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Affirmation of Experimental Results on Groundnut-Based Millet Intercropping System at Farmers Field under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The research aims to tackle the issue of low groundnut productivity in rainfed areas and low-fertility marginal lands, which is below the national average, leading to economic constraints for farmers. Millets, known for their resilience, are considered suitable for cultivation in challenging environments. Intercropping, growing multiple crops simultaneously, is recognized as an essential system to mitigate erratic climatic conditions and act as insurance against uncertainties. The experiment evaluates the productivity and profitability of an intercropping system combining groundnut and millets in a rainfed ecosystem. The goal is to provide a sustainable and economically viable option for farmers in such areas by leveraging the robustness of millets and improving agricultural outcomes and resilience to climate-related risks. A field experiment was carried out during Kharif 2017-18, 2018-19 and 2019-20 at Zonal Agricultural and Horticultural

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Research Station, Babbur farm, Hiriyur. An experiment was laid out with randomized complete block design (RCBD) with ten treatments and was replicated thrice. Treatments comprises of testing of sole groundnut, finger millet and foxtail millet against intercropping of groundnut with finger millet, little millet and foxtail millet at 5:2 and 6:1 row proportion. The results of pooled data indicated that significantly higher groundnut pod equivalent yield (2123 kg/ha) was recorded with Groundnut + finger millet (5:2) as compared to other treatments. However, significantly higher net returns (Rs. 58532/ha) and B:C ratio (2.55) were recorded with Groundnut + foxtail millet (6:1) as compared to other treatments.

Keywords: Intercropping systems; groundnut + foxtail millet; groundnut + millets; groundnut pod equivalent yield.

1. INTRODUCTION

Groundnut (*Arachis hypogaea*), often referred to as the "king of oilseeds," is a significant oilseed crop grown in the tropical and subtropical areas of the world. Also known as "poor man's almond," groundnut is a vital food and economic crop. “It belongs to the Leguminoceae family. In India, groundnut cultivation spans across 6.09 million hectares with a production of 10.21 million tonnes and a productivity of 1676 kg/ha. Gujarat is the leading producer, contributing 40.42 per cent of the country's groundnuts, followed by Rajasthan with 18.91 per cent, Tamil Nadu with 9.25 per cent, Andhra Pradesh with 7.62 per cent, and Karnataka with 6.62 per cent” [1]. “Karnataka alone cultivates groundnuts on 0.70 million hectares, yielding 0.68 million tonnes at a productivity of 966 kg/ha considerably lower than the national average. This reduced productivity is primarily due to the crop being grown under rainfed conditions and on low fertile marginal lands, which are prone to the uncertainties of monsoon. Challenges such as erratic and insufficient rainfall, combined with pest damage, can lead to low yields and in extreme cases, complete crop failure. Millets, known for their resilience, can thrive in adverse agro-climatic conditions and are integral to the food security of communities reliant on livestock. Intercropping, a recommended strategy to combat aberrant climate conditions, involves growing two or more crops concurrently on the same field” [2]. This agroecological approach is efficient in the use of light, water, nutrients and land [3,4,5]. Benefits of intercropping over sole cropping include enhanced disease and pest control [6], greater adaptability under stress, and the ability to maintain yield stability [7]. Cereal and legume intercropping has gained global acceptance as a means of improving crop productivity within sustainable farming systems. Of the many combinations, millet and peanut intercropping is particularly well-suited to water-limited areas [8]. Legumes like groundnuts enrich soil fertility through biological nitrogen fixation, reducing the need for nitrogenous fertilizers [9]. These intercropping systems serve as strategic risk management tools [10], with groundnuts enhancing sustainability and monetary returns. When establishing a dependable income stream, incorporating a compatible pulse or cereal crop such as millets with groundnuts is recommended. In this context, a study was conducted to investigate the impact of the groundnut + millets intercropping system on yield and economic advantages under the rainfed condition.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

The field experiment was conducted at Zonal Agricultural and Horticultural Research station, Babbur farm, Hiriyur during *kharif* 2017-18, 2018-19 and 2019-20 under rainfed situation which is comes under central dry zone of Karnataka. The experimental site is situated at 13º 57’ 32” North latitude and 70º 37’ 38” East longitude and at an altitude of 606 meters above MSL. The soil of the experimental site is belonged to order *Vertisol* with slightly alkaline pH (8.10), low in organic carbon (1.90 g/kg), available nitrogen (258 kg/ha), medium in available phosphorus (35 kg/ha) and potassium (315 kg/ha) (Table 1).

2.2 Design of Experiment and Treatment Details

The experiment was laid out in complete randomized block design (RCBD) concept consist of ten treatments with three replications. The treatment comprises of T_1: Sole groundnut, T_2: Sole finger millet,T_3: Sole little millet, T_4: Sole foxtail millet, T_5: Groundnut + finger millet (5:2), T_6: Groundnut + little millet (5:2), T_7: Groundnut + foxtail millet (5:2), T_8: Groundnut + finger millet (6:1), T_9: Groundnut + little millet (6:1)

Table 1. Chemical properties of the soil at the experimental site

Sl. No.	Particulars	Status
1.	pH	8.10
2.	Organic carbon (g/kg)	1.90
3.	Available Nitrogen (kg/ha)	258
4.	Available Phosphorus (kg/ha)	35.0
5.	Available potassium (kg/ha)	315

and T_{10}: Groundnut + foxtail millet (6:1). The cultivar used are for groundnut - G-2-52, finger millet - ML-365, little millet - Sukshema and foxtail millet - HMT 100-1. Best performed intercropping system *i.e*., Groundnut + foxtail millet (6:1) was taken for farm trial at different locations *viz*., Hiiyur, Kathalagere and Chitradurga during *kharif* 2020 and 2021.

2.3 Data Collection for Analysis

The crops were harvested separately from the net plot at physiological maturity and were threshed manually and pod and grain yield were weighed from the net plot and converted into kg ha^{-1}. Intercrop yields were computed as groundnut pod equivalent yields (GPEY). GPEY is a simple expression in an intercropping to compare the economics of intercrops by converting grain/seed/economic part. in terms of gross returns/net returns for valid comparison. The economics was worked out from prevailing market prices of inputs and outputs for different treatments.

2.4 Statistical Analysis

The data recorded during the investigation were compiled and analysed for statistical significance as per the analysis of variance for the randomized complete block design (RCBD). Fisher's method of analysis of variance (ANOVA) as described by Gomez and Gomez [11] was adopted for the purpose. Standard error of mean and coefficient of variability have been worked out for a set of observations under each character at *P*=0.05 to interpret the significance. The analysis was carried out using Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1 Productivity of Groundnut + Millets Intercropping Systems

Growing of crops as a sole crop found to be risky under rainfed conditions due to low and erratic rainfall, which ultimately results in low productivity. Under such conditions in order to achieve higher productivity intensification and diversification of crops is essential. In the present investigation, the result revealed that higher groundnut pod yield (2383 kg/ha) and gross returns (Rs. 111838/ha) were obtained in sole groundnut, this could be due to optimum plant population in sole groundnut and compared to intercropping groundnut (Table 2). Unlike observed in sole millets. Among the intercropping systems, groundnut + finger millet (5:2) recorded significantly higher groundnut pod equivalent yield (GPEY) of 2124 kg/ha than other treatments. However, it was statistically on par with Groundnut + little millet (5:2), Groundnut + foxtail millet (5:2), Groundnut + finger millet (6:1), Groundnut + little millet (6:1) and Groundnut + foxtail millet (6:1). "It was mainly due to more space available between two millet rows thus there is a better availability of light lead to higher yield of groundnut in the intercropping system and thereby envisages effective utilization of the resources along with millets". Shwethanjali et al. [12]. "Yield of any crop depended on its yield parameters. Significantly higher number of pods and pod weight per plant were recorded under groundnut intercropped with foxtail millet at ratio of 6:1 followed by little millet and finger millet. This mainly due to variation in translocation of photosynthates from source to sink as there is a greater availability of light due to differential growth habit and its efficient use, less competition for resources by component crops and efficient utilization of available resources". Maitra et al. [13] and Bassi and Dugje [14].

When comparing returns, it is found that higher net returns (Rs. 58532/ha) and B:C ratio (2.55) was recorded with Groundnut + foxtail millet (6:1) as compared to other treatments (Table 2). It was mainly due to higher groundnut pod equivalent yield and lower cost of cultivation under intercropping systems of Groundnut + foxtail millet (6:1) than other intercropping systems. Intercropping of groundnut + foxtail millet (6:1) recorded higher B:C ratio (2.55) to the tune of 23% as compared to sole groundnut (1.96). The above findings are in accordance

Table 2. Groundnut pod yield, millet grain yield, groundnut pot equivalent yield and economics of groundnut and millet based intercropping systems under rainfed conditions

Treatments	Groundnut Pod Yield (kg/ha)			Mean	Millet Grain Yield (kg/ha)	GPEY (kg/ha)	LER	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
	2017	2018	2019							
T_1: Sole groundnut	1862	2565	2721	2383	-	2383	1.00	111838	54766	1.96
T_2: Sole finger millet	-	-	-	-	2257	1174	1.00	51316	24103	1.89
T_3: Sole little millet	-	-	-	-	1531	757	1.00	35889	13314	1.59
T_4: Sole foxtail millet	-	-	-	-	1870	758	1.00	35454	13195	1.59
T_5: Groundnut + finger millet (5:2)	1260	1517	1620	1475	1158	2124	1.20	97371	56935	2.41
T_6: Groundnut + little millet (5:2)	1334	1634	1745	1571	754	1989	1.22	90992	53431	2.42
T_7: Groundnut + foxtail millet (5:2)	1486	1656	1768	1636	900	2060	1.24	91709	53726	2.41
T_8: Groundnut + finger millet (6:1)	1590	1723	1840	1717	671	1971	0.99	93693	53257	2.32
T_9: Groundnut + little millet (6:1)	1683	1850	1975	1836	482	1972	1.04	93805	56244	2.50
T_{10}: Groundnut + foxtail millet (6:1)	1744	1910	2039	1897	575	2015	1.05	96237	58532	2.55
S.Em±	95	156	6.86	86	76	124	0.05			
C.D. (*P*=0.05)	286	479	21.14	260	228	372	0.17			

Note: GPEY – Groundnut Pod Equivalent Yield; LER- Land Equivalent Ratio; B:C ratio- Benefit Cost

with the Yadav et al. [15] and Padhi et al. [16]. This was mainly due to low COC especially seed price of groundnut and higher yield of millets. LER all the intercropping treatments in the present study recorded more than one value indicating the yield advantage in all intercropping systems. “This might be due to higher yield of groundnut in the intercropping system and thereby envisages effective utilization of the resources along with millets. Higher yield levels under intercropping systems were mainly due to variation in translocation of photosynthates from source to sink as there is a greater availability of light due to differential growth habit and its efficient use, less competition for resources by component crops and efficient utilization of available resources”. Prasanna Kumar et al. [17] and Patil et al. [18].

3.2 Results of Farm Trial

The study conducted on-farm trials for two consecutive years (2020 and 2021) to investigate the impact of different cropping systems under rainfed conditions. It revealed that growing crops as a sole crop in such conditions poses risks due to low and erratic rainfall, resulting in low productivity. To achieve higher productivity, the study suggests intensification and diversification of crops. The study specifically focused on evaluating the performance of a groundnut-based intercropping system with foxtail millet crops at different locations. The intercropping system involved planting groundnut and foxtail millet together, which proved to be beneficial.

The results indicated that the intercropping system produced approximately 10.35 % higher groundnut pod equivalent yield, reaching 2066 kg/ha, compared to the sole groundnut yield of 1852 kg/ha (Table 3). Additionally, the net returns from the intercropping system were significantly increased, reaching Rs. 69159/ha, compared to the normal sole groundnut which generated net returns of Rs. 49795/ha. This represents a considerable increase of 29% in net returns when adopting the intercropping method compared to growing groundnut alone.

Furthermore, the study showed that the intercropping treatment with groundnut and foxtail millet (6:1) recorded a higher benefit-cost ratio (B:C ratio) of 2.72, which was 25 % higher compared to the B:C ratio of 2.05 observed in the case of sole groundnut. The B:C ratio is a key indicator of economic profitability in agriculture, and the higher value achieved through intercropping demonstrates its economic viability and potential benefits.

One of the major advantages of the intercropping system in rainfed conditions is its ability to act as a natural insurance against total crop failure. The intercropped crops provide mutual support and resilience, reducing the risk of complete failure in case of adverse weather events or other challenges. This aspect enhances production sustainability and helps farmers cope with the uncertainties associated with rainfed agriculture. In conclusion, the study provides valuable evidence supporting the adoption of groundnut-based intercropping with foxtail millet as an effective strategy to enhance productivity, increase net returns, and improve production sustainability under rainfed conditions. By diversifying and intensifying their cropping systems, farmers can mitigate risks and achieve more stable and profitable outcomes in challenging environments characterized by low and erratic rainfall.

Table 3. Yield and economics farm trial at different locations

Parameters	Technology					
	Groundnut + Foxtail millet (6:1)			Sole groundnut		
	2020	2021	Mean	2020	2021	Mean
Groundnut Pod yield (kg/ha)	1675	1663	1669	1901	1803	1852
Foxtail millet yield (kg/ha)	884	1011	948	-	-	-
GPEY (kg/ha)	2050	2082	2066			
Gross returns (Rs. /ha)	107994	111217	109606	99953	95034	97494
Net returns (Rs. /ha)	67691	70626	69159	51456	48134	49795
B:C ratio	2.67	2.77	2.72	2.07	2.03	2.05

4. CONCLUSION

In conclusion, the study confirms that cultivating crops as sole crops under rainfed conditions is risky due to the adverse effects of low and erratic rainfall, leading to reduced productivity. To achieve higher productivity in such challenging conditions, it is essential to adopt intensification and diversification of crops. Intercropping of groundnut + foxtail millet (6:1) was found profitable and efficient intercropping system.

The farm trial reveals that adopting an intercropping system with groundnut and foxtail millet resulted in a 10.35 % increase in groundnut pod equivalent yield as compared to sole groundnut. This intercropping approach also led to significantly higher net returns representing a substantial 29 % increase compared to the net returns from normal sole groundnut cultivation. Moreover, the intercropping treatment with groundnut and foxtail millet (6:1) showed a higher benefit-cost ratio (B:C ratio) of 2.72, indicating greater economic profitability compared to the B:C ratio of 2.05 observed in sole groundnut cultivation. This suggests that intercropping has economic viability and potential benefits, making it a promising approach to enhance agricultural productivity and financial returns.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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