Indian Journal of Weed Science **52**(2): 153–159, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Intercrops and weed management effect on productivity and competition indices of cotton

A. Sathishkumar*, G. Srinivasan, E. Subramanian and P. Rajesh[1]

TNAU, Agricultural College and Research Institute, Madurai, Tamil Nadu 625 104, India

[1]Department of Crop Management, RVSAC, Thanjavur, Tamil Nadu 613 402, India

**Email: sathishkumar08668@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00028.3

Type of article: Research article

Received : 17 February 2020
Revised : 6 May 2020
Accepted : 8 May 2020

Key words
Cotton
Allelopathy
Sunflower
Intercropping
Weed management
Productivity

ABSTRACT

Field experiments were conducted during summer 2016 and winter 2016-17 at Agricultural College and Research Institute, Madurai to study the allelopathic effect of different intercrops and tree leaf extracts in managing weeds and increasing productivity of cotton. The cotton + sorghum intercropping system registered lower weed density at 20, 40 and at 60 days after seeding (DAS) during both the seasons. Among the weed management practices, lower weed density was recorded with pre-emergence application of pendimethalin at 1.0 kg/ha at 20 DAS and with hand weeding twice at 20 and 40 DAS at 40 and 60 DAS during studied periods. The highest cotton equivalent yield (389, 419 kg/ha), land equivalent ratio (1.52, 1.54), monetary equivalent ratio (1.18, 1.17) and system productivity (2.13, 2.39 t/ha) were recorded in cotton + sunflower intercropping system with hand weeding twice at 20 and 40 DAS during both the years. Among the combined applications of intercropping system and tree leaf extracts, cotton + sunflower (1:1) + pre-emergence application of *Mangifera indica* leaf extract at 30% + hand weeding at 40 DAS registered the maximum cotton equivalent yield (349, 374 kg/ha), land equivalent ratio (1.31, 1.34), monetary equivalent ratio (1.0, 1.02) and system productivity (1.81, 2.07 t/ha) during summer 2016 and winter 2016-17, respectively.

INTRODUCTION

Cotton (*Gossypium hirsutum*) is one of the major commercial crop in India. Cotton is known for the fibre and oil from seed, which plays a prominent role in the national and international economy. The early slow growth and adoption of wider spacing favours the weeds to grow luxuriously in cotton fields. Weeds remove about 30-50% of applied fertilizer, 20-40% moisture (Jayakumar *et al.* 2008) and reduce seed cotton yield by 13-41% (Iqbal and Cheema 2008). Weeds, besides removing moisture and nutrients, harbour insects and diseases. Poor crop stand due to weed competition has been found to lower production by 30-90% depending upon weed pressure (Singh 2014). Manual weed management practices are laborious and expensive. In spite of herbicides being effective in increasing yield, indiscriminate use of herbicides has resulted in serious ecological implications such as development of herbicide resistance weeds and shift in weed population (Jabran *et al.* 2010). Recently, research attention has been focused to find out alternative strategies for chemical weed control in several crops (Muhammad *et al.* 2014). Reduction in herbicide use is one of major goals of modern agriculture and there is much emphasis in search for alternative weed management strategies that are cheap, safe and sustainable (Hozayn *et al*. 2011). Allelopathy is considered as an effective, economical and environment friendly weed management approach (Iqbal and Cheema 2009).Weed density and biomass may substantially be reduced through intercropping (Poggio 2005). Singh *et al.* (2003) indicated that growing companion plants, which are selectively allelopathic to weeds, may provide a cost effective alternative to the use of synthetic chemicals. The slow initial growth coupled with indeterminate growth habit favours the growing of intercrops in cotton without affecting it's yield (Javid and Anjum 2006). Intercropping has unique capacity to raise the unit profitability without disturbing the cotton ecosystem (Harisudan *et al.* 2009). Hence, the present study was carried out to study the efficacy of intercrops and plant leaf extracts in managing weeds and increase the productivity of cotton.

MATERIALS AND METHODS

Field experiments were conducted at Agricultural College and Research Institute, Madurai during summer 2016 and winter 2016-17. Twenty four treatment combinations comprised of four intercropping as main plots, I_1- cotton + sorghum (1:1), I_2 - cotton + sunflower (1:1), I_3 - cotton + sesame (1:1), I_4- sole cotton, and six weed management practices as sub plots, W_1 - *Prosopis juliflora* leaf extract 30% pre-emergence application (PE) + one hand weeding on 40 days after seeding (DAS), W_2 - *Annona squamosa* leaf extract 30% PE + one hand weeding on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one hand weeding on 40 DAS, W_4 - pendimethalin 1.0 kg/ha PE + one hand weeding on 40 DAS, W_5 - two hand weeding at 20 and 40 DAS, W_6 - control (no weeding or spray). The experiments were laid out in a split plot design with three replications. Healthy and viable seeds of cotton variety '*SVPR 4*' were sown as base crop at the rate of 15 kg/ha. Main cotton crop was sown with row to row spacing of 75 cm and plant to plant spacing of 30 cm, on the same day intercrops were sown in between two rows of cotton crop following 1:1 ratio for main and intercrops. Pre-emergence (PE) application of pendimethalin at 1.0 kg/ha was done at 3 DAS. The plant to plant spacing adopted for intercrop was 30 cm. Leaves of *Prosopis juliflora, Annona squamosa* and *Mangifera indica* at vegetative stage were collected and washed gently with tap water for a few seconds to remove contaminants like dust etc. The fresh leaves of above species were cut into small species, soaked in alcohol and water 1:1 proportion and kept for overnight. After 12 hours, soaked leaves were ground with the help of mixer grinder. From the paste, the leaf extract of each botanical species was prepared by filtration which represented 100% stock solution (Sripunitha 2009). From the stock solution, 30% concentration was prepared and sprayed on 3 DAS by using knapsack sprayer as per the treatment schedule.

Land equivalent ratio (LER)

Land equivalent ratio is the relative land areas under sole crop required to produce the same yield as obtained under a mixed or inter cropping system at the same level of management. It was calculated by the formula suggested by Willey (1979).

$$LER = \frac{Ya}{Sa} + \frac{Yb}{Sb}$$

Where,

Ya and Yb = Yield of individual crop 'a' and 'b', respectively in mixture

Sa and Sb = Yields of individual crop 'a' and 'b', respectively in pure stand

Cotton equivalent yield (CEY) and system productivity (kg/ha)

It was calculated by the formula suggested by Willey (1979)

$$CEY = \frac{\text{Yield of intercrop x Price of intercrop}}{\text{Price of cotton}}$$

System productivity = (CEY + Yield of cotton)

$$\text{In terms of money} = \frac{\text{System productivity (₹/ha)}}{\text{Agricultural year (365 days)}}$$

Competition index (CI)

It is a measure to find out the yield of various crops when grown together as well as separately. It indicates the yield per plant of different crops in mixture and their respective pure stand on a unit area basis. If the yield of any crop, grown together is less than its respective yield in pure stand then it is harmful association but on increased yield means positive benefit (Donald 1963).

$$CI = \frac{(Yaa - Yab) \times (Ybb - Yba)}{Yaa \times Yab}$$

Where,

Yaa = Yield in pure stand of crop 'a'

Ybb = Yield in pure stand of crop 'b'

Yab = Mixture yield of crop 'a' grown with 'b'

Yba = Mixture yield of crop 'b' grown with 'a'

Monetary equivalent ratio (MER)

Monetary Equivalent Ratio (MER) is defined as the sum of the ratios of intercrop monetary returns to the highest sole crop monetary return from the entire land area occupied by all intercrops per unit time (Adetiloye and Adekunle 1989). Mathematically MER can be expressed as

$$MER = (ra + rb + rc) / Ra$$

Where,

ra, rb, rc is the monetary returns from intercrops

'Ra' is the highest sole crop monetary return

RESULTS AND DISCUSSION

Total weed density

Among the intercropping system, the cotton + sorghum intercropping system registered lower weed density (**Table 1** and **2**) and biomass (**Table 3** and **4**) during both the seasons and it was at par with cotton + sesame intercropping system. Sole cotton registered higher weed density during both the years. Among the weed management practices, pendimethalin at 1.0 kg/ha PE significantly reduced the weed density and biomass at 20 DAS during the

both the years. This was followed by *Mangifera indica* leaf extract at 30% PE. At 40 and 60 DAS, hand weeding twice at 20 and 40 DAS recorded lower weed density and biomass. It was followed by pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS. The maximum weed density was recorded under control during both the seasons.

The interaction effect was significant between intercropping system and weed management practices at 20, 40 and at 60 DAS. The combination of cotton + sorghum intercropping system with pendimethalin at 1.0 kg/ha PE was more efficient in reducing the total weed density and biomass at 20 DAS during Summer 2016 and Winter 2016-17 and it was on par with intercropping of cotton + sesame intercropping system with pendimethalin at 1.0 kg/ha PE. At 40 and 60 DAS, cotton intercropped with sorghum + hand weeding at 20 and 40 DAS registered the lowest weed density and biomass during both the years. This was comparable with intercropping of cotton + sesame intercropping system and hand weeding at 20 and 40 DAS and

Table 1. Effect of intercropping system and weed management practices on total weed density (no./m^2) in cotton during summer 2016

Treatment	20 DAS					40 DAS					60 DAS				
	I_I	I_2	I_3	I_4	Mean	I_I	I_2	I_3	I_4	Mean	I_I	I_2	I_3	I_4	Mean
W_1	5.67	5.82	5.76	6.39	5.91	7.24	8.24	7.56	9.23	8.07	5.12	5.52	5.46	6.34	5.61
	(31.7)	(33.3)	(32.7)	(40.3)	(34.5)	(52.0)	(67.3)	(56.7)	(84.7)	(65.2)	(25.7)	(30.0)	(29.3)	(39.7)	(31.2)
W_2	5.93	6.10	6.07	6.77	6.22	8.32	8.65	8.46	9.77	8.80	5.76	5.90	5.84	6.77	6.07
	(34.7)	(36.7)	(36.3)	(45.3)	(38.2)	(68.7)	(74.3)	(71.0)	(95.0)	(77.2)	(32.7)	(34.3)	(33.7)	(45.3)	(36.5)
W_3	4.74	5.08	4.92	5.37	5.03	6.23	6.89	6.54	7.06	6.68	4.74	4.88	4.78	5.18	4.90
	(22.0)	(25.3)	(23.7)	(28.3)	(24.8)	(38.3)	(47.0)	(42.3)	(49.3)	(44.2)	(22.0)	(23.3)	(22.3)	(26.3)	(23.5)
W_4	3.67	4.53	4.06	4.67	4.23	5.31	5.85	5.64	6.07	5.72	4.02	4.26	4.26	4.41	4.24
	(13.0)	(20.0)	(16.0)	(21.3)	(17.6)	(27.7)	(33.7)	(31.3)	(36.3)	(32.2)	(15.7)	(17.7)	(17.7)	(19.0)	(17.5)
W_5	7.34	7.63	7.38	9.50	7.96	4.26	4.85	4.78	5.11	4.75	3.14	3.39	3.39	3.72	3.41
	(53.3)	(57.7)	(54.0)	(89.7)	(63.7)	(17.7)	(23.0)	(22.3)	(25.7)	(22.2)	(9.3)	(11.0)	(11.0)	(13.3)	(11.2)
W_6	7.82	8.28	8.05	9.70	8.46	10.22	11.34	10.95	12.72	11.31	10.78	11.68	11.37	14.13	11.99
	(60.7)	(68.0)	(64.3)	(93.7)	(71.7)	(104.0)	(128.0)	(119.3)	(161.3)	(128.2)	(115.7)	(136.0)	(128.7)	(199.3)	(144.9)
Mean	5.86	6.24	6.04	7.07		6.93	7.64	7.32	8.33		10.78	11.68	11.37	14.13	
	(35.9)	(40.2)	(37.8)	(53.1)		(51.4)	(62.2)	(57.2)	(75.4)		(36.8)	(42.1)	(40.4)	(57.1)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.26	0.26	0.54	0.52		0.40	0.34	0.74	0.69		0.35	0.51	1.00	1.03	

Table 2. Effect of intercropping system and weed management practices on total weed density (no./m^2) in cotton during winter 2016-17

Treatment	20 DAS					40 DAS					60 DAS				
	I_I	I_2	I_3	I_4	Mean	I_I	I_2	I_3	I_4	Mean	I_I	I_2	I_3	I_4	Mean
W_1	4.74	4.92	4.78	6.10	5.14	6.67	7.38	6.94	8.09	7.27	4.78	4.95	4.85	5.79	5.09
	(22.0)	(23.7)	(22.3)	(36.7)	(26.2)	(44.0)	(54.0)	(47.7)	(65.0)	(52.7)	(22.3)	(24.0)	(23.0)	(33.0)	(25.6)
W_2	5.46	5.58	5.52	6.36	5.73	7.47	7.97	7.67	8.26	7.84	5.28	5.52	5.37	6.07	5.56
	(29.3)	(30.7)	(30.0)	(40.0)	(32.5)	(55.3)	(63.0)	(58.3)	(67.7)	(61.1)	(27.3)	(30.0)	(28.3)	(36.3)	(30.5)
W_3	3.94	4.49	4.49	4.67	4.40	5.87	6.10	6.07	6.39	6.11	4.18	4.49	4.42	4.56	4.41
	(15.0)	(19.7)	(19.7)	(21.3)	(18.9)	(34.0)	(36.7)	(36.3)	(40.3)	(36.8)	(17.0)	(19.7)	(19.0)	(20.3)	(19.0)
W_4	3.14	3.34	3.29	3.54	3.33	4.67	5.43	4.88	5.61	5.15	3.39	4.14	3.63	4.18	3.84
	(9.3)	(10.7)	(10.3)	(12.0)	(10.6)	(21.3)	(29.0)	(23.3)	(31.0)	(26.2)	(11.0)	(16.7)	(12.7)	(17.0)	(14.3)
W_5	6.79	6.96	6.89	8.42	7.27	3.67	4.10	3.76	4.45	4.00	2.48	3.03	2.80	3.14	2.86
	(45.7)	(48.0)	(47.0)	(70.3)	(52.7)	(13.0)	(16.3)	(13.7)	(19.3)	(15.6)	(5.7)	(8.7)	(7.3)	(9.3)	(7.7)
W_6	7.08	7.27	7.11	8.80	7.57	8.92	10.09	9.41	10.99	9.85	10.48	11.17	10.82	12.08	11.14
	(49.7)	(52.3)	(50.0)	(77.0)	(57.2)	(79.0)	(101.3)	(88.0)	(120.3)	(97.2)	(109.3)	(124.3)	(116.7)	(145.3)	(125.9)
Mean	5.19	5.43	5.35	6.32		6.21	6.85	6.46	7.30		5.10	5.55	5.32	5.97	
	(28.5)	(30.8)	(29.9)	(42.9)		(41.1)	(50.1)	(44.5)	(57.3)		(32.1)	(37.2)	(34.5)	(44.9)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.23	0.23	0.48	0.46		0.26	0.24	0.51	0.48		0.22	0.22	0.47	0.45	

Figures in the parenthesis are original values. Others are ($\sqrt{x+0.5}$).

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

intercropping of cotton + sunflower intercropping system and hand weeding at 20 and 40 DAS during the years crop growth. The reduction in total weed density and biomass were more pronounced in cotton + sorghum intercropping system. Intercropping of sorghum, sunflower and sesame in cotton recorded lower weed density than sole cotton. The total weed density was reduced (32.4, 31.8 and 35.6% at 20, 40 and at 60 DAS, respectively during summer 2016 and 33.6, 28.2 and 26.3% at 20, 40 and at 60 DAS, respectively during winter 2016-17) in cotton when intercropped with sorghum than sole cotton during both years of experimentation. Cotton intercropped with sorghum reduced the total weed biomass (21.1, 21.8 and 23.1% at 20, 40 and at 60 DAS, respectively during summer 2016 and 30.3, 22.4 and 21.2% at 20, 40 and at 60 DAS, respectively during winter 2016-17) during the both years. The reduction of weed density and biomass in intercropping might be due to establishment of intercrops on land surface which quickly smothered the weeds and prevented germination. Low weed density and biomass may also be reflective of the allelopathic impacts of sorghum and sunflower which were released by volatilization and root exudation. This fact is supported by Weston and Duke (2003) who reported

Table 3. Effect of intercropping system and weed management practices on total weed biomass (kg/ha) in cotton during summer 2016

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	11.89	12.32	12.01	13.88	12.53	16.30	17.26	16.71	20.38	17.66	11.32	11.75	11.47	13.48	12.01
	(140.8)	(151.2)	(143.8)	(192.1)	(157.0)	(265.2)	(297.4)	(278.8)	(414.8)	(314.0)	(127.6)	(137.6)	(131.0)	(181.3)	(144.4)
W_2	12.82	13.36	13.07	14.43	13.42	17.59	19.76	18.79	21.05	19.30	11.78	12.86	12.19	13.84	12.67
	(163.9)	(178.0)	(170.4)	(207.8)	(180.0)	(308.9)	(390.1)	(352.4)	(442.4)	(373.4)	(138.3)	(164.9)	(148.1)	(191.1)	(160.6)
W_3	10.29	11.44	10.74	11.62	11.02	14.79	15.17	14.90	15.92	15.20	9.65	10.69	10.43	10.91	10.42
	(105.3)	(130.4)	(114.8)	(134.5)	(121.2)	(218.3)	(229.6)	(221.5)	(252.9)	(230.6)	(92.6)	(113.7)	(108.2)	(118.6)	(108.3)
W_4	8.22	8.74	8.41	9.71	8.77	13.78	13.93	13.85	14.00	13.89	7.31	7.97	7.71	8.87	7.97
	(67.1)	(75.9)	(70.3)	(93.8)	(76.8)	(189.4)	(193.5)	(191.3)	(195.6)	(192.4)	(53.0)	(63.0)	(58.9)	(78.1)	(63.2)
W_5	14.23	14.61	14.39	15.82	14.76	11.57	12.21	11.95	12.52	12.06	6.31	6.72	6.53	6.92	6.62
	(201.9)	(213.0)	(206.6)	(249.9)	(217.8)	(133.4)	(148.6)	(142.2)	(156.2)	(145.1)	(39.3)	(44.7)	(42.2)	(47.4)	(43.4)
W_6	14.79	15.16	14.95	16.13	15.26	21.29	22.37	21.70	23.30	22.17	23.16	24.41	23.66	25.82	24.26
	(218.2)	(229.2)	(223.1)	(259.6)	(232.5)	(452.8)	(499.9)	(470.2)	(542.4)	(491.3)	(536.1)	(595.3)	(559.1)	(666.1)	(589.1)
Mean	12.04	12.61	12.26	13.60		15.89	16.78	16.32	17.86		11.59	12.40	12.00	13.31	
	(149.5)	(162.9)	(154.8)	(189.6)		(261.3)	(293.2)	(276.1)	(334.0)		(164.5)	(186.5)	(174.6)	(213.8)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.28	0.21	0.48	0.42		0.70	0.69	1.44	1.38		0.47	0.37	0.82	0.74	

Table 4. Effect of intercropping system and weed management practices on total weeds biomass (kg/ha) in cotton during winter 2016-17

Treatment	20 DAS					40 DAS					60 DAS				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	11.16	11.46	11.26	12.79	11.67	15.62	16.70	15.79	18.92	16.76	10.25	11.11	10.61	11.57	10.89
	(124.0)	(130.9)	(126.3)	(163.2)	(136.1)	(243.6)	(278.3)	(248.9)	(357.5)	(282.1)	(104.6)	(122.9)	(112.0)	(133.3)	(118.2)
W_2	11.69	12.56	12.00	13.08	12.33	16.98	18.21	17.38	19.66	18.06	11.28	11.45	11.35	12.44	11.63
	(136.1)	(157.2)	(143.5)	(170.6)	(151.8)	(287.9)	(333.1)	(301.4)	(385.9)	(326.6)	(126.7)	(130.5)	(128.4)	(154.2)	(134.9)
W_3	9.61	10.76	10.31	12.50	10.80	13.43	14.72	13.14	15.31	14.15	8.37	9.04	8.48	9.99	8.97
	(91.9)	(115.2)	(105.7)	(155.7)	(117.1)	(179.9)	(216.2)	(172.1)	(233.9)	(200.5)	(69.6)	(81.2)	(71.4)	(99.4)	(80.4)
W_4	7.42	8.22	7.62	10.33	8.40	12.37	12.55	12.48	13.06	12.62	6.49	7.20	6.99	7.84	7.13
	(54.5)	(67.1)	(47.6)	(106.3)	(71.4)	(152.5)	(157.1)	(155.3)	(170.1)	(158.7)	(41.6)	(51.3)	(48.4)	(60.9)	(50.5)
W_5	12.64	12.99	12.74	15.44	13.45	10.36	11.68	10.49	11.95	11.12	4.95	5.48	5.16	5.64	5.31
	(159.3)	(168.3)	(161.9)	(237.8)	(181.8)	(106.9)	(135.9)	(109.6)	(142.3)	(123.7)	(24.0)	(29.5)	(26.1)	(31.3)	(30.4)
W_6	13.63	14.76	14.11	15.62	14.53	20.27	21.41	20.67	22.13	21.12	22.37	24.24	23.50	24.91	27.73
	(185.4)	(217.4)	(198.6)	(243.5)	(211.2)	(410.0)	(457.9)	(426.7)	(489.4)	(446.1)	(499.7)	(587.3)	(551.8)	(619.9)	(564.7)
Mean	11.03	11.79	11.34	13.29		14.84	15.88	14.99	16.84		10.62	11.42	11.02	12.07	
	(125.2)	(142.7)	(132.3)	(179.5)		(230.2)	(262.7)	(235.7)	(296.5)		(144.4)	(167.1)	(156.3)	(183.2)	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.44	0.37	0.81	0.75		0.48	0.39	0.85	0.78		0.42	0.27	0.66	0.55	

Figures in the parenthesis are original values. Others are ($\sqrt{x+0.5}$).

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

that suppression of weeds might be due to allelopathic compounds released through root exudation of intercrops. Sorghum and sunflower are reported to have high allelopathic potential, containing several allelochemicals such as sorgoleone, glycosides, terpenoids, flavonoids, alkaloids and phenolics (Iqbal and Cheema 2008). If intercrops are more effective than sole crops in usurping resources from weeds or suppressing weed growth through allelopathy, less weed growth may be obtained (Oliveira *et al*. 2011, Poggio 2005 and Iqbal 2007). Among the weed management practices, in the early stages of the crop growth (20 DAS), total weed density and biomass were reduced greatly by the PE application of pendimethalin at 1.0 kg/ha. This might be due to the fact that initial flush of weeds could not emerge due to effect of pendimethalin. These results were in accordance with that of Chaudhary *et al*. (2011) who observed an effective weed control with PE application of pendimethalin. But at later stages of crop growth (40 and 60 DAS), total weed density and bio mass of grass, sedge and BLW weed density were reduced by hand weeding twice at 20 and 40 DAS. This was due to the early emerging weeds were controlled by first hand weeding and late emerging weeds were removed by second hand weeding with better removal of underground root portions.

Cotton equivalent yield (CEY) and land equivalent ratio (LER)

Crop equivalent yield and land equivalent ratio is an important index assessing the performance of different crops under a set of given circumstances (**Table 5**). Among the treatments, intercropping of cotton + sunflower with hand weeding twice at 20 and 40 DAS produced the maximum cotton equivalent yield and land equivalent ratio during both the years, which was followed by intercropping of cotton + sunflower with PE application of pendimethalin at 1.0 kg/ha + hand weeding at 40 DAS. This may be attributed to better performance and yields of both the component crops under intercropping system. This was accordance with findings of Gajendra *et al.* (2017) and Abdel-Galil and Abdel-Ghany (2014). The lowest CEY and LER was registered with intercropping of cotton + sesame with control and lowest LER was recorded with intercropping of cotton + sorghum with control.

Relative yield total (RYT) and competition index (CI)

Relative yield total and competitive index was considerably influenced by the intercropping system and weed management practices (**Table 6**). Cotton + sesame intercropping system with hand weeding twice at 20 and 40 DAS recorded the highest relative yield total and the lowest value of competitive index during summer 2016 and Winter 2016-17. This was followed by cotton + sesame with PE application of pendimethalin at 1.0 kg/ha + hand weeding at 40 DAS. Abdel-Galil and Abdel-Ghany (2014) reported that groundnut + sesame (3:1) intercropping system recorded higher relative yield of groundnut. Efficiency of productivity in intercropping might be increased by minimizing the interspecific competition between the component populations for growth limiting factors (Dhima *et al.* 2007). The lowest RYT and highest competition index was registered with intercropping of cotton + sorghum with control.

System productivity (t/ha), system productivity (₹/ha/day) and monetary equivalent ratio (MER)

Among the treatments, intercropping of cotton + sunflower with hand weeding twice at 20 and 40

Table 5. Effect of intercropping system and weed management practices on cotton equivalent yield (kg/ha) and land equivalent ratio (LER) in cotton during summer 2016 and winter 2016-17

Treatment	CEY										LER									
	2016					2016-17					2016					2016-17				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	260	320	253	-	278	269	340	290	-	300	0.70	1.26	1.11	-	1.02	0.70	1.21	1.11	-	1.11
W_2	252	303	232	-	262	264	320	273	-	286	0.66	1.12	1.03	-	0.94	0.67	1.14	1.03	-	1.03
W_3	265	349	263	-	292	276	374	292	-	314	0.78	1.31	1.16	-	1.08	0.77	1.34	1.17	-	1.17
W_4	272	372	299	-	314	281	396	324	-	334	0.90	1.48	1.31	-	1.23	0.90	1.49	1.33	-	1.33
W_5	280	389	317	-	329	287	419	338	-	348	0.94	1.52	1.36	-	1.27	0.91	1.54	1.37	-	1.37
W_6	126	128	106	-	120	137	137	121	-	132	0.39	0.44	0.42	-	0.42	0.42	0.48	0.46	-	0.46
Mean	243	310	245	-		252	331	273	-		0.73	1.19	1.07	-		0.73	1.20	1.08	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	27	26	39	35		35	31	41	38		0.08	0.08	0.15	0.14		0.08	0.07	0.16	0.15	

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

Table 6. Effect of intercropping system and weed management practices on relative yield total and competition index of cotton

Treatment	Relative yield total (RYT)										Competition index (CI)									
	2016					2016-17					2016					2016-17				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	0.33	0.64	0.66	-	0.54	0.34	0.62	0.66	-	0.54	1.77	0.12	0.07	-	0.65	1.59	0.15	0.07	-	0.60
W_2	0.32	0.57	0.61	-	0.50	0.32	0.58	0.60	-	0.50	2.01	0.22	0.10	-	0.78	1.81	0.19	0.10	-	0.70
W_3	0.37	0.66	0.69	-	0.57	0.37	0.69	0.70	-	0.59	1.27	0.10	0.05	-	0.47	1.23	0.08	0.05	-	0.45
W_4	0.41	0.75	0.78	-	0.65	0.42	0.77	0.79	-	0.66	0.81	0.02	0.01	-	0.28	0.74	0.02	0.01	-	0.26
W_5	0.43	0.77	0.80	-	0.67	0.42	0.79	0.82	-	0.68	0.71	0.01	0.01	-	0.24	0.71	0.01	0.00	-	0.24
W_6	0.18	0.22	0.24	-	0.21	0.20	0.24	0.27	-	0.24	4.55	2.03	0.88	-	2.49	3.59	1.60	0.69	-	1.96
Mean	0.34	0.60	0.63	-		0.35	0.62	0.64	-		1.85	0.42	0.19	-		1.61	0.34	0.15	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.02	0.02	0.06	0.06		0.03	0.02	0.08	0.07		0.10	0.09	0.18	0.17		0.12	0.10	0.20	0.18	

Table 7. Effect of intercropping system and weed management practices on system productivity and monetary equivalent ratio of cotton during summer 2016

Treatment	System productivity (t/ha)					System productivity in terms of money (₹/ha/day)					Monetary equivalent ratio (MER)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	1.00	1.76	1.70	-	1.48	123	217	210	179	182	0.55	0.98	0.95	-	0.83
W_2	0.94	1.55	1.58	-	1.36	116	191	195	175	169	0.52	0.86	0.88	-	0.75
W_3	1.15	1.81	1.77	-	1.57	141	223	218	199	195	0.64	1.00	0.98	-	0.87
W_4	1.35	2.07	2.00	-	1.81	166	255	247	213	220	0.75	1.15	1.11	-	1.00
W_5	1.41	2.13	2.08	-	1.87	174	262	256	222	229	0.78	1.18	1.16	-	1.04
W_6	0.57	0.60	0.63	-	0.60	70	74	77	69	73	0.32	0.33	0.35	-	0.33
Mean	1.07	1.65	1.63	-		132	204	201	176		0.59	0.92	0.91	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.07	0.10	0.18	0.18		6	9	19	21		0.03	0.04	0.07	0.07	

Table 8. Effect of intercropping system and weed management practices on system productivity and monetary equivalent ratio of cotton based intercropping system during winter 2016-17

Treatment	System productivity (t/ha)					System productivity In terms of money (₹/ha/day)					Monetary equivalent ratio (MER)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_1	1.12	1.85	1.88	-	1.61	138	228	231	204	200	0.55	0.91	0.92	-	0.79
W_2	1.05	1.75	1.73	-	1.51	130	215	213	186	186	0.52	0.86	0.85	-	0.74
W_3	1.25	2.07	2.00	-	1.77	154	255	246	224	220	0.61	1.02	0.98	-	0.87
W_4	1.51	2.32	2.27	-	2.03	186	287	280	241	249	0.74	1.14	1.12	-	1.00
W_5	1.52	2.39	2.33	-	2.08	188	294	288	251	255	0.75	1.17	1.15	-	1.02
W_6	0.70	0.73	0.78	-	0.73	86	90	96	85	89	0.34	0.36	0.38	-	0.36
Mean	1.19	1.85	1.83	-		147	228	226	199		0.59	0.91	0.90	-	
	I	W	I at W	W at I		I	W	I at W	W at I		I	W	I at W	W at I	
LSD (p=0.05)	0.07	0.11	0.18	0.19		8	12	23	24		0.03	0.04	0.08	0.09	

I_1- Cotton + sorghum (1:1), I_2 - Cotton + sunflower (1:1), I_3 - Cotton + sesame (1:1), I_4- Sole cotton, W_1 - *Prosopis juliflora* leaf extract 30% PE + one HW on 40 DAS, W_2 - *Annona squamosa* leaf extract 30% PE + one HW on 40 DAS, W_3 - *Mangifera indica* leaf extract 30% PE + one HW on 40 DAS, W_4 - Pendimethalin 1.0 kg/ha PE + one HW on 40 DAS, W_5 - Two HW at 20 and 40 DAS and W_6 - Control (no weeding or spray)

DAS (I_2 W_5) recorded the highest system productivity and monetary equivalent ratio which was followed by intercropping of cotton + sesame intercropping system with hand weeding twice at 20 and 40 DAS (**Table 7** and **8**). Hence, it may be inferred that the higher CEY of intercropping system was mainly due to an additional yield of intercrops as a bonus in intercropping system and also higher yield of cotton coupled with higher market price of components crops under the same intercropping system. The results were in close conformity with Gajendra *et al.* (2017). Aasim *et al.* (2008) also revealed that positive monetary index obtained from intercropping of cotton with cowpea and sorghum. The lowest system productivity and monetary equivalent ratio was registered with intercropping of cotton + sorghum with control.

It may be concluded that cotton + sunflower intercropping system with pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS or cotton + sesame intercropping system with pendimethalin at 1.0 kg/ha PE + hand weeding at 40 DAS may be suggested for

better in weed control, higher yield and economic returns. Alternatively, cotton + sunflower or cotton + sesame intercropping system with *Mangifera indica* leaf extract at 30% PE + hand weeding at 40 DAS were also found to be effective in reducing the weed density and biomass and enhanced the productivity of cotton and economic returns.

REFERENCES

Aasim M, Ejaz MU and Karim A. 2008. Yield and competition indices of intercropping cotton (*Gossypium hirsutum* L.) using different planting patterns. *Journal of Agricultural Sciences* **14**: 326–333.

Abdel-Galil, AM and Abdel-Ghany REA. 2014. Effect of groundnut – sesame intercropping and nitrogen fertilizer on yield, yield components and infection of root – rot and wilt diseases. *International Journal of Plant & Soil Science* **3**(6): 623–643.

Adetiloye PO and Adekunle AA. 1989. Concept of monetary equivalent ratio and its usefulness in the evaluation of intercropping advantages. *Tropical Agriculture* **66**: 337–341.

Chaudhary SU, Iqbal J, Hussain M and Wajid A. 2011. Economical weed control in lentils crop. *Journal of* Animal *and* Plant *Sciences* **21**(4): 734–737.

Dhima KV, Lithourgidis AS, Vasilakoglou IB and Dordas CA. 2007. Competition indices of common vetch and cereal intercrops in two seedling ratio. *Field Crops Research* 100: 249–256.

Donald CM. 1963. Competition among crop and pasture plants. *Advances in Agronomy* **15**: 1–118.

Gajendra Singh, Pushkar Choudhary, Dharmraj Saini and Bhanwar Lal Jat. 2017. Effects of legume intercrops on growth, yield and economics of hybrid American cotton under controlled condition. Global *Journal* of *Bio-Science and Bio Technology* **6**(1): 61–82.

Harisudan C, Senthivel S, Arulmozhiselvan K, Vaidyanathan R and Manivannan V. 2009. Blackgram as intercrop in cotton – A Review. *Agricultural Reviews* **30**(3): 219–223.

Hozayn M, Lateef EMA, Sharar FF and Monem AAA. 2011. Potential uses of sorghum and sunflower residues for weed control and to improve lentil yields. *Allelopathy Journal* **27**(1): 15–22.

Iqbal J and Cheema ZA. 2008. Purple nutsedge (*Cyperus rotundus* L.) management in cotton with combined application of sorgaab and S - metolachlor. *Pakistan Journal of Botany* **40**(6): 2383–2391.

Iqbal J and Cheema ZA. 2009. Response of purple nutsedge (*Cyperus rotundus* L.) to crop extracts prepared in various solvents. *Allelopathy Journal* **23**(2): 450–452.

Iqbal J. 2007. *Management of Purple Nutsedge in Cotton Through Allelopathy, Intercropping and Crop Water Extracts Combined with Reduced Herbicide Rates*. PhD Dissertation, University of Agriculture, Faisalabad, Pakistan.

Jabran K, Cheema ZA, Farooq M and Hussain M. 2010. Lower doses of pendimethalin mixed with allelopathic crop water extracts for weed management in canola (*Brassica napus*). *International Journal* of *Agriculture* and *Biology* **12**: 335–340.

Javaid A and Anjum T. 2006. Control of *Parthenium hysterophorus* (L.) by aqueous extracts of allelopathic grasses. *Pakistan Journal of Botany* **38**(1): 139–145.

Jayakumar M, Ponnuswamy K and Amanullah MM. 2008. Effect of sources of nitrogen and intercropping on weed control, growth and yield of cotton. *Research Journal* of *Agriculture* and *Biological Sciences* **4**(2): 154–158.

Muhammad Nawaz Kandhro, Shamsuddin Tunio, Inayatullah Rajpar and Qamaruddin Chachar. 2014. Allelopathic impact of sorghum and sunflower intercropping on weed management and yield enhancement in cotton. *Sarhad Journal of Agriculture* **30**(3): 311–318.

Oliveira AM, Silva PSL, Albuquerque CC, Azevedo CMSB, Cardoso MJ and Oliveira OF. 2011. Weed control in corn via intercropping with gliricidia sown by broadcasting. *Planta Daninha* **29** (3): 535–543.

Poggio SL. 2005.Structure of weed communities occurring in monoculture and intercropping of pea and barley. *Agriculture*, *Ecosystems and Environment* **109**(1-2): 48–58.

Singh HP, Batish DR and Kohli RK. 2003. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. *Critical Reviews in Plant Science* **22**: 239–311.

Singh S. 2014. Sustainable weed management in cotton. *Haryana Journal of Agronomy* **30**(1): 1–14.

Sripunitha A. 2009. Herbal hydration-dehydration treatments for Improving Vigour, Viability and Productivity in Tomato (*Lycopersicon esculentum*. Mill) cv. *'PKM1'*. M.Sc., Thesis, Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu.

Weston A and Duke SO. 2003. Weed and crop allelopathy. *Critical Reviews in Plant Science* **22**: 367–389.

Willey RW. 1979. Intercropping - its importance and research needs. Intercrop Competition and yield advantage. *Field Crops Abstract* **32**: 1–10.