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RESEARCH PAPER

Growth and yield of soybean and millets in intercropping systems

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Abstract: A field experiment was conducted at Agricultural Research Station, Bailhongal, Belagavi district, Karnataka on mixed red and black medium soil during *kharif*-2016 to study the growth and yield of soybean and millets in intercropping systems (foxtail millet, finger millet and little millet) under different row proportions. The experiment was laidout in randomized completely block design with ten treatment combinations replicated thrice.Millets were intercropped with soybean at different row proportions (2:1 and 4:2) along with sole millets and soybean. Significantly higher leaf area (LA), leaf area index (LAI), number of branches and total dry matterwas recorded in sole soybean. Whereas, significantly lower leaf area, leaf area index, number of branches and total dry matter was recorded in 2:1 row ratio of soybean + little millet intercropping system. Similarly, among the millets sole foxtail millet recorded significantly higher leaf area, leaf area index, number of branches and total dry matter accumulation where as lower leaf area, leaf area index, number of tillers was recorded in soybean +little millet intercropping systems. Further, seed weight plant^{-1}, grain weight in 30 cm row length of millets, soybean equivalent yield (SEY), land equivalent ratio (LER), area time equivalent ratio (ATER) were higher in 4:2 row ratio of soybean + foxtail millet compared to any of the sole and intercropping of soybean and little millet in 2:1row ratio. Similarly, gross returns, net returns and B-C ratio were significantly higher in 4:2 row ratio of soybean + foxtail millet.

Key words: Cropping system, Intercropping, Millets, Soybean

Introduction

Intercropping of different cereals, millets, pulses and oilseed crops simultaneously on the same piece of land with or without any row will minimizes the risk of crop failures, acts as barrier for pests, improves soil fertility and makes the farmer self-sufficient. It is often stated that pests will be less damaging in fields with a mixture of crops than in fields with a single crop, also known as monocultures (Willey, 1979).

Soybean is a major oil seed crop of the world grown in an area of 121.1 million hectare with production of 340.8 million tonnes and productivity of 2,810kg ha^{-1} (Anon., 2016). In world, it is being cultivated mainly in USA, Brazil, China, Argentina and India. In India, it is grown over an area of 10.02 million hectare with production of 114.9 million tonnes and productivity of 1,047 kg ha^{-1} (Anon., 2016). Soybean is an introduced and commercially exploited crop in India. The crop is also called as "Golden bean" or "Miracle crop" of the 21st century on account of its multiple uses. It has highest protein (40%), rich in oil (20%), lysine and vitamins A, B and D. It is also rich source of minerals and essential amino acids. Hence, it is highly potential crop among grain legume crops for combating acute malnutrition.

On global basis minor millets are cultivated with an area of 4.17 million hectare with an annual production of 3.0 million tonnes with productivity of 901.7 kg ha^{-1}. Whereas in India, millets are being cultivated with an area of 1.88 million hectare producing 1.80 million tonneswith productivity of 1186 kg ha^{-1}. In Karnataka, minor millets including ragi are cultivated with an area of 0.64 million hectare producing 1.0 million tonnesof grains with productivity of 1,512 kg ha^{-1}. While minor millet excluding finger millet are cultivated on an area of 0.2 lakh hectare with annual production of 0.1 lakh tonnes with productivity of 500 kg ha^{-1} (Anon., 2016**).**

Material and methods

A field experiment was conducted at Agricultural Research Station, Bailhongal, Belagavi district, Karnataka on mixed red and black mediumsoil during *kharif*-2016 to study the growth and yield of soybean (*Glcine max* L.Merr. and foxtail millet (*Eleusine coracana* L, finger millet (*Setaria italica* L.) and little millet (*Panicum sumatrense* Roth ex Roemer & Schultes in intercropping systems.The total rainfall received from January 2016 up to end of December 2016 was 427.9 mm as against average 613 mm rainfall of previous 15 years accounting an overall deficit of 31.3 per cent. Rainfall received during cropping period from 27thJune to 28thof September was 302.1 mm.

Leaf area of soybean was measured by disc method as suggested by Vivekanandan *et al.* (1972). Similarly, Leaf area of millets was recorded by using leaf area meter. Leaf area index was worked out by dividing the leaf area plant^{-1} by land area occupied by the plant (Sestak *et al.,* 1971). Five randomly selected plants were used to record the dry matter production at all the stages of soybean and millets. The plants were uprooted and oven dried separately at 70°C for 48 hours and the dry weight (g plant^{-1}) was recorded. To count the number of tillers, 30 centimeter row length was marked randomly at two spots in each plot, tillers were counted and expressed as number of tillers per 30 centimeter row length. The harvested main shoot panicles from 30 centimeter row length were dried, hand threshed and grain weight was recorded, averaged and expressed in g.

Soybean equivalent yield (SEY) of intercropping system was calculated by taking into account the seed yield of component crop and the prevailing market price of both millet and soybean expressed in terms of kg hectare^{-1}.

$$SEY\ (kg\ ha^{-1}) = \text{yield of soybean in intercropping system } (kg\ ha^{-1}) + \text{Yield of millet } (kg\ ha^{-1}) + \frac{\text{Market price of millet } (₹\ /kg^{-1})}{\text{Market price of soybean } (₹\ kg^{-1})}$$

Land equivalent ratio (LER) was worked out by using the formula of Willey (1979).

$$LER = LA + LB = \frac{YA}{SA} + \frac{YB}{SB}$$

Where,

LA and LB are the LER for the individual crops

YA and YB are the individual crop yield of A and B in the intercropping system

SA and SB are sole crop yield of A and B

Area time equivalent ratio (ATER): It was calculated as suggested by Heibsch and Macollam (1987).

$$ATER = \frac{(Ry \times tp) + (Ry \times tc)}{T}$$

Where,

Ry = Relative yield of species P or C

t = Duration (days) for species P or C

T = Total duration (days) of the intercropping system.

Economics: Feasibility of cultivation of intercrops was worked out by taking into consideration of crops gross return, net return and B:C ratio.

Results and discussion

At 30 DAS, significantly higher leaf area plant^{-1} was recorded in sole soybean (6.40 dm^2). Among the intercropping systems, higher leaf area of soybean was recorded in 4:2 row ratio of soybean + foxtail millet (5.25 dm^2). It was on par with 2:1 row ratio of soybean + foxtail millet (5.23 dm^2) and 4:2 row ratio soybean + finger millet (5.19 dm^2). Significantly lower leaf area plant^{-1} was recorded in 2:1 row ratio of soybean + little (5.09 dm^2). A similar trend of leaf area plant^{-1}was also recorded at 60 and 90 DAS.At 30 DAS, significantly higher leaf area index was recorded in sole soybean (2.133) compared to any intercropping systems. Among the intercropping systems, higher leaf area index of soybean was recorded in 4:2 row ratio of soybean + foxtail millet (1.75). It was on par with 2:1 row ratio of soybean + foxtail millet (1.73) and 4:2 row ratio of soybean + little millet (1.71). Significantly lower leaf area index was recorded in intercropping of soybean + little millet in 2:1 row ratio (1.70). A similar trend of leaf area index was also recorded at 60 and 90 DAS (Table 1). On other hand Aravinda *et al.* (2004) showed that planting ratio of maize and groundnut in maize + groundnut intercropping system did not bring any changes in LAI of maize. significantly higher total dry matter plant^{-1} was recorded in sole soybean (3.07 g) compared to any intercropping systems. Among the intercropping systems, higher total dry matter plant^{-1} of soybean was recorded in 4:2 row ratio of soybean + finger millet (2.57g).It was on par with 4:2 row ratio ofsoybean + foxtail millet (2.43 g) and 4:2 row ratio of soybean + little millet (2.17 g). Significantly lower total dry matter plant^{-1}was recorded in 2:1 row ratio of soybean + little millet (2.07 g) (Table 2).Number of branches plant^{-1} did not differ significantly at 30, 60 and 90 DAS. There was no significant difference among pearl millet with mothbean or clusterbean intercropping systems for growth characters viz., plant height, dry matter plant^{-1} and length of roots (Kiroriwal and Yadav 2013).

At 30 DAS, significantly more number of tillers in 30 cm row length was recorded in sole foxtail millet (23.3) compared to any intercropping systems. Among the intercropping systems, more number of tillersin 30 cm row length was recorded in 4:2 row ratio of soybean + foxtail millet (22.9) and it was on parwith 2:1 row ratio of soybean + foxtail millet (21.0). These results are

Table 1. Growth attributes of soybean and millets in intercropping systems

Cropping systems	Leaf area plant^{-1} (dm^2)						Leaf area index					
	30 DAS		60 DAS		90 DAS		30 DAS		60 DAS		90 DAS	
	Soybean	Millets	Soybean	Millets	Soybean	Millets	Soybean	Millets	Soybean	Millets	Soybean	Millets
Soybean + foxtail millet (2:1)	5.23	225.0	10.37	799.3	4.00	430.67	1.74	0.75	3.46	2.67	1.33	1.44
Soybean + foxtail millet (4:2)	5.25	227.0	10.55	802.0	4.17	440.33	1.75	0.76	3.52	2.68	1.39	1.47
Soybean + finger millet (2:1)	5.17	230.0	10.30	810.7	3.61	459.67	1.72	0.77	3.43	2.70	1.20	1.53
Soybean + finger millet (4:2)	5.17	233.0	10.51	817.0	4.03	471.30	1.73	0.78	3.50	2.72	1.34	1.57
Soybean + little millet (2:1)	5.09	219.3	10.03	799.0	3.80	333.02	1.70	0.73	3.34	2.66	1.27	l.ll
Soybean + little millet (4:2)	5.12	222.9	10.31	802.5	3.96	343.10	1.71	0.74	3.44	2.67	1.32	1.14
Sole soybean	6.40	-	12.29	-	5.47	-	2.13	-	4.10	-	1.82	-
Sole foxtail millet	-	236.5	-	815.7	-	445.67	-	0.79	-	2.72	1.49	
Sole finger millet	-	229.7	-	806.3.	-	492.00	-	0.76	-	2.69	-	1.64
Sole little millet	-	223.5	-	801.7	-	355.67	-	074	-	2.70	-	1.20
S.Em±	0.26	1.38	0.52	1.28	0.17	1.73	0.09	0.01	0.17	0.01	0.06	0.01
C.D. at 5%	0.78	3.99	1.53	3.73	0.46	5.01	0.26	0.03	0.29	0.03	0.17	0.03

Table 2. Total dry matter production in soybean and millets in intercropping systems (g plant $^{-1}$)

Cropping systems	Total dry matter accumulation plant^{-1}						
	30 DAS		60 DAS		90 DAS		At harvest
	Soybean	Millets	Soybean	Millets	Soybean	Millets	Millets
Soybean + foxtail millet (2:1)	2.27	7.91	9.23	18.20	17.21	24.01	28.93
Soybean + foxtail millet (4:2)	2.43	8.50	9.50	18.90	17.62	24.66	29.47
Soybean + finger millet (2:1)	2.43	5.80	9.00	16.20	16.02	20.87	24.94
Soybean + finger millet (4:2)	2.57	6.22	9.09	16.50	16.42	21.42	25.98
Soybean + little millet (2:1)	2.07	1.76	8.87	4.70	15.20	9.28	15.27
Soybean + little millet (4:2)	2.17	1.75	9.00	5.50	15.49	9.72	15.92
Sole soybean	3.07	-	10.63	-	18.64	-	-
Sole foxtail millet	-	9.09	-	20.76	-	26.15	30.28
Sole finger millet	-	7.39	-	18.14	-	25.61	27.80
Sole little millet	-	1.78	-	6.69	-	12.19	16.72
S.Em±	0.09	0.25	0.29	0.51	0.25	0.50	0.73
C.D. @ 5%	0.28	0.72	0.86	1.47	0.73	1.46	2.10

in conformity with the findings of Shivaraj *et al.* (2015) who reported that, growth parameter such as plant height, leaf area, leaf area index and total dry matter production was significantly higher in 4:2 row ratios of groundnut + millets intercropping treatments. Significantly lower number of tillersin 30 cm row lengthwas recorded in 2:1 row ratioof soybean + little millet (12.3). A similar trend on number of tillers in 30 cm row length was also recorded at 60 and 90 DAS.

Significantly higher seed weight plant^{-1}of soybean was recorded in sole crop of soybean (15.20 g) compared to any intercropping systems. Among the intercropping systems, higher seed weight plant^{-1}of soybean was recorded in 2:1 row ratio of soybean + foxtail millet(14.64g). It was on par with 4:2 row ratio of soybean + foxtail millet (14.50g) and 2:1 row ratio of soybean + finger millet (13.62 g). Significantly lower seed weight plant^{-1}of soybeanwas recorded in 2:1 row ratioof soybean + little millet (12.69 g). Higher grain weight of milletsin 30 cm row length was recorded in sole foxtail millet (87.30 g) compared to any intercropping systems. Among the intercropping systems, higher grain weight of millets in 30 cm row length was recorded in 4:2 row ratio of soybean + foxtail millet (85.37g). It was on par with 2:1 row ratio of soybean + foxtail millet (84.37g) and4:2row ratio of soybean + finger millet (75.79 g). Lower grain weight of millets in 30 cm row length was recorded in 2:1 row ratioof soybean + little millet (10.43 g). of millets was recorded in sole foxtail millet (3.49 g) compared to any intercropping (Table 3).

Significantly higher soybean equivalent yield was recorded in 4:2 row ratio of soybean + foxtail millet(2,334 kg ha^{-1}).It was on par with 2:1 row ratio of soybean + foxtail millet (2,310 kg ha^{-1}) and 4:2 ratio of soybean + finger millet (2,120 kg ha^{-1}). whereas, soybean equivalent yield was lower in sole crop of little millet (1,521kg ha^{-1}). Significantly higher land equivalent ratiowas recorded in 4:2 row ratio of soybean + foxtail millet (1.50) compared to any intercropping systems. It was on par with 2:1 row ratio of soybean + foxtail millet (1.49) and 4:2 row ratio of soybean +finger millet (1.47). Similarly Yamuna *et al.* (2015) reported that higher maize equivalent yield (9,863 kg ha^{-1}), land equivalent ratio (1.85), area time equivalent ratio (1.49), net returns (₹10,237 ha^{-1}) and B:C ratio (4.37) were recorded with paired row maize intercropped with pigeonpea at 45x75 cm spacing as compared to sole maize. The reason for increase in growth and yield parameters was mainly due to efficient utilization of available resources *viz.,* space, nutrients and light compared to other intercropping systems.Similarly higher growth in terms of leaf area and dry matter accumulation was a result of better growth and development of soybean in sole

Table 3. Growth and yield parameters of soybean and millets in intercropping systems

Cropping systems	Number of branches/plant in soybean			Number of tillers/hill			Grain weight	
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	Soybean/ plant	Millets/ 30 cm row
Soybean + foxtail millet (2:1)	3.56	4.77	6.55	21.0	27.7	22.8	14.50	84.3
Soybean + foxtail millet (4:2)	3.57	4.86	6.63	22.9	28.2	24.0	M.6-1	85.3
Soybean + finger millet (2:1)	3.44	4.67	6.40	16.5	21.0	1 6.4	13.62	74.8
Soybean + finger millet (4:2)	3.48	5.02	6.81	17.6	22.6	16.9	13.48	75.7
Soybean + little millet (2:1)	3.36	4.69	6.32	12.3	18.9	17.8	12.69	10.4
Soybean + little millet (4:2)	3.43	4.43	6.44	13.6	19.6	19.0	12.81	10.8
Sole soybean	3.80	5.00	7.06	-	-	-	15.20	
Sole foxtail millet	-	-	-	23.3	29.0	24.6	-	87.3
Sole finger millet	-	-	-	18.2	23.3	19.3	-	77.1
Sole little millet	-	%	-	14.0	20.4	178	-	11.9
S.Em- ±	0.14	0.17		1.14	0.95	1.15	0.14	0.47
C.D. at 5 %	NS	NS	NS	3.32	2.76	3.35	0.42	1.36

soybean compared to intercropping systems. Maitra *et al.* (2001) reported that among intercropping systems, finger millet + groundnut in 4:1 row ratio recorded higher dry matter accumulation and crop growth rate; whereas, finger millet + soybean in 4:1 row ratio recorded higher leaf area index. Prasannakumar *et al.* (2009) recorded significantly higher grain yield in sole pigeonpea compared to pigeonpea + little millet intercropping system.

Significantly higher area time equivalent ratio was recorded in 4:2 row ratios of soybean + little millet (1.47). It was on par with 2:1 row ratio of soybean + little millet (1.46) and4:2 row ratio of soybean + foxtail millet (1.40). And lower area time equivalent ratiowas recorded in sole crop (1.0). Gross returns was significantly higher in4:2 row ratio of soybean + foxtail millet (₹ 96,403 ha^{-1}) compared to any intercropping systems andit was on par with 2:1 row ratio of soybean + foxtail millet (₹ 94,724 ha^{-1}). Significantly lower gross returns wasrecorded in sole little millet (₹ 37,931 ha^{-1}). Net returns was significantly higher in 4:2 row ratio of soybean + foxtail millet (₹ 68,457 ha^{-1}) compared to any intercropping systems andit was on par with 2:1 row ratio of soybean + foxtail millet (₹ 66,779 ha^{-1}). Significantly lower net returns were recorded in sole little millet (₹ 20,783 ha^{-1}). BC ratio was also significantly higher in 4:2 row ratio of soybean + foxtail millet (2.45) compared to any intercropping systems andit was on par with 2:1 row ratio of soybean + foxtail millet (2.39). Significantly lower BC ratio was recorded in sole little millet (1.21) (Table 4).

Increased economic returns was attributed by higher market prices coupled with better utilization of resources. The results corroborate the findings of Iqbal *et al.* (2013) who recorded the maximum plant height, leaf area and dry weight in pearl millet + clusterbean followed by pearl millet + cowpea compared to sole pearl millet. Sharma and Gupta (2001) noticed that pearl millet plants grew taller in association with cowpea and mungbean, dry matter accumulation was slightly more in pearl millet + mungbean. Pradhan *et al.* (2014) who reported highest finger millet yieldin intercropping system compared to sole in term of monetary returns. He also reported that highest yield was recorded in finger millet + pigeon pea intercropping, followed by horse gram and black gram and minimum was in finger millet + niger intercropping.The economic analysis showed that, gross returns was significantly higher in 4:2 row ratio of soybean + foxtail millet (₹ 96,403 ha^{-1}) and it was on par with 2:1 row ratios of soybean + foxtail millet (₹ 94,724 ha^{-1}) and 4:2 row ratio of finger millet (₹ 87,178 ha^{-1}). Gross returns was significantly lower in sole little millet (₹ 37,931 ha^{-1}). Similarly, net returns was significantly higher in 4:2 row ratio soybean + foxtail millet (₹ 68,457 ha^{-1}) and it was on par with 2:1 row ratio soybean + foxtail millet (₹ 66,779 ha^{-1}). Net returns was significantly lower in sole little millet (₹ 20,783 ha^{-1}). Prabhakar *et al.* (2016) also obtained higher net returns (₹ 4,76,361 ha^{-1}) and B:C ratio (2.36) were realized when maize was sown two weeks after sowing of field pea compared to other intercropping systems. On the contrary, maximum benefit-cost ratio was realized with soybean + foxtail millet in 4:2 row ratio (2.45) and it was on par with 2:1 row ratio of soybean + foxtail millet (2.39). While the least benefit-cost ratio was in sole little millet.

Conclusion

It was concluded that, sole soybean recorded significantly higher leaf area, leaf area index, number of branches plant^{-1}and total dry matter plant^{-1} compared to intercropped treatments. Whereas, sole foxtail millet recorded higher leaf area, leaf area index, number of tillers in 30 cm and total dry matter plant^{-1}, grain yield panicle^{-1}and grain weight in 30 cm row length compared to sole finger millet and sole little millet. Among the intercropped treatments, soybean + foxtail millet in 4:2 and 2:1 row ratio showed higher yield and economic returns.

Table 4. Production and profitability of soybean and millets in intercropping systems

Cropping systems	SEY(kg ha^{-1})	LER	ATER	G.R	N.R	B:C
Soybean + foxtail millet (2:1)	2,310	1.49	1.39	94,724	66,779	2.39
Soybean + foxtail millet (4:2)	2,334	1.50	1.40	96,403	68,457	2.45
Soybean + finger millet (2:1)	2,116	1.45	1.28	87,054	58,433	2.01
Soybean + finger millet (4:2)	2,120	1.47	1.29	87,178	58,557	2.05
Soybean + little millet (2:1)	1,940	1.37	1.46	82,199	54,115	1.93
Soybean + little millet (4:2)	1,959	1.39	1.47	82,735	54,651	1.95
Sole soybean	2,255	1.00	1.00	78,585	49,558	1.71
Sole foxtail millet	1,901	1.00	1.00	48,690	30,824	1.73
Sole finger millet	1,805	1.00	1.00	46,558	26,951	I.I-7
Sole little millet	1,521	1.00	1.00	37,931	20,783	1.21
S.Em±	73.3	0.01	0.01	488.08	488.08	0.02
C.D. at 5 %	211.7	0.02	0.02	1409.67	1409.67•	0.04

Note: SEY-Soybean equivalent yield, LER-Land equivalent ratio, ATER-Area time equivalent ratio, G.R- Gross returns (₹ ha^{-1}), N.R-Nct returns (₹ ha^{-1})

Market price of the produce as per CACP-2017 (commission on agricultural costs and prices) Soybean - ₹ 2,900 q^{-1} foxtail millet - ₹ 2,200 q^{-1}, finger millet - ₹2,200 q^{-1} and little millet - ₹ 2,100 q^{-1}.

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