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Studies on Evaluation of Competitive Indices, Yield and Economics of Finger Millet + Black Gram in Inter Cropping System

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Abstract

A field investigation on 'Intercropping of black gram [*Vigna mungo* (L.) Hepper.] in finger millet [*Eleusine coracana* (L.) Gaertn.] under different methods of establishment' was conducted during *kharif* 2012-13 at Agriculture College, Hassan, University of Agricultural Sciences, Bangalore, Karnataka. The results revealed that higher LER (1.11), RCC (4.12), ATER (1.04), Agressivity (0.26) FEY (3357.62 kg/ha) were recorded in transplanted finger millet + blackgram (4:1) inter cropping system under transplanted method of finger millet establishment than sole crop of finger millet and other ratios of blackgram. Significantly higher uptake of nitrogen (73.9 kg/ha), phosphorous (14.45kg/ha) and potash (32.29kg/ha) was noticed in finger millet + blackgram (4:1). Significantly higher net returns was recorded with transplanted finger millet + blackgram 4:1 row proportion (Rs.45,864 ha^{-1}) lowest net returns was recorded with direct sown finger millet + blackgram 1:1 row proportion (Rs.23,472 ha^{-1}).

Keywords: Intercropping, LER, CEY, Finger millet, Blackgram

Intercropping ensures efficient utilization of light and other resources available at crop geometry, reduces soil erosion, suppresses weed growth and thereby helps to maintain stability in the crop yields. It also makes sure the land occupancy and thereby higher net returns. Traditional mixed/ intercropping system is normally followed by many farmers to meet their domestic demands. Selection of crops and cropping systems in relation to soil and climate is a key factor for successful crop production. Finger millet was predominant crop in *Alfisols* of Southern Karnataka. Intercropping is a system of growing more than one crop species on the same piece of land at the same time. The benefits perceived or realized by intercropping systems include greater land use efficiency and improvement in soil fertility. Several factors like cultivar selection, seeding ratios, planting pattern and competition between mixture components affect the growth of species in intercropping. An experiment was undertaken to assess the feasibility of raising blackgram as intercrop along with finger millet to enhance the productivity and profitability of finger millet + blackgram intercropping system in southern transition zone of Karnataka (STZ) and also to assess the competitive indices in intercropping system under different row ratio.

Material and Methods

The field experiment was conducted at Agriculture College, Hassan situated in Southern Transitional Zone of Karnataka (STZ), with a latitude of 13^0 00^1 to 29^0 30^1 North, longitude of 76^0 06^1 to 13^0 06^1 East and an altitude of 943 meters above mean sea level. Actual weather parameters for the year 2013 (January 2013 to December 2013) indicated that normally total rainfall of the region is about 1000 mm. The maximum and minimum temperature was 37 °C and 17 °C, respectively with relative humidity of 80 per cent are prevailing in this zone. The soil of experimental site is sandy loam, neutral in soil reaction, low in organic carbon, medium in available N and K and high in available P. The experiment was consisted of two factors with twelve treatment combinations in total, laid in factorial randomized complete block design with three replications. The recommended dose of fertilizer of 50:40:25 kg NPK ha^{-1} was used for finger millet and 25:50:25 kg NPK ha^{-1} was used for blackgram. Based on population combinations, fertilizer was applied in intercropping system. Sowing was done on 21st July 2013 and transplanting was done on 13th August 2013. Intercrop of blackgram was sown during transplanting and drill sowing method of establishment. Certified

The Mysore Journal of Agricultural Sciences

seeds of finger millet (GPU 28) and blackgram (T-9) were selected and seeds were sown with a spacing 30 cm between rows and 10 cm between seeds (line sowing in finger millet) and on the same day nursery also prepared for transplanting treatments of finger millet. Sowing was done on 21st July 2013 and transplanting was done on 13th August 2013. Blackgram was sown in two different times, during drill sowing and during transplanting separately as an intercrop. At maturity, the fresh weights of main crop and intercrops were estimated on per plot basis after uprooting the plants, besides their economic yields. The yield and biomass production values were then scaled up to hectare basis. Net returns were worked out to evaluate the economics of the system. Intercropping efficiency was evaluated by comparing the productivity of a given area of intercropping systems with that of sole crops using the competition functions described below.

Land equivalent ratio (LER): LER used in the criterion for measuring efficiency of intercropping advantage using the resources of environment compared with monocropping (Mead and Willey, 1980). It introduces the ground area (ha) needed in sole cropping to produce the equal yield of intercropping. LER compares yields from growing two or more crops together with yields from growing the same crop in monocultures or pure stands. LER was calculated based on the following formula:

$$LER = \frac{Yij}{Yii} + \frac{Yji}{Yjj}$$

Where Yii and Yjj denote yield of crops i and j in sole cropping and Yij and Yji the corresponding yield in intercropping. An LER of 1.0 indicates that intercropping and sole cropping have yield equivalence. LER >1.0 indicates that intercropping has a yield advantage over sole cropping while an LER <1.0 indicates a disadvantage of intercropping.

Relative Crowding Coefficient (RCC)

Competition intensity of finger millet in relation to blackgram in an intercropped experiment with replacement arrangement (De Witt, 1960) could be calculated as follows:

$$Ka = \frac{Yab \times Zba}{(Yaa - Yab) \times Zab}$$

TABLE 1

Different intercropping indices in finger millet + blackgram under different method of establishments

Treatment	LER	RCC	ATER	Aggressively	FEY
T_1 (E_1I_1) Sole finger millet	-	-	-	-	3146
T_2 (E_1I_2) Sole blackgram	-	-	-	-	2468
T_3 (E_1I_3) Finger millet + blackgram (1:1)	0.91	0.76	0.77	0.10	2586
T_4 (E_1I_4) Finger millet + blackgram (2:1)	0.83	0.53	0.73	-0.04	2428
T_5 (E_1I_5) Finger millet + blackgram (3:1)	0.98	0.94	0.89	-0.09	2907
T_6 (E_1I_6) Finger millet + blackgram (4:1)	1.11	4.12	1.04	0.14	3357
T_7 (E_2I_1) Sole finger millet	-	-	-	-	2886
T_8 (E_2I_2) Sole blackgram	-	-	-	-	2407
T_9 (E_2I_3) Finger millet + blackgram (1:1)	0.84	0.58	0.77	0.10	2231
T_{10}(E_2I_4) Finger millet + blackgram (2:1)	0.82	0.47	0.74	0.08	2271
T_{11}(E_2I_5) Finger millet + blackgram (3:1)	0.92	0.71	0.85	0.15	2564
T_{12} (E_2I_6) Finger millet + blackgram (4:1)	1.01	1.71	0.95	0.26	2847

E : Methods of establishment in finger millet
E1 : Transplanting
E2 : Direct sown
I : Intercropping row proportions
I1 : Sole finger millet
I2 : Sole black gram
I3 : Finger millet + blackgram (1:1)
I4 : Finger millet + blackgram (2:1)
I5 : Finger millet + blackgram (3:1)
I6 : Finger millet + blackgram (4:1)

Where,

Ka = Relative density coefficient of finger millet

Yaa = Yield of finger millet in monoculture

Yab = Yield of finger millet intercropped with blackgram

Zab = Mixing rate of finger millet

Zba = Mixing rate of blackgram

If Ka = 1, inter specific and intra specific competition have been equal. If relative crowding coefficients for each inter cropped species (Ka and Kb) differed from 1, dominant crop is the one which has higher RCC and other one with lower RCC.

$$\text{Area Time Equivancy Ratio (ATER)} = \frac{(\text{Rya X ta}) + (\text{Ryb X tb})}{\text{T}}$$

Where, Ry = relative yield of species a or b *i.e.,* yield of intercropping/yield of main crop, t = duration (days) for species a or b and T = duration (days) of the intercropping system (Heibsch and McCollum, 1987).

$$\textit{Aggressivity (Aab)} = [\text{Yba/Ybb X Zba Yab/Yaa X Zab}]$$

Where, Yab and Yba are the individual crop yields in intercropping and Yaa and Ybb are their yields as sole crop. Zab and Zba proportion of land area occupied on intercropping when compared to sole crop for species a and b, respectively (McGilchrist, 1965).

FER: Finger millet equivalent yield of the total economic yield of crop. The equivalent yield was calculated using formula: (Prasad and Shrivastava, 1991).

$$\text{FER} = \frac{\text{Economic yield of black gram (t/ha) x monetary value of black gram (Rs/ha)}}{\text{Monetary value of finger millet (Rs/ha)}}$$

Results and Discussion

Higher l and equivalent ratio was recorded in transplanted finger millet + blackgram (4:1) inter cropping system (1.11) under transplanted method of finger millet establishment than sole crop of finger millet followed by with same ratio of 4:1 (1.01) under drill sown method of finger millet establishment. The lowest l and equivalent ratio was recorded in direct sown finger millet + blackgram (2:1) inter cropping system (0.82) under drill sown condition. Higher the LER, higher the yield advantages, indicating greater biological feasibilities and yield advantages of intercropping in finger millet than growing finger millet alone. This may be due to combined effect of better utilization of growth resources than sole cropping of component crops resulting in higher productivity per unit area. Reduction in grain yield due to intercropping and combined yield advantage was also reported.

Higher Relative crowding coefficient was recorded in transplanted finger millet + black gram (4:1) inter cropping system (4.12) followed by same ratio under drill sown method of finger millet establishment. The lowest relative crowding coefficient was recorded in transplanted finger millet + black gram (2:1) inter cropping system (0.53). Higher Area time equivalent ratio was recorded in transplanted finger millet + blackgram (4:1) intercropping system (1.04) while lowest area time equivalent ratio was recorded in direct sown finger millet + blackgram (1:1) inter cropping system (0.71). Area time equivalent ratio observed from intercropping system of finger millet and blackgram was higher than that obtained from either of the sole crops. Higher ATER under intercropping of finger millet and blackgram indicates that not only the efficient use of land, but efficient use of time. Among the intercropping treatments, finger millet black gram (4:1) with transplanting method of establishment (1.045) recorded higher ATER value. Also reported higher ATER in finger millet + pigeon pea intercropping system as compared to sole cropping system.

Higher aggressivity was recorded in direct sown finger millet + blackgram (4:1) intercropping system (0.26) and the lowest aggressivity was recorded in transplanted finger millet + blackgram (2:1) inter cropping system (-0.04). Aggressivity values were lower in intercropping finger millet + blackgram under transplanted method of crop establishment. A positive value indicates finger millet is dominant while blackgram is dominated. The negative values in transplanted method of finger millet with 2:1 and 3:1 was clearly indicated that blackgram is dominant while finger millet is dominated. Similar type of observation was also made by Adikant Pradhan *et al*. (2014).

Higher finger millet equivalent yield was recorded in transplanted finger millet + blackgram (4:1) inter

The Mysore Journal of Agricultural Sciences

cropping system (3357) and the lowest finger millet equivalent yield was recorded in direct sown finger millet + blackgram (1:1) (2231). While introducing blackgram with varied row proportion as intercrop in finger millet, finger millet population was reduced by blackgram to an extent of 20 per cent in case of 4:1 and 33 per cent in case of 2:1 row proportion and 50 per cent in 1:1 row proportion. Though, yield of finger millet was reduced due to intercropping, the finger millet equivalent yield was higher in the intercropping systems. The higher finger millet equivalent yield of 3358 kg ha^{-1} was recorded by finger millet + blackgram 4:1 with transplanting method of establishment and was closely followed by finger millet + black gram in 3:1 row proportion (2907 kg ha^{-1}). The higher finger millet equivalent yield in these treatments may be attributed for better utilization of growth resources as reflected due to higher intercrop yield and higher prevailing market price for blackgram. In addition to this, the aggressivity (0.14) indicate better feasibility of introducing blackgram as intercrop in finger millet at 4:1 row proportion.

Sole finger millet seed yield (3146 kg ha^{-1}) and (2886 kg ha^{-1}) and straw yield (12,136 kg ha^{-1}) and (10683 kg ha^{-1}), respectively were significantly higher in transplanted and drill sown condition as compared to intercropping system under different row ratio in two different methods of finger millet establishment). However, among intercropping systems finger millet + blackgram in 4:1 row ratio under transplanted method of finger millet establishment was recorded significantly higher seed yield (2870 kg ha^{-1}) and (213 kg ha^{-1}) and straw /haulm yield (10260 kg ha^{-1}) (24646 kg ha^{-1}), respectively. Similar type of observation was also made by Adikant Pradhan *et al*. (2014).

Significantly a higher gross and net return was recorded with transplanted finger millet + blackgram 4:1 row proportion. While the lowest gross and net return was recorded with direct sown finger millet + black gram 1:1 row proportion. Higher B:C was recorded in direct sown sole finger millet (2.31) and the lowest B:C was recorded with transplanted finger millet + blackgram 2:1 row proportion (1.04). Regardless of row proportion, the treatments which are having transplanting method of establishment recorded higher cost of cultivation due to extra operations done in transplanting method of establishment. Similar results are recorded by Mohan kumar *et al.* (2012). Similar trend was observed in case of gross returns and net returns. Finger millet + black gram row proportion of 4:1 with transplanting method of establishment recorded higher gross returns and net returns.

Though, intercrop yields were lower than their respective sole yields, they produced higher equivalent yield and income in combination. The results with intercropping of finger millet + pigeon pea at 4:2 row ratio. But direct sown sole finger millet registered higher B:C ratio as compared other row proportions of intercropping systems (2.31). It was attributed due to reduced cost of cultivation hence the benefit cost ratio was observed to be higher.

Total Nutrient Uptake in Finger Millet

Total uptake of Nitrogen, Phosphorus and potassium in finger millet was reported in Table 3.

i) Nitrogen

Significant differences were observed in uptake of nitrogen with respect to row proportions. Significantly higher uptake of nitrogen was recorded sole crop (I_1:26.97 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:26.52 kg ha^{-1}). Lowest uptake of nitrogen was recorded with 1:1 row proportion (I_3:23.93 kg ha^{-1}). None of the method of establishment and their interactions with row proportions found non-significant (Table 3).

ii) Phosphorus

Significant differences were observed in uptake of phosphorus with respect to row proportions. Significantly higher uptake of phosphorus was recorded by sole crop (I_1:8.76 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:8.61 kg ha^{-1}). Lowest phosphorus uptake was recorded with 1:1 row proportion (I_3:7.50 kg ha^{-1}). None of the method of establishment and

TABLE 2

Yield (kg ha^{-1}) and economics (Rs.ha^{-1}) of finger millet + black gram inter cropping system under different method of establishments

Treatments	Grain Yield		Straw/ Haulmyield		Cost of cultivation	Gross returns	Net returns	B:C
	Finger millet	Black gram	Finger millet	Black gram				
T_1 (E_1I_1) Sole finger millet	3146	-	12136	-	24,379	66,080	41,701	1.71
T_2 (E_1I_2) Sole blackgram	-	1066	-	5455	15,669	60,620	39,100	1.82
T_3 (E_1I_3) Finger millet + blackgram (1:1)	1520	466	6306	2153	25,357	54,320	28,963	1.14
T_4 (E_1I_4) Finger millet + blackgram (2:1)	1720	310	6796	1443	24,990	51,000	26,010	1.04
T_5 (E_1I_5) Finger millet + blackgram (3:1)	2260	283	9020	1133	24,772	61,060	36,288	1.46
T_6 (E_1I_6) Finger millet + blackgram (4:1)	2870	213	10260	816	24,646	70,510	45,864	1.86
T_7 (E_2I_1) Sole finger millet	2886	-	10683	-	21,520	51,840	36,177	2.31
T_8 (E_2I_2) Sole blackgram	-	1053	-	5416	15,663	50,560	34,897	2.23
T_9 (E_2I_3) Finger millet + blackgram (1:1)	1286	413	4480	2076	23,388	46,860	23,472	1.00
T_{10} (E_2I_4) Finger millet + blackgram (2:1)	1646	273	5273	1320	22,569	47,700	25,131	1.11
T_{11} (E_2I_5) Finger millet + blackgram (3:1)	2076	213	8606	1106	22,378	53,850	31,472	1.41
T_{12} (E_2I_6) Finger millet + blackgram (4:1)	2466	166	8763	780	22,267	59,800	37,533	1.68
S. Em±	92.00	25.25	273.36	96.14	-	2972.70	2972.70	0.13
CD (0.05)	273.36	75.02	591.39	285.67	-	6248.61	6248.61	0.28

E : Methods of establishment in finger millet
E1 : Transplanting
E2 : Direct sown
I : Intercropping row proportions
I1 : Sole finger millet
I2 : Sole blackgram
I3 : Finger millet + blackgram (1:1)
I4 : Finger millet + blackgram (2:1)
I5 : Finger millet + blackgram (3:1)
I6 : Finger millet + blackgram (4:1)

their interactions with row proportions found non significant.

iii) Potassium (kg ha^{-1})

Significant differences were observed in uptake of potassium with respect to row proportions. Significantly higher uptake of potassium was recorded by sole crop (I_1:87.39 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:83.66 kg ha^{-1}). Lowest potassium uptake was recorded in 1:1 row proportion (I_3:75.84 kg ha^{-1}). None of the method of establishment and their interactions with row proportions found non significant (Table 3).

Uptake by Finger Millet

Nitrogen uptake by finger millet grain, straw and total nitrogen uptake was significantly higher in sole finger millet which was on par with finger millet + blackgram 4:1 and 3:1 row proportions (Table 3). The higher nutrient uptake in these row proportions could be attributed to enhanced nutrient availability to the plants resulting in higher dry matter production over 1:1 and

TABLE 3

Uptake of NPK (kg ha^{-1}) by finger millet as influenced by finger millet + blackgram intercropping system

Treatments	Nitrogen (kg ha^{-1})			Phosphorous (kg ha^{-1})			Potassium (kg ha^{-1})		
	Grain	Straw	Total Uptake	Grain	Straw	Total Uptake	Grain	Straw	Total Uptake
Method of establishment									
E_1:Transplanting	46.16	25.97	72.13	5.07	3.26	8.33	23.02	59.38	82.40
E_2:Direct sowing	44.51	25.04	69.55	4.91	3.16	8.07	22.39	57.75	80.14
S.Em.±	0.61	0.34	0.95	0.06	0.04	0.11	0.30	0.76	1.06
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Row proportion									
I_1: Sole FM	47.94	26.97	74.91	5.33	3.43	8.76	24.41	62.97	87.39
I_3: 1:1	42.54	23.93	66.47	4.57	2.94	7.50	21.19	54.65	75.84
I_4: 2:1	43.17	24.28	67.45	4.69	3.01	7.70	21.58	55.68	77.27
I_5: 3:1	45.89	25.81	71.70	5.13	3.30	8.43	22.96	59.23	82.20
I_6: 4:1	47.14	26.52	73.66	5.24	3.37	8.61	23.37	60.29	83.66
S.Em.±	0.96	0.54	1.50	0.10	0.07	0.17	0.47	1.21	1.68
CD (p=0.05)	2.86	1.61	4.46	0.30	0.20	0.50	1.39	3.59	4.98
Interaction									
E_1I_1	48.26	27.14	75.40	5.34	3.44	7.66	24.68	63.67	88.35
E_1I_3	43.38	24.40	67.78	4.66	3.00	7.93	21.53	55.54	77.07
E_1I_4	43.96	24.72	68.68	4.83	3.10	8.57	21.70	55.98	77.69
E_1I_5	47.28	26.59	73.87	5.22	3.35	8.71	23.24	59.96	83.21
E_1I_6	47.94	26.97	74.91	5.30	3.41	7.34	23.94	61.75	85.69
E_2I_1	47.63	26.79	74.42	5.32	3.42	7.47	24.14	62.28	86.42
E_2I_3	41.71	23.46	65.17	4.47	2.87	8.29	20.84	53.77	74.61
E_2I_4	42.38	23.84	66.22	4.55	2.92	8.51	21.47	55.38	76.84
E_2I_5	44.50	25.03	69.53	5.05	3.25	8.78	22.68	58.51	81.19
E_2I_6	46.34	26.07	72.41	5.18	3.33	8.73	22.80	58.82	81.62
S.Em.±	1.36	0.76	2.12	0.14	0.09	0.24	0.66	1.71	2.37
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Methods of establishment
E_1: Transplanting
E_2: Direct sowing

Row proportion (Finger millet + Blackgram)
I_1: Sole finger millet
I_3: Finger millet + blackgram (1:1)
I_4: Finger millet + blackgram (2:1)
I_5: Finger millet + blackgram (3:1)

2:1 row proportions. Method of establishment and interactions are not shown any significant differences. Higher grain and straw yields were observed in sole finger millet and finger millet + blackgram intercropping system. It is known fact that the finger millet is N responsive, producing higher biomass per unit of external application. The N uptake was very high in sole finger millet (74.91 kg ha^{-1}) which was on par

with finger millet + blackgram 4:1 (73.66 kg ha^{-1}) and 3:1 (71.70 kg ha^{-1}) row proportions, as compared to 1:1 and 2:1 row proportions. It might be due to favorable influence of nitrogen on root proliferation and anchorage which in turn absorb higher amounts of nutrients from rhizosphere and supply to the crop resulting in higher dry matter production.

The enhanced values of yield attributing characters witnessed the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency which might have contributed for higher nutrient uptake. Significantly higher phosphorous uptake was also observed in sole finger millet (8.76 kg ha^{-1}) which was on par with finger millet + blackgram 4:1 (8.61 kg ha^{-1}) and 3:1 (8.43 kg ha^{-1}) row proportions (Table 4). This was attributed further to the root proliferation. Significant improvement in K uptake by finger millet grain and straw was observed with the sole finger millet (8.76 kg ha^{-1}) which was on par with finger millet + blackgram 4:1 (8.61 kg ha^{-1}) and 3:1 (8.43 kg ha^{-1}) row proportions (Table 3). The increased K concentration in the soil with increased population of finger millet have resulted in increased uptake. Further, the nutrient losses might be lower in K (Table 3). Potassium has a key role in activation of enzymes, photosynthesis and protein synthesis. The continuous availability of K and higher efficiency resulted in more uptake of potassium as compared to other row proportions.

Total Nutrient Uptake in Blackgram

Total uptake of Nitrogen Phosphorus and Potassium in blackgram (kg ha^{-1}) was reported in Table 4

i) Total Uptake of Nitrogen (kg ha^{-1})

Significant differences were observed in uptake of nitrogen with respect to row proportions. Significantly higher uptake of nitrogen was recorded in sole crop (I_2:78.71 kg ha^{-1}). Lowest uptake of nitrogen was recorded with 3:1 row proportion (I_5:73.10 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:73.98 kg ha^{-1}). None of the Interactions with row proportions found non significant.

ii) Total Uptake of Phosphorus (kg ha^{-1})

Significant differences were observed in uptake of phosphorus with respect to row proportions. Significantly higher uptake of phosphorus was recorded in sole crop (I_2:15.63 kg ha^{-1}). Lowest uptake of phosphorus was recorded with 3:1 row proportion (I_5:14.18 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:14.45 kg ha^{-1}). None of the Interactions with row proportions found non significant.

iii) Total Uptake of Potassium (kg ha^{-1})

Significant differences were observed in uptake of potassium with respect to row proportions. Significantly higher uptake of potassium was recorded in sole crop (I_2:34.0 kg ha^{-1}). Lowest uptake of potassium was recorded with 3:1 row proportion (I_5:31.71 kg ha^{-1}) which was on par with 4:1 row proportion (I_6:32.29 kg ha^{-1}). None of the Interactions with row proportions found non significant.

Uptake by Blackgram

Nitrogen uptake in blackgram was significantly higher in sole blackgram (Table 4). The higher nutrient uptake could be attributed to increased plant population of blackgram. The N uptake by blackgram was higher in sole blackgram (79.83 kg ha^{-1}) as compared to the row proportions (Table 4). It might be due to nitrogen fixation from atmosphere to nodules that creates favorable influence of nitrogen on root proliferation and anchorage which in turn absorb higher amounts of nutrients from rhizosphere and supply to the crop resulting in higher dry matter production as also reported by Mohankumar *et al*. (2012). The enhanced values of yield attributing characters witnessed the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency which might have contributed for higher nutrient uptake. Higher phosphorous uptake was also observed in sole blackgram (15.63kg ha^{-1}), which on par with finger millet + blackgram row ratio of 1:1 and 2:1 (14.45 kg ha^{-1} and 14.18 kg ha^{-1}, respectively) (Table 4). Higher K uptake was also observed in sole blackgram (34.00 kg ha1), followed by finger millet + blackgram row ratio of 1:1 and 2:1 (32.29 kg ha^{-1} and 31.71 kg

TABLE 4

Uptake of NPK (kg ha^{-1}) by blackgram as influenced by finger millet + blackgram intercropping system

Treatments	Nitrogen (kg ha^{-1})			Phosphorous (kg ha^{-1})			Potassium (kg ha^{-1})		
	Grain	Straw	Total Uptake	Grain	Straw	Total Uptake	Grain	Straw	Total Uptake
Method of establishment									
E_1:Transplanting	50.89	21.81	72.70	8.61	5.74	14.36	8.70	23.52	32.21
E_2:Direct sowing	49.97	21.42	71.39	8.46	5.64	14.11	8.45	22.85	31.30
S.Em.±	0.79	0.34	1.12	0.15	0.10	0.26	0.13	0.34	0.47
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Row proportion									
I_1: Sole FM	55.10	23.61	78.71	9.38	6.25	15.63	9.18	24.82	34.00
I_3: 1:1	51.78	22.19	73.98	8.67	5.78	14.45	8.72	23.57	32.29
I_4: 2:1	51.17	21.93	73.10	8.51	5.67	14.18	8.56	23.15	31.71
I_5: 3:1	47.13	20.20	67.33	8.22	5.48	13.70	8.44	22.83	31.27
I_6: 4:1	46.98	20.13	67.12	7.92	5.28	13.20	7.97	21.54	29.51
S.Em.±	1.24	0.53	1.78	0.24	0.16	0.40	0.20	0.54	0.74
CD (p=0.05)	3.70	1.58	5.28	0.72	0.48	1.20	0.60	1.61	2.20
Interaction									
E_1I_1	52.01	22.29	74.31	8.84	5.89	14.74	8.80	23.79	32.59
E_1I_3	51.60	22.11	73.71	8.58	5.72	14.30	8.75	23.65	32.40
E_1I_4	47.55	20.38	67.93	8.29	5.53	13.81	8.60	23.25	31.85
E_1I_5	47.40	20.32	67.72	7.97	5.31	13.28	8.01	21.65	29.66
E_1I_6	51.56	22.10	73.65	8.50	5.67	14.16	8.64	23.36	31.99
E_2I_1	50.75	21.75	72.49	8.43	5.62	14.05	8.38	22.65	31.02
E_2I_3	46.70	20.02	66.72	8.15	5.43	13.58	8.29	22.40	30.69
E_2I_4	46.56	19.95	66.51	7.88	5.25	13.13	7.93	21.43	29.36
E_2I_5	55.88	23.95	79.83	9.39	6.26	15.65	9.33	25.24	34.57
E_2I_6	54.31	23.28	77.59	9.37	6.25	15.61	9.02	24.40	33.42
S.Em.±	1.76	0.75	2.51	0.34	0.23	0.57	0.28	0.77	1.05
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Methods of establishment
E_1: Transplanting
E_2: Direct sowing

Row proportion (Finger millet + Blackgram)
I_1: Sole finger millet
I_3: Finger millet + blackgram (1:1)
I_4: Finger millet + blackgram (2:1)
I_5: Finger millet + blackgram (3:1)

ha^{-1}, respectively). Increased population of blackgram and less competition for nutrients and also less nutrient losses in K besides (Table 4.12 and Fig. 5.14), blackgram can also compete for K uptake significantly. Potassium has a key role in activation of enzymes, photosynthesis and protein metabolism. The continuous availability of K and higher efficiency resulted in more uptake of potassium as compared to recommended doses.

Economics of Finger Millet + Blackgram Intercropping

Effect of finger millet + blackgram intercropping system and their interaction effects on cost of

cultivation, gross returns, net returns and B:C ratio were reported in Table 5.

TABLE 5

Economics of finger millet + blackgram intercropping system under different methods of establishments

Treatments	Cost of cultivation (Rs.ha^{-1})	Gross returns (Rs.ha^{-1})	Net returns (Rs.ha^{-1})	B:C
T_1	24,379	66080	41701	1.71
T_2	15,663	60620	39100	1.82
T_3	25,357	54320	28963	1.14
T_4	24,990	51000	26010	1.04
T_5	24,772	61060	36288	1.46
T_6	24,646	70510	45864	1.86
T_7	21,520	51840	36177	2.31
T_8	15,663	50560	34897	2.23
T_9	23,388	46860	23472	1.00
T10	22,569	47700	25131	1.11
T11	22,378	53850	31472	1.41
T12	22,267	59800	37533	1.68
S.Em.±	-	2972.70	2972.70	0.13
CD (p = 0.05)	-	6248.61	6248.61	0.28

Methods of establishment
E_1: Transplanting
E_2: Direct sowing

Row proportion (Finger millet + Blackgram)
I_1: Sole finger millet
I_3: Finger millet + blackgram (1:1)
I_4: Finger millet + blackgram (2:1)
I_5: Finger millet + blackgram (3:1)

Maximum cost of cultivation of Rs.25,357 ha^{-1} was recorded with transplanted method of establishment 1:1 row proportion and lowest was recorded in sole early sown blackgram (15,663 ha^{-1}). Gross returns differed significantly due to intercropping of blackgram in finger millet as well as method of establishment. Significantly higher Gross returns was recorded with transplanted finger millet + blackgram 4:1 row proportion (70,510 ha^{-1}) lowest gross returns was recorded with direct sown finger millet + blackgram 1:1 row proportion (46,860 ha^{-1}). Net returns differed significantly due to intercropping of blackgram in finger millet as well as method of establishment. Significantly higher net returns was recorded with transplanted finger millet + blackgram 4:1 row proportion (45,864 ha^{-1}) lowest net returns was recorded with direct sown finger millet + blackgram 1:1 row proportion (23,472 ha^{-1}). B:C differed significantly due to intercropping of blackgram in finger millet. Higher B:C is recorded in direct sown sole finger millet (2.31) and the lowest B:C was recorded with Transplanted finger millet + blackgram 2:1 row proportion (1.04).

The study disclosed immense potential of legume crops in mixed farming system, which is an eco-friendly and beneficial approach to arrest the decline of soil fertility and yield of other crops. A finger millet + blackgram intercropping system could be (4:2) economically and environmentally advantageous under rainfed conditions in Southern Transitional Zone of Karnataka. The complementary use of nutrient and water sources by the intercrop components and the need for reduced external inputs resulting from cereal/pulse intercropping are favourable, based on the findings in this study, we propose that intercropping blackgram with 100 per cent populations of finger millet at a density not exceeding 75 per cent black gram may improve overall yields and incomes.

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