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Grain legume as a doable remunerative intercrop in rainfed cotton

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ABSTRACT

A field experiment was conducted during 2004-05 to 2006-07 at Central Institute for Cotton Research, Regional Station, Coimbatore on a slightly alkaline medium fertile sandy clay loam soil to compare the viability and cost effectiveness of grain legume as an intercrop vis-à-vis diverse soil moisture conservation options in rainfed cotton. Here the objective is to find out the suitability of grain legumes as the intercrop to improve productivity and profitability in rainfed cotton in comparison to *in-situ* land configurations. Results revealed that simple *in-situ* land configuration measures through furrow opening at each inter-row of a rainfed cotton after last interculture resulted in obtaining significantly higher leaf area index (LAI 3.7), per plant bolls (14.7), burst bolls (10.2) and yield (33.4 g) that enhanced per unit area dry matter production (5,408 kg/ha) and seed cotton yield (1,699 kg/ha) over the control. Yet, growing of a urdbean crop as an intercrop at 1:1 row ratio (in additive series) had an additional yield of 311 kg/ha resulting in realization of the highest seed cotton equivalent yield of 1,902 kg and net return of Rs. 42,805/- per hectare. The intercropping system was remunerative over a range of soil moisture conservation techniques and other pulse based intercropping systems. The intercropping favoured for in terms of both relative production (34.6%) and relative economic efficiency (38.2%) besides obtaining higher nutrient uptake, rainfall use efficiency (33.7 kg/ha-cm), and above all, a better area-time equivalent ratio (1.22).

Key words: Benefit:cost ratio, Cotton equivalent yield, Grain legume, Intercropping, Intercrop efficiency, Soil moisture conservation

Cotton (*Gossypium hirsutum* L.) is one of the most important cash crops of India playing a dominant role in the industrial and agricultural economy of Indian subcontinent. India ranks first in world acreage (10.2 m ha) with a 33% of total cotton area. With a production of 29.5 m bales (one bale = 170 kg), it is also ranked second only next to China. Yet on crop productivity front (only 494 kg lint/ha), it lags behind the world average of 725 kg lint/ha mainly due to unavailability of irrigation. The rainfed cotton alone in India constitutes about 60% of total area with the productivity of 325 kg lint/ha, affecting its acceptance as a profitable cropping enterprise (AICCIP 2010). Being mostly planted at wider row spacing with limited elasticity for better crop performance in terms of unit area seed production, it provides as a suitable candidate crop for growing an appropriate companion or inter-crop. In this way, the rainfed cotton can be remunerative with additional returns, possibly from a soil restorer grain legume with low water requirements besides better utilizing the stored soil moisture which otherwise is subjected to evaporative loss or removal by weeds.

As a rule, mixing of crop seeds especially of a seed legume before sowing is the normal rule practised by farmers' under dryland situation. Yet, higher yield is obvious when competition in the inter-species of the mixture is lower over intra-species competition. It is reported that intercropping is spread over 12 m ha in South Asia (Woodhead *et al*. 1994). As the farmers are reluctant to grow short duration legumes like mungbean, urdbean and soybean as a sole crop, they seek an opportunity to grow these as an intercrop, possibly in wide-row planted crops like cotton. Here also, the advantage is to increase in acreage of both the crops, although productivity may not increase to the significant level as it is warranted by many factors.

Although, adoption of suitable soil conservation practices like *in-situ* land configurations do provide a good cotton crop likely to be less affected by terminal moisture stress, yet growing an intercrop is certainly viable and remunerative. With uncertainty in both intensity (28.2-97.4 cm in the last decade) and frequency of rainfall over large tract of rainfed ecosystem, productivity and profitability of cotton growing areas are becoming unsustainable, if cultivation of monocrop (cotton) is practiced. Moreover, over the years, variability in rainfall pattern and its uneven distribution is more conspicuous confirming the rule of nature rather than the exception. This in turn needs at least a second crop to revive the productivity of rainfed production systems. Since studies on comparison of physical parameters of soil and water conservation practice vis-à-vis grain legume intercropping are lacking, the current trial was undertaken.

MATERIALS AND METHODS

Field experiments were conducted during 2004-05 to 2006-07 at Central Institute for Cotton Research, Regional Station, Coimbatore (11°N Latitude, 77°E longitude and 427.6 m above MSL). The soil was sandy clay loam in texture, low in available N (182 kg/ha), medium in available phosphorus (8 kg/ha) and very high in available potash (600 kg/ha). The field was relatively flat with uniform slope of 0.5%. The soil of the experimental field is well drained, medium deep (90 cm) black sandy clay loam in texture. The plot size was 7.5 m × 6.5 m. The crop received rainfall of 525.6, 722.0 and 446.4 mm and the effective rainfall of 312.8, 398.8 and 253.6 mm respectively during the year of 2004-05, 2005-06 and 2006-07, respectively. The experiment was laid out in a thrice replicated randomized block design with seven treatments *viz*., rainfed control, furrow opening in each inter-row of cotton, furrow opening at alternate inter-row of cotton, tied hoeing, cotton + soybean, cotton + urdbean and cotton + mungbean. Grain legumes were intercropped at 1:1 row ratio under additive series.

The field was ploughed once with tractor drawn mould board plough and then harrowed. Furrows were opened manually by a spade after completion of last intercultural operations as per the treatments. Small banks and buffer channels were provided and maintained between 2 m area of the plots to divert runoff water and prevent water flow into adjacent plots, if any.

Medium staple cotton cultivar 'LRA 5166' was selected for the trial. For intercropping treatments, 'CO 6' of mungbean, 'Vamban-3' of urdbean and 'JS 335' of soybean varieties were taken up. Cotton was sown at 60 × 30 cm, while one row of grain legumes (soybean, urdbean and mungbean) was planted in each inter-row of cotton. Recommended dose of 40 kg of N, 20 kg of P_2O_5 and 20 kg of K_2O was applied to cotton with 50% of N and full dose of P and K were applied as basal, while the rest of N was top dressed in cotton after assessing availability of sufficient soil moisture (at around 6 weeks). No additional fertilizer was applied for grain legume intercrop. Recommended plant protection measures were adopted to protect the crop from pests and diseases when these are above the economic threshold level (ETL).

Soil moisture changes were monitored at frequent intervals with two increments of soil depth (0-30 and 30-60 cm). Soil samples were drawn with a screw auger and soil moisture per cent was estimated by gravimetric method. Soil moisture availability is worked out at different depths of soil from soil moisture content, bulk density and soil depth. Rainfall use efficiency was worked out by using the formula as suggested by Rajendran (1991) and is expressed in kg of seed cotton yield or equivalent yield per ha-cm. Growth attributes, yield parameters and seed yield were recorded during the course of investigation. Area time equivalent ratio (ATER, Heibsch 1980) providing more realistic comparison of the yield advantage of intercropping over monocropping was also estimated by using both area and time taken by the component crops in an intercropping system.

Fibre quality parameters *viz*., ginning out turn (GOT), seed index, lint index, 2.5% span length, maturity ratio, uniformity ratio, micronaire, fibre strength and fibre elongation were also analyzed. Fibre quality index (FQI= LT/vM, where L, 2.5% span length (mm), T, fibre bundle tenacity at 3.2 mm gauge (g/tex) and M, micronaire Value), count (C=0.196 FQI – 16) and count strength product (CSP=1.740 FQI + 1600) were also worked out. All the quality parameters except GOT, seed index and lint index were analyzed by using high volume instruments (HVI, Statex-Fibrotex model).

Relative production efficiency (RPE) was calculated on the basis of capacity of the system for production in relation to existing system and was expressed in percentage and is calculated as 'RPE= (EYD-EYE)*100/EYE', where, EYD is the equivalent yield under improved/diversified system, while EYE is the existing system yield. Relative economic efficiency (REE) is a comparative measure of economic gains over the existing system and is expressed in percentage as 'REE = (DNR-ENR)*100/ENR)' where, DNR is the net return obtained under improved/diversified system, while ENR is net return in the existing system. Pooled analysis was made from three years data to assess the effect of soil moisture conservation techniques and intercropping on growth characters, yield attributes, yield and quality. Gross return, net return and benefit: cost ratio (BCR) were derived on the basis of prevailing market price of inputs and outputs.

RESULTS AND DISCUSSION

Growth and yield attributes: A perusal of Tables 1 & 2 reveals that cotton growth parameters *viz*., leaf area index (LAI), per plant bolls and dry weight at 120 DAS as well as yield attributes *viz*., burst bolls and single plant yield were significantly influenced by the treatments. Amongst the physical measures, opening of furrow at each inter-row recorded significantly higher LAI (3.7), per plant bolls (14.7), burst bolls (10.2) and yield (33.4 g), and dry matter production (5,408 kg/ha) over the rainfed control. Opening of furrow at each inter-row produced similar effects with those in other soil conservation measures *viz*., alternate inter-row opening and tied hoeing which in fact, is attributed to availability of conserved soil moisture following altered land configurations. In rainfed control, water easily drained out/used up resulting in decreased availability of stored soil moisture especially at the later growth stages and consequently reduced growth and yield attributes in cotton. Even intercropping in case of non-compact and faster developing genotype of mungbean interfered with the growth of cotton crop and adversely affected the dry matter accumulation of cotton plant (4,056 kg/ha), while it did not show up in urdbean (4,556 kg/ha) and soybean (4,256 kg/ha) system. It showed the importance of alternative grain legume intercrops *viz*., urdbean and soybean. Similarly, Tomar *et al*. (1994) observed that dry matter of cotton was not influenced by intercropping of urdbean and bolls per plant was found to be similar under both sole cotton and cotton + urdbean.

Yield of component crops: Pooled data on seed cotton yield revealed that although both alternate inter-row furrow opening (1,656 kg/ ha) and tied hoeing (1,596 kg/ha) were similar to that of opening of furrow in each inter-row of cotton, yet the later soil moisture conservation practice produced significantly

Table 1. Growth analysis and attributes of cotton under grain legume intercropping and physical manipulation of soil

Treatments	Plant height (cm)	Nodes/ plant (no.)	LAI	Bolls/plant (no.)	Dry weight (kg/ha)	CGR ($g/m^2/day$)		RGR (mg/g/day)		NAR (mg/cm/day)	
						45-90 DAS	91-120 DAS	45-90 DAS	91-120 DAS	45-90 DAS	91-120 DAS
Rainfed control	91.0	21.4	2.9	11.2	4,527	4.4	7.1	39.0	21.2	1.62	1.57
Furrow at each inter-row	94.8	22.4	3.7	14.7	5,408	6.0	7.5	43.0	18.0	2.04	1.37
Furrow at alternate inter-row	90.9	21.1	3.7	13.9	4,977	5.8	6.3	42.3	15.9	1.96	1.11
Tied hoeing	88.6	21.6	3.7	14.5	5,103	5.7	6.9	41.8	17.2	2.06	1.26
Cotton + soybean	88.2	22.2	2.5	12.3	4,256	4.9	5.6	42.5	16.9	2.09	1.35
Cotton + urdbean	92.8	23.0	2.4	10.8	4,556	4.6	6.9	39.7	20.1	1.73	1.60
Cotton + mungbean	94.4	22.5	2.9	10.7	4,056	4.5	5.5	41.3	17.5	1.76	1.21
CD (P=0.05)	NS	NS	0.6	3.9	787						

Table 2. Effect of diverse soil conservation techniques on yield, economics, moisture and intercropping efficiency

Treatments	Burst bolls/ plant (no.)	Single plant yield (g)	Seed cotton yield (kg/ha)	Intercrop yield (kg/ha)	SCEY (kg/ha)	GR* (Rs/ha)	CC (Rs/ha)	NR (Rs/ha)	BCR	LER	RPE (%)	REE (%)	RUE (kg/ha -cm)	ATER
Rainfed control	8.3	26.2	1,413	-	1,413	48,042	17,065	30,977	2.82	-	-	-	25.0	-
Furrow at each inter-row	10.2	33.4	1,699	-	1,699	57,766	18,495	39,271	3.11	-	20.2	26.8	30.1	-
Furrow at alternate inter-row	10.6	31.3	1,656	-	1,656	56,304	18,280	38,024	3.08	-	17.2	22.7	29.3	-
Tied hoeing	10.0	30.0	1,596	-	1,596	54,264	17,980	36,284	3.01	-	13.0	17.1	28.3	-
Cotton + soybean	8.6	26.5	1,385	365	1,605	54,573	21,425	33,148	2.55	1.5	13.6	7.0	28.4	1.26
Cotton + urdbean	8.6	26.8	1,472	311	1,902	64,665	21,860	42,805	2.96	1.4	34.6	38.2	33.7	1.22
Cotton + mungbean	7.4	22.1	1,173	328	1,655	56,282	20,365	35,917	2.76	1.3	17.2	15.9	29.3	1.05
CD (P=0.05)	2.7	6.5	220											

*GR = Gross return, CC = Cost of cultivation, NR = Net return, BCR = Benefit cost ratio, LER = Land equivalent Ratio, SCEY = Seed cotton equivalent yield, RPE =Relative production efficiency, REE = Relative economic efficiency, RUE = Rainfall use efficiency, ATER = Area time equivalent ratio.

higher seed cotton yield (1,699 kg/ha) over the rainfed control. In rainfed control, runoff water led to reduction in moisture availability especially in later crop growth stages and consequently reduced seed cotton yield significantly. The results confirmed the findings that soil moisture conservation is a viable proposition for yield formation in case of unavailability of irrigation facility or even in presence of poor quality of irrigation water.

On the contrary, pooled seed cotton yield under intercropping *viz*., cotton + soybean (1,385 kg/ha) and cotton + urdbean (1,472 kg/ha) were similar to sole crop yield (1,413 kg/ha), thereby indicating non-competitiveness amongst components of an intercropping system, and was corroborated by Khan *et al.* (2001). The results implied that due to compact growth, one row of urdbean or soybean between the cotton inter-rows produced additional yield without affecting the growth and performance of the main crop of cotton. However, cotton with mungbean registered the lowest mean seed cotton yield (1,173 kg/ha) which was 17 % lesser than the sole crop. Reduced seed cotton yield in cotton + mungbean may also be due to non-compact growth of the intercrop, resulting in fierce competition for resources and thus, influencing its growth, development and yield.

Intercropping of soybean, urdbean and mungbean between cotton rows recorded an average grain yield of 365, 311 and 328 kg/ha respectively (Table 2). Intercropping efficiency indices *viz*., LER and ATER were higher with cotton + soybean (1.5 and 1.26) followed by cotton + urdbean (1.4 and 1.22) and the least one was obtained under cotton + mungbean because of competition due to component crop.

In terms of system productivity, cotton + urdbean recorded maximum seed cotton equivalent yield (1,902 kg/ha) followed by cotton + mungbean (1,655 kg/ha) and cotton+soybean (1,605 kg/ha). Although *in-situ* conservation practices especially furrow opening at each inter-row produced comparatively higher yields over other physical means including control, yet it was not superior to cotton + urdbean intercropping system. In fact, it out yielded over the best mechanical practice *viz*., furrow opening at each inter-row by 12% thereby depicting the importance of grain legume intercropping in overall performance of component crops and the system as a whole.

Consumptive use: Seasonal consumptive use of water calculated for 2004-05, 2005-06 and 2006-07 were 35.1, 27.9 and 33.9 cm respectively with the mean value of 32.3 cm. Since the crops were raised in *rabi* season (September – March) that led to less evaporative demands and in turn resulted in low water use for all the experimental seasons. The mean data for different crop intervals revealed that consumptive use was 3.7, 8.6, 13.5 and 6.5 cm for 0-25, 26-70, 71-120 and 121-150 DAS and the corresponding effective rainfall of above intervals were 8.9, 18, 4 and 1.3 cm respectively. Comparison between consumptive use and effective rainfall, showed that crop water requirement for first 70 days was adequate for crop growth while moisture stress was observed from 71 to 150 DAS due to insufficient rainfall.

Growth analysis: Analysis of crop growth rate (CGR) showed that moisture conservation by physical means through furrow opening at each inter-row (6.0 and 7.5 g/m^2/day) during 45-90 and 91-120 DAS respectively (Table 1) registered higher growth rate. Moreover, cotton under legume intercropping showed similar growth rate as that of rainfed sole crop. Wankhade (1994) also showed that CGR was not affected by intercropping with urdbean. Relative growth rate and net assimilation rate showed decreasing trend from 45-90 to 91-120 DAS and no specific trend was observed amongst the treatments.

Soil moisture availability: Available soil moisture measured for 0-30 and 30-60 cm depth of soil profile was significantly influenced by soil moisture conservation practices including intercropping at different dates of sampling *viz*., at 75, 100, 120 DAS and harvest during 2004-05, at 40 DAS and harvest during 2005-06 and at 40, 95 DAS and at harvest during 2006-07 (Table 3 & 4). Amongst the physical means of agro-techniques, soil moisture conservation by opening furrow at each inter-row, at alternate inter-row and tied hoeing had significantly higher soil moisture availability over the control. More or less similar soil moisture content were evident under intercropping system as that of physical means depicting the fact that the moisture has been used up for intercrops also for their growth and development.

In addition, none of these treatments significantly influenced soil moisture content at 50 DAS (2004-05), 90 and 120 DAS (2005-06) and 80 DAS (2006-07) because of coincidence with continuous wet spell during the corresponding period. Soil moisture content reached to permanent wilting point at the crops' harvest because of higher utilization of moisture by crop to meet evapotranspiration demands without any supplementation of soil moisture through late season rain. In addition, between the two depths (0-30 and 30-60 cm), 0-30 cm had less soil moisture at different intervals during the crop growth cycle thereby revealing the fact that moisture extraction pattern is high at top soil even in a deep rooted crop like cotton either intercropped or not (Table 3 & 4).

NPK uptake in component crops: Total nutrient uptake (Fig. 1) was significantly influenced by the treatments as highest N uptake (172 kg/ha) and P uptake (28 kg/ha) were with cotton + mungbean. Intercropping of cotton favoured more uptake because of effective utilization of resource resulting in higher accumulation of biomass in addition to biological N fixation by legumes leading to higher nutrient uptake. Harisudan (2004) reported maximum N, P and K uptake under cotton + urdbean than sole cotton. Although physical soil moisture conservation measures registered significantly higher NPK uptake over the control yet these were lesser in comparison to intercropping as the latter involves two crops.

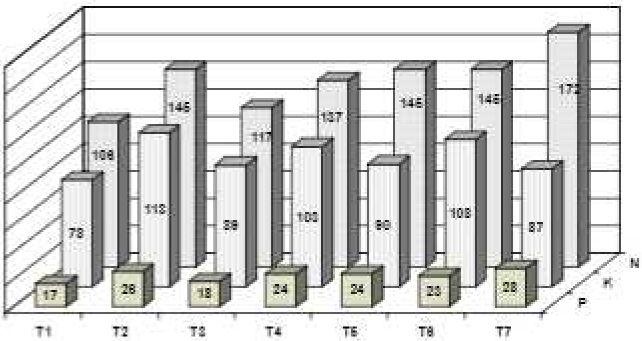

Fig 1. Nutrient uptake by soil moisture conservation techniques and grain legumes intercropping

Economics of grain legume intercropping: A comparison between physical means of water conservation vis-à-vis grain legume intercropping revealed that cotton + urdbean was more remunerative as it had the highest per hectare gross return (Rs. 64,665/-) and net return (Rs. 42,805/-) due to higher seed cotton equivalent yield; and was superior over any of the soil moisture conservation practices (Table 2). Thus, an additional yield accrued through legume intercrop in association with

Table 3. Dynamics in soil moisture content (cm/30 cm depth) under intercropping and physical manipulation of soil at different DAS (0-30 cm soil depth)

Treatments	2004-05					2005-06				2006-07			
	50	75	100	120	Harvest	40	90	120	Harvest	40	80	95	Harvest
Rainfed control	5.98	5.70	3.54	3.25	1.99	3.83	9.03	5.90	3.30	4.83	6.18	3.45	2.38
Furrow at each inter-row	6.53	7.27	4.41	4.21	2.14	4.27	8.91	6.09	4.43	5.27	6.77	3.88	2.61
Furrow at alternate inter-row	6.85	7.12	4.28	4.20	2.10	4.12	9.57	6.30	4.82	5.15	6.93	3.80	2.61
Tied hoeing	6.97	6.94	4.28	3.64	2.02	4.14	9.17	6.63	4.73	5.35	6.97	3.82	2.38
Cotton + soybean	7.05	6.29	3.56	3.54	2.01	4.07	8.54	7.01	3.31	5.07	6.53	3.29	2.42
Cotton + urdbean	5.98	6.15	3.76	3.64	1.94	3.97	9.40	7.33	3.24	5.15	6.42	3.48	2.57
Cotton + mungbean	6.10	6.30	3.63	3.45	1.89	3.85	9.45	6.86	3.12	4.91	6.30	3.37	2.38
CD (P=0.05)	NS	0.32	0.27	0.34	0.43	0.27	NS	NS	0.31	0.36	NS	0.36	0.36

Table 4. Dynamics in soil moisture content (cm/30 cm) under intercropping and physical manipulation of soil at different DAS (30-60 cm soil depth)

Treatments	2004-05					2005-06				2006-07			
	50	75	100	120	Harvest	40	90	120	Harvest	40	80	95	Harvest
Rainfed control	6.40	6.56	4.01	3.56	2.31	4.13	8.49	6.06	3.49	5.79	6.76	4.29	2.55
Furrow at each inter-row	6.80	7.36	4.87	4.62	2.39	5.13	8.18	6.26	5.13	6.24	7.13	4.62	2.75
Furrow at alternate inter-row	7.25	7.32	4.33	4.31	2.35	5.09	8.79	6.45	5.06	6.10	7.21	4.29	2.79
Tied hoeing	6.80	7.14	4.66	4.46	2.27	5.44	8.79	6.81	4.61	6.44	7.41	4.54	2.71
Cotton + soybean	6.97	6.56	4.21	4.09	2.09	4.92	7.54	7.21	3.58	5.92	6.84	4.41	2.59
Cotton + urdbean	6.20	6.42	4.12	3.97	2.11	4.53	8.76	7.44	3.32	6.03	6.80	4.21	2.51
Cotton + mungbean	6.72	6.71	3.89	3.86	2.15	4.21	8.98	7.05	3.15	5.71	6.80	4.17	2.59
CD (P=0.05)	NS	0.34	0.38	0.36	0.47	0.49	NS	NS	0.38	0.49	NS	0.45	0.32

main crop (cotton) yield resulted in additional return for the intercrop system. The system was more remunerative because of the demand for pulses *viz*., urdbean associated with high market price. Sivakumar (2003) observed higher market value of pulses, enhanced the profitability when pulses were intercropped with cotton. Similar results were also reported by many others (Kulkarni and Jiotode 2001, Nandini and Chellamuthu 2004).

In addition, amongst the intercrops, although cotton + soybean recorded the highest seed cotton and pulses grain yield, but lesser market prices for soybean (Rs 21/kg) in turn reduced the economic return considerably. Although production potential of soybean was better than urdbean, the prevailing rates of specific commodity made urdbean more viable and profitable over soybean (Giri *et al*. 2006). Tomar *et al*. (1994) and Wankhede *et al*. (2000) also reported higher monetary return with cotton + urdbean system. Similarly, relative production efficiency and relative economic efficiency were also maximum with cotton + urdbean, which were 34.6 and 38.6 % higher in respective values over the control. Rainfall use efficiency was also higher with cotton + urdbean.

On the contrary, because of less cost involved in imposing physical means of soil water conservation through furrow opening either at alternate or each inter-row, BCR was relatively higher (3.08-3.11) in these treatments. Yet, comparable BCR (2.96) was also obtained under cotton + urdbean. Thus, growing a urdbean crop as an intercrop at 1:1 row ratio (in additive series) had an additional yield of 311 kg/ha resulting in realization of the highest seed cotton equivalent yield and net return per hectare; and was doable in all respect.

The study suggested that for a resource poor farmer, cotton + urdbean was more efficient in respect of yield and diverse input use efficiencies under a rainfed ecosystem. It was remunerative over a range of soil moisture conservation practices and other grain legume intercropping systems.

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