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RESEARCH PAPER

Evaluation of productivity and profitability of millet and oilseed intercropping systems in the northern dry zone of Karnataka

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Abstract: A field experiment was conducted at AICRP for Dryland Agriculture, Regional Agricultural Research Station, Vijayapura, Karnataka to evaluate the productivity and profitability of millet and oilseed intercropping with row ratio under dryland conditions of the Northern Dry Zone of Karnataka. The experiment consisted of 16 treatments, including niger and sesame intercropping in 1:2, 3:3 and 2:4 row ratios with foxtail millet and little millet under replacement series. A significant variation in plant height, Total Dry Matter Production (TDMP), grains weight per 0.5-m row length, and test weight were observed in sole cropping and intercropping systems. The plant height of millet and oilseed crops was relatively less in the sole than in intercropping systems. The TDMP of foxtail millet and little millet was higher in sole than intercropping systems. Among the intercropping systems, foxtail millet + niger (2:4) recorded significantly highest plant height, TDMP, grains weight per 0.5-m row length (93.33 g), test weight (3.41 g) over sole foxtail millet and little millet. The maximum yield of foxtail millet was recorded in intercropping with niger in a 2:4 row ratio (762 kg ha^{-1}) and little millet in intercropping with sesame in a 2:4 row ratio (562 kg ha^{-1}). The system productivity was highest in foxtail millet + niger with a 2:4 row ratio (1916 kg ha^{-1}) followed by foxtail millet + niger with 1:2 row ratio intercropping systems. The system profitability in terms of net returns and the benefit-cost ratio was higher in foxtail millet intercropped with niger in 2:4 row ratio (28,642 ₹ ha^{-1}and 2.65, respectively) followed by foxtail millet + niger in 1:2 row ratio. Therefore, we conclude that the foxtail millet + niger (2:4) is a productive and profitable intercropping system for the Northern Dry Zone of Karnataka.

Key words: Equivalent yield, Intercropping, Millets, Oilseed, Row ratio, Sole cropping

Introduction

Intercropping is an ancient method of intensive agriculture that involves the cultivation of two or more crops simultaneously on the same piece of land. It is one means of increasing the income of a farming community under rainfed situations as it helps in better utilization of resources and ensures higher returns per unit area and time. Much research has shown that there is generally a trend toward higher yield under intercropping. Even in areas where the companion crop yield was substantially reduced, the total yield was greater in intercropping system. Intercropping different cereals, millets, pulses and oilseeds crops on the same piece of land simultaneously with or without any definite row proportion will minimize the risk of crop failures, act as barriers to pests, improve soil fertility and makes the farmer self–sufficient. It is often stated that pests would be more damaging in fields with a monocropping/single crop than in a mixture of crops (Emery *et al.,* 2021). Intercropping has been practiced in many parts of the world as a way to maximize land productivity naturally and sustainably. The idea behind the technique is that crops differ in their growth requirements, complement each other, and make efficient use of available resources. Intercropping is a more promising cropping system in dryland where uncertain, ill-.distributed and limited annual rainfall is more common.

Moreover, it is the most common practice used in sustainable agricultural systems that have an important role in increasing the productivity, profitability and stability of yield to improve resource utilization and environmental factors (Alizadeh *et al.,* 2010). Today, intercropping is commonly used in many tropical parts of the world, mainly by small-scale traditional farmers (Altieri, 1991). But, not practicing nutritious millet with minor oilseeds as they have many health benefits. Millets are important staple food crops to the millions of people in the arid and semiarid regions of the world due to their greater resistance to pests and diseases, good adaption to a wide range of environments and their good yielding capacity, and can withstand significant levels of salinity, short growing season, resistant to waterlogging, drought-tolerant, requires little inputs during growth and with increasing world population and decreasing water supplies, represents important crops for future human use. Growing sole millets is not much remunerative in agriculture's present scenario to consumers' diverse demand and a rapidly growing population. Hence, including legumes and oilseeds in millet-based cropping systems is necessary. The initially slow growth of millets will facilitate the better establishment of intercrops. The growing of intercrops will also suppress the unwanted weed growth and produce greater output from the unit area than the sole crop. Minor oilseeds are neglected by the farmers due to less oil content, low productivity, and requiring more management strategies. Niger (*Guizotica abyssinica* L.) and sesame (*Sesamum indicum* L.) are the minor oilseed crops, and foxtail millet (*Setaria italica*) and little millet (*Panicum sumatrense*) minor millet crops are predominantly grown under rainfed conditions.

Niger seed is used as human food, and it contains 37- 47 per cent oil. The oil is used for culinary purposes, manufacturing paints, soft soaps, lighting, and lubrication.

Niger seed cake is a valuable cattle feed, particularly for milch animals. Sesame (*Sesamum indicum* L.) considered being the oldest oilseed crop known to humanity. It is a crop grown by subsistence farmers at the edge of deserts, where no other crops grow. Sesame has been called a survivor crop, and sesame seeds are rich in several B-vitamins and dietary minerals, especially iron, magnesium, calcium, phosphorous, and zinc. The byproduct that remains after oil extraction from sesame seeds, also called sesame oil meal, is rich in protein (35-50 %) and is used for poultry and livestock feed. The increased interest resulted in an 82 per cent expansion of oilseed crop cultivation areas and about a 240 per cent increase in total world production over the last 30 years (Anon., 2012). Neither sole millet nor oilseeds are remunerative to the farmers; therefore, farmers were not practicing widely. The intensification of millet and oilseed based cropping systems is an alternative to increasing the area of these crops and maximizing the system productivity and farmers' income. In an intercropping system, millets produce foliage that provides shade over the soil during the initial stage of crop growth, which reduces light transmission on the component crop as the amount of light intercepted by the component crop in an intercropping system depends on the geometry, row proportion of the crops arranged and foliage architecture. This leads to changes in the crop microclimate, which directly influences plant growth and development and resource utilization, pest and disease incidence, predator population, and synergistic effect. There is no recommendation for millet and oilseed based intercropping systems with row proportions for the Northern Dry Zone of Karnataka under dryland conditions. Therefore, there is a need to identify suitable millet and oilseed intercropping systems. Keeping these points in view, the present experiment was planned to determine the suitable intercropping system with row proportion and its effect on system productivity and profitability.

Material and methods

The present study was conducted at AICRP for Dryland Agriculture, Regional Agricultural Research Station, Vijayapura, Karnataka, during the *Kharif* season of 2019. Vijayapura is located in Karnataka's northern dry zone area at 16^0 49' N latitude, 75^0 43' E longitude and an altitude of 593.8 m above mean sea level. The research area's rainfall is described by low to high variation. The maximum air temperature ranging from 39.7 to 40.5 ^{0}C was noticed in April and May months, and a minimum temperature of 16.0 ^{0}C was noticed in December month (Fig.1). The experimental area's average annual rainfall was 598.6 mm and was obtained on 40 rainy days. The actual rainfall received in 2019 was 569.8 mm and rainfall received during the growing season was 306.6 mm (June to September). The plant generally faced a moisture stress phase. Before sowing, the soil samples were taken for physico-chemical analysis. The soil of the experimental site was shallow black soil, having pH 8.34, electrical conductivity 0.17 dS m^{-1}, organic matter 0.51 %, available nitrogen 175 kg ha^{-1}, available phosphorus 33 kg ha^{-1} and available potassium 335 kg ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. The intercropping treatments comprised of

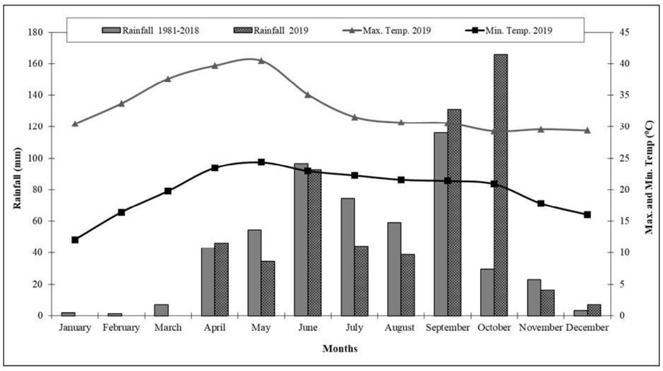

Fig. 1. Monthly meteorological data for the experimental year (2019) against normal for 38 years (2081-2018) at RARS, Vijayapura (Karnataka)

T_1: Foxtail millet + Niger (1:2), T_2: Foxtail millet + Niger (3:3), T_3: Foxtail millet + Niger (2:4), T_4: Foxtail millet + Sesame (1:2), T_5: Foxtail millet + Sesame (3:3), T_6: Foxtail millet + Sesame (2:4), T_7: Little millet + Niger (1:2), T_8: Little millet + Niger (3:3), T_9: Little millet + Niger (2:4), T_{10}: Little millet + Sesame (1:2), T_{11}: Little millet + Sesame (3:3), T_{12}: Little millet + Sesame (2:4), T_{13}: Sole Foxtail millet, T_{14}: Sole Little millet, T_{15}: Sole Niger, T_{16}: Sole Sesame.

The land was prepared to a fine seedbed by ploughing once after the harvest of the previous crop, followed by two harrowings. The recommended dose of fertilizer was applied to each plot based on the plant population occupied by each crop. The recommended dose of fertilizer for foxtail millet: 30:15:15, little millet: 30:15:15, niger: 20:40:20 and sesame: 40:25:25 N, P_2O_5 and K_2O kg ha^{-1}, respectively were used. Certified seeds of foxtail millet (Cv. DHFT-109-3), little millet (Cv. DHLM-36-3), niger (Cv. DNS-4), and sesame (Cv. DS-5) were used for sowing. All the crops were sown by providing the recommended spacing of 30 cm × 15 cm as per treatments (row proportions). All other agronomic practices were followed as per the package of practice.

Five millets and oilseeds plants were randomly selected from the net plot and tagged for data collection. The biometric data on plant height, total dry matter accumulation of millet and oilseeds, the number of panicles per 0.5-m row length, the number of pods per plant, millets grain weight (g per 0.5-m row length), oilseed seed weight (g per 0.5-m row length), the numbers of panicles/pods per plant and seed yield per plot were obtained from the net plot area. The system productivity in terms of foxtail millet equivalent yield (FMEY) of the intercropping system was calculated by considering the seed yield of component crops and the prevailing market price of both millets and oilseeds by using the following formulas. The total system productivity was obtained by summating the FMEY of componet crops in the intercropping system.

$$\text{FMEY (for oilseeds)} = \frac{\text{Yield of oilseeds (kg ha}^{-1}\text{)} \times \text{Price of oilseeds (₹ kg}^{-1}\text{)}}{\text{Price of millet (₹ kg}^{-1}\text{)}} + \text{Yield of millet (kg ha}^{-1}\text{)}$$

$$\text{FMEY (for Little millet)} = \frac{\text{Yield of Little millet (kg ha}^{-1}\text{)} \times \text{Price of Little millet (₹ kg}^{-1}\text{)}}{\text{Price of foxtail millet (₹ kg}^{-1}\text{)}}$$

Plants from each net plot area were harvested separately by leaving border rows. The seeds were winnowed and cleaned, and the weights of seeds obtained from each net plot were recorded and converted to kg ha^{-1}.

The data collected from the experiment at different growth stages were subjected to the statistical analysis described by Gomez and Gomez (1984). The level of significance used in the 'F' and 'T' tests was P=0.05. Critical difference (CD) values were calculated whenever the 'F' test was found significant.

Results and discussion

Effect on plant height

The growth of millet and oilseed was found to be affected by the intercropping systems. The plant height of millets was significantly influenced by the different intercropping systems and in comparison with their sole system (Table 1). Even though the results were not significant at 30 days after sowing, plant height of millet was found to be higher in intercrops than sole. At other growth stages under the treatment, foxtail millet + niger at a 2:4 ratio recorded higher plant height (105.3 cm at 60 DAS and 124.9 cm at harvest), followed by foxtail millet + niger at a 1:2 ratio (103.0 cm at 60 DAS and 122.4 cm at harvest) (Table 1). The plant height of 102.8 at 60 DAS and 120.5 at harvest was observed in sole foxtail millet and 75.3 and 102.4 at harvest, respectively in little millet.

Similarly, like millets, the plant height of oilseeds also differed due to intercropping and sole cropping systems. The plant height of 100.5 cm at 60 DAS and 107.5 cm at harvest in sole niger and 93.4 cm at 60 DAS and 100.0 cm at harvest in sole sesame were observed. Among the intercropping systems, the oilseeds plant was significantly higher in foxtail millet + niger at a 1:2 ratio (106.6 cm and 116.6 cm, at 60 DAS and harvest, respectively), which was on par with foxtail millet + niger (2:4) (102.3 cm and 114.8 cm at 60 DAS and harvest, respectively). However, a significantly lower plant height of oilseeds was observed in little millet + sesame (2:4) (91.0 cm). It may be due to the shade of the field favours growth with less evaporation due to greater canopy coverage, and increased resource use contributes to the least competition between the intercrops for different growth and other limiting resources. Sharmili and Manoharan (2018) also reported improvement in plant height in intercropping of little millet + black gram 8:2 row ratio (104.7 cm) over sole little millet.

Effect on total dry matter production (TDMP)

The sole foxtail millet was recorded with significantly higher TDMP (4.7 g, 30.0 g and 19.27 g per 0.5-m row length at 30, 60 DAS and harvest, respectively) (Table 2). Among the millets in intercropping systems, foxtail millet + niger with row proportions of 2:4 (27.2 g at 60 DAS and 17.6 g at harvest) recorded significantly higher TDMP of foxtail millet compared to other row ratios, which was followed by foxtail millet + niger (1:2) (Table 2) (10.8 g, 69.3 g and 45.2 g per 0.5-m row length at 30, 60 DAS and at harvest respectively). Similarly, among the oilseeds in intercropping systems, foxtail millet + niger (1:2) (66.6 g and 43.3 g per 0.5-m row length, at 60 DAS and harvest, respectively) recorded higher total dry matter production of foxtail millet compared to other row ratios, which was followed by foxtail millet + niger (2:4). The higher TDMP in the best treatment was due to better dry matter accumulation in leaf, stem and reproductive parts and the absence or less competition in millet and oilseed crops, which in turn maximizes total dry matter production by enhancing plant height, tillers and leaf area index (Srichandan and Mangaraj, 2015).

The reduction of dry matter production in some combination of intercropping systems might be due to the competition among the component crops for growth and limited resources like light,

Table 1. Plant height of millets and oilseeds as influenced by intercropping systems.

Treatment	Plant height (cm)					
	30 DAS		60 DAS		Harvest	
	Millets	Oilseeds	Millets	Oilseeds	Millets	Oilseeds
T_1 – Foxtail millet + Niger (1:2)	35.0	14.0	102.0	106.6	120.7	116.6
T_2 – Foxtail millet + Niger (3:3)	34.8	13.9	103.0	100.5	122.4	113.1
T_3 – Foxtail millet + Niger (2:4)	34.5	14.0	105.3	102.3	124.9	114.8
T_4 – Foxtail millet + Sesame (1:2)	34.9	13.1	100.6	96.1	114.5	106.0
T_5 – Foxtail millet + Sesame (3:3)	33.8	12.7	102.00	94.0	118.0	102.9
T_6 – Foxtail millet + Sesame (2:4)	33.5	13.0	102.3	102.0	116.4	104.2
T_7 – Little millet + Niger (1:2)	30.9	13.8	77.0	95.5	92.9	112.8
T_8 – Little millet + Niger (3:3)	29.6	12.6	78.0	98.3	95.6	108.5
T_9 – Little millet + Niger (2:4)	32.8	12.7	81.0	99.2	91.5	110.0
T_{10} – Little millet + Sesame (1:2)	31.1	12.5	72.8	97.0	93.9	101.8
T_{11} – Little millet + Sesame (3:3)	31.5	12.0	76.6	90.1	97.2	97.4
T_{12} – Little millet + Sesame (2:4)	33.1	12.4	76.3	90.0	91.0	99.3
T_{13} – Foxtail millet	34.0	-	102.8	-	120.5	-
T_{14} – Little millet	32.8	-	75.3	-	102.4	-
T_{15} – Niger	-	15.7	-	100.5	-	107.5
T_{16} – Sesame	-	14.3	-	93.4	-	100.0
S.Em±	1.65	0.86	2.95	3.28	4.15	5.57
C.D. (p=0.05)	NS	NS	8.58	9.53	12.06	16.09

DAS: Days after sowing; NS: Not significant

Table 2. Total dry matter production of millets and oilseeds as influenced by intercropping systems.

Treatment	Total dry matter production (g per 0.5-meter row length)					
	30 DAS		60 DAS		Harvest	
	Millets	Oilseeds	Millets	Oilseeds	Millets	Oilseeds
T_1 – Foxtail millet + Niger (1:2)	3.2	9.1	24.6	66.6	16.6	43.3
T_2 – Foxtail millet + Niger (3:3)	3.8	7.9	26.4	62.0	17.1	38.9
T_3 – Foxtail millet + Niger (2:4)	3.6	8.7	27.2	64.6	17.6	41.8
T_4 – Foxtail millet + Sesame (1:2)	3.2	7.3	22.9	61.1	15.7	38.4
T_5 – Foxtail millet + Sesame (3:3)	3.3	8.1	24.6	61.8	16.2	40.3
T_6 – Foxtail millet + Sesame (2:4)	3.5	8.5	25.5	62.7	16.6	40.8
T_7 – Little millet + Niger (1:2)	2.6	5.6	20.6	56.5	13.4	32.0
T_8 – Little millet + Niger (3:3)	2.8	6.0	21.2	57.3	13.8	33.4
T_9 – Little millet + Niger (2:4)	2.9	6.3	21.3	58.5	14.1	34.7
T_{10} – Little millet + Sesame (1:2)	3.1	7.0	21.9	59.7	14.9	35.4
T_{11} – Little millet + Sesame (3:3)	3.1	7.2	22.4	60.7	15.6	37.1
T_{12} – Little millet + Sesame (2:4)	2.5	5.4	20.2	55.7	12.2	31.3
T_{13} – Foxtail millet	4.7	-	30.0	-	19.2	-
T_{14} – Little millet	4.5	-	28.4	-	17.6	-
T_{15} – Niger	-	10.8	-	69.3	-	45.2
T_{16} – Sesame	-	10.5	-	68.1	-	43.8
S.Em±	0.10	0.23	0.81	1.81	0.52	1.64
C.D. (p=0.05)	NS	NS	2.37	5.26	1.53	4.75

DAS: Days after sowing; NS: Not significant

water, nutrients, etc., in all growth stages, which decreases the growth parameters *viz.*, plant height, tillers/branches, canopy covers, leaf area index, etc. As crop growth advances, the competition also increases. It decreases the dry matter accumulation of oilseeds in the intercropped system compared to their sole system. These results conform with the sesame + cotton intercropping system reported by Bhatt *et al.* (2010) and the suppression of sesame growth in the sesame-based intercropping system by Sarkar *et al.* (2003). Similarly, Shivaraj (2015) reported that the growing groundnut with foxtail millet in 4:2 reported considerably greater pod and haulm yield, followed by groundnut + little millet and groundnut + finger millet intercropping systems.

Effect on yield attributes

The yield attributes of millet like the number of panicles and grains weight per 0.5-m row length and test weight were recorded for both millets and oilseeds (Table 3). The number of panicles per 0.5-m row length was found to be increased in sole foxtail millet (42.67) and little millet (40.33). Among the intercropping systems, foxtail millet + niger (4:2) recorded the higher number of panicles (40.00), which was on par with the foxtail millet + niger with a 3:3 row ratio (39.33). The sole foxtail millet recorded significantly higher grain weight per 0.5-meter row length (99.40 g). In intercropping systems, more grain weight was recorded with foxtail millet + niger in a 2:4 (93.33 g), followed by foxtail millet + niger in a 3:3 row ratio (91.20 g). The test weight

Table 3. Yield attributes of millets and oilseeds as influenced by different intercropping systems.

Treatments	Millets			Oilseeds		
	No. of panicles	Grain weight (g)	Test weight (g)	No. of pods	Seed weight (g)	Test weight (g)
T_1 – Foxtail millet + Niger (1:2)	39.00	91.00	3.39	32.67	25.8	4.70
T_2 – Foxtail millet + Niger (3:3)	39.33	91.20	3.37	31.00	23.5	4.63
T_3 – Foxtail millet + Niger (2:4)	40.00	93.33	3.41	31.00	24.0	4.63
T_4 – Foxtail millet + Sesame (1:2)	37.00	86.67	3.25	29.67	20.8	4.50
T_5 – Foxtail millet + Sesame (3:3)	38.00	89.00	3.20	30.67	20.1	4.30
T_6 – Foxtail millet + Sesame (2:4)	37.67	88.67	3.27	30.33	19.3	4.33
T_7 – Little millet + Niger (1:2)	35.33	88.00	3.27	28.00	19.5	4.47
T_8 – Little millet + Niger (3:3)	36.00	89.00	3.35	29.00	20.1	4.17
T_9 – Little millet + Niger (2:4)	38.67	90.67	3.30	30.33	20.5	4.40
T_{10} – Little millet + Sesame (1:2)	34.00	81.00	3.13	26.33	19.1	4.27
T_{11} – Little millet + Sesame (3:3)	34.67	83.83	3.23	27.67	17.6	4.17
T_{12} – Little millet + Sesame (2:4)	35.33	85.67	3.16	28.00	18.8	4.20
T_{13} – Foxtail millet	42.67	99.40	3.38	-	-	-
T_{14} – Little millet	40.33	92.10	3.20	-	-	-
T_{15} – Niger	-	-	-	35.33	27.5	4.77
T_{16} – Sesame	-	-	-	33.07	22.5	4.50
S.Em±	1.47	2.94	0.17	1.18	0.93	0.21
C.D. (p=0.05)	4.26	8.54	NS	3.42	2.71	NS

NS: Not significant

of millets did not vary significantly in different intercropping and comparison with the sole system. However, the foxtail millet + niger (2:4) was observed numerically higher test weight (3.41 g) compared to intercropping systems, either foxtail millet or little millet.

Similarly, a significantly higher number of pods of oilseeds per plant was recorded with sole niger (35.3) and sole sesame (33.0) (Table 3). Among the intercropping systems, the higher pod of oilseeds per plant (32.6 and 31.0) was recorded in foxtail millet + niger (1:2) and foxtail millet + niger (2:4), respectively and were statistically on par with each other. Higher seed weight of oilseeds per 0.5-meter row length was recorded with sole niger (27.5 g), which was on par with sole sesame (22.5 g). Among the intercropping systems, the higher oilseeds seed weight per 0.5-meter row length was recorded with foxtail millet + niger (1:2) (25.8 g), which was on par with foxtail millet + niger (2:4). The test weight of oilseeds did not differ significantly due to intercropping systems. However, numerically higher test weight was recorded in sole niger (4.77 g), and in intercropping systems, foxtail millet + niger (1:2) observed higher test weight (4.70 g). According to Sharmili and Manoharan (2018), the yield attributes of little millet, like number of productive tillers per hill and test weight, were increased when intercropped with pulses like black gram and green gram in an 8:2 ratio. Shalini *et al.* (2019) also mentioned that intercropping of little millet and pigeonpea at proportions of 6:1 or 6:2 is beneficial for getting higher yield and yield attributes.

Effect on yield and system productivity

Pure cropping of foxtail millet (1433 kg ha^{-1}), little millet (1125 kg ha^{-1}), niger (538 kg ha^{-1}) and sesame (490 kg ha^{-1}) gave significantly higher grain yield than in intercropping systems (Table 4). Intercropping of these crops resulted in a greater reduction in grain yield than their sole crops. Among the intercropping systems, significantly higher grain yield (762 kg ha^{-1}) was recorded in foxtail millet + niger (2:4), which was on par with foxtail millet + sesame (2:4) and foxtail millet + niger (1:2). However, in millets, the lowest grain yield was recorded in little millet + niger (1:2) (473 kg ha^{-1}). The higher grain and straw yield in sole foxtail millet was mainly due to the higher plant population as it was replacement series. It is attributed to the better growth and yield parameters *viz.,* plant height and total dry matter production at different growth stages. Also, the yield attributes *viz.*, the number of panicles and seed weight per 0.5-meter row length and test weight. In the case of oilseeds, higher seed yield was recorded with the intercropping system of foxtail millet + niger (1:2) (457 kg ha^{-1}), which was on par with foxtail millet + sesame (2:4). Higher seed and stover yield in sole niger was mainly due to the contribution by the yield attributes *viz.,* the number of capsules per plant, seed weight per 0.5-meter row length and test weight of niger. A similar trend was also noticed in both crops' straw/stover yield.

The system productivity in terms of foxtail millet equivalent yield was calculated for comparing different intercropping systems with the sole (Table 4). The highest system productivity (1916 kg ha^{-1}) was recorded in the 2:4 row ratio of foxtail millet + niger (2:4) intercropping system which was closely followed by the 1:2 row proportion of the same intercropping system (1890 kg ha^{-1}) but was significantly superior over all other intercropping and sole crops. The higher system productivity in the 2:4 row ratio was due to the higher yield of foxtail millet and niger coupled with better utilization of the natural resources by the component crops in intercropping system. Also, it might be due to the higher contribution by foxtail millet and niger seed yield and their market price coupled. The higher system productivity in these intercropping might be due to the higher light absorption values leading to a higher accumulation of photosynthates, which increases the yield of the system. Similar results were also reported by Mallikarjun *et al.* (2018) under the 1:1 row ratio in foxtail millet + pigeonpea, Mahto *et al.* (2007) under finger millet + pigeonpea and Pandit *et al.* (2020) under pearl millet + pigeonpea intercropping systems. Sharmili *et al.*

Table 4. Grain yield of millets, oilseeds and system productivity as influenced by different intercropping systems

Treatments	Millet yield (kg ha^{-1})	Oilseed yield (kg ha^{-1})	System productivity* (kg ha^{-1})
T_1 – Foxtail millet + Niger (1:2)	657	457	1890
T_2 – Foxtail millet + Niger (3:3)	625	343	1552
T_3 – Foxtail millet + Niger (2:4)	762	428	1916
T_4 – Foxtail millet + Sesame (1:2)	589	383	1716
T_5 – Foxtail millet + Sesame (3:3)	615	370	1706
T_6 – Foxtail millet + Sesame (2:4)	687	342	1694
T_7 – Little millet + Niger (1:2)	473	408	1748
T_8 – Little millet + Niger (3:3)	499	330	1572
T_9 – Little millet + Niger (2:4)	540	387	1780
T_{10} – Little millet + Sesame (1:2)	488	368	1462
T_{11} – Little millet + Sesame (3:3)	523	350	1470
T_{12} – Little millet + Sesame (2:4)	562	338	1497
T_{13} – Foxtail millet	1433	-	1433
T_{14} – Little millet	1125	-	750
T_{15} – Niger	-	538	1310
T_{16} – Sesame	-	490	915
S.Em±	40	20	52
C.D. (p=0.05)	116	59	149

*Foxtail millet equivalent yield (FMEY)

Table 5. System profitability (economics) as influenced by millet-oilseed based intercropping systems

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns(₹ ha^{-1})	Benefit-cost ratio
T_1 – Foxtail millet + Niger (1:2)	13,483	41,572	28,089	3.08
T_2 – Foxtail millet + Niger (3:3)	13,481	34,144	20,663	2.53
T_3 – Foxtail millet + Niger (2:4)	13,518	42,160	28,642	3.12
T_4 – Foxtail millet + Sesame (1:2)	13,496	37,762	24,266	2.80
T_5 – Foxtail millet + Sesame (3:3)	13,525	37,524	23,999	2.77
T_6 – Foxtail millet + Sesame (2:4)	13,531	36,611	23,080	2.70
T_7 – Little millet + Niger (1:2)	13,526	38,455	24,929	2.84
T_8 – Little millet + Niger (3:3)	13,528	34,582	21,054	2.56
T_9 – Little millet + Niger (2:4)	13,562	39,168	25,606	2.89
T_{10} – Little millet + Sesame (1:2)	13,539	32,166	18,627	2.38
T_{11} – Little millet + Sesame (3:3)	13,572	32,344	18,772	2.38
T_{12} – Little millet + Sesame (2:4)	13,575	32,940	19,365	2.43
T_{13} – Foxtail millet	12,480	31,533	19,053	2.53
T_{14} – Little millet	12,520	39,584	27,064	3.16
T_{15} – Niger	14,875	33,334	18,459	2.24
T_{16} – Sesame	14,100	33,072	18,972	2.35
S.Em±	-	1,284	1,284	0.10
C.D. (p=0.05)	-	3,710	3,710	0.28

(2019) reported higher little millet yields in the 4:2 row ratio in the little millet + pigeonpea intercropping system. The millet-based intercropping not only improves the system productivity and also provides fodder for livestock and ameliorates microclimate and soil fertility. Derebe *et al.* (2021) reported the higher yield advantage under finger millet + sweet lupine and finger millet + cowpea intercropping systems, and also finger millet + sweet lupine is preferred first by farmers for its high grain yield, soil fertility improvement and its suitability for human and animal feed.

Based on these results, it can be summarised that for increasing the productivity per unit area in millet and oilseed intercropping systems on shallow soils, the growing of foxtail millet and niger in a 2:4 row ratio is superior over other intercropping systems and also growing sole crops alone.

System profitability

The system profitability is calculated by evaluating the intercropping systems for their higher economics. There was an increase in gross returns, net returns and benefit: cost ratio (Table 5) in intercropping systems compared to sole crops. In all intercropping treatments, significantly higher gross and net returns were recorded in foxtail millet + niger (2:4) (₹ 42,160 and 28,642 ha^{-1}) compared to other sole and intercropping systems, which was followed by foxtail millet + niger (1:2). The lowest net returns were recorded in sole foxtail millet (₹ 31,533 ha^{-1}). The higher gross and net returns in intercropping systems were mainly due to the higher yield of foxtail millet and niger and the higher market price of the niger. Similarly, Meena *et al.* (2008) concluded that growing sesame with cluster bean in a 1:2 row proportion gives higher net returns ₹ 2724 ha^{-1} and BC ratio of 1.67 over monocropping of cluster bean. Our study recorded a significantly higher benefit-cost ratio in sole little millet (3.16) compared to other sole and intercropping systems. Among the intercropping systems, foxtail millet + niger (2:4) (3.12) recorded a significantly higher benefit-cost ratio compared to other intercropping systems, which was on par with foxtail millet + niger (1:2). The higher profitability might be due to the higher market price of niger and the lower cost of cultivation in these treatments. Lower B:C ratio was due to the higher cost of cultivation and lower market price. The results align with the findings of Sunilkumar *et al.* (2013). They reported significantly higher gross returns, net returns, and B:C ratio obtained in pearl millet + cowpea intercropping systems. Yadav *et al.* (2013) observed that sesame + green gram noticed a higher net return and BC ratio than other intercropping systems.

Conclusion

We conclude that intercropping of foxtail millet + niger in a 2:4 row ratio is superior for higher system productivity and profitability over other millet-based intercropping systems *viz.,* foxtail millet + niger, foxtail millet + sesame, little millet + niger and little millet + sesame in 1:2, 3:3 and 2:4 row proportions. Therefore, we recommend the foxtail millet + niger (2:4) is the best-suited intercropping system for the Northern Dry Zone of Karnataka.

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