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Assessment of finger millet-based intercropping strategies under rainfed condition

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ABSTRACT

The present investigation was carried out during kharif season of 2023 at the Agronomy research farm in the School of Agricultural Sciences (SAS), Nagaland University, Medziphema. The soil of the experiment field is sandy-loamy texture. The organic carbon content is high, phosphorus and potassium are available in medium level and nitrogen is low. The experiment comprised of 13 treatments which were laid out in Randomized Block Design with 3 replications under replacement series of intercropping. It included 1 base crop (finger millet) and 3 intercrops (black gram, sesame and upland paddy) with 3 different row ratios (1:1, 2:1 and 3:1) along with sole crops. The varieties used were Bharathi for finger millet, SBC-51 for black gram, CAU-R2 for upland paddy and GT 10 for sesame. The results indicated that intercropped finger millet yielded numerically lower grain yield to that of sole cropping. Among the intercropping systems, T_7 [finger millet + black gram (3:1)] performed better in terms of plant population m^{-2} at 20 DAS (24.67), plant height at harvest (111.46 cm), CGR at 40-60 DAS (6.43 g m^{-2} day^{-1}), green leaves $plant^{-1}$ at 60 DAS (12.67), LAI at 40 DAS (1.79), ear heads m^{-2} (109.67), fingers $earhead^{-1}$ (7.03), grains $earhead^{-1}$ (7.46 g), grain and straw yield (1439.00 and 3057.33 kg ha^{-1} respectively), HI (32%).The findings further revealed that the intercropping system T5[finger millet + black gram (1:1)] recorded the highest LER (1.10), FMEY (1869.37 kg ha^{-1}), PYD (86%), aggressivity (+0.21) and competition ratio (1.21) for the intercrop.

Keywords: Black gram, finger millet, intercropping, sesame, upland paddy

INTRODUCTION

Finger millet, known as Ragi [*Eleusine coracana* (L.) Gaertn.], belongs to the Poaceae family and its genus name Eleusine honors the Greek goddess of cereals. In India, Finger millet ranks third in terms of cultivation area, production and productivity among millets, being utilized for both grain and fodder. Millets, also termed as 'Nutri-cereals,' are crucial for food and nutritional security, offering sustainability in drylands under intercropping systems. They are also recognized as 'famine reserves' due to their extended shelf life of over two years without deterioration (Sahu and Sharma, 2013). According to the Ministry of Agriculture and Farmers Welfare- 2023, finger millet is cultivated in an area of 1.1 million hectares with a production of 1.6 million tonnes giving an average productivity of 1.5 tonnes per hectare. In the Asia-Pacific region, India leads with a production of 12,490 metric tonnes, accounting for 80% of the total, followed by China with 2,300 metric tonnes (Tonapi *et al.,* 2015; Ashoka *et al.,* 2020; Anonymous, 2022). In the current agricultural landscape of India, solely focusing on millet cultivation may not be economically rewarding enough to meet the diverse demands of consumers and the rapidly expanding population. Therefore, there is a pressing need for crop diversification. The decreasing amount of land available per person emphasizes the need for both time-based and space-based intensification of agricultural practices (Kiwia *et al.,* 2019). Intercropping, as a method of crop diversification, is recognized as a crucial strategy for promoting sustainable development (Jensen *et al.,* 2015). Intercropping involves cultivating multiple crops simultaneously on the same plot of land to increase yield, optimize resource utilization, enhance functional diversity and reduce the risks associated with biotic and abiotic factors (Nigade *et al.,* 2012). Selecting suitable row ratios in intercropping is crucial to achieve the highest grain yield possible. By planting crops with differing growth habits together, they can complement each other and improve overall resource utilization efficiency. In our ongoing research, we're exploring the practice of intercropping finger millet with cereals like upland paddy, oilseeds such as sesame and pulses like black gram. The aim is to diversify

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finger millet cultivation to enhance and stabilize productivity in rainfed upland areas. Additionally, relying solely on millet cultivation, such as finger millet, often doesn't yield significant returns and fails to meet the varied demands of consumers. By utilizing the initial slow growth phase of finger millet, we can effectively cultivate short-duration crops alongside, optimizing land use and productivity. Rice holds a significant position among cereal crops. However, upland rice cultivation in rainfed conditions often encounters various agroclimatic challenges, leading to instability in both yield and income. One effective approach to address this issue is through intercropping systems. Sesame (*Sesamum indicum* L.), a minor oilseed crop Known as "til" covers an area of 19.53 lakh hectares, producing approximately 7.84 lakh tonnes annually with a productivity of 463 kg ha^{-1}. India ranks first globally in terms of area, production and export of sesame (Anonymous, 2014).

Pulses are highly valued as primary sources of dietary protein. They have been documented to fix nitrogen in the range of 72-350 kg ha^{-1} annually (Tiwari and Shivhare, 2016). Pulses such as black gram (*Vigna mungo*) hold promise as intercrops alongside finger millet in rainfed conditions. Furthermore, integrating fast-growing pulses into intercropping systems can effectively mitigate weed related challenges. Intercropping millets with legumes offers multiple benefits such as increased productivity, resource efficiency, soil fertility enhancement, reduced chemical fertilizer dependence, water runoff control, erosion mitigation and biodiversity promotion (Jan *et al.,* 2016; Jensen *et al.,* 2020; Padhi *et al.,* 2010; Maitra *et al.,* 2019). Studies highlight improved productivity, profitability, resource utilization, soil conservation and fertility enhancement, emphasizing the role of legumes in nitrogen fixation and leaf litter contribution. Intercropping has been shown to provide greater stability in terms of soil fertility maintenance, yield improvement and economic returns compared to sole cropping, as noted by Machado (2009).

MATERIALS AND METHODS

The field experiment was conducted to study the growth and yield of finger millet under intercropping systems during *kharif* season, 2023 at the experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema, Nagaland, India. The average rainfall varies between 1800-2000 mm annually. The mean temperature ranges from 21-30°C during summer and rarely goes below 8°C in winter due to high atmospheric pressure. Soil was sandy loam having pH 5.5. Experiment was laid out in a randomized block design (RBD) comprised of 13 treatments, *viz*. T_1: Finger millet sole; T_2: Black gram sole; T_3: Paddy sole; T_4: Sesame sole; T_5: Finger millet + Black gram (1:1); T_6: Finger millet + Black gram (2:1); T_7: Finger millet + Black gram (3:1); T_8: Finger millet + Paddy (1:1); T_9: Finger millet + Paddy (2:1); T_{10}: Finger millet + Paddy (3:1); T_{11}: Finger millet + Sesame (1:1); T_{12}: Finger millet + Sesame (2:1) and T_{13}: Finger millet + Sesame (3:1), replicated thrice. The seeds were sown on 26th June 2023 by following recommended seed rate of 10 kg ha^{-1} for finger millet, 15 kg ha^{-1} for black gram, 80 kg ha^{-1} for upland paddy and 5 kg ha^{-1} for sesame respectively. Healthy seeds were selected which were treated with Carbendazim 12% + Mancozeb 63% WP @ 2.5 g kg^{-1} of seed before the sowing. Farmyard manure (FYM) containing 0.52 per cent N, 0.20 per cent P_2O_5 and 0.43 per cent K_2O was used as organic manure. Recommended dose of fertilizer i.e., nitrogen @ 40 kg ha^{-1}, phosphorus @ 20 kg ha^{-1} and potassium @ 20 kg ha^{-1} (N- P_2O_5-K_2O) in the form of Urea, SSP and MOP respectively were applied. Urea was applied in split doses whereas SSP and MOP were applied as basal dose according to the pre-planned dose made for each plot.

Data observation and statistical analysis:

Data pretending to plant population (m^{-2}) at 20 DAS, plant height (cm) at harvest, Crop growth rate (g m^{-2} day^{-1}) at 40- 60 DAS, Relative growth rate (g g^{-1} day^{-1}) at 40- 60 DAS, Green leaves $plant^{-1}$ at 60 DAS and Leaf area index (LAI) at 60 DAS were taken prior to harvesting from 5 tagged plants from each plot. Likewise, yield attributes, viz. Number of ear heads (m^{-2}), Number of fingers $earheads^{-1}$, Finger length (cm), weight of grains $earhead^{-1}$, Test weight (g), Grain yield (kg ha^{-1}), Straw yield (kg ha^{-1}) and Harvest index (%) were recorded after harvest. Intercropping indices like Land equivalent ratio (LER), Aggressivity (A), Competition ratio (CR), Finger millet equivalent yield (FMEY) and Percentage yield difference (PYD) were also recorded.

RESULTS AND DISCUSSION

Growth parameters

All the growth attributes of finger millet were superior under sole cropping compared to all intercropping system (Table 1). Kumar and Ray (2020), Nigade *et al.* (2012) and Ramamoorthy *et al.* (2004) also reported similar results of low growth characters of finger millet in intercropping. Next to sole finger millet, when it is intercropped with black gram (3:1) performed significantly higher than the rest of the treatments. Among intercropping system, significantly highest plant population (24.67 m^{-2} at 20 DAS) was recorded under finger millet with black gram (3:1). Plant height (111.4 cm) was recorded significantly highest in T_6 (finger millet + Black gram (2:1)) and T_7 (finger millet + Black gram (3:1)). Green leaves $plant^{-1}$ at 60 DAS (13.00) and Crop growth rate (6.49 g m^{-2} day^{-1}) of finger millet was significantly higher in sole crop of finger millet. Among different intercropping's, green leaves (12.67), crop growth rate (6.43 g m^{-2} day^{-1}) and Leaf area index (3.73) of finger millet was higher when finger millet intercropped with Black gram (3:1). Reddy *et al.* (2023) reported that increases in crop growth rate and relative growth rate are mainly mediated by an increase in leaf area index.

Table 1: Effect of intercropping on growth parameters of finger millet

Treatment	Plant population (m^{-2}) at 20 DAS	Plant height (cm) at harvest	Crop growth rate (g m^{-2} day^{-1}) at 40-60 DAS	Relative growth rate (g g^{-1} day^{-1}) at 40- 60 DAS	Green leaves $plant^{-1}$ at 60 DAS	Leaf area index (LAI) at 60 DAS
T1: Finger millet sole	33.00	116.3	6.49	0.05	13.00	2.93
T2: Black gram sole	-	-	-	-	-	-
T3: Paddy sole	-	-	-	-	-	-
T4: Sesame sole	-	-	-	-	-	-
T5: F + BG (1:1)	18.33	109.1	6.23	0.05	11.67	3.38
T6: F + BG (2:1)	22.67	111.4	6.31	0.05	10.67	3.00
T7: F + BG(3:1)	24.67	111.4	6.43	0.05	12.67	3.73
T8: F+ R (1:1)	17.67	101.6	5.63	0.06	11.33	2.72
T9: F + R (2:1)	22.00	101.0	5.98	0.05	11.00	3.46
T10: F + R (3:1)	23.00	104.6	6.05	0.05	10.33	3.32
T11: F + S (1:1)	18.00	107.2	5.71	0.05	10.33	2.40
T12: F + S (2:1)	22.33	107.7	6.11	0.05	12.33	3.33
T13: F + S (3:1)	24.00	109.5	6.16	0.05	11.67	2.30
SEm ±	0.29	1.62	0.17	0.003	0.65	1.09
CD (P=0.05)	0.85	4.81	0.51	NS	NS	NS

F-Finger millet. BG-Black gram, R-Rice, S-Sesame

Yield Parameters

The sole crop of finger millet recorded the highest ear heads (124.00 m^{-2}), Fingers $earhead^{-1}$ (7.20), Grains $earhead^{-1}$ (7.77 g), Test weight (2.77 g), grain yield (1915 kg ha^{-1}), straw yield (3917.98 kg ha^{-1}) and Harvest index (32.84 %) which was significantly superior over rest of the treatments, while finger length (8.47 cm) was significantly high when Finger millet intercropped with Black gram (1:1) (Table-2). Sheoran *et al.* (2010) reported that performance of crops in pure stand compared to its intercropping stand may be attributed to the absence of interspecific competition and limited distribution of habitat having more photosynthetic efficiency, better light interception, higher dry matter accumulation and translocation of manufactured food material from the source (vegetative parts) to sink (reproductive organ by seed). Among different intercropping's more ear heads (109.6 m^{-2}), fingers $earhead^{-1}$ (7.03), Grains $earhead^{-1}$ (7.46 g), Test weight (2.75 g), grain yield (1439 kg ha^{-1}), straw yield (3057.33 kg ha^{-1}) and Harvest index (32%) was recorded where finger millet was intercropped with black gram in 3:1 ratio. Grain and straw yield of finger millet were reduced considerably when inter cropped with legumes compared with the pure stand of finger millet as reported by Singh and Arya (1999) and Maitra *et al.* (2001). Such reduction was due to decrease in plant stand compared to that of sole cropping

of finger millet. Siddeswaran *et al.* (1989). also noticed reduction in grain and straw yields of finger millet under intercropping situation. Both sole cropping and intercropping had no significant effect on the test weight of finger millet. The lack of variation in the thousand grain weight or test weight might be due to the fact that test weight is a prime yield determinant, which has been identified as a genetic character of crops least affected by the environment (Ashraf *et al.* 1999).

Table 2: Effect of intercropping on yield parameters of finger millet

Treatment	Ear heads m^2	Fingers earhead^{-1} (no's)	Grains earhed^{-1} (g)	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T1: Finger millet sole	124.00	7.20	7.77	2.77	1915.00	3917.98	32.84
T2: Black gram sole	-	-	-	-	-	-	-
T3: Paddy sole	-	-	-	-	-	-	-
T4: Sesame sole	-	-	-	-	-	-	-
T5: Finger millet + BG (1:1)	82.16	6.53	6.43	2.56	956.17	2039.00	31.92
T6: Finger millet + BG(2:1)	99.33	6.60	7.25	2.62	1275.00	2719.33	31.92
T7: Finger millet + BG (3:1)	109.67	7.03	7.46	2.75	1439.00	3057.33	32.00
T8: Finger millet + Paddy (1:1)	78.00	5.80	4.22	2.37	950.00	2031.00	31.87
T9: Finger millet + Paddy (2:1)	97.67	5.73	5.00	2.59	1273.83	2801.00	31.26
T10: Finger millet + Paddy (3:1)	101.00	5.87	5.23	2.64	1431.67	3048.00	31.96
T11: FM + Sesame (1:1)	80.33	6.33	5.71	2.43	954.67	2033.67	31.95
T12: FM + Sesame (2:1)	99.00	6.40	5.90	2.60	1274.67	2711.00	31.98
T13: FM + Sesame (3:1)	105.33	6.53	6.21	2.71	1434.67	3050.67	31.99
SEm ±	1.00	0.15	0.24	0.89	4.83	20.98	0.13
CD (P=0.05)	2.97	0.43	0.72	NS	14.35	62.33	0.39

BG-Black gram, FM-Finger millet

Intercropping indices

Among the tested intercropping systems, the highest aggressiveness (+0.21) was observed for black gram in the combination finger millet + black gram (1:1) T_5. This was followed with aggressiveness values of +0.19 and +0.18 for black gram in finger millet + black gram (2:1) T_6 and (3:1) T_7 respectively. The lowest aggressiveness (-0.21) was noted for finger millet in finger millet + black gram (1:1) T_5, Maitra *et al.* (2001) observed finger millet to be dominated by legumes as indicated by negative aggressivity (-2.44) values of finger millet and positive values (2.44) for legumes. The highest LER of 1.10 was observed for the combination of finger millet + black gram (1:1) T_5, which was followed by finger millet + black gram (3:1) T_7 with LER of 1.07. Among the different intercropping systems, the highest CR (1.21) was observed for black gram in finger millet + black gram (1:1) T_5, which was followed with CR values of 1.19 and 1.18 for black gram in finger millet + black gram (2:1) T_6 and (3:1) T_7. The lowest CR (0.83) was recorded for finger millet in finger millet + black gram (1:1) T_5. Similar finding was observed by Jakhar *et al.* (2015) in strip combination of finger millet and groundnut 6:4 row proportion recorded that higher value (1.33) of CR for finger millet of its intercropping with groundnut which indicated that it was more competitive to groundnut because it had rapid initial growth rate leading to competition for resources with finger millet. Highest FMEY was recorded in T_7-finger millet + black gram (3:1) which was followed by finger millet + black gram (1:1) T_5 and (2:1) T_6 with 1869.37 and 1868.72 kg ha^{-1} respectively. The lowest FMEY of 1658.60 kg ha^{-1} was observed in finger millet + paddy (1:1) T_8. similar finding was observed by Shashidhara *et al.* (2000) in finger millet + pigeon pea in 4:2 row ratio resulted in higher FMEY 1663 kg ha^{-1} as compared to 3:1 (1486 kg ha^{-1}) and 5:1 (1527 kg ha^{-1}) row ratios and sole crop of finger millet. The findings revealed that the highest PYD was recorded in finger millet + black gram (1:1) T_5 with 10.86 %, which was followed by finger millet + black gram (2:1) T_6 with 6.29 %. Conversely, the lowest PYD of -2.71 % was observed in finger millet + paddy (1:1) T_8. Similar finding was noted by Reddy *et al.* (2023).

Table 3: Effect of intercropping of finger millet on different competition indexes and finger millet equivalent yield (FMEY) and percentage yield difference (PYD)

Treatment	Land equivalent ratio (LER)	Aggressivity (A)		Competition ratio (CR)		Finger millet equivalent yield (FMEY) kg ha^{-1}	Percentage yield difference (PYD) %
		Combination with intercrops	Combination with finger millet	Finger millet	Intercrops		
T_1: Finger millet sole	-	-	-	-	-	-	-
T_2: Black gram sole	-	-	-	-	-	-	-
T_3: Paddy sole	-	-	-	-	-	-	-
T_4: Sesame sole	-	-	-	-	-	-	-
T_5: FM + BG (1:1)	1.109	-0.219	0.219	0.831	1.218	1869.37	10.86
T_6: FM + BG (2:1)	1.063	-0.192	0.192	0.849	1.193	1868.72	6.295
T_7: FM + BG (3:1)	1.048	-0.183	0.183	0.849	1.183	1882.39	4.787
T_8: FM + Paddy (1:1)	0.973	0.043	-0.043	1.047	0.960	1658.60	-2.710
T_9: FM + Paddy (2:1)	0.982	0.048	-0.048	1.054	0.952	1745.03	-1.786
T_{10}: FM + Paddy (3:1)	0.985	0.049	-0.049	1.056	0.949	1783.95	-1.549
T_{11}: FM + Sesame (1:1)	1.031	-0.068	0.068	0.939	1.067	1719.49	3.120
T_{12}: FM + Sesame (2:1)	0.996	0.006	-0.006	1.012	0.992	1748.65	-0.355
T_{13}: FM + Sesame (3:1)	0.980	0.077	-0.077	1.083	0.922	1765.86	-2.028

CONCLUSION

The current study concluded that when finger millet was cultivated as sole crop recorded highest grain yield, straw yield and harvest index. Among intercropping systems treatment 7, which involved intercropping of finger millet with black gram at 3:1 ratio, recorded highest yield for both grain and straw, along with the best harvest index and FMEY. To enhance the income of finger millet farmers, it is recommended to adopt intercropping of finger millet with black gram as a more sustainable and productive farming practice.

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