ANSF
APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
17(1), 117 - 125 (2025)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Evaluating the performance of millet-based pulse intercropping on weed dynamics, nutrient uptake and productivity of little millet (*Panicum sumatrense* L.) under rainfed condition

A. R. Viveka Vadhani*
Division of Agronomy, Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India
R. Mohanapriya
Division of Agronomy, Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India
R Susan Poonguzhali
Division of Soil science & Agricultural chemistry, Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India
K. Sharmili
Division of Agronomy, Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India
V. Jawahar
Division of Agronomy, Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India

*Corresponding author. E-mail: vivekavadhania24@karunya.edu.in

Article Info
https://doi.org/10.31018/jans.v17i1.6049
Received: August 07, 2024
Revised: January 31, 2025
Accepted: February 05, 2025

How to Cite
Vadhani, A.R. V. *et al.* (2025). Evaluating the performance of millet-based pulse intercropping on weed dynamics, nutrient uptake and productivity of little millet (*Panicum sumatrense* L.) under rainfed condition. *Journal of Applied and Natural Science*, 17(1), 117 - 125. https://doi.org/10.31018/jans.v17i1.6049

Abstract
In the current state of agricultural production, practising sole cropping alone is not remarkably lucrative to meet the demands of a rapidly expanding population and malnutrition, and it is imperative to integrate pulses into the millets production system to stabilize production. Considering this, a field experiment was conducted at Karunya Institute of Technology and Sciences, Coimbatore, during the 2023–2024 *rabi* season to identify suitable component crop and their row pattern to enhance the productivity of little millet (ATL 1) under rainfed conditions. It was laid out in randomized block design, with eleven treatments and three replications. The treatments include little millet intercropping with black gram, green gram, red gram, cowpea and Bengal gram at 4:1 and 6:1 ratios, along with little millet sole cropping. The results showed that higher plant height (34.2, 127.6 & 133.6 cm) and DMP (2409, 5463 & 5943 kg ha^{-1}) was observed in little millet + black gram (4:1) (T_2) at 30, 60 DAS and at harvest stage which also recorded the maximum grain and straw yield of 1326 and 4109 kg ha^{-1} with a higher microbial population. Little millet + cowpea (4:1) (T_8) registered lower weed density (8.4, 5.9 & 4.5 m^{-2}), dry weight (9.0, 5.9 & 4.5 g m^{-2}) and higher weed control efficiency during all stages. The NPK uptake of the base crop was higher in little millet + black gram (6:1) (T_3) (40.8, 5.7 & 33.5 kg ha^{-1}). For intercrops, it was higher in little millet + cowpea (4:1) (T_8) (5.7, 1.6 & 3.6 kg ha^{-1}).

Keywords: Intercropping, Little millet, Microbial population, Nutrient uptake, Weed dynamics

INTRODUCTION

In India, the area of cultivation of minor millets is around 4.28 lakh ha, with production and productivity of 3.84 lakh tonnes and 18,958 kg ha^{-1}. In Tamil Nadu, the area under minor millets is about 0.15 million hectares with a production and productivity of 0.18 lakh tonnes and 1178 kg ha^{-1} (Department of Agriculture & Farmers Welfare, 2023). Little millet is well known in Tamil Nadu and has grown quite extensively in several parts of the country. It is strongly associated with tribal agriculture (Sivagamy *et al*., 2020). A long-standing technique of intensive agriculture is intercropping, which has been used worldwide to increase land productivity sustainably and naturally. The theory underlying the method is that different crops have different requirements for growth, complement one another and utilize resources more efficiently.

From the current agricultural perspective, cultivating millets alone is not very profitable, considering the variety of customer demands and the continuously expanding population. Therefore, it is imperative that legumes can be included in millet-based intercropping systems. Choosing a suitable millet variety is crucial in millet/legume intercropping because of the quick development rate of both crops (Bassi and Dugje, 2016). Minor millets' initial slow growth will help the intercrops' early establishment more successfully. In addition, intercropping inhibits the growth of noxious weeds and increases yield per unit area than sole cropping (Kumar and Ray, 2020). Legumes and cereals interplanted together is a productive way to increase biomass yield, make efficient use of land and stabilize output. Reduced plant spacing enhances soil plant coverage, lessens weed competition, and reduces soil surface evaporation, which helps the crop grow and yield more while using less water (Oliveira *et al*., 2017). Because of this, present research was undertaken to determine the appropriate intercropping combination for little millet (ATL 1) under rainfed conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during *rabi* 2023-2024 at Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu. The variety ATL 1 of little millet was used as a main crop with a duration of 85 – 90 days and the selected intercrops were black gram (VBN 8), green gram (VBN 3), red gram (APK 1), cowpea (CO 2) and Bengal gram (CO 3) which was intercropped at 4:1 and 6:1 row ratio in replacement series under rainfed condition in the western zone of Tamil Nadu. During cropping, the maximum and minimum temperatures ranged from 29.54°C to 18.20°C, respectively. A total rainfall of 532.88 mm was received in 42 rainy days with a mean relative humidity of 85.99 %.

Treatment details

The experiment was designed in randomized block design (RBD) with eleven treatments and three replications *viz.*,T_1-little millet sole crop, T_2-little millet + black gram (4:1), T_3-little millet + black gram (6:1), T_4-little millet + green gram (4:1), T_5-little millet + green gram (6:1), T_6-little millet + redgram (4:1), T_7-little millet + redgram (6:1), T_8-little millet + cowpea (4:1), T_9-little millet + cowpea (6:1), T_{10}-little millet + bengal gram (4:1) and T_{11}-little millet + bengal gram (6:1).

Observations recorded

Plant height (cm) was measured at 30, 60 DAS and harvest stage from the ground level to tip of the plant. Five plants were selected at random and the samples were oven dried at 80 ± 2°C for 72 hours during all three stages of observation and the dry matter production was computed per unit area and expressed in kg m^{-2}. The weeds were counted in each plot at 15, 30 and 45 DAS and expressed in nos. m^{-2}. The weeds were removed from the sampling area, oven-dried at 60°C using hot air oven and expressed in g m^{-2}. Weed control efficiency was calculated by the following formula:

$$WCE = \frac{W_{PC} - W_{PT}}{W_{PC}} \text{ X } 100 \qquad \text{Eq.1}$$

Where,
WPC-Weed density in control plot
WPT-Weed density in treatment plot

The matured panicles were harvested from the net plot, sun dried, and threshed manually. After the harvest of the panicles, all the plants were cut above the ground level. Later it was sun-dried and weighed. The grain and straw yield were calculated and expressed in kg ha^{-1}. HI was calculated by the ratio between economic yield and biological yield using the formula outlined by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \qquad \text{Eq.2}$$

Lal and Ray (1976) proposed grain equivalent yield (GEY), which is crop economics, by converting grain in terms of gross return for a valid comparison with GEY. The little millet equivalent yield of the intercropping system was calculated using the following formula, which is expressed in kg ha^{-1}.

$$GEY = \frac{\sum \text{Yi x Pi}}{\text{P (p)}} \qquad \text{Eq.3}$$

Where,
Yi-Yield of intercrop (kg ha^{-1})
Pi-Price of intercrop (₹ ha^{-1})
P(p)-Price of base crop (₹ ha^{-1})

Microbial analysis

The samples were analyzed for the population of total bacteria, fungi and actinobacteria using Nutrient glucose agar medium (Collings and Lyne, 1968), Martin's rose Bengal agar medium (Martin, 1950) and Kenknight's agar medium (Kenknight and Muncie, 1939) and it is expressed in CFU g^{-1}.

Plant sample analysis

Plant samples were collected at the harvest stage. After collecting plant samples, they were oven-dried at 65±5°C until a constant weight was reached and powdered in a Willey mill. The nutrient content of nitrogen uptake was analysed using the Microkjeldahl method by Humphries (1956), phosphorus uptake was estimated by Colorimetric estimation, suggested by Jackson and potassium uptake was analyzed by Flame photometric method recommended by Jackson (1973) and calculated using the following formula:

Nutrient uptake (kg ha^{-1})=(Nutrient content (%)/100) X dry weight of the plant (kg ha^{-1}) Eq.4

Statistical analysis

The data collected on various parameters were subjected to statistical analysis using ANOVA in randomized block design as given by Gomez and Gomez (1984). Critical difference was worked out at 5 % level of significance.

RESULTS AND DISCUSSION

Effect of intercropping on growth components of little millet

The growth components, *viz*., plant height and dry matter production, are furnished in Tables 1 & 2. Little millet plant height of 34.2, 127.6 and 133.6 cm and DMP values of 2409, 5463 & 5943 kg ha^{-1} at 30, 60 DAS and harvest stage was observed to be higher in little millet + black gram at 4:1 (T_2) which was statistically comparable with little millet + green gram at 4:1 (T_4). This is because the reproductive, leaf and stem tissues have higher concentrations of dry matter and, higher efficiency for photosynthesis and minimal competition for nutrients, light, water and other resources, which increases plant height, tillers and LAI maximizing the output of total dry matter. The results obtained on the growth parameters are in contrast with Aravind *et al*. (2023), who observed that foxtail millet + vegetable cowpea (4:1) increased the plant height and DMP of 120.7 cm and 6223.54 kg ha^{-1} than foxtail millet + green gram intercropping because of the complementary interaction on growth components due to increased light interception, soil moisture, and less intra-specific competition between the crops. Among all the treatments, the lower plant height with the values of 28.2, 96.7 and 99.4 cm during the two stages of observation and DMP of 896, 2597 and 2752 kg ha^{-1} was recorded in little millet + cowpea at 4:1 ratio (T_8). This may be attributed to the impact of cowpeas, which have climbing habits and suppressive effects, thus remarkably inhibiting the plant height of little millet. Also, the reduced growth parameters such as plant height, tillers, canopy covers, leaf area index, etc., caused by the competition between the component crops for growth and limited resources like light, water, nutrients, etc., during all growth stages, which eventually leads to lower dry matter accumulation in reproductive parts of the crop in intercropping system. Islam *et al*. (2018) also reported the antagonistic effect of cowpea on pearl millet at 1:2 ratio, which greatly reduced the growth components of pearl millet.

Effect of intercropping on weed characteristics

Effects of different pulse intercropping on weed dynamics are presented in Tables 3, 4 and 5. During all three stages of observations, the total weed density (8.4, 5.9 and 4.5 m^{-2}) and dry weight (9.0, 5.9 and 4.5 g m^{-2}) were found to be lower in little millet + cowpea (4:1) (T-$_8$) with higher WCE of 52, 64 & 72 %. This might be attributed to the shade impact and competition stress produced by the canopy of more crop plants in a unit area, which has a suppressive effect on associated weeds and may be responsible for decreasing weed population and weed dry biomass in intercropping systems. In contrast with the present study, Abbas *et al*. (2021) observed a reduced weed population in maize + green gram at 6:12 ratio due to the antagonistic effect for the vital resources, which leads to weeds out of competition. Similar results were reported by Ali *et al*.

Table 1. Effect of intercropping on plant height of little millet (cm)

	Treatments		Plant height (cm)		
			30 DAS	60 DAS	At harvest
T_1	Little millet sole crop - Control		35.1	109.6	113.4
T-$_2$	Little millet + Black gram	(4:1)	34.2	127.6	133.6
T_3	Little millet + Black gram	(6:1)	31.5	112.7	116.4
T-$_4$	Little millet + Green gram	(4:1)	33.9	126.8	132.8
T_5	Little millet + Green gram	(6:1)	31.3	112.4	116.5
T_6	Little millet + Redgram	(4:1)	32.7	115.7	120.7
T_7	Little millet + Redgram	(6:1)	30.5	110.5	114.6
T_8	Little millet + Cowpea	(4:1)	28.2	96.7	99.4
T_9	Little millet + Cowpea	(6:1)	29.8	107.5	111.3
T_{10}	Little millet + Bengal gram	(4:1)	32.2	114.3	118.7
T_{11}	Little millet + Bengal gram	(6:1)	30.2	109.1	112.6
	Mean		31.7	113.0	117.3
	Sed		3.12	4.56	4.63
	CD (P=0.05%)		NS	9.51	9.67

Table 2. Effect of intercropping on dry matter production of little millet (kg ha^{-1})

	Treatments		Dry matter production (kg ha^{-1})		
			30 DAS	60 DAS	At harvest
T_1	Little millet sole crop - Control		1882	4526	4944
T_{-2}	Little millet + Black gram	(4:1)	2409	5463	5943
T_3	Little millet + Black gram	(6:1)	1257	3708	3986
T_{-4}	Little millet + Green gram	(4:1)	1954	4628	5060
T_5	Little millet + Green gram	(6:1)	1240	3581	3840
T_6	Little millet + Redgram	(4:1)	1628	3896	4220
T_7	Little millet + Redgram	(6:1)	1193	3318	3562
T_8	Little millet + Cowpea	(4:1)	896	2597	2752
T_9	Little millet + Cowpea	(6:1)	1144	3244	3447
T_{10}	Little millet + Bengal gram	(4:1)	1613	3883	4192
T_{11}	Little millet + Bengal gram	(6:1)	1175	3272	3506
	Mean		1490	3829	4132
	Sed		103	298	316
	CD (P=0.05%)		215	622	659

Table 3. Effect of intercropping on total weed density (Nos. m^{-2}) of little millet

	Treatments		Total weed density (Nos. m^{-2})		
			15 DAS	30 DAS	45 DAS
T_1	Little millet sole crop - Control		12.1 (145.5)	9.9 (97.9)	8.4 (70.6)
T_{-2}	Little millet + Black gram	(4:1)	9.2 (84.4)	7.4 (53.8)	5.6 (31.0)
T_3	Little millet + Black gram	(6:1)	9.7 (93.4)	8.2 (67.4)	6.3 (38.9)
T_{-4}	Little millet + Green gram	(4:1)	9.4 (88.7)	7.8 (60.2)	5.8 (32.7)
T_5	Little millet + Green gram	(6:1)	9.9 (97.0)	8.4 (70.0)	6.5 (42.1)
T_6	Little millet + Redgram	(4:1)	10.2(104.1)	8.4 (70.4)	6.7 (44.7)
T_7	Little millet + Redgram	(6:1)	10.5 (109.4)	9.0 (80.6)	7.1 (49.6)
T_8	Little millet + Cowpea	(4:1)	8.4 (70.5)	5.9 (34.9)	4.5 (20.1)
T_9	Little millet + Cowpea	(6:1)	8.9 (79.6)	6.4 (40.5)	5.2 (26.6)
T_{10}	Little millet + Bengal gram	(4:1)	10.9 (117.5)	9.1 (82.1)	7.6 (57.7)
T_{11}	Little millet + Bengal gram	(6:1)	11.1 (122.2)	9.3 (86.2)	7.9 (61.4)
	Mean		10.0	8.2	6.5
	Sed		1.0	0.8	0.6
	CD (P=0.05%)		2.0	1.6	1.3

*Data were subjected to square root transformation. Values in parenthesis are original value

(2021) in pearl millet + mung bean at 3:3 row ratio of 30cm intra and 30cm inter-strip distances, which effectively reduced weed population. Significant increases in total weed density of 12.1, 9.9 and 8.4 m^{-2} and dry weight of 12.8, 9.8 and 8.2 g m^{-2} were observed in little millet sole crop (T_1) at all stages of observation. This could be due to the fact that although the crop was planted at a closer spacing, the tall growth habit of little millet may have allowed more light to pass into the inter-row areas, which benefited the weed growth in the solitary crop. Similar trends were noticed in maize sole cropping (Naher *et al.,* 2018).

Effect of intercropping on grain equivalent yield (GEY)

Increased GEY in the intercropping system may have contributed to the yield advantages obtained (Table 6). The higher little millet grain equivalent yield was obtained in little millet + black gram (4:1) with the value of 1643 kg ha^{-1} (T_2) and little millet + green gram (4:1) (T_4) (1541 kg ha^{-1}). This could be due to variations in the price of each component crop, the yield of little millet, the individual component crop yield, and the efficient utilization of natural resources. The present study is conformity with Sridhar (2021) on maize + black gram (1:1) showed a significant increase in GEY of base crop due to better leguminous effect which elevated the maize yield.

Effect of intercropping on yield of little millet

The data regarding the grain yield of little millet ranged between 1506-797 kg ha^{-1} is presented in Fig 1. The higher grain yield of 1506 kg ha^{-1} was observed in T_1 -

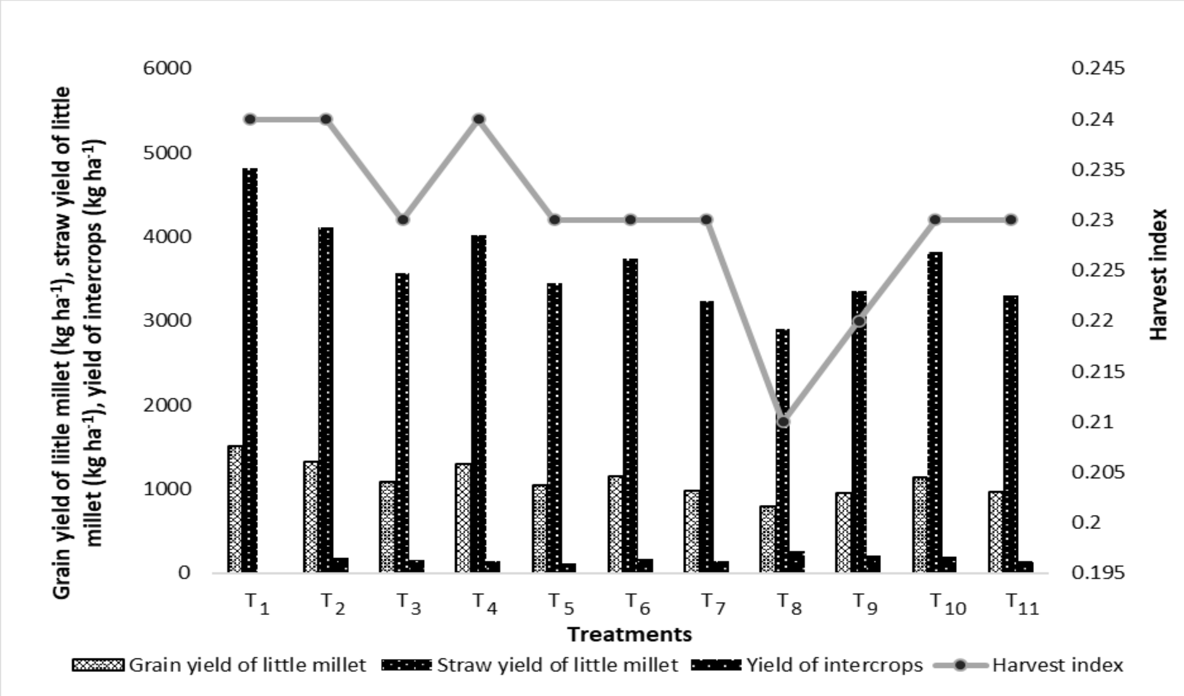

Fig. 1. *Effect of intercropping on yield of main crop and intercrops (kg ha^{-1}); T_1 – Little millet sole crop; T_2 – Little millet + black gram (4:1); T_3 – Little millet + Black gram (6:1); T_4 – Little millet + Green gram (4:1); T_5 – Little millet + Green gram (6:1); T_6 – Little millet + Red gram (4:1); T_7 – Little millet + Red gram (6:1); T_8 – Little millet + Cowpea (4:1); T_9 – Little millet + Cowpea (6:1); T_{10} – Little millet + Bengal gram (4:1); T_{11} – Little millet + Bengal gram (6:1).*

	Treatments		Weed dry weight (g m^{-2})		
			15 DAS	30 DAS	45 DAS
T_1	Little millet sole crop - Control		12.8 (162.9)	9.8 (96.4)	8.2 (67.0)
T-$_2$	Little millet + Black gram	(4:1)	9.8 (95.9)	7.4 (54.5)	5.5 (30.3)
T_3	Little millet + Black gram	(6:1)	10.3 (106.0)	8.3 (68.5)	6.2 (37.8)
T-$_4$	Little millet + Green gram	(4:1)	10.1 (100.8)	7.8 (60.4)	5.7 (31.9)
T_5	Little millet + Green gram	(6:1)	10.5 (110.2)	8.4 (70.8)	6.4 (40.5)
T_6	Little millet + Redgram	(4:1)	10.9 (118.0)	8.4 (70.1)	6.6 (43.0)
T_7	Little millet + Redgram	(6:1)	11.2 (124.5)	9.0 (80.6)	6.9 (47.5)
T_8	Little millet + Cowpea	(4:1)	9.0 (80.5)	5.9 (34.9)	4.5 (20.2)
T_9	Little millet + Cowpea	(6:1)	9.5 (90.5)	6.4 (40.6)	5.2 (26.6)
T_{10}	Little millet + Bengal gram	(4:1)	11.6 (133.5)	9.1 (81.6)	7.4 (54.8)
T_{11}	Little millet + Bengal gram	(6:1)	11.8 (138.4)	9.3 (85.3)	7.7 (58.1)
	Mean		10.7	8.2	6.4
	Sed		1.0	0.8	0.6
	CD (P=0.05%)		2.0	1.6	1.3

*Data were subjected to square root transformation. Values in parenthesis are original value

little millet sole crop, which was followed by T_2 - little millet + black gram at 4:1 ratio and T_4 - little millet + green gram at 4:1 ratio produced a grain yield of 1326 and 1298 kg ha^{-1}, respectively which were statistically comparable with each other. The higher yield of little millet has been attributed to a number of characteristics, including better space use, efficient use of sunshine, nutrients, and water, as well as enhanced N efficiency. The results of the present study are parallel with those of Victor et al. (2023), who worked on a maize-based pulse intercropping system with a notable increase in maize sole crop followed by maize + green gram (4:1) treatment combinations. Little millet + cowpea at 4:1 ratio (T_8) recorded the lower grain yield of 797 kg ha^{-1}. This may be due to intense competition among the intercropping treatments, resulting in lower values of various growth and yield parameters and higher competitive nature of the cowpea for the growth resources. These results coincide with the findings of Tekie and Angiras (2019), where pearl millet yield was less in pearl millet +cowpea intercropping at 1:1 ratio because of the lower plant population in intercropping

Table 5. Effect of intercropping on weed control efficiency (%) of little millet

	Treatments		Weed control efficiency (%)		
			15 DAS	30 DAS	45 DAS
T_1	Little millet sole crop - Control		-	-	-
T_{-2}	Little millet + Black gram	(4:1)	42	45	56
T_3	Little millet + Black gram	(6:1)	36	31	45
T_{-4}	Little millet + Green gram	(4:1)	39	39	54
T_5	Little millet + Green gram	(6:1)	33	28	40
T_6	Little millet + Redgram	(4:1)	28	28	37
T_7	Little millet + Redgram	(6:1)	25	18	30
T_8	Little millet + Cowpea	(4:1)	52	64	72
T_9	Little millet + Cowpea	(6:1)	45	59	62
T_{10}	Little millet + Bengal gram	(4:1)	19	16	18
T_{11}	Little millet + Bengal gram	(6:1)	16	12	13

Table 6. Effect of intercropping on grain equivalent yield (GEY) (kg ha^{-1}) of little millet

	Treatments		GEY
T_{-2}	Little millet + Black gram	(4:1)	1643
T_3	Little millet + Black gram	(6:1)	1343
T_{-4}	Little millet + Green gram	(4:1)	1541
T_5	Little millet + Green gram	(6:1)	1242
T_6	Little millet + Redgram	(4:1)	1428
T_7	Little millet + Redgram	(6:1)	1204
T_8	Little millet + Cowpea	(4:1)	991
T_9	Little millet + Cowpea	(6:1)	1110
T_{10}	Little millet + Bengal gram	(4:1)	1523
T_{11}	Little millet + Bengal gram	(6:1)	1267
	Mean		1329
	Sed		52
	CD (P=0.05%)		110

Table 7. Effect of intercropping on soil microbial dynamics (CFU g^{-1} of soil) of little millet

Treatments			Bacteria (x 10^6 CFU g^{-1})	Fungi (x 10^3 CFU g^{-1})	Actinobacterial (x 10^4 CFU g^{-1})
T_1	Little millet sole crop - Control		32.85	22.09	23.35
T_{-2}	Little millet + Black gram	(4:1)	46.94	31.65	39.78
T_3	Little millet + Black gram	(6:1)	37.63	26.87	25.38
T_{-4}	Little millet + Green gram	(4:1)	45.81	31.13	36.52
T_5	Little millet + Green gram	(6:1)	37.77	25.32	24.21
T_6	Little millet + Redgram	(4:1)	41.75	29.18	31.56
T_7	Little millet + Redgram	(6:1)	38.26	26.22	25.82
T_8	Little millet + Cowpea	(4:1)	43.00	28.34	35.86
T_9	Little millet + Cowpea	(6:1)	37.39	25.72	28.63
T_{10}	Little millet + Bengal gram	(4:1)	41.56	28.38	30.41
T_{11}	Little millet + Bengal gram	(6:1)	36.45	23.36	24.66
	Mean		39.95	27.11	29.65
	SEd		2.31	1.97	1.80
	CD (P=0.05%)		4.81	4.11	3.76

treatments in comparison with sole cropping. Regarding the yield of the intercrops, the cowpea yield was maximum in little millet + cowpea (T_8). This is because of the absorption of more solar light as it is a tall, statured crop when compared to the main crop. Intercropping of little millet + green gram at 6:1 ratio (T_5) recorded the lower yield of intercrops. This may be attributed to leguminous crops being shadowed by taller plants, and the primary cause of the production reduction was most likely a decrease in solar radiation received, which impacted the rate of photosynthesis and the subsequent transfer of photosynthates from source to sink. The findings were in agreement with Derebe *et al.* (2021) under finger millet-based legume intercropping system at 1:1 ratio where the yield of cowpea and soybean recorded higher and lower yield of 1054 kg ha^{-1}

and 61.78 kg ha^{-1}.

Effect of intercropping on microbial population

Effect of intercropping on soil microbial biomass is furnished in Table 7. Among different treatment combinations, the bacterial, fungal and actinobacterial populations were higher in little millet + black gram at 4:1 ratio (T_2) with the values of 46.94 x 10^6 CFU g^{-1}, 31.65 x 10^3 CFU g^{-1} and 39.78 x 10^4 CFU g$^{□1}$, respectively and it remained at par with little millet + green gram at 4:1 ratio (T_4). This may be attributed to legumes actually enhancing the functional variety of the soil microbial population, which in turn promotes plant growth and enhances the characteristics of the soil. Under legume intercropping, the higher soil respiration indicates an increased rate of organic matter decomposition by soil microbes. The minimum bacterial, fungal and actinobacterial population was observed under little millet sole crop (T_1) with 32.85 x 106, 22.09 x 103 and 23.35 x 104 CFU g-1 values. This may be because no other legume benefited from maximizing the microbial count and lesser soil C content than other intercropping treatments. Similarly, an increased microbial population due to the synergistic effect of legumes were reported by Keerthanapriya *et al*. (2019) in little millet-based intercropping and Daisy *et al*. (2018) in Bt cotton-based pulse intercropping in comparison with sole crop.

Effect of intercropping on plant nutrient uptake

The influence of various pulses intercropping on NPK uptake is depicted in Fig 2 & 3. Among different intercropping combinations, little millet + black gram at 6:1 ratio (T_3) registered maximum NPK uptake of 40.8, 5.7 and 33.5 kg ha^{-1} and it was statistically parallel with T_5 - little millet + green gram (6:1), T_2 - little millet + black gram (4:1). This may be due to the minimal nutrient competition in 6:1 ratio because of the lesser number of intercrop rows when compared to 4:1 row ratio treatments. Wang *et al*. (2018) also observed that interspecies interaction among the intercropped pulses with finger millet resulted in better resource sharing and temporal optimization that increased growth and nutrient uptake. The lowest NPK uptake of 16.6, 2.0 and 13.8 kg ha^{-1} was noticed in little millet + cowpea (4:1) (T_8). The reason might be the antagonistic effect of the intercrops for nutrients as the trailing growth nature of the cowpea completely inhibited the main crop growth, eventually leading to the minimum nutrient uptake, resulting in lower yield and dry matter accumulation. In contrast with the present work, Ram and Meena (2014) observed that higher N & P uptake were noticed in pearl millet sole cropping than in other intercropping treatments, while the lower values were observed under pearl millet + mung bean at 1:7 ratio, which may be attributed to the maximum availability of all resources

Table 8. Pearson correlation matrix for growth components, weed indices, microbial dynamics, NPK uptake and yield of little millet

	Pearson correlation										
	Plant height	DMP	Weed density	Dry weight	WCE	LM NPK uptake	Intercrop NPK uptake	Microbes	GEY	Yield of intercrop	Yield of little millet
Plant height	1	0.870**	-0.018	-0.019	0.017	0.610**	-0.003	0.527**	0.518**	-0.146	0.957**
DMP		1	0.147	0.148	-0.148	0.276	-0.369	0.393	0.114	-0.382	0.897**
Weed density			1	0.999**	-0.999	-0.328	-0.801	-0.644	-0.431	-0.742	-0.425
Dry weight				1	-0.999	-0.331	-0.805	-0.648	-0.436	-0.746	-0.428
WCE					1	0.327	0.801**	0.646**	0.429	0.742	0.425
LM NPK uptake						1	0.454	0.374	0.777**	0.183	0.021
Intercrop NPK uptake							1	0.600**	0.755**	0.909**	-0.688
Microbes								1	0.638**	0.617**	0.064
GEY									1	0.637**	0.259
Yield of intercrop										1	0.682**
Yield of little millet											1

**Correlation is significant at 0.01 level (2 tailed); DMP – Dry matter production; WCE – Weed control efficiency; LM – Little millet; GEY – Grain equivalent yield

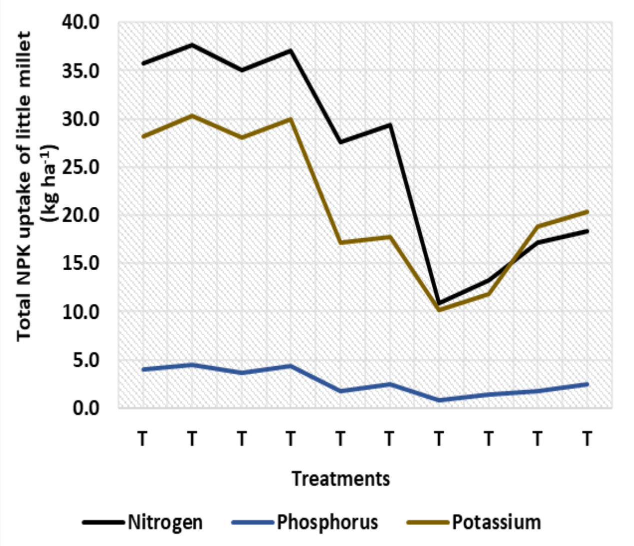

Fig. 2. *Effect of intercropping on total NPK uptake of little millet (kg ha^{-1});T_2 – Little millet + black gram (4:1); T_3 – Little millet + Black gram (6:1); T_4 – Little millet + Green gram (4:1); T_5 – Little millet + Green gram (6:1); T_6 – Little millet + Red gram (4:1); T_7 – Little millet + Red gram (6:1); T_8 – Little millet + Cowpea (4:1); T_9 – Little millet + Cowpea (6:1); T_{10} – Little millet + Bengal gram (4:1); T_{11}– Little millet + Bengal gram (6:1).*

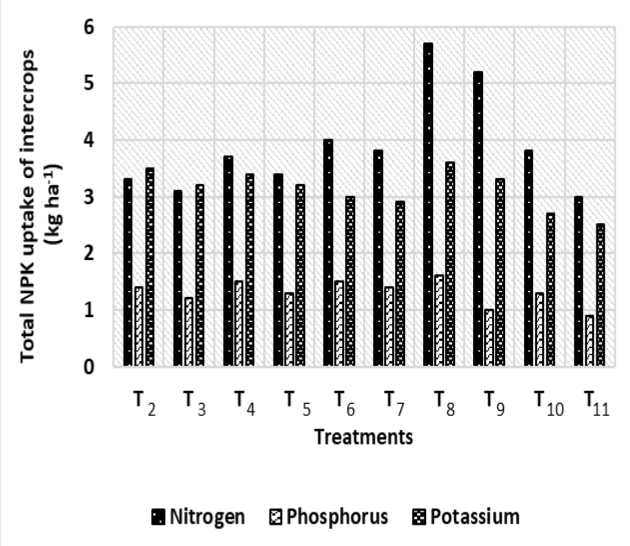

Fig. 3. *Effect of intercropping on total NPK uptake of intercrops (kg ha^{-1});T_2 – Little millet + black gram (4:1); T_3 – Little millet + Black gram (6:1); T_4 – Little millet + Green gram (4:1); T_5 – Little millet + Green gram (6:1); T_6 – Little millet + Red gram (4:1); T_7 – Little millet + Red gram (6:1); T_8 – Little millet + Cowpea (4:1); T_9 – Little millet + Cowpea (6:1); T_{10} – Little millet + Bengal gram (4:1); T_{11}– Little millet + Bengal gram (6:1).*

for better nutrient uptake as there was no competition due to intercrops.

Correlation

Pearson correlations between the growth of weeds, microbes, nutrients, and yield of little millet are presented in Table 8. Little millet grain yield was positively and significantly correlated with plant height (r = 0.957**), DMP (r = 0.897**), WCE (r = 0.425), NPK uptake (r = 0.021), microbial population (r = 0.064) and grain equivalent yield (r = 0.259). Whereas the grain yield was negatively correlated with weed density (r = -0.425), weed dry weight (r = - 0.428), NPK uptake of intercrops (r = -0.688). The results of this correlation study concluded that intercropping of pulses with little millet at an appropriate proportion significantly increased the grain yield of little millet under rainfed conditions.

Conclusion

The present study reported that little millet + black gram at 4:1 ratio (T_2) increased the little millet plant height (133.6 cm), DMP (5943 kg ha^{-1}), yield (1326 kg ha^{-1}), microbial biomass *viz*., bacteria (46.94 x 10^6 CFU g^{-1}), fungi (31.65 x 10^3 CFU g^{-1}) and actinobacteria (39.78 x 10^4 CFU g^{-1}) and NPK uptake (40.8, 5.7 and 33.5 kg ha^{-1}) with reducing weed population. It was positively correlated with all the growth parameters and negatively influenced by weed dynamics. Hence, it can be concluded that a little millet-based pulse intercropping system is the most beneficial combination for increasing little millet yield under rainfed conditions in the western zone of Tamil Nadu.

ACKNOWLEDGEMENTS

The author wishes to express her profound gratitude to the Dean of School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore for allowing them to perform the field experiment and laboratory analytical work.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Abbas, R. N., Arshad, M. A., Iqbal, A., Iqbal, M. A., Imran, M., Raza, A. & Hefft, D. I. O. (2021). Weeds spectrum, productivity and land-use efficiency in maize-gram intercropping systems under semi-arid environment. *Agronomy*, 11(8), 1615. https://doi.org/10.3390/agronomy11081615
2. Ali, S., Umar, M., Khan, B. A., Ahmed, I., Manzoor, A., Riaz, M. S. & Nawaz, A. (2021). Enhancement in the Productivity and Economics of Pearl Millet and Mung Bean Inter Cropping System through Different Sowing Geometries in Pothwar. *Pakistan Journal of Agricultural Research*, 34(4).https://dx.doi.org/10.17582/journal.pjar/2021/34.4. 889.896
3. Aravind, K., Vadivel, N., Kumar, G. S., Ravichandran, V. &

Bharathi, C. (2023) Performance of Foxtail Millet based Intercropping System for Improving the Productivity, Sustainability and Economics in Western Zone of Tamil Nadu Under Irrigated Conditions. *International Journal of Plant & Soil Science*, *35*(19), 1824-1829. https://doi.org/10.9734/ijpss/2023/v35i193733.
4. Bassi, J. A. & Dugje, I. Y. (2016). Effects of intercropping selected legumes on growth and yield of pearl millet in a Nigerian Sudan Savannah. *Research Journal of Agriculture and Environmental Management*, *5*(2), 037-047. https://www.researchgate.net/publication/303924426
5. Collings, C.H. & Lyne, M.P. (1968). Microbiological methods, 5th Edition, Butter Worth, London.
6. Daisy, M., Rajendran, K., & Amanullah, M. M. (2018). Effect on microbial population, quality parameters and green fodder yield of leguminous crops under Bt cotton intercropping system. *Int J Curr Microbiol App Sci*, *7*, 332-337.https://doi.org/10.20546/ijcmas.2018.701.037.
7. Department of Agriculture & Farmers Welfare, MoA & FW, Government of India, 2023-2024.Retrieved from https://apeda.gov.in/milletportal/files/Statewise_Millet_Production.pdf
8. Derebe, B., Worku, A., Chanie, Y. & Wolie, A. (2021). On-farm participatory evaluation and selection of legumes intercropped with finger millet (*Eleusine coracana* L) in Western Amhara. *Heliyon*, *7*(11).https://doi.org/10.1016/j.heliyon.2021.e08319.
9. Donald, C.M. & Hamblin, J. (1976) The Biological Yield and Harvest Index of Cereals as Agronomic and Plant Breeding Criteria. *Advances in Agronomy*, 28, 361-405. https://doi.org/10.1016/S0065-2113(08)60559-3
10. Gomez, K. A. & Gomez, A. A. (1984). Statistical procedures for agricultural research. John Wiley & Sons.
11. Humphries, E. C. (1956). Mineral components and ash analysis. *Moderne Methoden der Pflanzenanalyse/Modern Methods of Plant Analysis: Erster Band/Volume I*, 468-502. https://doi.org/10.1007/978-3-662-25300-7_17
12. Islam, N., Zamir, M. S. I., Din, S. M. U., Farooq, U., Arshad, H., Bilal, A. & Sajjad, M. T. (2018). Evaluating the intercropping of millet with cowpea for forage yield and quality. *American Journal of Plant Sciences*, *9*(9), 1781-1793.doi:10.4236/ajps.2018.99130.
13. Jackson, M.L. (1973). Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd.
14. Keerthanapriya, S., Hemalatha, M., Ramanathan, S. P. & Prabina, B. J. (2019). Studies on Microbial Dynamics in Little Millet (*Panicum sumatrense* L.) based Intercropping System under Rainfed Condition. *International Journal of Current Microbiology and Applied Sciences*, *8*(6), 819-830.https://doi.org/10.20546/ijcmas.2019.806.099
15. Kenknight, G. & Muncie, J.H. (1939). Isolation of phytopathogenic actinomycetes. *hytopath.,* 29: 1000- 1001.
16. Kumar, B. & Ray, P. K. (2020). Performance of intercropping of legumes with finger millet (*Eleusine coracana*) for enhancing productivity, sustainability and economics in Koshi region of Bihar. *Journal of Pharmacognosy and Phytochemistry*, *9*(3), 1568-1571.
17. Lal, R. B. & Ray, S. (1976). Economics of crop production of different cropping intensities [India]. *Indian Journal of Agricultural Sciences*, 46.
18. Martin JP. (1950). Use of acid, rose Bengal and streptomycin in the plate method for estimating soil fungi. *Soil Science* 69:215.
19. Naher, Q., Karim, S. M. R., & Begum, M. (2018). Performance of legumes on weed suppression with hybrid maize intercropping. *Bangladesh Agronomy Journal*, *21* (2), 33-44.
20. Oliveira, L. B. D., Barros, R. L. N., Magalhães, W. B. D., Medici, L. O. & Pimentel, C. (2017). Cowpea growth and yield in sole crop and intercropped with millet. *Revista Caatinga*, 30, 53-58. https://doi.org/10.1590/1983-21252017v30n106rc
21. Ram, K. & Meena, R. S. (2014). Evaluation of pearl millet and mungbean intercropping systems in Arid Region of Rajasthan (India). *Bangladesh Journal of Botany*, *43*(3), 367-370. http://banglajol.info/index.php/BJB/article/view/21616/14842.
22. Rawat, B., Kumar, R., Kamboj, N. K., Gupta, G. & Jain, B. T. (2017). Nutrient Management in Pearl Millet Based Intercropping Systems under Rainfed Situations. *Research Journal of Agricultural Sciences*, *8*(5), 1118-1121.https://www.researchgate.net/publication/347994554
23. Sivagamy., K., Ananthi, K., Kannan, P., Vijayakumar, M., Sharmili, K., Rajesh, M. & Parasuraman, P. (2020). Studies on Agro Techniques to Improve the Productivity and Profitability of Samai+ Red gram Intercropping System under Rainfed Conditions. *International Journal of Current Microbiology and Applied Sciences,* 9(6), 4126-4130. https://doi.org/10.20546/ijcmas.2020.906.484
24. Sridhar, H. S. (2021). Competitive functions, pest dynamics and bio-economic analysis in traditional maize and legumes intercropping systems under rainfed situation of South India. *Indian Journal of Traditional Knowledge* (IJTK), 20(3), 827-837. doi:10.56042/ijtk.v20i3.30361
25. Tekie, B. A. & Angiras, N. N. (2019). Performance of pearl millet (*Pennisetum glaucum* (L.) R. Br.) based legume intercropping systems at Hamelmalo. *International Journal of Innovative Science and Research Technology*, *4*, 757-62. ISSN No:-2456-2165
26. Victor, V. P., Sharmili, K., Kumar, P. D., Minithra, R. & Balaganesh, B. (2023). Performance of Pearl Millet and Pulses Based Intercropping System under Rainfed Condition. *International Journal of Environment and Climate Change*, 13(8), 747-752. doi:10.9734/IJECC/2023/v13i82006.
27. Wang, Y., Qin, Y., Chai, Q., Feng, F., Zhao, C. & Yu, A. (2018). Interspecies interactions in relation to root distribution across the rooting profile in wheat-maize intercropping under different plant densities. *Frontiers in Plant Science,* 9, 483-512. https://doi.org/10.3389/fpls.2018.00483.