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Bioefficacy of sequential application of herbicides in cotton

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Abstract

A field experiment was conducted for two years during *kharif* 2011-12 and 2012-13 to study the bio-efficacy of sequential application of herbicides in Bt cotton. Ten weed control treatments were tested in randomised block design and they were replicated thrice. The mean of two years data indicated that, all the herbicide treatments significantly reduced dry weight of weeds over unweeded control. Among the herbicide treatments sequential application of Pyrithiobac sodium at 0.125 kg/ha as pre emergence followed by (fb) Pyrithiobac sodium at 0.125 kg/ha as post emergence, Butachlor at 1.5 kg/ha fb Butachlor at 1.5 kg/ha and Pendimethalin 38.7% CS 0.68 kg/ha fb Pendimethalin 38.7% CS 0.68 kg/ha were quite effective in controlling weeds which reflected in significantly decreased weed dry weight and increased weed control efficiency. These three herbicide treatments also recorded significantly higher yield (2863, 2830 and 2725 kg/ha, respectively). The growth and yield parameters followed similar trend as that of yield. The weed index was also lower in the above three treatments (11.43, 12.45 and 15.45 %, respectively) compared to un weeded control (76.56 %).

Keywords: Bt cotton, kapas yield, sequential application of herbicides, weed index, weed dry weight, WCE

Introduction

Cotton (*Gossypium* spp.) is an important commercial fibre crop grown under diverse agro-climatic conditions around the world. It is called as a “white gold” and as “king of fibre crops”. It is cultivated in tropical and sub tropical regions of more than 111 countries. It provides the main raw material for textile industry. Cotton is the most important global cash crop and controls economy of many nations. It provides gainful employment to several million people during its cultivation, trade, processing, manufacturing and marketing. Cotton and cotton textile industries are engines of economic growth in both developed and developing countries.

India is the largest producer of cotton occupies 37.56 % of world cotton area and produces 24.26% of world cotton production. In India, it is grown in an area of 13.0 m ha with a production of 295 lakh bales and productivity of 494 kg/ha. In Karnataka it is grown in an area of 5.50 lakh ha with production of 18.00 lakh bales and productivity of 556 kg/ha (Anon., 2019) [1].

The productivity of cotton in the country is far below the world average (764 kg/ha). Major hurdle for the productivity of the crop being cultivated in rainfed areas with predominantly in small holdings. Yield level in small holdings are often reduced because of competition among crops for land and labour, leading to lack of timeliness in field operations and to difficulties in weed control, insect control and picking (Hamdy *et al.*, 1994 [11]). Ramasundaram and Hemchandra (2001) [26] reported that plant density followed by pest control and weed control are the biggest contributors to yield gap, represented by the difference between the recommended method using suitable stand density, weed management and pest control with a highest yield of 1910 kg/ha and the actual farmers production practices (802 kg/ha).

Cotton crop is unable to express its full potential because of biotic and abiotic stresses encountered during its life cycle. Among various factors like poor plant population, damage due to insect pests, imbalanced use of fertilisers and weeds, weeds alone reduce the seed cotton yield to the extent of 30 per cent. The yield losses due to weed competition in cotton crop are estimated to vary from 40 to 85% (Jain *et al.*, 1981 [12], Brar and Gill, 1985 [5], Deshmukh and Mudholkar, 1988 [7] and Shelke and Bhosle, 1990 [31]). Therefore, control of weeds is essential to reduce the yield gap between actual and potential yield. Among the different agronomic constraints that would influence the productivity of cotton crop, weed infestations have historically been a major issue.

Management of weeds is considered to be an important step for achieving higher productivity. Despite many advances in weed management technology, cotton growers still face significant challenges from weeds.

The initial slow growth of cotton accompanied by wider spacing provide a greator window for weed competition, where plants cannot compete with the fast growing weeds particularly during initial 50 to 60 days. Cotton seedlings have relatively poor vigour and competetor against weeds. Even moderate weed infestations can reduce cotton yields. Weed control needs to be maintained for at least 10 to 14 weeks after cotton emergence to achieve maximum cotton yields (Graham Charles, 2002 [10]).

In cotton, weeds cause several direct and/or indirect negative impacts, such as reducing crop yield, reducing fiber quality, reducing irrigation efficiency, increasing production costs and serving as hosts and habitats for insect pests, disease-causing pathogens, nematodes and rodents. Weeds can directly hinder cotton growth by competing for available resources such as light, moisture, nutrients, space and in some cases, by releasing allelopathic or growth-suppressing chemicals. However, the degree of damage from weed competition depends on the weed species composition, weed densities and duration of weed-crop competition.

Timely and effective weed management practices also play an important role in boosting the productivity of cotton. To sustain crop productivity, the elimination of crop weed competition is of prime importance. Under Indian conditions, normally weeding is done 3 to 4 times manually for the above reasons. For this, the number of labours required for weeding is high and in the present context the labour is not available, whose cost is ever increasing, resulting in increased cost of cultivation. Further, in many instances it is difficult to control weeds through cultural operations due to unfavorable weather conditions *viz.*, incessant rains, wetness, dry condition, *etc.* Thus the progressive modernization of agriculture involving intensive use of herbicide is gaining popularity in recent years due to lower cost, easy and timely application and effectiveness in controlling weeds.

A number of broad spectrum herbicides (Pendimethalin, Butachlor, Alachlor, Diuron Pyrithiobac and Oxyfluorfen) are available for use in cotton. These herbicides are quite effective in controlling annual weeds during critical period of crop weed competition.

In long duration, initial slow growth crop like cotton weeds flourish even after critical period of crop weed competition and it is difficult to achieve effective weed control with single application of herbicides (pre emergence or post emergence). Hence, in order to control weeds for a longer period of crop growth there is needs to apply herbicides on sequential basis. Studies conducted by various authors clearly indicated that sequential application of herbicides will provide consistent weed control than single application (Singh, *et al.*, 2004 [32], Nadanassababady, *et al.*, 2000 [19]). A well planned pre emergence followed by post emergence will provide more consistent weed control. The most complete sequential application of herbicide includes use of pre emergence herbicides with on key broadleaf weeds that also provides at least some early season control of grasses, followed by post emergence herbicides with activity on grasses and broadleaf weeds.

Further, a well-planned sequential application of herbicide is the need of the hour to provide more consistent weed control for longer period especially conventional method of weed control are difficult to practice due to unfavorable weather conditions. Therefore the present investigation was undertaken to study the Bio efficacy of sequential application of herbicides on weed control and growth and yield of Bt cotton.

Material and Methods

Field experiment was conducted for two years in Agricultural Research Station Dharwad in Bt cotton during *kharif* seasons of 2011-12 and 2012-13. The soil of the experimental site was medium deep black (clayey) with low available nitrogen, medium P_2O_5 and high available K_2O. The experiment was laid out in randomised complete block design with 10 treatments and replicated thrice. The Bt cotton hybrid Mallika was sown on 23rd June 2011 and 6th July 2012 at a spacing of 90 cm X 45 cm. The recommended dose of 100:50:50 kg N, P_2O_5 and K_2O per ha was applied in the form of urea, diammonium phosphate and muriate of potash to all plots uniformly. Herbicides were sprayed as per treatments with knapsack sprayer @750 lit/ha. Visual observations were recorded after pre emergence application and post emergence spray to know the extent of toxicity caused by different herbicides on crop and the extent of weed control by different weed control treatments as given by Rao (1986) [27]. Observation on weed dry weight was recorded from one square meter quadrat at 20, 40 and 60 days after sowing (DAS). Weed control index (WCI) denotes the magnitude of reduction in weed dry weight due to weed control treatments. It was calculated by using the formula given by Mishra and Tosh (1979) [17].

$$\text{WCI} = \frac{\text{Weed dry weight in unweeded control (g)} - \text{Weed dry weight in treatment (g)}}{\text{Weed dry weight in unweeded control (g)}} \times 100$$

Weed index is the reduction in crop yield due to presence of weeds in comparison with weed free check plot. It expresses the competition offered by the weeds as measured by reduction in yield owing to their presence. It was worked out by using the formula as given by Gill and Vijay Kumar (1969) [8].

$$\text{Weed Index (\%)} = \frac{X - Y}{X} x100$$

Where,
X = Total seed cotton yield from weed free plot
Y = Yield from the treatment plot for which weed index is to be worked out.

Leaf area index (LAI) was worked out by dividing the leaf area per plant by the land area occupied by the plant. This formula suggested by Sestak *et al.* (1974) [29].

$$\text{LAI} = \frac{\text{Leaf area plant}^{-1}\ (\text{dm}^2)}{\text{Land area occupied by the plant (dm}^2)}$$

Observations on crop were recorded as per the standard procedure. This weed dry weight data were subjected to square root transformation of $\sqrt{X + 1.0}$ before analysis. Fischer's method of analysis of variance was used for analysis and interpretation of the data as outlined by Gomez and Gomez (1984) [9]. The level of significance used in 'F' and 'T' tests was p=0.05. Critical differences were calculated wherever 'F' test was significant. The results of mean data of two years are discussed since the results during both the years were consistent.

Results and Discussions
The dominant weeds observed in the experimental area were, *Brachiaria eruciformis, Cynodon dactylon, Dinbra retraflexa and Digitaria marginata* among the grassy weeds, *Cyperus rotundus* among the sedges and among the broad leaved weeds *Acalypha indica, Ageratum conyzoides, Alternanthera sessilis, Amaranthus viridis, Commelina benghalencis, Convolvulus arvensis, Corchorus trilocularis, Crozophora rottleri, Digera arvensis, Euphorbia hirta, Mollugo disticha, Parthenium hysterophorus, Phyllanthus medraspatensis, Phyllanthus niruri* and *Trichodesma zeylanicum*. Similar flux of weed flora associated with cotton crop was also observed by Arun (1990) [2], Patil (1999) [22], Bharathi *et al.* (2011) [3] and Prabhu *et al.* (2011) [24].

Effect of sequential application of herbicides on weeds
Weed dry weight differed significantly due to weed control treatments (Table 1). At all the crop growth stages, the lowest weed dry weight was noticed in weed free check. This could be attributed to control of weeds by hand weeding at regular intervals, which resulted in reduced dry matter production of weeds. On the other hand, weedy check recorded the highest weed dry weight. This was mainly due to higher and uninterrupted growth of weeds resulting in greater crop weed competition due to better use of growth resources. These results are in conformity with the findings of Patil (2010) [23] and Rajkumara (2009) [25].

All the herbicide treatments recorded significantly lower weed dry weight at all the stages compared to weedy check. The decreased dry weight of weeds in all the herbicide treatments could be attributed to decreased weed population with better control and increased weed control index.

At 20 DAS, all the herbicide treatments recorded significantly lower weed dry weight compared to sequential application of pendimethalin 30% EC @ 1.5 kg/ha fb pendimethalin 30% EC @ 1.5 kg/ha(T_1), alachlor 50% EC @ 2.0 kg/ha fb alachlor 50% EC @ 2.0 kg/ha(T_3) and recommended practice (T_8). At later stages sequential application of pyrithiobac sodium 10% EC @ 0.125 kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha (T_7) recorded significantly lower weed dry weight (1.04, 1.26 and 1.62, at 20, 40 and 60 DAS, respectively) and this was on par with the sequential application of butachlor 50% EC @ 1.5 kg/ha fb butachlor 50% EC @ 1.5 kg/ha, pendimethalin 38.7% CS @ 0.68 kg/ha fb pendimethalin 38.7% CS @ 0.68 kg/ha and weed free check. The lower weed dry weight in the above treatments was mainly due to lower population of grasses, sedges and broad leaved weeds. Reasons could be attributed to direct phytotoxic effect of sequential application of herbicides as well as cumulative effect of herbicides sprayed as pre emergence. Pyrithiobac is readily absorbed by plant roots following pre emergence application and by plant foliage following post emergence application and inhibit acetolactate synthase in susceptible plants. The results are in conformity with the findings of Muthusankaranarayanan *et al.* (1988) [18] and Panwar *et al.* (1999) [21]. Pre emergence and post emergence use of pyrithiobac sodium in cotton provides excellent selective control of many troublesome weeds (Snipes and Seifert, 2003) [34].

Performance of crops is directly related to the weed control index and inversely related to the weed index. In the present study among the weed control treatments, sequential application of pyrithiobac sodium 10% EC @ 0.125kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha, butachlor 50% EC @ 1.5 kg/ha fb butachlor 50% EC @ 1.5 kg/ha, pendimethalin 38.7% CS @ 0.68 kg/ha fb pendimethalin 38.7% CS @ 0.68 kg/ha and oxyfluorfen 23.5% EC @ 0.2 kg/ha fb oxyfluorfen 23.5% EC @ 0.2 kg/ha recorded the maximum weed control index at all the stages (Table 1). The higher weed control index with these treatments could be attributed to lower weed dry weight and weed number in these treatments. These results corroborate with the findings of Muthusankaranarayanan *et al.* (1988) [18], Panwar *et al.* (1999) [21] and Nalini *et al.* (2011) [20].

Weed index, which is a measure of yield reduction due to weed competition, was the highest in weedy check (76.56%) (Table 2). This was due to lower seed cotton yield in weedy check as a consequence of severe competition offered by unchecked weed growth for nutrients, moisture and light as indicated by poor growth and yield components. The lowest weed index was recorded with sequential application of pyrithiobac sodium 10% EC @ 0.125 kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha (11.43%) and it was followed by butachlor 50% EC @ 1.5 kg ha^{-1} fb butachlor 50% EC @ 1.5 kg/ha, pendimethalin 38.7% CS @ 0.68 kg/ha fb pendimethalin 38.7% CS @ 0.68 kg/ha, oxyfluorfen 23.5% EC @ 0.2 kg/ha fb oxyfluorfen 23.5% EC @ 0.2 kg/ha and recommended practice and these were on par with each other. This was mainly due to the higher seed cotton yield realized in these treatments due to improved growth as a consequence of effective control of weeds and reduction in the crop weed competition. This might have enabled the crop to take up more nutrients. Brar and Gill (1993) [5] also found poor yield of cotton due to severe competition for growth resources offered by rapid growth of weeds. Such yield reduction due to weed competition was also observed by Shelke and Bhosle (1990) [31], Thind *et al.* (1995) [36] and Bharathi *et al.* (2011) [3].

Effect of sequential application of herbicides on cotton
Herbicides are often selective and crop specific. Understanding the suitable time of herbicide application is more important to avoid crop damage since their specific nature of mode of action. If we use pre emergence herbicides as post emergence there may be chances of crop injuries though selective to specific crop. Therefore, the rating of toxicity was carried in the investigation after each time spray. At pre emergence spray, among the different herbicides, pre emergence application of oxyfluorfen 23.5% EC @ 0.2 kg/ha indicated slight toxicity on cotton at 7th DAS. There was slight stunting and scorching symptoms on cotyledons. The symptoms resulted in little stand loss at 14 DAS. These symptoms persisted up to 35 DAS and later on crop recovered. Some scorching symptoms were also observed in sequential application in the same treatment but these symptoms were not persisted after 28 days after sequential application. Sreenivas (2000) [35] also observed the injurious effect of oxyfluorfen (@ 0.25 kg/ha) on cotton. Sequential application of other tested herbicides were safe for cotton. Pyrithiobac has been reported to control troublesome broadleaf weeds when applied as pre plant incorporation, pre emergence and post emergence application without adverse effects on cotton growth and yield (Jordan *et al.*, 1993a [13], 1993b [14]; Keeling *et al.*, 1993 [15]; Shankale *et al.*, 1996[30]; Snipes and Allen, 1996 [33]).

Yield is the net result of various interactions *viz.*, climate, soil moisture, growth components, crop-weed competition, nutrient uptake by crop and weeds and various physiological processes occurring within plant during the growing period. Weeds offer serious competition to cotton and cause drastic reduction of yield. Timely control of weeds helps to reduce the crop weed competition and ultimately better utilization of resources to produce higher yield.

Seed cotton yield varied significantly due to different weed management practices (Table 2). Significantly the highest seed cotton yield was obtained with weed free check (3219 kg/ha) compared to any other treatments and weedy check (763 kg/ha). The weed free check recorded 322 per cent higher yield than weedy check. Among the herbicide treatments, sequential application of pyrithiobac sodium 10% EC @ 0.125 kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha recorded significantly higher seed cotton yield (2863 kg/ha) followed by butachlor 50% EC @ 1.5 kg/ha fb butachlor 50% EC @ 1.5 kg/ha (2830 kg ha^{-1}), pendimethalin 38.7% CS @ 0.68 kg/ha fb pendimethalin 38.7% CS @ 0.68 kg/ha (2725 kg/ha), oxyfluorfen 23.5% EC @ 0.2 kg/ha fb oxyfluorfen 23.5% EC @ 0.2 kg/ha (2738 kg/ha) and recommended practice (2675 kg/ha) which were on par. The increase in yield in these treatments was to the tune of 275, 271, 257, 259 and 251 per cent over unweeded check, respectively. The higher seed cotton yield in these treatments could be attributed to improved yield components *viz.*, number of bolls/plant, boll weight and seed cotton yield/plant. This improvement in turn was due to improved growth attributes such as higher total dry matter production and distribution in different parts, higher leaf area, leaf area index and sympodial branches/plant.

Thus, the improvement in crop growth and yield components was the consequence of lower crop weed competition occurred due to weed free environment with sequential application of herbicides, which shifted the balance in favour of crop in the utilization of nutrients, moisture, light and space. Such improvement in growth and yield parameters and yield due to reduced weed competition was also reported by Sadangi and Barik (2007) [28], Prabhu *et al.* (2011) [24] and Bharathi *et al.* (2011) [3].

Differences in seed cotton yield among different weed management practices observed were largely because of differences in yield as well as growth components. Significant differences in the seed cotton yield per hectare could be attributed to the significant differences in the yield components (Table 2) such as, number of bolls per plant and boll weight. Weed free check recorded significantly higher number of bolls per plant (22.23), which is the most important factor deciding the seed cotton yield per plant. Among the herbicide treatments, sequential application of pyrithiobac sodium 10% EC @ 0.125 kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha, butachlor 50% EC @ 1.5 kg/ha fb butachlor 50% EC @ 1.5 kg/ha and pendimethalin 38.7% CS @ 0.68 kg/ha fb pendimethalin 38.7% CS @ 0.68 kg/ha (20.60, 20.27 and 19.23, respectively) recorded significantly higher number of bolls/ plant.

Boll weight also varied with weed management practices. Significantly larger sized bolls (6.13 g) were noticed in plots kept free from weeds throughout the season. Among the herbicide treatments, sequential application of pyrithiobac sodium fb pyrithiobac, butachlor fb butachlor, pendimethalin 38.7% CS fb pendimethalin 38.7% and oxyfluorfen fb oxyfluorfen recorded significantly higher boll weight (5.92, 5.88, 5.83 and 5.79 g, respectively). It can be attributed to higher leaf area, leaf area index and thus greater photosynthesis and dry matter production and also better translocation of metabolites for boll development. It was due to reduced weed competition in these treatments. On the other hand, significantly smaller sized bolls (5.15 g) were noticed in the plots where the weeds left undisturbed throughout the season. These results are in conformity with the findings of Prabhu *et al.* (2011) [24] and Kelaginamani (1997) [16].

The differences in various yield components of Bt cotton, which led to the significant yield differences among weed management practices could be traced back to differences in growth components. Total dry matter production (Table 3) differed significantly. Weed free check recorded significantly higher total dry matter production. Among the herbicide treatments, sequential application of pyrithiobac sodium 10% EC @ 0.125 kg/ha fb pyrithiobac sodium 10% EC @ 0.125 kg/ha recorded significantly higher total dry matter production (269.8 g/plant) which was on par with sequential application of butachlor 50% EC @ 1.5 kg/ha fb butachlor 50% EC @ 1.5 kg/ha (264.4 g/plant). This was the result of luxuriant crop growth as indicated by higher plant height (118.5 cm), higher number of monopodial (3.10) and sympodial (18.6) branches and higher leaf area index (2.08) which ensured higher dry matter production and its distribution in different parts like stem, leaves and reproductive parts.

On the other hand, total dry matter production was significantly lower in weedy check (107.6 g/plant). Sequential application of pendimethalin 30% EC fb pendimethalin 30% EC, alachlor fb alachlor and diuron fb diuron recorded significantly lower dry matter among the herbicide treatments but they remained significantly high compared to weedy check. The decrease in the total dry matter production of cotton in weedy check may be well associated with severe competition from profusely grown weeds with crop for moisture, nutrients, light and space. Since weeds being wild forms have greater competitive ability than domestic crops. Kelaginamani (1997) [16] and Bouchagier *et al.* (2008) [4] also noticed reduction in dry matter due to uncontrolled weeds.

Table 1: Total dry weight of weeds (g/m^2) and Weed control Index (%) as influenced by sequential application of herbicides in Bt cotton. (Pooled mean of 2011-12 and 2012-13)

No.	Treatments	Total dry weight of weeds (g/m^2)			Weed control Index (%)		
		20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1	Pendimethalin 30% EC @ 1.5 kg/ha fb Pendimethalin 30% EC @ 1.5 kg/ha	1.49 * (1.28)	2.72 (6.50)	3.17 (9.17)	89.04	83.77	90.80
T_2	Pendimethalin 38.7% CS @ 0.68 kg/ha fb Pendimethalin 38.7% CS @ 0.68 kg/ha	1.03 (0.07)	1.49 (1.25)	2.21 (4.00)	99.30	96.88	95.93
T_3	Alachlor 50% EC @ 2.0 kg/ha fb Alachlor 50% EC @ 2.0 kg/ha	1.31 (0.73)	2.39 (4.83)	2.89 (7.50)	93.58	87.93	92.52
T_4	Butachlor 50% EC @ 1.5 kg/ha fb Butachlor 50% EC @ 1.5 kg/ha	1.00 (0.00)	1.46 (1.17)	1.97 (2.92)	100.00	97.10	97.10
T_5	Diuron 80% WP @ 1.0 kg/ha fb Diuron 80% WP @ 1.25 kg/ha	1.04 (0.08)	2.02 (3.25)	3.01 (8.08)	98.89	91.73	91.88
T_6	Oxyfluorfen 23.5% EC @ 0.2 kg/ha fb Oxyfluorfen 23.5% EC @	1.00 (0.00)	1.52 (1.33)	2.31 (4.42)	100.00	96.79	95.56

	0.2 kg/ha						
T_7	Pyrithiobac-sodium 10% EC @ 0.125 kg/ha fb Pyrithiobac-sodium 10% EC @ 0.125 kg/ha	1.04 (0.08)	1.26 (0.58)	1.62 (1.67)	99.07	98.54	98.29
T_8	RPP: Pendimethalin 30 EC @ 1.5 kg/ha + HW at 40 DAS + IC at 60 DAS	1.23 (0.52)	2.16 (3.75)	2.81 (7.00)	95.23	91.37	92.89
T_9	Weed free check	1.00 (0.00)	1.14 (0.30)	1.29 (0.67)	100.00	99.26	99.32
T_{10}	Unweeded check	3.46 (11.17)	6.59 (42.75)	10.07 (100.50)	--	--	--
	SEm±	0.09	0.11	0.20	1.10	1.04	0.91
	C D @ 5%	0.26	0.34	0.60	3.28	3.16	2.97

fb: followed by, IC: Intercultivation, HW: hand weeding, DAS: Days after sowing, Values in parenthesis indicate original values,
* $\sqrt{X + 1.0}$ transformed values T_1 to T_7 – Intercultivation at 30 and 60 DAS RPP: Recommended package of practice

Table 2: Yield and yield components of Bt cotton as influenced by sequential application of herbicides. (Pooled mean of 2011-12 and 2012-13)

Tr. No.	Treatments	Total number of bolls/plant	Boll weight (g)	Seed cotton yield kg/ha	Weed Index (%)
T_1	Pendimethalin 30% EC @ 1.5 kg/ha fb Pendimethalin 30% EC @ 1.5 kg/ha	17.17	5.62	2416	25.46
T_2	Pendimethalin 38.7% CS @ 0.68 kg/ha fb Pendimethalin 38.7% CS @ 0.68 kg/ha	19.23	5.83	2725	15.94
T_3	Alachlor 50% EC @ 2.0 kg/ha fb Alachlor 50% EC @ 2.0 kg/ha	17.93	5.62	2468	23.93
T_4	Butachlor 50% EC @ 1.5 kg/ha fb Butachlor 50% EC @ 1.5 kg/ha	20.27	5.88	2830	12.45
T_5	Diuron 80% WP @ 1.0 kg/ha fb Diuron 80% WP @ 1.25 kg/ha	17.87	5.69	2548	21.13
T_6	Oxyfluorfen 23.5% EC @ 0.2 kg/ha fb Oxyfluorfen 23.5% EC @ 0.2 kg/ha	19.07	5.79	2738	15.07
T_7	Pyrithiobac-sodium 10% EC @ 0.125 kg/ha fb Pyrithiobac-sodium 10% EC @ 0.125 kg/ha	20.60	5.92	2863	11.43
T_8	RPP: Pendimethalin 30 EC @ 1.5 kg/ha + HW at 40 DAS + IC at 60 DAS	18.83	5.72	2675	17.26
T_9	Weed free check	22.23	6.13	3219	-
T_{10}	Unweeded check	7.40	5.15	763	76.56
	SEm±	0.48	0.06	93	2.01
	C D @ 5%	1.45	0.19	278	6.48

fb: followed by, IC: Intercultivation, HW: hand weeding, DAS: Days after sowing, RPP: Recommended package of practice, T_1 to T_7 – Intercultivation at 30 and 60 DAS

Table 3: Growth Parameters (at harvest) of Bt cotton as influenced by sequential application of herbicides. (Pooled mean of 2011-12 and 2012-13)

Tr. No.	Treatments	Plant height (cm)	Leaf area Index	Monopodial branches/ plant	Sympodial Branches / plant	Total dry matter production (g/plant)
T_1	Pendimethalin 30% EC @ 1.5 kg/ha fb Pendimethalin 30% EC @ 1.5 kg/ha	103.5	1.64	2.43	16.1	208.3
T_2	Pendimethalin 38.7% CS @ 0.68 kg/ha fb Pendimethalin 38.7% CS @ 0.68 kg/ha	112.8	1.92	2.83	17.9	239.3
T_3	Alachlor 50% EC @ 2.0 kg/ha fb Alachlor 50% EC @ 2.0 kg/ha	106.9	1.74	2.50	17.0	213.8
T_4	Butachlor 50% EC @ 1.5 kg/ha fb Butachlor 50% EC @ 1.5 kg/ha	115.3	2.07	2.97	18.6	264.4
T_5	Diuron 80% WP @ 1.0 kg/ha fb Diuron 80% WP @ 1.25 kg/ha	104.9	1.74	2.47	16.8	217.3
T_6	Oxyfluorfen 23.5% EC @ 0.2 kg/ha fb Oxyfluorfen 23.5% EC @ 0.2 kg/ha	112.3	1.84	2.77	17.9	232.7
T_7	Pyrithiobac-sodium 10% EC @ 0.125 kg/ha fb Pyrithiobac-sodium 10% EC @ 0.125 kg/ha	118.5	2.08	3.10	18.6	269.8
T_8	RPP: Pendimethalin 30 EC @ 1.5 kg/ha + HW at 40 DAS + IC at 60 DAS	110.0	1.84	2.57	17.8	235.0
T_9	Weed free check	126.8	2.21	3.20	19.9	295.6
T_{10}	Unweeded check	62.8	0.67	1.77	9.1	107.6
	SEm±	2.8	0.06	0.07	0.4	6.1
	C D @ 5%	8.4	0.17	0.22	1.1	18.2

fb: followed by, IC: Intercultivation, HW: hand weeding, DAS: Days after sowing, RPP: Recommended package of practice, T_1 to T_7 – Intercultivation at 30 and 60 DAS.

Conclusion

From this study it can be concluded that effective control of weeds, higher growth and yields of Bt cotton can be obtained with sequential application of pyrithiobac sodium fb pyrithiobac sodium, butachlor fb butachlor and pendimethalin 38.7% CS fb pendimethalin 38.7% CS.

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