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Growth and Yield of Intercrop *Kharif* Pulses and Performance of Fingermillet + *Kharif* Pulses Intercropping System as Influenced by Different Row Ratios

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ABSTRACT

Background: The increasing pressure on land resources, climate variability and need for sustainable intensification, cultivating pulses with fingermillet appears as a practical and ecologically sound strategy in rainfed agriculture. Legume inclusion provides sustainability to non-legume cereal components by enriching soil fertility, increasing system productivity and economic returns. Fingermillet + pulses intercropping system helps to conserve moisture, improve soil physical properties and buildup soil fertility.

Methods: A field experiment was conducted in randomized block design on the Experimental Farm of the College of Post Graduate Studies in Agricultural Science, CAU(I), Kyrdemkulai, Meghalaya during *kharif* season of 2023 and 2024 to assess the performance of fingermillet + *kharif* pulses intercropping system as well as growth and yield behaviour of intercrop *kharif* pulses *viz*., greengram and blackgram as intercrops with different row ratios.

Result: Among the fingermillet + greengram intercropping treatments, the highest value of growth parameters, yield attributes and yield of greengram were found with fingermillet + greengram at 3:3 row ratio followed by 2:2. Similarly, under differnent fingermillet + blackgram intercropping treatments, 3:3 row ratio recorded highest values of growth parameters, yield attributes and yield of blackgram. However, fingermillet + greengram at 4:2 row ratio registered significantly more FMEY (3.2 t ha^{-1}) and LER (1.34) as compared to sole fingermillet among the different fingermillet pulses intercropping system. Furthermore, fingermillet + *kharif* pulses intercropped treatments were able to maintain higher levels of available soil N after completion of the two years experiment.

Key words: Fingermillet, Intercropping, Land equivalent ratio, Pulses, Row ratio.

INTRODUCTION

Crop diversification through intercropping has been recognized as a key pillar for ensuring sustainable development (Jensen *et al*., 2015). Due to population expansion and development of urban clusters as well as industrial growth in the developing world, the land availability for cultivation of crops has seen a decline. Hence, a high intensity cropping system may be the most reliable alternative for increasing agricultural productivity and overall production (Anchal and Sharma, 2025). Intercropping is an efficient approach to increase productivity per unit area per unit time compared to sole cropping (Mitra, 2020).

Pulses are the backbone of Indian agriculture due to their significant role in human and animal nutrition, soil ameliorative properties, environmental sustainability and economic viability. The leguminous crop like greengram (*Vigna radiata*) and balckgram (*Vigna mungo*) are well suited component crops for intercropping system due to its structural featured like root nodules for nitrogen fixation, complementary root systems and diverse canopy architectures.

Fingermillet [*Eleusine coracana* (L.) Gaertn.] is a climate-resilient cereal cultivated widely in tropical and subtropical regions (Patil *et al*., 2019). It is well-known for its low water requirement, thriving with only about 28% of the water needed for rice cultivation (Triveni *et al*., 2017; Aliveni *et al*., 2025). Fingermillet + pulses intercropping systems help to conserve moisture, improve soil physical properties and buildup of soil fertility (Dass and Sudhishri, 2010). Fingermillet is a very compatible crop and can accommodate in any cropping system such as intercropping, sequential cropping, strip cropping, mixed cropping and crop rotation *etc*. (Meena *et al*., 2017; Krishna *et al*., 2020).

Keeping a view of the above said discussion, the present study was under taken for a consecutive period of two years to study the growth and yield of intercropped pulses with fingermillet under various row ratios as well as performance of fingermillet + *kharif* pulses intercropping in mid hills of Meghalaya.

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MATERIALS AND METHODS

A two years field experiment was conducted at the Experimental Farm of the College of Post Graduate Studies in Agricultural Science, Kyrdemkulai, CAU(I), Meghalaya during *kharif* seasons of 2023 and 2024. During the experimental period, the crop received a total rainfall of 1819.6 mm in 2023. During 27th to 42nd standard week of 2023, the experimental crop received 1169 mm of maximum rainfall, maximum and minimum temperature ranged from 27.0°C to 34.0°C and 24.0°C to 31.0°C respectively and RH ranges from 66 to 82%. In 2024, the maximum rainfall, maximum and minimum temperature and RH was recorded during 27th to 42nd week were 1183.8 mm, 27.8 to 31.4°C and 25.6 to 27.2°C, 71.1 to 82.5%, respectively. The experimental soil was moderately acidic (pH 4.72), high in organic carbon (0.79%), low in soil available N (316.20 kg ha^{-1}), P_2O_5 (8.45 kg ha^{-1}) and medium in soil available K_2O (115.5 kg ha^{-1}). The field experiment was conducted in randomized block design with 3 replications consisting of fifteen treatments as T_1- Sole fingermillet (FM), T_2- Sole greengram (GG), T_3- Sole blackgram (BG), T_4- fingermillet + Greengram (1:1), T_5- fingermillet + Greengram (2:1), T_6 - fingermillet + Greengram (2:2), T_7 - fingermillet + Greengram (3:3), T_8 - fingermillet + Greengram (4:2), T_9 - fingermillet + Greengram (2:2 paired) T_{10}- fingermillet + Blackgram (1:1), T_{11}- fingermillet + Blackgram (2:1), T_{12} - fingermillet+ Blackgram (2:2), T_{13} - fingermillet + Blackgram (3:3), T_{14} - fingermillet + Blackgram (4:2), T_{15} - fingermillet + Blackgram (2:2 paired).

The entire experimental area was ploughed twice with power tiller and then harrowed to obtain fine tilth. Farm yard manure (FYM) @ 5 t ha^{-1} and recommended doses of fertilizer (RDF) @ 40:20:20 kg ha^{-1} were applied to fingermillet while pulse crops were fertilized with RDF @ 20:40:20 kg ha^{-1} in proportion to their plant population in different treatments. All the experimental crops were grown as per the recommended package of agronomic practices except for the row ratio that varied as per the treatments. The entire fingermillet + *kharif* pulses intercropping was done under replacement series wherein population of fingermillet was replaced to adjust the rows of intercrop legumes in various row ratios except for paired row planting treatment. Spacing of 25 × 10 cm and 30 × 10 cm were maintained with fingermillet and pulses, respectively in sole and replacement series. However, paired rows were prepared by reducing the spacing of two rows of fingermillet to 15 cm leaving 45 cm spacing between the pairs and two rows of inter crop pulses were sown in 45 cm space available in between two pairs of fingermillet maintaining its 100% plant population. The crop varieties used were VL 376 for fingermillet, SGC 16 for greengram and SBC 40 for blackgram.

Five randomly selected pulses plants were tagged for recording observation on crop growth and yield attributes in each plots. The growth parameters like plant height (cm) and dry matter per plant were recorded at physiological maturity while LAI was recorded at pod development stage on these tagged plants. Grain yield of pulses was converted into fingermillet equivalent yield (FMEY) by using following formula suggested by Lal and Ray, (1976). Land equivalent ratio (LER) was calculated by using formula suggested by Willey, (1979). Furthermore, soil available nitrogen (kg ha^{-1}) after completion of the experiment was worked out by using the standard method of alkaline permanganate oxidation method as described by Subbiah and Asija, (1956).

The pooled mean of the two years data collected from the experimental field and soil analytical study in laboratory were statistically analyzed as per the procedure given by Gomez and Gomez, (1984) to compare the treatment means for analyzing their effect on different parameters under study.

RESULTS AND DISCUSSION

Growth and growth attributes

Table 1 ravealed that sole greengram recorded significantly maximum plant height (37.15 cm) which was statistically at par with all FM+GG intercropping treatments. However, the maximum plant height was observed in FM+GG at 3:3 row ratio (36.95 cm) that was statistically at par with all other FM+GG intercropping treatments. Furthermore, among the FM+BG intercropping treatments, sole BG recorded the maximum height (34.69 cm) that was statistically at par with T_{10}, T_{13}, T_{14} and T_{15}. The greater plant height recorded in sole crops of greengram and blackgram can be attributed to higher intra-specific competition for light and nutrients, which induces vertical growth as a survival strategy. In contrast, the reduced height of pulses under intercropping with finger millet may be explained by lower plant density, availability of inter-row spaces and complementary resource use, which minimizes competitive stress for water, nutrients and light. These findings are consistent with the observations of Pradhan *et al.* (2014).

In case of LAI, there were significant differences among the treatments under FM+GG intercropping, where T_2 recorded significantly more LAI (3.71), which was statistically at par with FM+GG at 3:3 row ratio. However, T_7 recorded maximum LAI among the FM+GG intercropping treatments and was statistically at par with T_5, T_6 and T_8. This indicates that optimized spatial arrangements and balanced plant density in FM+GG facilitate better canopy development and light interception. In contrast, within the FM+BG intercropping systems, the sole BG recorded significantly maximum LAI (2.02) as compared to all other treatments. Furthermore, T_{13} recorded maximum LAI (1.82) that was statistically at par with T_{10}, T_{11}, T_{12} and T_{14} (1.75, 1.68, 1.75 and 1.81, respectively) under different FM+BG intercropping treatments. The overall reduction in LAI under intercropping may be explained by intensified below ground competition arising from the high rooting densities of cereals and pulses when grown together (Anil *et al.*, 1998),

coupled with the shading effect of the taller finger millet canopy, which reduced light availability to the companion pulses. These factors collectively constrained leaf expansion and canopy growth in pulses under intercropped conditions, thereby leading to lower LAI compared to sole crops.

Under FM+GG intercropping treatments, the sole greengram recorded statistically maximum dry matter production (9.41 g pl^{-1}), which was at par with T_6 and T_7. However, FM+GG at 3:3 row ratio showed significantly superior dry matter of greengram (8.44 g pl^{-1}) than all the row ratios except T_4, T_6 and T_8. In case of FM+BG intercropping, there was no significant difference among the treatments. Finger millet, being a taller crop, likely exerted a shading effect on the intercropped pulses, thereby reducing their growth compared to sole cropping. Reddy *et al.* (2023) also reported the reductions in plant height, LAI and dry matter accumulation of component crops under intercropping relative to sole cropping. The enhanced performance of sole greengram and blackgram may also be influenced by belowground interactions commonly observed in millet-legume intercropping systems, where competition for soil resources restricts pulse growth. Higher plant height and LAI in sole pulses facilitated greater interception and utilization of solar radiation, resulting in increased photosynthetic activity and higher dry matter accumulation (Sudhakar, 2011).

Root growth and nodulation

Row ratio suitably affected the root growth of pulses, however it was found that root dry weight, number of nodules per plant and nodule dry weight were non-significant irrespective of the treatments. Though it was non-significant but higher nodules numbers per plant was found with FM+GG and FM+BG at 3:3 row ratio which was more than sole GG and sole BG, respectively. Since effective nodules serve as the primary sites of symbiotic nitrogen fixation, the higher number of effective nodules observed under intercropping compared to sole greengram and blackgram suggests enhanced atmospheric nitrogen fixation in the crop mixture (Kafeel *et al.*, 2023).

Yield attributes and yield

The pooled mean of two years data of fingermillet with greengram and blackgram intercropping experiment (2023 and 2024) pertaining to yield attributes and yield presented in Table 2. In case of greengram, the number of pods per plant was significantly higher under sole (16.8), ans was statistically at par with T_5, T_6 and T_8. However, among the intercropping system of fingermillet with greengram, it was observed that T_7 recorded the higher number of pods per plant (15.6) that was statistically at par with T_4, T_5, T_6 and T_8. Furthermore, under different intercroppings of fingermillet and blackgram, the highest number of pods per plant was recorded in T_{13} (17.8), which was statistically at par with T_{12} (17.7). The number of seeds per pod and thousand seed weight were remained unaffected by the treatments.

In case of greengram, the significantly highest grain yield (0.90 t ha^{-1}) and biological yield (3.9 t ha^{-1}) were observed under sole. However, among the FM+GG intercropping systems, T7 recorded significantly higher grain yield (0.65 t ha^{-1}) and biological yield (2.4 t ha^{-1}) compared to all other treatments. The grain yield attained in T_7 was 46% higher than T_5 and T_9, 23.1% higher than T_6 and 38.4% more than T_4 and T_8. Furthermore, the sole crop blackgram recorded significantly higher grain and biological yield (0.85 t ha^{-1} and 2.4 t ha^{-1}, respectively) than

Table 1: Growth parameters of greengram and balckgram as influenced by intercropping with fingermillet (Pooled mean of two years).

Treatments	Plant height (cm)	LAI	Dry matter (g pl^{-1})	Root dry weight (g)	Nodule (Nos. pl^{-1})	Dry weight of nodule (mg pl^{-1})
T_2 - Sole GG	37.15	3.71	9.41	0.94	10.13	16.22
T_4 - FM+GG (1:1)	36.51	2.63	7.72	0.97	11.95	17.83
T_5 - FM+GG (2:1)	36.72	2.75	6.71	1.08	12.99	18.54
T_6 - FM+GG (2:2)	36.30	2.81	8.18	1.11	13.35	18.94
T_7 - FM+GG (3:3)	36.95	2.87	8.44	1.21	14.28	21.02
T_8 - FM+GG (4:2)	36.23	3.25	7.97	1.27	13.85	18.77
T_9 - FM+GG (2:2 Paired)	35.07	2.50	6.81	1.00	11.94	17.13
SEm±	2.2	0.18	0.53	0.07	1.04	1.48
CD (p≤0.05)	6.84	0.55	1.42	0.21	NS	NS
T_3 - Sole BG	34.69	2.02	7.57	0.77	10.10	15.66
T_{10} - FM+BG (1:1)	28.83	1.75	6.42	1.04	11.60	17.73
T_{11} - FM+BG (2:1)	27.54	1.68	6.74	1.15	11.81	16.74
T_{12} - FM+BG (2:2)	28.52	1.75	6.62	0.99	12.01	17.53
T_{13} - FM+BG (3:3)	30.76	1.82	7.52	1.19	12.83	18.32
T_{14} - FM+BG (4:2)	32.55	1.81	6.62	1.04	12.21	18.16
T_{15} - FM+BG (2:2 Paired)	30.21	1.62	6.56	0.93	10.76	16.37
SEm±	1.91	0.06	0.45	0.09	0.74	1.05
CD (p≤0.05)	5.89	0.16	NS	NS	NS	NS

all the intercropping treatments with fingermillet. However, among intercropping treatments of fingermillet and blackgram, the highest grain yield (0.45 t ha^{-1}) was recorded in T_{10} which was 11.1 % more than T_7 and 22.2 per cent more than all other treatments. The harvest index (HI) was non-significant irrespective of the treatments.

The higher yields of sole crops may be attributed to greater plant density and the absence of interspecific competition, which is consistent with the findings of Ndakidemi and Dakora, (2007) and Paslawar *et al.* (2024). The superior LAI, dry matter accumulation and yield of sole greengram and blackgram can be explained by the larger photosynthetic surface associated with higher population density (Tajul *et al*., 2013). In the intercropping system, the higher yield of greengram observed in T_7 may be due to an optimal balance of light, nutrients and water, coupled with reduced competition and greater row numbers that enhanced growth parameters. By contrast, the lowest yield was recorded in the 2:2 paired row arrangement of FM+GG, which likely resulted from excessive intra-crop competition among pulses as well as interspecific competition with finger millet due to narrow row spacing and very high plant populations. These results highlight the importance of row ratio in determining the balance between competition and complementarity among component crops, which ultimately governs system productivity (Patel *et al*., 2020; Rangasami *et al*., 2024).

Performances of FM+*Kharif* pulses intercropping

Fingermillet equivalent yield

Crop equivalent yield has been identified as one among the efficient indices capable of assessing the overall production potential of intercropping systems (Reddy *et al*., 2023). In present investigation, maximum FMEY was received with FM+ GG (4:2) (3.1 t ha^{-1}) which was statistically at par with T_1, T_4, T_7 and T_{14}, among the fingermillet pulses intercropping. Higher FMEY with both pulses in intercropping justified that the overall productivity of FM+pulses was significantly higher for intercropping than sole croppings. Though intercropping FM+GG and FM+BG at 4:2 row ratio yielded lower grain yield of greengram and blackgram than 3:3 row ratio, it achieved a higher FMEY because of significantly more fingermillet grain yield due to large population of fingermillet with these treatments, showing the effectiveness of this combination in maximizing resource use efficiency. Similar results were reported by Patel *et al.* (2020).

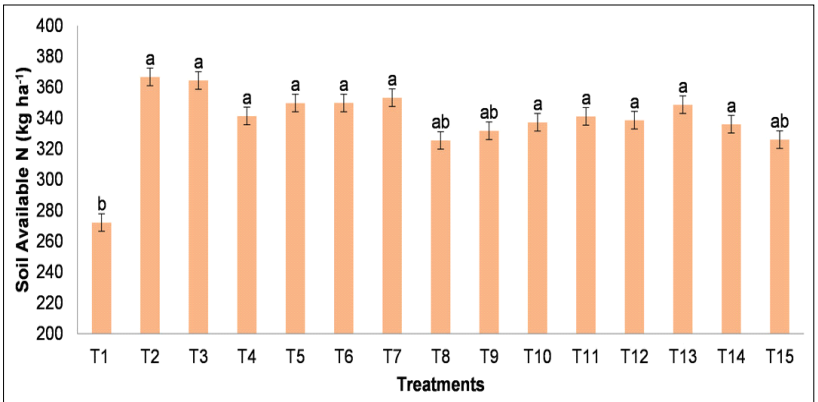
Land equivalent ratio

In this investigation, LER for various row ratio of FM+GG intercropping varied from 1.01 to 1.34 while for FM+BG intercropping it ranged from 1.01 to 1.25 shown a clear advantage of FM+pulses intercropping with all the row ratios than sole cropping. The significantly highest value

Table 2: Yield attributes and yield of pulses, fingermillet equivalent yield and land equivalent ratio as influenced by intercropping with fingermillet (Pooled mean of two years).

Treatments	Pods pl^{-1}	Seeds pod^{-1}	Test weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	FMEY (t ha^{-1})	LER
T_1 - Fingermillet (FM)	-	-	-	-	-	-	2.8	-
T_2 - Greengram (GG)	16.8	9.9	35.3	0.90	3.9	23.0	1.9	-
T_4 - FM+GG (1:1)	14.9	8.1	33.3	0.40	1.4	27.0	2.7	1.07
T_5 - FM+GG (2:1)	13.3	8.4	36.2	0.35	1.7	.22.0	2.9	1.21
T_6 - FM+GG (2:2)	15.0	9.1	31.8	0.50	2.0	25.0	2.1	1.31
T_7 - FM+GG (3:3)	15.6	9.4	35.9	0.65	2.4	26.0	2.6	1.33
T_8 - FM+GG (4:2)	14.9	8.4	32.3	0.40	1.8	24.0	3.1	1.34
T_9 - FM+GG (2:2 paired)	12.8	7.9	32.0	0.35	1.4	27.0	2.2	1.01
SEm±	0.88	0.51	1.39	0.04	0.16	1.97		
CD (p≤0.05)	2.71	NS	NS	0.13	0.48	NS		
T_3 - Blackgram (BG)	20.3	8.7	34.7	0.85	2.4	36.0	1.6	-
T_{10} - FM+BG (1:1)	15.6	7.6	31.7	0.45	1.3	36.0	3.4	1.08
T_{11} - FM+BG (2:1)	13.6	7.4	33.0	0.35	1.2	30.0	2.3	1.18
T_{12} - FM+BG (2:2)	17.7	7.9	31.3	0.35	1.5	24.0	2.3	1.09
T_{13} - FM+BG (3:3)	17.8	8.1	29.9	0.40	1.6	26.0	2.0	1.09
T_{14} - FM+BG (4:2)	15.7	8.0	32.4	0.35	1.4	28.0	2.9	1.25
T_{15} - FM+BG (2:2 Paired)	13.5	7.1	30.2	0.35	1.0	36.0	2.0	1.01
SEm±	0.35	052	1.18	0.04	0.16	2.08	0.2	0.09
CD (p≤0.05)	2.20	NS	NS	0.12	0.39	NS	0.7	0.26

FMEY - fingermillet equivalent yield; LER - Land equivalent ratio.



Error bars represent the standard deviation (SD) of the mean. Different letters above the error bars indicate significant differences at p≤0.05.

Fig 1: Soil available nitrogen as influenced by intercropping with fingermillet.

of LER was obtained with FM+GG at 4:2 ratio (1.34), which was statistically at par with T_5, T_6, T_7, T_{11}, T_{12}, T_{13} and T_{14}. This trend in LER could also be attributed to better light interception as a result of better leaf area distribution as well as efficient light utilization as a result of intercepted light being spread over a greater leaf surface area (Dass and Sudhishri, 2010).

Soil available nitrogen

Soil available nitrogen after completion of the two years experiment varied significantly by different row ratios of intercropping treatments with both the pulses (Fig 1). The figure also revealed that there was a positive change in soil available nitrogen (N) in all row ratios of intercropping treatments with both the pulse crops than initial. Furthermore, soil available nitrogen after fingermillet+ pulses intercropping was significantly higher compared to sole fingermillet. Under different fingermillet pulses intercropping, the highest value of available N was recorded with sole GG (367 kg ha^{-1}) followed by sole BG (365 kg ha^{-1}). However, except T_8,T_9 and T_{15}, the rest treatments were statistically at par. Sole crops of greengram and blackgram were observed to leave the soil more fertile with respect to available soil nitrogen than their intercrops with fingermillet. A positive change in both the sole crops of *kharif* pulses and their intercropping with FM in various row ratios was the result of symbiotic biological N fixation as reported by various early workers (Patel *et al.*, 2020; Anchal and Sharma, 2025).

CONCLUSION

From the investigation, it can be concluded that inercropping of finger millet + greengram and finger millet + blackgram at 3:3 row ratio performed well in terms of growth and yield. In case of greengram, finger millet + greengram (4:2) showed better system performance in terms of crop equivalent yield and LER. However, for blackgram, 4:2 row ratio of finger millet + blackgram recoreded best. Hence, these were the most efficient intercropping system and a viable option for higher productivity in North Eastern hilly region. Furthermore, our study showed a positive effect of intercropped pulses for enchanting soil available nitrogen. The results indicate towards a suitable interaction between the two crops, which can help in efficient utilization of resources and enhanced overall productivity.

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Disclaimers

The opinions and findings presented in this article are the exclusive responsibility of the authors and do not necessarily reflect the perspectives of their respective institutions. While the authors ensure the accuracy and comprehensiveness of the information provided, they do not assume liability for any consequential or incidental damage arising from the utilization of this material.

Informed consent

The authors affirm that the submitted work has not been previously published. They further confirm that the manuscript is not under review by any other publication and that all authors have given their consent for its publication. This study did not involve the use of animals or human participants. Therefore, approval from an Institutional Animal Ethics Committee or Human Ethics Committee was not required.

Conflict of interest

The authors declare that there are no conflicts of interest related to this manuscript. Potential competing interests have been duly considered in the disclosure of the research work. The authors undertake full responsibility for the accuracy of the data, statements and opinions presented in the manuscript.

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