson (2004). The biological yield is a function of the stover yield. Zinc is critical to the growth and development of tryptophan, a necessary amino acid for plant growth and development. Both Sharma *et al.,* (2012) and Singh *et al.,* (2016) found the same results in their research.

Economics

Cost of cultivation (INR 38,144.00), Gross return (INR 1,09,857.70), Net return (INR 71,713.74) and Benefit cost ratio (1.88) were found higher with application of Trichoderma 5 g/kg seed + Zinc 25 kg/ha. it might be attributed to increase grain and stover yield with Trichoderma and Zinc application. The value of increased yield was much more than the cost of Biofertilizers and Zinc application which increased Net returns and B:C ratio. On the basis of results, Trichoderma 5 g/kg seed + Zinc 25 kg/ha earned maximum net return which was found higher than other treatment. Due to per unit cost of Biofertilizers is lower when supplied through urea as compared to other sources which directly reflect the net returns and B:C ratio. These results collaborate to the findings with Jakhar *et al.,* (2006), Sharma *et al.,* Kumar *et al.,* (2008), Kumar *et al.,* ((2007) and Singh *et al.,* (2007).

Conclusion

In the light of above study, it may be concluded that application of Biofertilizers that is Trichoderma 5 g/kg seed + Zinc 25 kg/ha is a fitting practice for augmenting higher sorghum yields for farmers and was found to be more productive in Growth attributes, Yield attributes and yield since the findings were recorded are based on the research done in one season it may be repeated for further confirmation.

Acknowledgement

For providing the facilities needed to carry out the research, the authors are grateful to the Department of Agronomy at the Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology and Sciences, (U.P.) India.

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