Integrated weed management in *Bt* cotton (*Gossypium hirsutum* L.) under UKP command area of Karnataka

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ABSTRACT

A field experiment was conducted during *kharif* of 2012-13 at Agricultural College farm, Bheemarayanagudi, Shahapur (Karnataka) under UKP command area to develop effective weed management strategy. The experiment comprised of 14 treatments having two PRE (diuron, pendimethalin) and five POST (propaquizafop, quizalofop ρ tefuryl, fenoxaprop ρ ethyl, quizalofop ethyl and pyrithiobac sodium applied twice at 20 and 40 DAS individually or in sequence with pendimethalin PRE) herbicides and weedy and weed free-check. Among the post emergent herbicides, pyrithiobac sodium 10 EC used alone twice or in sequence with pendimethalin PRE recorded lower weed dry weight and higher weed control efficiency throughout. Of all the treatments, pendimethalin 38.7 CS @ 1.5 kg a.i. ha^{-1}PRE fb pyrithiobac sodium 10 EC @ 1.25 kg a.i. ha^{-1}POST + IC at 60 DAS recorded the lowest weed count, highest seed cotton yield (2,569 kg ha^{-1}) and net monetary returns (75, 670 Rs. ha^{-1}). Pendimethalin 38.7 CS PRE followed with quizalofop ethyl 5 EC @ 0.05 kg a.i. ha^{-1}or propaquizalofop 10 EC @ 0.1 kg a.i. ha-1 at 30-35 DAS were the next efficient treatments.

Keywords: *Bt* cotton, nutrient uptake, LAI, pre- and post emergent herbicides, seed cotton yield, weed count, WCE

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), an important natural fibre of commercial significance is grown extensively in the world particularly in India and more so in Karnataka. With the advent of *Bt* cotton, crop scenario witnessed tremendous change in area, production and utilization of cotton. *Bt* cotton is intensively cultivated in the Northern dry zone of the Karnataka (Zone 2 and 3) covering partly the Tungabhadra and Upper Krishna irrigation Commands (TBP and UKP) on black soils. The area under this crop in these commands is increasing over the past half a decade occupying more than 0.15 m ha during 2009-10. The average seed cotton yield is around 2.0 t per ha which in fact is far less than actual potential yield. Since, the crop has long growth cycle, it has to pass through frequent rains/irrigations and therefore, weed problem is a serious production constraint. In fact, losses caused by weeds in cotton range from 50 to 85 per cent depending upon the nature and intensity of weeds [1]. Most often due to incessant rains during *kharif* season hand weeding and intercultivation become difficult excessive moisture in black cotton soils. Further, labours being

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scarce and costly, growers are forced to fall back on chemicals for weed control. Therefore, there is need for selective broad spectrum herbicides [1].

The critical period of weed competition is from 15 to 60 days [1] and weed management systems during this period should prevent weed interference, be economical and sustainable, reduce weed seed bank in soil, prevent weed resistance, and neither injure cotton nor reduce quantity of lint yield. However, weedicides are crop/species specific and their dose and time of application is location and crop specific. Identification of such herbicide; their rates and time is of paramount importance in the sustainable cotton production.

Pendimethalin and diuron are selective and conspicuous pre-emergent herbicides being used in weed control programmes in cotton which virtuously control annual grasses and broad leaf weeds. These herbicides do not control perennial or well established weeds. For post emergence control, Propaquizafop 10% EC is the useful herbicide of the aryloxyphenoxy propionates family. It is used against a wide range of annual and perennial grasses for selective weed control in many broadleaf crops globally such as sugar beet, oilseed rape, soybeans, sunflower, other field crops, vegetables, fruit trees, vineyards and forestry. This herbicide is selective to all major broadleaf crops, during all their stages of development [2]. Similarly fenoxaprop ethyl and quizalofop ethyl are systemic herbicides with a specific target site action. On the other hand, phyrithiobac is a broad spectrum systemic herbicide used to kill the emerged weeds. These new herbicides could be used in cotton either alone repeatedly or in sequence with pre emergent herbicides. Hence, a study was undertaken to develop an effective integrated weed management strategy in irrigated cotton on black soils in the UKP command area during 2012-13 growing season.

MATERIALS AND METHODS

The field experiment was conducted during growing period of 2012-13 at Agricultural College farm, Bheemarayanagudi, Shahapur (Karnataka) falling under UKP Command area. The soil of experimental site was medium deep black soil, medium in organic carbon (0.7%), low in available nitrogen (252 kg ha^{-1}), medium in available phosphorus (33 kg ha^{-1} P_2O_5) and high in potash (297 kg ha^{-1} K_2O). The experiment comprised of fourteen treatments viz., unweeded check (T_1), weed free check (T_2), diuron 80 WP (@ 1.5 kg a.i. ha^{-1} PRE fb IC and HW at 30, 45 and 60 DAS, T_3), pendimethalin 38.7 CS (@ 0.68 kg a.i. ha^{-1} PRE fb IC and HW at 45 DAS, T_4), propaquizafop 10 EC (@ 0.1 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_5), quizalofop ρ tefuryl 4.41 EC (@ 0.044 kg a.i. ha^{-1} POE at 20 and 40 DAS + IC at 60 DAS, T_6), fenoxaprop ρ ethyl 9.3 EC (@ 0.1 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_7), quizalofop ethyl 5 EC (@ 0.05 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_8), pyrithiobac sodium 10 EC (@ 0.125 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_9), pendimethalin PRE fb propaquizafop 10 EC @ 0.1 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{10}), pendimethalin PRE fb quizalofop ρ tefuryl 4.41 EC @ 0.044 kg a.i. ha^{-1} POE at 30-35 DAS IC at 60 DAS (T_{11}), pendimethalin PRE fb fenoxaprop ρ ethyl 9.3 EC @ 0.1 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{12}), pendimethalin PRE fb quizalofop ethyl 5 EC @ 0.05 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60DAS (T_{13}) and pendimethalin PRE fb pyrithiobac sodium 10 EC @ 0.125 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{14}). The experiment was laid out in a randomized complete block design with three replications. Cotton (cv. Arya *Bt* BG II) was sown on 10th July of 2012 with a spacing of 90 cm between rows and 60 cm between plants. Fertilizer application (150:75:75 kg ha^{-1} N, P_2O_5 and K_2O) was done as per the recommendation. The crop was irrigated twice at 20 days interval after cessation of monsoon. Crop prophylactic measures were taken as and when necessary. The weed density (m^{-2}), and weed control efficiency (%) was recorded at 20, 40 and 60 DAS and at harvest. Total weed dry weight was measured at harvest. Observations on cotton LAI, yield parameters and

yield, nutrient uptake and net returns were recorded and subjected for statistical analysis and interpretation.

RESULTS AND DISCUSSION

Unweeded check recorded higher weed count since beginning (63 m^{-2} at 20 DAS); the density was in parity for the initial 20 days in fields treated with POE herbicides (T_5 to T_9) (Table 1). Weed density with PRE herbicides (diuron and pendimethalin) was lower and overall trend remained same up to 60 DAS. This could be attributed to the selective action of these systemic herbicides. Diuron inhibits the hill reaction in photosynthesis and thereby knocks down the weed [3]. Similarly, pendimethalin disrupts the cell division and cell elongation in the shoot and root meristems of susceptible plants [4]. At 40 DAS, treatments receiving sequential application of pendimethalin followed by post emergent herbicides along with single intercultivation recorded significantly lower weed density compared to unweeded check as well as recommended treatments (T_3 and T_4). Pendimethalin fb pyrithiobac sodium + IC had least weed population (16.67 m^{-2}) and was significantly superior to other chemical treatments. Here, pyrithiobac sodium inhibited the enzyme acetolacetate synthase having a key role in fatty acid biosynthesis [5] and complimented the action of pendimethalin when used in sequence. Similarly, propaquizafop, quizalofop ρ tefuryl, fenaxoprop ethyl and quizalofop ethyl complimented pendimethalin due their inhibitory action on enzyme Acetyl CoA corboxilase (Accase) [1]; degree of control, nevertheless, varied with chemical and the dozes used. Further from 60 DAS onwards up to harvest, there was no significant effect of weeds on crop, because by then the cotton crop itself could smother the associated freshly germinating or emerging weeds due to its fully developed canopy as evidenced from LAI.

Leaf area index, a derivative of leaf area, increased with advancement in age up to 90 DAS and thereafter decreased towards maturity (Table 1). At 45 DAS, weed free check recorded the highest leaf area index (1.15) and was on par with rest of treatments except pendimethalin + IC + HW (1.02), pendimethalin fb propaquizafop + IC (1.01) and diuron + IC and HW (1.00) while, the lowest leaf area index (0.84) was recorded in unweeded check (0.84). At 90 DAS, also the highest leaf area (1.61) was recorded in weed-free check and was on par with all other treatments except unweeded check which had the lowest leaf area index (1.23). Similar trend prevailed at 135 DAS and at first picking time (at harvest). The reduced availability of light intensity and nutrients, and the microclimate in particular probably were not congenial for weeds with the advancement of cotton growth. The impact of cotton crop was specially aided by the intercultivation carried out at 60 DAS which took care of weeds that have emerged in between cotton rows. In general, all the treatments (except T_1) reduced weed density, wherein the least weed density (10.67 m^{-2}) was observed in pendimethalin fb pyrithiobac sodium + IC followed by other treatments viz., T_{11}, T_9, T_{10} and T_{13}. The results are conformity with earlier findings [2,6].

As a consequence of variation in weed density weed control efficiency varied significantly among treatments (Table 1). At 20 DAS, the highest weed control efficiency (55.73%) was recorded with diuron 80 WP @ 1.5 kg a.i. ha^{-1} and pendimethalin 38.7 CS @ 0.68 kg a.i. ha^{-1}. This fact highlights importance of effectiveness of both chemicals at early growth stage of cotton. Diuron helps the crop to establish better and make early growth under weed free situation. Dinitro analine herbicide pendimathalin also has similar effects [4]. It has been earlier reported that application of pendimethalin efficiently controlled the grassy weeds in cotton [7]. The finding corroborate well with earlier works [8,9]. However, pre emergent herbicides were not effective in controlling the weeds for longer period [10]. It has been revealed that sequential use of pre emergent and post emergent herbicides controlled weeds effectively [11,12]. In the present study also, at 40 DAS, the maximum weed control efficiency was observed in pendimethalin fb pyrithiobac sodium + IC (94%) which was on par with pendimethalin fb quizalofop ethyl + IC (90.03%) and pendimethalin

fb propaquizafop + IC (89.62%). At harvest the highest weed control efficiency was observed with pendimethalin fb pyrithiobac sodium + IC (88.61%); twice application of pyrithiobac sodium at 20 and 40 DAS + I C (82.05%) was at par. Results are in agreement with earlier works [13,14].

Table. 1 Weed density, weed control efficiency and leaf area index as influenced by different weed management practices in *Bt* cotton.

Treatments	Total weed density per m^2				Weed control efficiency (%)				Leaf area index (LAI)			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	45 DAS	90 DAS	135 DAS	At harvest
T_1	8.00 (63.00)	11.08 (121.67)	13.00 (168.00)	8.22 (66.67)	0.00	0.00	0.00	0.00	0.84	1.23	1.18	0.85
T_2	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100.0	100.0	100.0	100.0	1.15	1.61	1.60	1.37
T_3	4.68 (21.00)	5.52 (29.67)	5.48 (29.33)	4.82 (22.33)	55.73	79.73	51.53	53.19	1.00	1.54	1.44	1.21
T_4	5.05 (24.67)	8.72 (75.00)	6.68 (43.67)	5.31 (27.33)	49.70	48.94	42.67	44.34	1.02	1.52	1.42	1.16
T_5	7.74 (59.00)	7.08 (49.33)	5.94 (34.33)	5.50 (29.33)	2.93	71.83	79.05	80.71	1.07	1.54	1.44	1.21
T_6	7.70 (58.33)	7.74 (59.00)	6.27 (38.33)	6.22 (37.67)	1.25	62.75	76.19	77.86	1.04	1.52	1.43	1.17
T_7	7.68 (58.00)	7.83 (60.33)	6.29 (38.67)	6.24 (38.00)	4.14	60.98	75.27	77.27	1.05	1.50	1.46	1.19
T_8	7.96 (62.33)	7.23 (51.33)	6.16 (37.00)	4.54 (19.67)	6.02	72.41	77.82	79.16	1.07	1.54	1.43	1.17
T_9	7.77 (59.33)	5.88 (33.67)	5.38 (28.00)	3.87 (14.00)	6.61	76.20	82.05	83.38	1.05	1.49	1.44	1.18
T_{10}	5.16 (25.67)	5.50 (29.33)	5.06 (24.67)	3.91 (14.33)	50.40	89.62	81.95	85.95	1.01	1.50	1.44	1.18
T_{11}	5.15 (25.67)	6.90 (47.00)	5.74 (32.00)	3.74 (13.00)	47.54	85.49	78.97	80.97	1.09	1.54	1.45	1.19
T_{12}	4.89 (23.00)	7.20 (51.00)	5.72 (32.00)	5.00 (24.00)	49.83	84.46	77.83	80.17	1.09	1.49	1.45	1.19
T_{13}	5.03 (24.33)	5.57 (30.00)	4.80 (22.00)	4.20 (16.67)	46.43	90.03	83.21	82.77	1.09	1.50	1.41	1.17
T_{14}	5.25 (26.67)	4.20 (16.67)	4.12 (16.00)	3.41 (10.67)	45.41	94.02	87.61	88.61	1.08	1.53	1.44	1.17
S. Em±	0.19	0.22	0.18	0.14	2.57	1.58	2.89	3.19	0.04	0.06	0.05	0.07
CD at 5%	0.55	0.65	0.52	0.41	7.47	4.59	8.40	9.28	0.11	0.17	0.16	0.21

*Figures in the parenthesis are original values, Data subjected for transformation using $(x+1)^{\frac{1}{2}}$, where x is weed count.

Further, nutrient uptake by cotton was greatly influenced by weed control treatments (Table 2). Of these, weed free treatment recorded the highest nutrient uptake (157, 45.67 and 157.67 kg ha^{-1}, N, P and K) closely followed by pendimethalin fb pyrithiobac sodium + IC (156.17, 45.14 and 155.25 kg ha^{-1}, N, P and K). In fact the nutrient uptake was the function of crop dry matter and nutrient content of plants. Higher nutrient uptake with these treatments was due to minimum weed competition particularly during critical period which helped in better uptake of nutrients and in turn improved plant growth [15]. Probably, this has also helped in further partitioning of photosynthates to fruiting parts. Results revealed highest and lowest number of bolls per plant (44 and 26, respectively) with weed-free check and unweeded check (Table 2). Treatments T_{10} (44 $plant^{-1}$), T_{14} (43 $plant^{-1}$) and T_{13} (43 $plant^{-1}$) also recorded higher numbers of bolls in ascending order and were on par with weed free check. Similarly, good opened bolls per plant were higher in weed free check; T_{14} and T_{13} were on par (42, 41and 41 $plant^{-1}$, respectively) and were significantly superior to other treatments. The least number of good opened bolls (19 $plant^{-1}$) was recorded in unweeded check. On the other hand, number of bad opened bolls per plant was the highest (7) in unweeded check among all. Treatments weed free check, T_{13} and T_{14} were on par with each other and recorded lower number of bad opened bolls (2 $plant^{-1}$). All the treatments including weed free (7.83) were comparable (weedy 7.83) in seed index but were superior to unweeded check (5.63) (Table 2). The highest lint index (4.43) was observed in weed free check and was on par with all the sequential herbicide treatments viz., T_{13} (4.28), T_{10} (4.28), T_{14} (4.26), T_{12} (4.19) and T_{11} (4.16) (Table 2). The

lowest lint index (3.39) was observed in unweeded check. The improved crop growth and fruiting parts due to weed control ultimately had significant influence on seed cotton yield. Among the chemical treatments sequential applications of pendimethalin PRE fb pyrithiobac sodium POST + IC produced higher seed cotton per plant (144 g) followed by the treatment receiving pendimethalin PRE fb quizalofop ethyl 5 EC (140 g) or propaquizafop 10 EC (137 g) POST + IC which were on par with weed free check (154.52 g) while weedy check had lowest seed cotton per plant (88.80 g). As a consequence sequential applications of pendimethalin PRE fb pyrithiobac sodium POST + IC produced higher seed cotton per hectare (2569 kg) among herbicidal treatments followed by the treatment receiving pendimethalin PRE fb quizalofop ethyl 5 EC (2333 kg) or propaquizafop 10 EC (2361 kg) POST + IC which were on par with weed free check (2695 kg) while weedy check had lowest seed cotton per hectare (1478 kg). Yield increments with former treatments were to the tune of 73.81, 57.84, 59.7 percent, respectively over unweeded check owing to reduction in weed count, weed dry matter yield and corresponding improvement in weed control efficiency and consequent improvement in growth of cotton due to improved nutrient uptake (Table 2).

Table 2. Nutrient uptake, bolls, seed and lint index, seed cotton yield and net returns as influenced by weed management practices in *Bt* cotton.

Treatments	Nutrient up take (kg ha^{-1})			Opened bolls plant^{-1}			Seed index	Lint index	Seed cotton yield (g plant^{-1})	Seed cotton yield (kg ha^{-1})	Net return (Rs ha^{-1})
	N	P	K	Good	Bad	Total					
T_1	71.67	24.33	71.67	19	7	26	5.63	3.39	88.80	1478	35082
T_2	157.00	45.67	157.67	42	2	44	7.83	4.43	154.52	2695	76197
T_3	145.33	37.94	140.58	36	3	39	7.13	3.67	115.77	1977	53451
T_4	144.33	38.32	139.57	36	3	39	7.69	3.64	108.29	1839	48995
T_5	137.19	38.25	142.82	31	3	34	7.41	3.70	117.35	2007	53017
T_6	133.92	35.42	136.51	27	4	31	7.71	3.61	100.85	1701	42494
T_7	132.23	35.33	136.00	28	4	32	7.62	3.63	98.37	1655	38776
T_8	139.01	38.80	143.47	31	3	34	7.76	3.79	118.09	2020	55458
T_9	141.67	41.09	145.46	32	4	36	7.78	3.86	123.89	2128	55019
T_{10}	153.75	43.80	152.65	41	3	44	7.66	4.28	137.84	2361	68502
T_{11}	151.07	42.28	150.59	37	3	40	7.63	4.16	118.72	2032	55815
T_{12}	149.05	41.53	148.22	38	3	41	7.74	4.19	117.98	2018	54356
T_{13}	155.55	44.50	153.51	41	2	43	7.72	4.28	140.36	2333	68234
T_{14}	156.17	45.14	155.25	41	2	43	7.77	4.26	144.10	2569	75670
S.Em±	1.68	0.75	1.95	0.64	0.30	0.55	0.33	0.10	5.93	105	4409
CD at5%	4.89	2.19	5.67	1.85	0.87	1.60	0.97	0.29	17.23	305	12817

The results are in agreement with previously published data [1]. The net return per rupee spent was also the highest in weed free check (3.65) which was on par with pedimethalin followed by pyrithiobac sodium coupled with one intercultivation (3.35) (Table 2). Even though the weed free check had higher B:C ratio, farmers are not able to maintain the weed free condition throughout the cropping period due to labour scarcity, high cost and seasonal demand. Therefore, the best alternative is to adopt integrated weed management involving pendimethalin PRE (1-2 days of sowing) - pyrithiobac sodium/quizalofop ethyl POST (30-35DAS) + intercultivation at 60 DAS.

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