Influence of cropping system and Nutrient Management Practices on the Yield, and Economics of Pearl Millet [*Pennisetum glaucum*]

Abstract :

The Field experiments were conducted to evaluate the effect of cropping systems and nutrient management practices on the yield, and economics of pearl millet in the School of Agricultural Science, Karunya Institute of Technology and Sciences, Coimbatore, India). The experiments were laid out in Factorial Randomized Block Design (FRBD) with two factors (Cropping system and Nutrient management) and three replications for two consecutive seasons in 2022-23. The study comprised three cropping system treatments namely C_1 – Sole Pearl millet cropping, C_2 - Pearl millet + Black gram intercropping (1:1), C_3 – Pearl millet + Cowpea intercropping (1:1) along with four nutrient management treatments *viz.,* N_1 - 100% Recommended dose of fertilizer (RDF) @80:40:40 kg of N, P_2O_5, and K_2O/ha., N_2– 75% RDF + *Azospirillum* @2kg/ha and Phosphate solubilizing bacteria (PSB) @2kg/ha, N_3 – 75% RDF + Soil application of *Azospirillum* (2kg/ha) and PSB (2kg/ha) + Foliar spray of 2% urea @ 15 and 35 days after transplanting (DAT), N_4 – 75% RDF + Soil application of *Azospirillum* (2kg/ha) and PSB (2kg/ha) + Foliar spray of Panchagavya3% @ 15 and 35 DAT. The results of the experiment revealed that the intercropping of black gram or cowpea in pearl millet proves to be beneficial and advantageous in terms of, grain yield and returns per rupee invested, rather than going for the sole cropping of pearl millet. On the other hand, reduced application of inorganic recommended dose of fertilizers by 25% with the inclusion of biofertilizers like *Azospirillum* and phosphate solubilizing bacteria, along with the foliar application of 2% urea or 3% Panchagavya will be an economically viable and environmentally sustainable nutrient management practice for improving the yield of pearl millet.

Keywords: Nutrient Management, Intercropping, Pearl millet, Panchagavya, Urea 2% spray, Azospirillum and PSB.

1. INTRODUCTION :

Pearl millet (*Pennisetum glaucum* L.) is a significant cereal staple crop in India and throughout the world which plays a very important role in global food production. Pearl millet is nutritionally superior to many other cereals as it is a good source of protein (12.1%), fats (5.0%), carbohydrates (69.4%), and minerals (2.3%). It is an ideal crop for arid and hot climates as it has an inherent capacity to thrive under low moisture and nutrient-depleted soil conditions. The major pearl millet growing states in India are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, and Haryana. In India pearl millet cultivation occupies an area of about 6.70 M ha with a total production of 9.62 M tonnes and an average yield of about 1436 kg ha^{-1} (DES 2021-22) [1].

Nutrient management is one of the most important ways for improving the qualitative and quantitative crop yield, which can be achieved by adopting adequate soil nutrient management treatments [2,3]. Nitrogen (N) and Phosphorus (P) are the essential nutrients for enhancing the crop yield and its economic efficiency. In most of the pearl millet cultivation regions, continuous use of inorganic fertilizers has deteriorated the soil health and nutrient availability, which has triggered poor productivity of the crop. Farmers are being pushed to use more and more fertilizers to cope with the above situation which is leading to higher costs of production. Under this situation, effective nutrient management practices in pearl millet can improve its productivity alongside reducing the production costs. For better farm management and sustainable production, integrated use of chemical fertilizers and organic amendments like farmyard manure (FYM), are often recommended. In addition, supplemental nutrient assistance in the form of foliar nutrient spray, particularly in times of soil moisture stress, could be an effective way for enhancing the crop growth and yield. These water-soluble and liquid fertilizers when applied directly over the leaves, enable the plants to quickly absorb the vital nutrients. Pearl millet yield has been positively impacted by the foliar application of NPK fertilizers. Bio enhancers like Panchagavya, when applied as a foliar spray, could create stimuli in the plant system and increase the production of growth regulators in the plant metabolism due to the presence of hormones like indole acetic acid and gibberellic acid.[4] On the other hand, the use of biofertilizers in combination with chemical and other organic sources of plant nutrients will assist in preserving productivity and soil wellness for sustainable crop production. Biofertilizers, in turn, are low-cost input technology which can help minimizing the dependency on synthetic fertilizers, while leading to a pollution-free ecosystem in crop cultivation, which is desperately required [5].

Intercropping of pulses with millets is yet another proven strategy to increase the crop yield and soil health. In terms of resource utilization and productivity, intercropping of pearl millet with pulses can be advantageous because the legumes fix the atmospheric nitrogen, stabilize the yield, and promote the soil quality. Intercropping is an effective practice to augment the total productivity per unit area per unit time compared to sole cropping through the effective use of resources[6]. Intercropping approach aids in limiting the risk of crop failures associated with the main crop while diversifying the agricultural production as well. Intercropping with legumes and integrating chemical fertilizers with organic amendments and, foliar nutrition are necessary for the sustained production of pearl millet. This integrated approach will support the overall sustainability of pearl millet farming by maintaining higher yields and lowering the cost of production. Keeping in view of the above scenario, the study was conducted to understand the comparative response of integrating chemical fertilizers with organic amendments, foliar nutrition, and leguminous intercropping on the agronomic traits of pearl millet at different phenological stages. We hypothesized that this integrated approach will enhance the nutrient use efficiency and, thereby increase the crop growth and yield. The study also aimed to optimize a definite combination of nutrient management practices in terms of sustainable pearl millet production.

2. MATERIALS AND METHODS:

The field experiment was carried out by conducting two consecutive field trials. The first trial was conducted from mid-September 2022 to December 2022 and the second trial during mid-January 2023 to March 2023 on the instructional farm (South), School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore (Tamilnadu). The farm is geographically located at 10^0 56' N latitude and 76^0 44' E longitude at an elevation of 474 m above the mean sea level. The soil was silty clay loam in texture, with a bulk density of 1.16 g cc^{-1}, a pH of 5.36, and an EC of 0.06 dS m^{-1}. The soil was high in organic carbon, medium in available nitrogen, high in phosphorus, and medium in potassium. Pearl millet TNAU cumbu hybrid CO 9 with a duration of 75 – 80 days was used as the main crop for this experiment. The seedlings were raised in a nursery bed and transplanted 15 days after sowing with a uniform spacing of 45 x 15 cm. Two different leguminous crops of different growth stature *viz.,* black gram (VBN 8) and cowpea (VBN 3) were tested as intercrops in a ratio of 1:1 following an additive series to study the response of pearl millet under the intercropping situation.

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with 2 factors namely, cropping system and nutrient management practices with a combination of 12 treatments, which were replicated thrice. The treatment comprises three cropping system treatments namely C_1 – Sole Pearl millet cropping, C_2 - Pearl millet + Black gram intercropping (1:1), C_3 – Pearl millet + Cowpea intercropping (1:1) along with four nutrient management treatments *viz.,* N_1 - 100% Recommended dose of fertilizer (RDF) @80:40:40 kg of N, P_2O_5, and K_2O/ha., N_2– 75% RDF+ *Azospirillum* @2kg/ha and Phosphate solubilizing bacteria (PSB) @2kg/ha, N_3 – 75% RDF + Soil application of *Azospirillum* (2kg/ha) and PSB (2kg/ha) + Foliar spray of 2% urea @ 15 and 35 days after transplanting (DAT), N_4 – 75% RDF + Soil application of *Azospirillum* (2kg/ha) and PSB (2kg/ha) + Foliar spray of Panchagavya3% @ 15 and 35 DAT. The entire quantity of phosphorous and potassium and half of the nitrogen were provided as basal application and the remaining nitrogen was top dressed at 15 and 30 DAT. The foliar sprays of urea 2% and panchagavya 3% were mixed with water and sprayed using a knapsack sprayer. Farm Yard Manure @ 12.5 t ha^{-1} was applied basally for all treatment plots.

The data collected on various characters studied during the experiment were subjected to statistical analysis in a factorial randomized block design (FRBD). The significance of the difference was tested by the "F" test at a 5 percent level.

3. RESULTS AND DISCUSSION

3.1.Effect of the cropping systems and nutrient management practices on the yield attributes of pearl millet

The yield attributes of pearl millet in response to the cropping system and nutrient management treatments are presented in the table.1

3.1.1 Effect of cropping systems

The results revealed that the intercropping treatments resulted in a higher yield attributing characters when compared to the sole crop of pearl millet. The maximum number of effective tillers (3.76 and3.82), length of earhead (22.61 and 25.73 cm), grith of earhead (10.91 and12.49 cm), and test weight (11.33,and12.95 g) were obtained from the treatment C_2 - Pearl millet + Black gram intercropping (1:1), which was on par with the treatment C_3 – Pearl millet + Cowpea intercropping (1:1) during both the field trials.

The treatment C_1, sole cropping of pearl millet recorded a lower number of effective tillers (3.2 and 3.34), length of earhead (20.95 and 22.55 cm), grith of earhead (9.65 and 1.60 cm), and test weight (9.99, and 11.39 g) during both the field trials when compared with the intercropping treatments.

The increase in yield attributes in intercropping treatments might be due to the complementary effect of black gram and cowpea on pearl millet. This is due to the fact that the pulse crops are leguminous in nature and can fix atmospheric nitrogen in the soil. On the other hand, these intercrops also act as a cover crop and decrease the weed infestation in the fields, thus reducing the weed competition on pearl millet during the critical stages of crop growth. This result substantiates the findings of other researchers Triveni *et al*., 2017 [7], and Bado *et al*., 2022 [8].

3.1.2 Effect of nutrient management practices

The results of the different nutrient management treatments revealed that the integrated nutrient treatment N_3 - 75% RDF + *Azospirillum* and PSB along + foliar application of 2% urea @ 15 and 35 DAT has significantly increased the number of effective tillers (4.05 and 4.22), length of earhead (24.99 and 27.95 cm), grith of earhead (11.71 and, 13.24 cm), and test weight (12.06 and, 13.88 g) during both the field trials, and was statistically on par with the other integrated nutrient treatment N_4 – 75% RDF + Soil application of *Azospirillum* (2kg/ha) and PSB (2kg/ha) + Foliar spray of Panchagavya3% @ 15 and 35 DAT. The lower number of effective tillers (3.13 and 3.08), length of earhead (20.45 and 21.46 cm), grith of earhead (9.10 and 10.28 cm), and test weight (9.29 and 10.85 g) were obtained from the pure inorganic nutrient treatment N_1 - 100% RDF during both the trials, and it was statistically on par with the integrated nutrient treatment N_2 - 75% RDF + *Azospirillum* and PSB. The higher yield attributes obtained under the integrated nutrient treatments N_3 and N_4 may be due to the combined action of inorganic and organic amendments which could have initiated a better balance and higher availability of essential nutrients. The use of biofertilizers might have amplified the availability of nitrogen through fixation and solubilization of phosphorous in the soil, which could have led to better root and shoot development. On the other hand, the foliar application of urea and panchagavya could have influenced the crop for the rapid and effective absorption of essential nutrients, and various enzymes. The findings coincide with the study made by Divya *et al.* (2017) [9], Reddy *et al.* (2018) [10], and Kumar *et al*. (2022) [11].

3.1.3 Interaction effect

The combined effect of cropping systems and nutrient management treatments does not reach the level of significance for all yield attributes.

3.2 Effect of the cropping systems and nutrient management practices on the Yield of pearl millet

Table 2. illustrates the effect of cropping systems and the nutrient management practices on the yield of pearl millet.

3.2.1 Effect of cropping systems

According to the results obtained by both the trials, it is evident that the pearl millet black gram intercropping system of 1:1 ratio (C_2) recorded significantly higher grain yield (3023.48, and 3084.34 kg ha^{-1}) and straw yield (5843.97 and 6554.23 kg ha^{-1}). However, it was found to be statistically on par with pearl millet cowpea intercropping system of 1:1 ratio (C_3) The lowest values of grain yield (2646.15, and 2694.06 kg ha^{-1}) and straw yield (5043.13, and 5724.88 kg ha^{-1}) were recorded under the sole cropping system (C_1).

The increase in yield might be owing to the inclusion of legumes under millet cropping that could have initiated the legume effect, thus improving the nutrient availability to the crop and it also could have lessened the depletion of soil NPK compared to the sole cropping. It was evident from the study that the growing of pulses as intercrops are less competitive and more complementary with pearl millet. The intercropping led to better land use efficiency and weed smothering effect which was in agreement with the findings of Dwivedi *et al* (2012) [12] and Bado *et al*., 2022 [8].

3.2.2 Effect of nutrient management practices

Among the integrated nutrient management treatments, the combined application of 75% RDF + *Azospirillum* and PSB along with the foliar application of urea 2% at 15 and 45 DAT (N_3) produced maximum grain yields (3222.32, and 3321.65 kg ha^{-1}) and stover yields (6133.21 and 7058.51 kg ha^{-1}) during both the trails, which were at par with the treatment 75% recommended dose of fertilizers + *Azospirillum* and PSB and foliar application of Panchagavya 3% spray at 15 and 45 DAT (N_4). Treatment with 100% RDF application (N_1) recorded the lowest grain yields (2529.28 and 2567) and stover yields (5003.1 and 5454.88) during both seasons.

The overall increase in grain and stover yields during the two consecutive trials under the integrated nutrient treatments N_3 and N_4 might be due to the synergistic effect of the combination of organic and inorganic sources of nutrients. Moreover, the foliar application of nutrients might have resulted in better nutrient absorption and translocation by the crop, which could have accelerated the photosynthetic activity and adequate biomass accumulation, by increasing a better source-sink mobility. Similar results were reported by Tomar *et al*. (2019) [13], Arya *et al.* (2022) [14] and Sakpal *et al.* (2022) [15].

3.2.3 Interaction effect

The interaction between cropping system treatments and nutrient management treatments is not significant under the yield parameter.

3.3. Economics

A non-statistical data on the economics cropping system and nutrient management treatments taken for the study during both trials are presented in graphs 1 and 2.

It is evident from the results of the study that the highest net returns (₹168478 per hectare), and benefit-cost ratios for both cropping seasons were obtained from the treatment with the combination of C_2N_3 - black gram intercropping and the integrated application of 75% RDF + *Azospirillum* and PSB + foliar application of 2% urea @ 15 and 35 DAT and it was closely followed by the combination of cowpea intercropping treatment with the same integrated nutrient treatment (C_3N_3)

The highest economic efficiency in intercropping treatments is caused by the additional income of black gram and cowpea which increased the gross income significantly. The lesser use of inorganic fertilizer also paved the way for the reduction in the cost of production which ultimately resulted in high monetary returns. These results are in line with Renu *et al.* (2018) [16], Patel *et al.* (2021) [17], Gayethri *et al*. (2022) [18]

4. CONCLUSION

Based on the results of the experiment it can be concluded that the intercropping of black gram or cowpea in pearl millet proves to be beneficial and advantageous in terms of, grain yield and returns per rupee invested, rather than going for the sole cropping of pearl millet. On the other hand, reduced application of inorganic recommended dose of fertilizers by 25% with the inclusion of biofertilizers like *Azospirillum* and phosphate solubilizing bacteria, along with the foliar application of 2% urea or 3% Panchagavya will be an economically viable and environmentally sustainable nutrient management practice for improving the yield of pearl millet. In the future, long-term studies can be conducted to evaluate the sustainability and resilience of the treatments under different climatic conditions to validate better strategies that are cost-effective and environmentally sustainable.

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Table 1. Yield attributes of pearl millet recorded in the field trials

	Treatments	I Trial				II Trail			
		Effective tillers	Earhead length (cm)	Earhead grith (cm)	Test weight (g)	Effective tillers	Earhead length (cm)	Earhead grith (cm)	Test weight (g)
A.	**Cropping systems**								
C1	Sole pearl millet cropping	3.20	20.95	9.65	9.99	3.34	22.55	10.60	11.39
C2	Pearl millet + Black gram intercropping (1:1)	3.76	23.61	10.91	11.33	3.82	25.73	12.49	12.95
C3	Pearl millet + Cowpea intercropping (1:1)	3.75	22.31	10.63	11.11	3.75	25.69	12.16	12.55
	S.E. +	0.16	0.93	0.43	0.47	0.18	1.22	0.59	0.61
	CD at 5%	0.34	1.94	0.90	0.98	0.38	2.55	1.22	1.27
B.	**Nutrient management**								
N1	100% RDF (NPK-80:40:40)	3.13	20.45	9.10	9.29	3.08	21.46	10.28	10.85
N2	75% RDF + *Azospirillum* + PSB	3.28	20.84	9.50	10.12	3.18	22.10	10.64	11.29
N3	75% RDF + *Azospirillum* + PSB + Urea 2%	4.05	24.99	11.71	12.06	4.22	27.95	13.24	13.88
N4	75% RDF + *Azospirillum* + PSB + Panchagavya 3%	3.83	24.23	11.28	11.77	4.08	27.10	12.83	13.17
	S.E. +	0.18	1.07	0.50	0.54	0.21	1.41	0.68	0.70
	CD at 5%	0.39	2.24	1.03	1.13	0.44	2.55	1.41	1.46
C.	**Interaction**								
	S.E. +	0.31	1.86	0.86	0.94	0.36	2.44	1.17	1.21
	CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

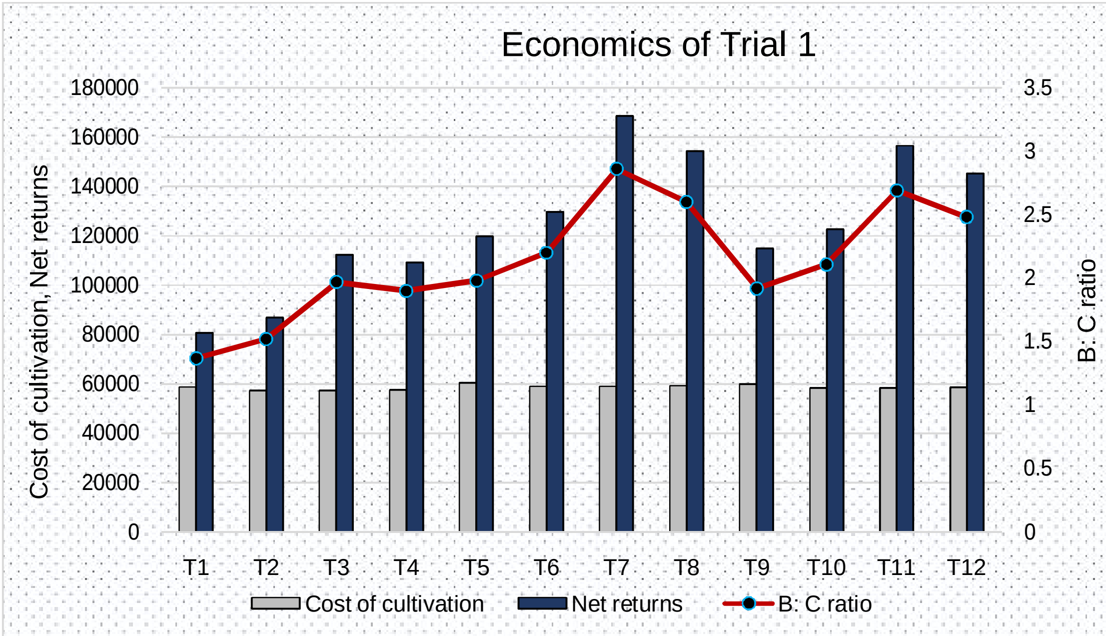
**Data represented are mean values of three replicates.*

Table 2. The yield of pearl millet recorded in the field trials

	Treatments	I Trial			II Trial		
		Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index
A.	**Intercropping systems**						
C1	Sole pearl millet cropping	2646.15	5043.13	34.41	2694.06	5724.88	32.00
C2	Pearl millet + Black gram intercropping (1:1)	3023.48	5843.97	34.10	3084.34	6554.23	35.00
C3	Pearl millet + Cowpea intercropping (1:1)	2958.29	5668.12	34.26	2963.48	6297.40	34.00
	S.E. +	142.22	272.14	1.68	144.15	306.32	1.67
	CD at 5%	296.86	568.02	NS	300.88	639.37	NS
B.	**Integrated Nutrient management**						
N1	100% RDF (NPK-80:40:40)	2529.28	5003.10	33.58	2567.00	5454.88	31.66
N2	75% RDF + *Azospirillum* + PSB	2687.15	5088.61	34.56	2651.57	5634.58	33.00
N3	75% RDF + *Azospirillum* + PSB + Urea 2%	3222.32	6133.21	34.45	3321.65	7058.51	36.33
N4	75% RDF + *Azospirillum* + PSB + Panchagavya 3%	3065.16	5848.69	34.40	3115.62	6620.69	35.33
	S.E. +	164.23	314.24	1.940	166.45	353.71	1.93
	CD at 5%	342.78	655.89	NS	347.43	738.28	NS
C.	**Interaction**						
	S.E. +	284.45	544.27	3.36	288.30	612.64	3.34
	CD at 5%	NS	NS	NS	NS	NS	NS

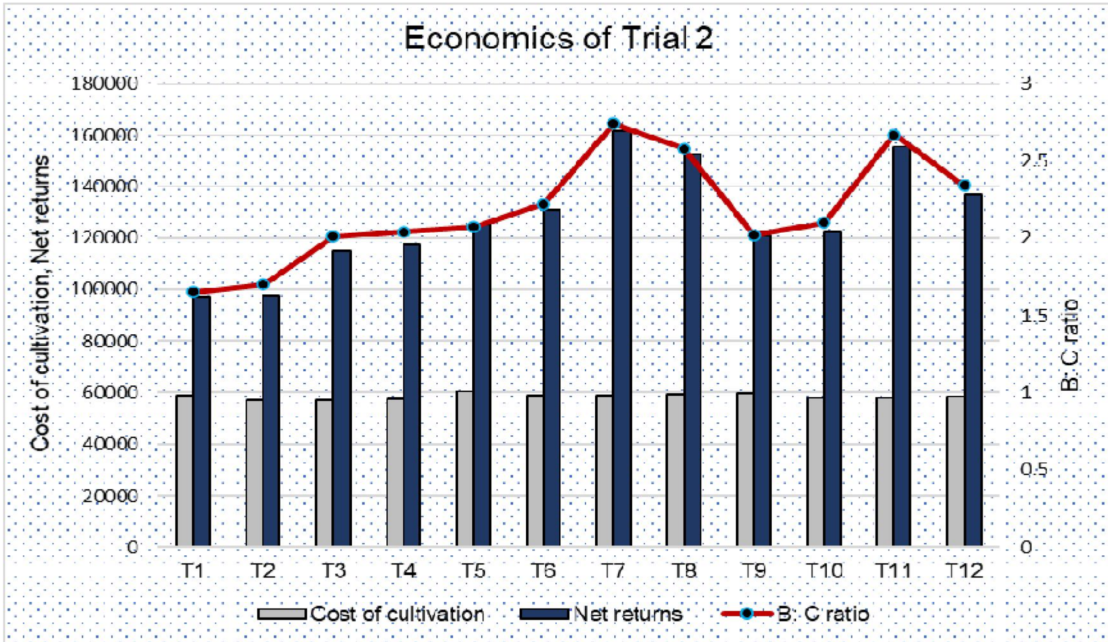
**Data represented are mean values of three replicates.*

Graph 1. The total cost of cultivation (₹ ha^{-1}), Net returns (₹ ha^{-1}), benefit-cost ratio of first trial



T_1 - Sole pearl millet cropping +100% RDF, T_2 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB, T_3 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_4 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray, T_5 - Black gram intercropping (1:1) +100% RDF, T_6 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB, T_7 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_8 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray, T_9 - Cowpea intercropping (1:1)+100% RDF, T_{10} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB, T_{11} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_{12} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray

Graph 2. The total cost of cultivation (₹ ha^{-1}), Net returns (₹ ha^{-1}), benefit-cost ratio of second trial



T_1 - Sole pearl millet cropping +100% RDF, T_2 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB, T_3 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_4 - Sole pearl millet cropping + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray, T_5 - Black gram intercropping (1:1) +100% RDF, T_6 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB, T_7 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_8 - Black gram intercropping (1:1) + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray, T_9 - Cowpea intercropping (1:1)+100% RDF, T_{10} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB, T_{11} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB + Urea 2% spray, T_{12} - Cowpea intercropping (1:1) + 75% RDF + Azospirillum + PSB + Panchagavya 3% spray