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Suganthi S
Ph.D. Scholar, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Raja D
Principal, Adhiparasakthi Horticultural College, Kalavai, Tamil Nadu, India

Corresponding Author:
Raja D
Principal, Adhiparasakthi Horticultural College, Kalavai, Tamil Nadu, India

Influence of supplemental irrigation on yield and indices in cotton based intercropping system

Suganthi S and Raja D

Abstract
A field experiment was conducted during *Kharif* season of 2018-19 in farmer's field to evaluate the supplemental irrigation in intercropped cotton under rainfed *Vertisols*. The experiment was laid out in strip plot design and replicated thrice. The treatments in vertical strip included SI_0 - no supplemental irrigation (rainfed), SI_1 - supplemental irrigation at vegetative stage, SI_2 - supplemental irrigation at squaring to peak flowering stage, SI_3 -supplemental irrigation at boll development stage, SI_4 - supplemental irrigation at vegetative, squaring to peak flowering and boll development stage and SI_5 - supplemental irrigation at wilting symptom appearance. The horizontal strip includes cotton alone (IC_0), cotton + blackgram (1:3) (IC_1), cotton + clusterbean (1:3) (IC_2) and cotton + coriander (1:4) (IC_3). The result of the field experiment revealed that supplemental irrigation at wilting symptom recorded higher yield and was comparable with supplemental irrigation at all the stages. Among intercropping system, cotton + blackgram (1:3) recorded higher seed cotton yield. But, cotton + clusterbean (1:3) registered significantly higher value in other parameters such as, Land Equivalent Ratio, Area Time Equivalent Ratio, Income Equivalent ratio which in turn increased cotton equivalent yield than the sole cotton.

Keywords: Cotton, intercropping, supplemental irrigation (SI), clusterbean, blackgram, coriander

Introduction
Cotton is known as white gold. India ranks the first in acreage (12.2 m ha) which accounts for 32 per cent of the total world cotton area and contributes 21 per cent (36.1 m bales) of world cotton production. The average productivity of cotton in India is 502 kg ha^{-1} which is far below than world average yield of 705 kg ha^{-1}. In Tamil Nadu, cotton is cultivated in an area of 0.14 m ha with a production of 0.6 m t and the average productivity is 729 kg ha^{-1} which is higher than national average productivity (Indiastat, 2018) [4]. Cotton provides direct livelihood to 6.0 million farmers and about 40 to 50 million people are employed directly in cotton trade and it's processing. About 14.0 per cent of industrial production and 4.0 per cent of the GDP is contributed by the textile sector (CICR, 2011). In India, 65 per cent of the cotton cultivation is under rainfed condition (Malavath *et al.*, 2014) [7].

Soil moisture is most important factor for enhanced growth and production of cotton under rainfed condition. Among different growth stages of cotton, reproductive stages are much sensitive than vegetative stage. About 47 per cent of yield reduction in rainfed treatment was noticed when compared to irrigation four times at vegetative, flowering, boll formation and later stages in summer cotton in Pakistan (Usman *et al.*, 2010) [10]. Water stress for twenty days at the stages of early flowering to full flowering and at full flowering to full bolling, reduced the seed cotton yield of 42 per cent and 31 per cent, respectively (Luo *et al.*, 2015). Low and improper distribution of rainfall in rainfed situation is due to high evaporative demand which in turn limits the cotton yield. To alter the risk of the rainfed crop, supplemental irrigation at critical growth stages of crop or irrigation based on evaporative demand is essential.

Farmers may not interested to invest more in rainfed due to the failure of the crop. To reducing the risk in monocrop cultivation, intercropping is done which helps to utilize the resource available in a wide-spaced cotton crop with slow establishment at the initial stage. Intercropping is the best way to utilize the natural resources which have different duration for growth, light, nutrient and water requirement with varied root depth between base crop and intercrop (Sankaranarayanan *et al.*, 2012) [8]. Hence to avoid the poor yielding of cotton due to moisture stress at critical stages and to secure the income of farmers in rainfed areas through identifying the best suited intercrops under cotton, the present study is formulated.

Material and Methods

A field study (2018-19) was conducted during *Kharif* season at farmer's field, Thalaivasal block, Thittacheri (Village), Salem, Tamil Nadu, India. 11°26'N and longitude of 78°44'E with an altitude of 160 m above mean sea level which is in the Northwestern Agro-climatic Zone of Tamil Nadu. The soil texture of the field was clay loam (38.8% clay, 32.8% silt and 28.4% sand). The nutrient available in the experimental soil was low in available nitrogen (143.0 kg ha^{-1}), low in phosphorus (10.9 kg ha^{-1}) and medium in potassium (253.4 kg ha^{-1}). The amount and distribution of rainfall was 449 mm with 25 rainy days.

The field trail was laid out in strip-plot design with three replications in flat bed method. The variety used for cotton was RCH *BGII* 659, blackgram was VBN 6, clusterbean was Darsha and coriander was Aroma. The treatments in the vertical strip is irrigation based on critical growth stages included no supplemental irrigation (rainfed) (SI_0), supplemental irrigation at vegetative phase (SI_1), supplemental irrigation at squaring to peak flowering stage (SI_2), supplemental irrigation at boll formation stage (SI_3), supplemental irrigation at vegetative, squaring to peak flowering and boll formation stages (SI_4) and supplemental irrigation at wilting symptom appearance (SI_5). Horizontal strip included four intercropping system *viz.*, sole cotton (IC_0), cotton + blackgram (IC_1), cotton + clusterbean (IC_2) and cotton + coriander (IC_3). The sowing of cotton was done at the spacing of about 100 cm × 60 cm. Spacing adopted for blackgram was 30 cm × 10 cm and clusterbean was 30 cm × 15 cm. coriander seeds requirement were sown as solid row spacing of 20 cm and thinned for grains at 15 cm apart between plants.

Recommended dose of fertilizers (125:60:75 kg NPK ha^{-1}) for cotton was applied into split doses. Half the quantity of N and K_2O was applied as basal and the remaining half was applied one part at 45 DAS and other at 65 DAS. Full dose of P_2O_5 was applied as basal after the receipt of rainfall. Every time, irrigation was given based on the availability of soil moisture which was measured by using soil moisture meter (PMS714) and was done through the pipe into the plot of about 50 mm at a irrigation. The soil moisture availability was verified at various depths and was correlated with the available moisture estimated by using pressure plate apparatus of about 11.8 per cent. A deficit condition occurred once in vegetative, next at squaring stage to flowering; and twice in boll development stage.

To evaluate the competition indices in supplemental irrigation with intercropping system treatments, formulae for various indices were used. Cotton equivalent yield was calculated based on prevailing market prices with the following formula.

$$\text{Seed cotton equivalent yield (kg ha}^{-1} = \frac{Y_i \times P_i}{P_b} + Y_b \text{ (kg ha}^{-1})$$

Where,

Y_i = Yield of intercrop (kg ha^{-1}),
Y_b = Yield of base crop (kg ha^{-1}),
P_i = Price of intercrop (₹ kg^{-1}), and
P_b = Price of base crop (cotton) (₹ kg^{-1}).

Land equivalent ratio (LER) was calculated using the formula proposed by Willey and Osiru (1972).

$$LER = \left(\frac{Y_{ij}}{Y_{ii}}\right) + \left(\frac{Y_{ji}}{Y_{jj}}\right)$$

Where,

Y = Yield per unit area,
Y_{ii} *and* Y_{jj} =

Sole crop yields of the component crops i and j, respectively and

Y_{ij} *and* Y_{ji} = Intercrop yields.

Area time equivalent ratio was calculated by using the formula given by of Hiebsch and McCollum (1987).

$$ATER = \frac{(Rya \times ta) + (Ryb \times tb)}{T}$$

$$Ry = \frac{\text{Yield of intercrop per hectare}}{\text{Yield of sole crop per hectare}}$$

Where,

Ry = Relative yield of species a (main crop)and b (intercrop),
t = Duration (days)for species a and b, and
T = Duration (days)for the intercropped system.

In income equivalent yield, the monetary value of the crop yield is taken instead of yield and worked out as in the case of LER, which gives the IER. It is the ratio of the area needed under sole cropping to that of intercropping, at the same management level, to produce the same amount of gross income (Ghaffarzadeh, 1997) [1].

$$IER = \frac{Iab}{Iaa} + \frac{Iba}{Ibb}$$

Where,

I_{aa} = Gross income of component 'a' in pure stand,
I_{bb} = Gross income of component 'b'in pure stand,
I_{ab} = Gross income of component 'a' in mixed stand with 'b', and
I_{ba} = Gross income of component 'b' in mixed stand with 'a'.

Statistical analysis was done by using the procedure given by Gomez and Gomez (2010). The level of significance at 5% of probability of critical difference values were used to know the best treatment among different treatments.

Result and Discussion

Seed cotton Yield

During 2018-19, there existed a moisture stress during vegetative, squaring to peak flowering and boll formation stages. So, supplemental irrigation at wilting symptom appearance (SI_5) recorded significantly higher yield (2408 kg ha^{-1}) and was on par with supplemental irrigation at all the stages of cotton (SI_4). This might be due to continuous irrigation led to higher yield recorded. But, it next line was supplemental irrigation at all stages of cotton (SI_4) and was on par with supplemental irrigation at squaring to flowering stages (2108 kg ha^{-1}). Provision of supplemental irrigation at squaring to flowering stage of cotton which is the most critical stage for irrigation ensured the reaction of squares and flowers and in turn increased the boll numbers and yield of cotton. Similar result was observed by Luo *et al.* (2015). The lowest seed cotton yield was recorded in supplemental irrigation at the vegetative stage (1996 kg ha^{-1}) and was on par with no supplemental irrigation (1837 kg ha^{-1}) which indicates the lesser sensitivity of cotton to these stages.

Higher seed cotton was observed in sole cotton (2084 kg ha^{-1}) than all other intercropped cotton. Significantly lower seed cotton yield was recorded in cotton + blackgram (1:3), cotton + clusterbean (1:3) and cotton + coriander (1:4) (Table 1). The sole cotton yield was higher compared to intercropped cotton might be due to non-competition for the natural resources. The result obtain was in accordance with observation of Kumar *et al.* (2017) [5].

Cotton equivalent yield

In 2018-19, 23.5 per cent and 20.8 per cent increase of cotton equivalent yield over rainfed or no supplemental irrigation (control) was registered in supplemental irrigation at wilting symptom appearance and supplemental irrigation at all stages (vegetative, squaring to peak flowering and boll development), respectively. The lower cotton equivalent yield was recorded in supplemental irrigation at the vegetative stage with an increase of 9.2 per cent over rainfed condition (control) and was on par with no supplemental irrigation. This might be due to increased yield of cotton in supplemental irrigation at wilting symptom appearance by higher utilization of the water availability which in turn increased the cotton equivalent yield.

Among intercropping systems, cotton + clusterbean (1:3) recorded significantly higher cotton equivalent yield (4156 kg ha^{-1}) over sole cotton yield (2362 kg ha^{-1}), respectively. This was due to higher green pod yield of clusterbean even with minimum cost led to increase the cotton equivalent yield. A similar result was obtained to Kumar *et al.* (2017) [5]. It was followed by cotton + blackgram (1:3) and was on par with cotton + coriander (1:4) during both years.

Indices

Land Equivalent Ratio (LER)

The supplemental irrigation treatments didn't have any significant difference on the Land Equivalent Ratio in cotton based intercropping system. Among intercropping system, LER recorded a significantly higher value (1.98) in cotton + clusterbean (1:3) and was on par with cotton + blackgram (1:3) among intercropping systems. Increased clusterbean yield, increased the cotton equivalent yield and in turn land equivalent ratio. Similar, results were observed by Singh *et al.* (2017) [9] and Kumar *et al.* (2017) [5].

Area Time Equivalent Ratio (ATER)

As like LER, the area time equivalent ratio was also not altered by the supplemental irrigation to cotton. Higher area time equivalent ratio of 1.54 was noted in cotton + clusterbean (1:3) and cotton + coriander (1:4); and was followed by cotton + blackgram (1:3). This result indicated that cotton + clusterbean and cotton + coriander might utilize comparably higher resources compared to other intercropping system.

The difference was due to higher yield of clusterbean provided a way to increase the value of area time equivalent ratio in cotton + clusterbean (1:3). Similarly, coriander was longer duration crop with higher yield produced both in greens and grains by optimum utilization of resources. Similar result was observed by Sankaranarayanan *et al.* (2012) [8].

Income Equivalent Ratio (IER)

The income equivalent ratio values obtained in the study noticed no significant difference in supplemental irrigation treatments. Regarding income equivalent ratio, higher values (1.70) was noticed in cotton + clusterbean (1:3) than other intercropping systems. This might be due to increased cotton equivalent yield led to the betterment of income equivalent.

Table 1. Effect of supplemental irrigation on yield of cotton and intercrops in cotton based intercropping system

Treatment	Seed cotton yield (kg ha^{-1})	Blackgram yield (kg ha^{-1})	Clusterbean yield (kg ha^{-1})	Coriander yield (kg ha^{-1})
Supplemental Irrigation (SI)				
SI_0 - No SI (rainfed)	1837	607	10413	159 (83)
SI_1 - SI at vegetative stage	1996	610	10939	293 (139)
SI_2 - SI at squaring to flowering stage	2108	637	11713	321 (87)
SI_3 - SI at boll development stage	2096	613	10633	335 (92)
SI_4 - SI at all the stages of cotton	2308	593	12887	328 (99)
SI_5 - SI at wilting symptom appearance	2408	589	13025	342 (152)
SEd	91	-	-	-
CD (P=0.05)	202	-	-	-
Intercropping System (IC)				
IC_0 - sole cotton	2084	-	-	-
IC_1 - cotton + blackgram (1:3)	2029	802	14009	419 (203)
IC_2 - cotton + clusterbean (1:3)	1993	-	-	-
IC_3 - cotton + coriander (1:4)	1938	-	-	-
SEd	62	-	-	-
CD (P=0.05)	127	-	-	-

Interaction effect was not significant

Values in paranthesis was yield of coriander greens. Yield of intercrops was not statistically analysed

Table 2: Effect of supplemental irrigation in cotton based intercropping system on Cotton Equivalent Yield (CEY), Land Equivalent Yield (LER), Area Time Equivalent Ratio (ATER) and Income Equivalent Ratio (IER)

Treatment	Cotton Equivalent Yield (kg ha^{-1})	Land Equivalent Ratio (LER)	Area Time Equivalent Ratio (ATER)	Income Equivalent Ratio (IER)
Supplemental Irrigation (SI)				
SI_0 - No SI (rainfed)	2554	1.76	1.40	1.56
SI_1 - SI at vegetative stage	2812	1.89	1.50	1.65
SI_2 - SI at squaring to flowering stage	2967	1.88	1.47	1.64
SI_3 - SI at boll development stage	2906	1.84	1.45	1.61
SI_4 - SI at all the stages of cotton	3225	1.87	1.46	1.62
SI_5 - SI at wilting symptom appearance	3337	1.91	1.50	1.66
SEd	117	0.06	0.05	0.05
CD (P=0.05)	260	NS	NS	NS
Intercropping System (IC)				
IC_0 - sole cotton	2362	-	-	-
IC_1 - cotton + blackgram (1:3)	2747	1.89	1.32	1.64
IC_2 - cotton + clusterbean (1:3)	4156	1.98	1.54	1.70
IC_3 - cotton + coriander (1:4)	2603	1.71	1.54	1.53
SEd	106	0.05	0.04	0.05
CD (P=0.05)	214	0.10	0.08	0.11

Interaction effect was not significant

Sole cotton in intercropping system (1.00) was not included in LER and ATER

Cost of cotton - ₹55 kg^{-1}, Cost of blackgram - ₹60 kg^{-1}, Clusterbean- ₹10 kg^{-1} and; coriander (grains) - ₹100 kg^{-1} and (greens) - ₹30 kg^{-1}.

Duration of cotton - 150 days, blackgram-65 days, clusterbean- 90 days and coriander- 120 days

Conclusion

It is concluded that supplemental irrigation at wilting symptom appearance or supplemental irrigation at all stages of cotton increases the cotton equivalent yield and in intercropping system, cotton + clusterbean increased the cotton equivalent yield. It ultimately increases the livelihood of the farmers.

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