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Review Article

A Review on Weed Management in Bt-Cotton

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A B S T R A C T

Cotton is highly vulnerable to weed competition especially in the initial stage of growth. As the cotton is slow growing crop while the growth of many weeds is very fast therefore, they produce competition and also suppress the growth of cotton. Cotton being a long duration crop, the critical period of weed competition prevails up to 60 to 90 DAS and during this period the crop needs weed free condition for better results. Losses caused by weeds in cotton ranges from 50 to 85 per cent depending upon the nature and intensity of weeds (Prabhu, 2012). Weeds exhibit allelopathy, competition and parasitism. It is common practice with the farmers to take up manual weeding and frequent inter cultivation (hoeing) in cotton. But scarcity of labour and high soil moisture conditions due to frequent irrigation or heavy rains during *kharif* make the farmers unable to take up timely cultural practices including hand weeding, besides such operations are time consuming, expensive and tedious. Hence, it has become imperative to control weeds by using herbicides in critical period and to get higher yields. Successful cotton production depends on an integrated management strategy that recognizes and adapts to the unique characteristics of the crop. Hence a brief review is presented on the nature of weed spectrum in cotton, competition between crops and weeds, different weed management practices and their effect on growth and yield of cotton.

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the predominant fiber crop and plays a pivotal role in agriculture, industrial development, employment generation and economic development of India. It is also called as "King of fibers" and "white gold " due to higher economical values among all cash crops in India. It is cultivated in an area of 118.81 lakh ha. with a total production of 352 lakh bales and its productivity is 503 kg lint ha^{-1} (Annual Report of AICCIP 2015-16). Weeds are major obstacles in successful cultivation of cotton. Cotton is highly vulnerable to weed competition especially in the initial stage of growth. Ayyadurai, *et al.,* (2013) reported that yield reduction due to weed in Bt. Cotton varies from 30 to 60 days of crop growth. Weed distribution and succession are always affected by management and environmental factors. Manual weeding has been synonymous with weed management for India since centuries, due to abundant availability of labour, cheaper labour costs and the nature of agriculture as an occupation. Hence, manual and mechanical methods were the prevalent weed management techniques used by farmers till the end of 1990s. During the

1990s, the nominal farm wages grew at 11.6% annually, while in the 2000s they rose at 8.9%. In the recent past, the growth was 17.8% during 2007-2008 and 2010-2011. The effect of increased wages and labour costs has concomitantly increased reliance on herbicides, applied alone or as a component of integrated weed management (IWM) [Rao *et al.,* 2014].

Integrated weed management approach based on critical period of crop weed competition, involving different direct and indirect control measures, has been developed and widely adopted by farmers to overcome weed problem in cotton in a sustainable way. The present review provides a broad overview of weeds of Bt cotton and their management as well as future outlook on developments in weed science in India. It includes weeds associated with Bt cotton, their critical stage, yield losses, cost-benefit analysis and suitable management practices. Care has also been taken to include the current status of weed research findings and adoptability challenges and opportunities for weed management.

Weed Spectrum in Field of Cotton Crop

Successful weed control programme depends mainly on the identification and understanding of weed community associated with crop. Weed flora differ widely in their diversity depending upon environmental and soil conditions and hence the information on the weed spectrum associated with cotton crop is essential for the formulation of effective weed management practices. Marnotte *et al.,* (1997) opined that effective long term weed management depends on a detailed knowledge of the development of weed flora under specific environmental conditions of the area and soil. A wide spectrum of weeds with greater adaptability to extremities of climatic, edaphic and biotic stresses is infesting the cotton fields. High persistence nature of weeds is attributed to their ability of high seed production and seed viability.

Cheema *et al.,* (2008) reported that all three different types of weeds, *viz.,* broad leaf weeds, grasses and sedges are noticed in Bt cotton fields. Broad leaf weeds comprising six species *viz., Trianthema portulacastrum* (L.), *Digera arvensis.* Forssk, *Amaranthus viridis* (L.), *Cucumis prophetarum* (L.), *Portulaca oleracea* (L.) and *Tribulus terrestris* (L.) was the dominant group with 54 per cent mean population followed by grasses like *Cynodon dactylon* (L.) Pers, *Dactyloctenum aegyptium* (L.), *Echinochloa colonum* (L.) Link occupying 31%. The lowest infestation of 15 per cent was that of sedges comprising a single species *viz., Cyperus rotundus* (L.) Among all the species *Trianthema portulacastrum* (L.) with 40 per cent density was the most serious weed infesting the trial field.

Rajput *et al.,* (2008) collected 76 species of weeds belonging to 21 families having at least 22 monocot species, of weeds belonging to Poaceae, Liliaceae and Cyperaceae; 57 broad leaved weeds species belonging to families Aizoaceae, Amaranthaceae, Asclepiadaceae, Asteraceae, Capparidaceae, Caesalpinaceae, Chenopodiaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Malvaceae, Portulaceae, Solanaceae, Tamaricaceae, Tiliaceae, Verbanaceae and Zygophylaceae were identified from the area, the species *Cyperus rotundus*, Cynodon *dactylon*, *Dicanthium annulatum*, *Erogristic poaeids*, *Chenopodium murale*, *C. alba*, *Meliolotus parvifolora*, *M. alba*, *Sporobolus cormendialens* and *Trianthema monogyna* are the most frequent weeds found in all cotton field of the study area.

Manikandan (2009) highlighted that the predominant weeds present in the experimental field of irrigated cotton were *Chloris barbata* and *Cynodon dactylon* under grasses, *Cyperus rotundus* under sedges and *Trianthema portulacastrum*, *Digera arvensis* and Parthenium under broad leaved weeds.

Bharathi *et al.,* (2011) reported that *Cyprus rotundus, Commalina bengalensis, Corchorus acutangulus, Amaranthus viridis, Abutilon indicum, Phyllanthus niruri, Celosia argentia,* Parthenium sp were the predominant weeds in experimental field of Bt cotton.

Prabhu (2012) advocated that predominant monocotyledonous weeds in the experiment were *Cyperus rotundus* L., *Cynodon dactylon* L. Pers, *Dinebra retroflexa, Echinochloa colonum* (L). Link, *Echinochloa crusgalli* (L.) Beauv and Tragus bifloris Schult. While common dicotyledonous weeds were *Abutilon indicum* (L.) Sweet, *Ageratum conyzoides* L., *Aristolochia bracteata Retz, Commelina benghalensis* L., *Cynaotis dactylon* L., *Digeria arvensis Forsk, Merremia emarginata* (L.) Cufod., *Mimosa pudica* L., *Parthenium hysterophorus* L., *Phyllanthus maderaspetensis, Phyllanthus fraternus* Webster, *Tribulus terrestris* L., *Xanthium strumarium* L., *Coccinia indica* and *Sesbania aculeata Pers*. Similar weed population was also reported by Khan and Khan (2003) and Shahzad *et al*., (2012).

Duraisamy *et al.,* (2013) observed that the broad leaved weeds dominated over grasses and sedge in transgenic maize and cotton crops. Among the weed species, *Trianthema portulacastrum, Cleome gynandra, Digera arvensis, Datura stramonium, Cynodon dactylon, Dactyloctenium aegyptium, Commelina bengalinsis* and *Cyperus rotundus* were predominant in maize field during both the seasons. Among broad leaved weeds, *Trianthema portulacastrum* was the dominant one during both the season of 2009 and 2010.

Ozaslan and Bukun (2013) conducted studies in Southeastern Anatolia Region of Turkey and result of the survey revealed that, 69 weeds specie were determined from 23 families and 49 genus, which were 1 seedless, 1 parasitic, 2 monocotyledoneae (monocots) and 21 dicotyledoneae (dicots). The most common species, found in more than 50% of cotton fields were *Xanthium strumarium* L. (common cocklebur), Physalis sp., *Amaranthus retroflexus* L. (amaranth), *Sorghum halepense* (L.) Pers. (johnson grass), *Solanum nigrum* L. (black nightshade), *Cyperus rotundus* L. (coco-grass) and *Portulaca oleracea* L. (pigweed).

Werth *et al.,* (2013) observe that in cotton based cropping systems a major species shift towards *Conyza bonariensis* and minor increase in *Sonchus oleraceus* at the end of the season. Several species including *C. bonariensis, S. oleraceus, Hibiscus verdcourtii* and *Hibiscus tridactylites, Echinochloa colona, Convolvulus sp., Ipomea lonchophylla*, *Chamaesyce drummondii, Cullen sp., Amaranthus macrocarpus,* and *Chloris virgata* were still present.

Ozaslan *et al.,* (2014) conducted a survey in Diyarbakır Province of Turkey the most common weeds in cotton production fields were *Xanthium strumarium* L. (common coclebur), *Sorghum halepense* (L.) Pers. (johnsongrass), *Amaranthus retroflexus* L. (common amaranth), *Cynodon dactylon* (bermudagrass), Physalis spp. (ground cherry) [*Physalis philadelphica Lam*. (Mexican groundcherry) and *Physalis angulata* L. (cutleaf groundcherry)], *Solanum nigrum* L. (black nightshade), *Portulaca oleracea* L. (purslane), *Cyperus rotundus* L. (nutgrass).

Ray *et al.,* (2014) reveals that 55 weeds belonging to 21 families and 47 genera have been reported in Bt cotton fields of Nimar region in Madhya Pradesh in which some exotic weeds were established as dominant in the Bt cotton field. Eleven weed have been recorded to be threatened in Nimar region due to of Bt cotton cultivation.

Singh *et al.,* (2014) conducted experiments, on comprising three Bt cotton hybrids in main, two plant geometries in sub and three nutrient levels in sub sub plots. He observed that, MRC-7361 recorded significantly the highest seed cotton yield (3121.6 kg ha^{-1}) followed by Bioseed 6488 (2649.5 kg ha^{-1}) and RCH 134 (2107.4 kg ha^{-1}). Owing to better fertilizer use efficiency (5.47) and water productivity (649.3 gm), highest net returns of < or = Rs.101047 ha^{-1} were observed with MRC7361 as compared to Bioseed 6488 (< or = Rs. 83343 ha^{-1}) and RCH134 (< or = Rs. 63014 ha^{-1}). Bolls per plant and benefit cost ratio was significantly enhanced under wider geometry of 67.5 x 90 cm. Application of 225 kg N, 45 kg P ha^{-1} produced significantly higher SCY (2825.9 kg ha^{-1}) owing to improved sympodias and bolls per plant than 150 kg N, 30 kg P ha^{-1} (2374.9 kg ha^{-1}) and 187.5 kg N, 37.5 kg P ha^{-1} (2677.6 kg ha^{-1}).

Critical Period of Crop Weed Competition

Papamichail *et al.,* (2002) reported that the presence of weeds for more than three weeks after crop emergence caused significant reduction in crop growth and lint yields. Cotton is very sensitive to weed competition in the first 60 days of crop growth.

Sivakumar and Subbian, (2002) observed 33–40% reduction in yield have been noted due to severe infestation of weed population. They also found higher weed biomass per square meter than that recorded in weed free treatments.

Webster (2005) found that the significant reduction in yield and yield attributes due to weed infestation over weed free treatments.

Spasova *et al.,* (2008) advocated the duration of weed presence with the crop and the time of weed emergence, generally affect crop-weed competition.

The critical period of crop-weed competition occurs when both the crop and weeds are in the same stage of growth. This period of weed-cotton competition varies from 3 to 9 weeks after sowing and depends on environmental factors and those related to both crop and weeds.

Ayyadurai and Poonguzhalan (2013) pointed that seed cotton yield loss increased in the duration of competition and maximum loss (96.5%) occurred due to full season competition. Seed cotton yield increased significantly with the increase in initial duration of weed free condition upto 80 DAS. Beyond 80 DAS, seed cotton yield was reduced considerably due to lower boll setting percentage. Critical period of weed competition was found to be 20 to 60 days after sowing. Poonguzhalan *et al.,* (2014) found that cotton was very sensitive to weed competition in the first 60 days of crop growth. The period of weed interference, crop damage and the critical period of crop-weed competition were 30 to 60 days which occupied 50 per cent of the whole cotton growing period. Seed cotton yield loss increased with the increase in the duration of competition and maximum loss was observed due to full season competition.

Tursun *et al.,* (2015) reported that the critical knowledge of crop-weed competition period is important for designing weed management strategies in cropping systems. Regardless of the N application rate, the relative yield of cotton decreased with increasing duration of weed-interference and increased with increasing duration of weed-free period. Depending on the N application rate, weedfree conditions need to be established as early as one week after crop emergence and maintained as late as eight weeks after crop emergence to avoid more than 5% loss in cotton yield. These findings could help cotton producers improve the cost effectiveness and efficacy of their weed management programme under different N application rates.

Weed Interference in Cotton

Weed infestation is one of the limiting factors in crop production. Cotton crop is very sensitive to weed competition as it grows relatively slow in the early stages. Weeds especially perennial weeds having high competition ability as these produce competition for natural resources there by affecting the productivity of cotton. Hence, the productivity of cotton is largely depends on a weed free condition particularly in their early growth periods. Cotton crop is slow in its initial growth stage and grown with wide spacing is subjected to severe weed competition during early stage that results in low yield. Wide spectrums of weeds with wider adaptability to extremities of climatic, edaphic and biotic stresses are infesting the cotton fields. High persistence nature of weeds is attributed to their ability of high seed production and seed viability (Nadanassababady *et al.,* 2001).

The degree of crop yield reduction due to weed interference depends on various factors, including type of weeds, their density and distribution, time of emergence of weed species relative to crop as well as soil characteristics such as type, moisture status, pH and fertility level (Papamichail *et al.,* 2002).

Salgado *et al.,* (2002) found that the period after cotton plant emergence and previous to weed interference, which reduced cotton yield in 5% was 8 days (DAE). The Total Period of Interference Prevention (TPIP) was 66 DAE and the Critical Period of Interference Prevention (CPIP) was between 8 to 66 DAE.

Hargilas *et al.,* (2015) observed that the sequential use of pendimethalin 30 EC @ 1.0 kg a.i ha^{-1} (PE) followed by pyrithiobacsodium 10 EC @ 62.5 g a.i ha^{-1} + Quizalofop ethyl 5 EC @ 50g a.i ha^{-1} (POE) at 25 DAS with one hoeing at 45 DAS has resulted in the lowest weed density of 19.67 and 12.33 with lowest weed dry weight of 15.73 and 10.13 g m^{-2} recorded at 30 and 60 DAS, respectively with the lowest total weed dry matter of 258.56kg ha^{-1}, which ultimately increased seed cotton yield significantly (4389 kg ha^{-1}) with maximum B: C of 4.74 against 3.98 calculated in weed free plot.

Effect of Weeds on growth, yield, yield attributes and quality parameters of Cotton

Anjum *et al.,* (2007) observed that all weed densities caused significant reduction in sympodial branches, total number of bolls per plant, and seed cotton weight per boll compared with weed free treatment. Minimum seed cotton yield (1455 kg ha^{-1}) was obtained at highest weed density (20 plants m^{-2}) of carpet weed compared with maximum seed cotton yield (2274 kg ha^{-1}) in weed free plots. Lint yield showed decreasing trend with increase in weed density. Patil *et al.,* (2007) found that weed competition throughout the crop growth period in irrigated cotton reduced the seed cotton and lint yield by 71.5% and 72.0%, respectively. Ginning percentage and lint index of cotton were highest under weed free treatment followed by post emergence spray of glyphosate at 1200 g a.i. ha^{-1} after 21 days of sowing with a follow up hand weeding at 42 DAS steple length was not influenced significantly.

Clewis *et al.,* (2008) advocated that lint yield of cotton increased by 420 kg ha^{-1} with the addition of s-metolachlor and glyphosate-TM early post treatments as compared with the systems without s-metolachlor post emergence application. Similar was the situation in respect of growth and physical parameters as well as fibre quality parameters of cotton.

Mushtaq and Cheema (2008) pointed that the weeds play a significant role in reducing the seed cotton yield on an average by 30% over Integrated Weed Management practices and weed free treatments. They also reported similar trend in fibre quality parameters, growth parameters as well as physical parameters.

Spasova *et al.,* (2008) found that the presence of weeds for more than three weeks after crop emergency caused significant reductions in crop growth and lint yields. However, weeds that emerged 11 weeks after crop emergence did not adversely affect yields. Total weed biomass increased with increasing time prior to weed removal. A weed-free period of 11 weeks after crop emergency was needed to prevent significant reductions in cotton height, biomass, number of squares and yield.

Everman *et al.,* (2009) observed excellent weed control (>91%) and also an increase in cotton lint yield up to 200 kg ha^{-1} when S-metolachlor applied as mid-post application as compared to glufosinate alone. Similar trend was also noted in case of growth and physiological parameters as well as fibre quality parameters. No remarkable variation was observed in G.O.T, but in nutrient uptake by plant did.

Veeramani *et al.,* (2009) reported that the growth parameters like plant height, sympodial, monopodial branches and dry matter production plant^{-1} were influenced well by the pre sowing practice with paraquat @ 0.40 kg ha^{-1} followed by slight hoeing owing to satisfactory control of weed density in these treatments. Under post sowing weed management practices, on 20 DAS fb glyphosate 1.5 kg ha^{-1} increased the plant height, physiological parameters and dry matter production plant-1over other treatments. Similar was the situation in case of net return, B: C and fibre quality parameters.

Wilson *et al.,* (2011) pointed out that diversifying herbicides reduced weed population and lowered the risk of weed population shifts and the associated potential for the evolution of glyphosate-resistant (GR) weeds in continuous GR crops. Altered weed management practices (e.g. herbicides or tillage) enabled by rotating crops, whether GR or non-GR, improves weed management practices in cotton. They also observed higher growth and yield as well as yield attributes in weed free treatments over un weeded treatments.

Poonguzhalan *et al.,* (2013) found that weed infestation in cotton has been reported to offer severe competition and causing yield reduction to an extent of 40 to 85 percent. Due to their high competitive ability, weeds compete for resources there by affecting productivity of cotton.

Hargilas *et al.,* (2015) advocated that the application of pendimethalin, quizalofop ethyl and pyrithiobac sodium did not injure cotton crop, however, foliar injuries were observed by directed spray of glyphosate. All the herbicides either used alone or in combination significantly influenced of plant height, number of bolls per plant, boll weight and seed cotton yield. Sequential application of Pre emergence + Post emergence application of herbicides with one hoeing kept the weeds under control and favoured to plant height against weedy check. Increased plant height under this treatment might be due to efficient utilization of moisture, nutrients and sunshine by cotton crop with proper aeration in the root zone, which enabled crop plants to explore their maximum potential in the presence of very less competition offered by weeds. The maximum gross return and net returns was calculated when the crop was kept free from weeds. However, the highest returns on per rupee spent (B: C) was calculated in sequential use of pendimethalin pre emergence followed by quizalofopethyl + pyrithiobac sodium post emergence.

Leela R *et al.,* (2016) observed more number of boles per plant, kapas yield per plant, kapas yield and economic analysis of different weed management practices showed higher gross returns, net returns and B;C with mechanical weeding thrice at 20, 40 and 60 DAS due to reduced cost of cultivation and increased yield. This inturn followed by pre emergence application of pendimethalin.

Effect of Weed Control Methods on growth, yield, yield attributes and quality parameters of Cotton

Though many pre emergence and post-emergence herbicides are available for controlling weeds, the complex weed flora in Bt cotton needs suitable combination of pre- and post-emergence herbicides to combat the weeds emerged during later stages of crop growth there by providing efficient weed management during critical period of crop-weed competition.

Manikandan (2009) stated that pre-emergence application of pendimethalin @ 4.0 kg ha^{-1} gave excellent control of grassy weeds, broad leaved weeds and sedge in experimental field of irrigated cotton. This was closely followed by pre-emergence application pendimethalin @ 2.5 kg ha^{-1} and pendimethalin @ 2.0 kg ha^{-1} along with hand weeding and earthing up at 45 DAS. These herbicidal treatments also recorded lesser dry weed weight and higher NPK uptake. The weed control efficiency was also higher under pendimethalin @ 4.0 kg ha^{-1}, 2.5 kg $ha^{-1}$and 2.0 kg ha^{-1} as compared to hand weeding due to germination of weeds immediately after hand weeding. He further reported that pre-emergence application of pendimethalin @ 2.0 kg ha^{-1}+ HW at 45 DAS gave higher seed cotton yield and yield attribute values over unweeded check.

Sivakumari and Mohan (2009) pointed that in general, CGR of cotton increased from the lowest at 30-60 DAS to the highest values at 90-120 DAS and decreased thereafter. The greater increase biomass in shorter period has resulted in high CGR values. Each successive increase of 60 kg N ha^{-1} up to 180 kg and 120 kg ha^{-1} has significantly increased flowers and bolls $plant^{-1}$ respectively.

Singh and Kokate (2010) reported that the best weed control of 96.8% and the highest seed cotton yield of 2671 kg ha^{-1} were recorded in the integration of pre and post-emergence treatment of pendimethalin @

1.00 kg a.i. ha^{-1} followed by glyphosate @ 1.00 kg a.i. ha^{-1} with 90.2% weed control and 2629 kg ha^{-1} yield as compared to un weeded check. They also found similar trend in respect of yield attributes, growth and physiological parameters as well as fibre quality characters. Aulakh *et al.,* (2011) advocated that the growth and biometric parameters as well as yield were recorded higher with integrated weed management system than glufosinate and conventional weed management systems. Similar trend was observed in case of net return, B: C and fibre quality, respectively.

Bharathi *et al.,* (2011) emphasized that seed cotton yield increased significantly due to application of weedicides applied as pre and post planting to the magnitude of 66-75% as compared to weedy check treatments.

The weed density and weed dry matter recorded lowest with the application of glufosinate ammonium 15% SL @ 375 g a.i. ha^{-1} and glufosinate ammonium 15% SL @ 450g a.i. ha^{-1} when compared to other treatments. The trend was almost similar in case of net returns, B: C and fibre quality parameters. Reverse was held true in case of germination of cotton seeds.

Neve *et al.,* (2011) simulated a model to explore management options to mitigate risks of glyphosate resistance evolution and they reported that, crop rotation reduced risks of resistance by approximately 50% and delayed the evolution of resistance by 2 to 3 years. They further reported that the pre and post application of glyphosate @ 1.00 kg a.i. ha^{-1} was found helpful for increasing the growth and yield components of cotton as compared to treatment control. Similar was the trend in net returns, B: C and fibre quality parameters. The situation was just vice versa in respect of germination of cotton crop.

Prabhu (2012) found that among the weed management treatments, weed free check recorded significantly higher uptake of nutrients (111.01, 31.21 and 129.11 NPK kg ha^{-1} and was followed by pendimethalin 38.7 CS (Pre) + quizalofopethyl 5 EC (post emergence) + IC and HW at 60 DAS. With regards to yield and economics, pendimethalin 38.7 CS (pre) + quizalofopethyl 5 EC (post emergence) + IC and HW at 60 DAS gave significantly higher seed cotton yield (14.06 q ha^{-1}) and higher gross returns (Rs 35,150 ha^{-1}), net returns (Rs 11,857 ha^{-1}) and B:C (1.51).

Hiremath *et al.,* (2013) found that Leaf area index, a derivative of leaf area, increased with advancement in age up to 90 DAS and thereafter decreased towards maturity. At 45 DAS, weed free check recorded the highest leaf area index and was on par with rest of treatments while, the lowest leaf area index was recorded in unweeded check. Further, nutrient uptake by cotton was greatly influenced by weed control treatments. Of these, weed free treatment recorded the highest nutrient uptake. The net return per rupee spent was also the highest in weed free check which was on par with pedimethalin followed by pyrithiobac sodium coupled with one intercultivation.

Patel *et al.,* (2013) observed that maximum dry weight of weeds was recorded at harvest in the weedy check. All the herbicides and cultural operations decreased significantly the weed density than weedy check. Low weed density as well as dry weed weight was recorded under Pendimethalin 1.0 kg/ha pre emergence+hand weeding at 30 and 60 DAS followed by fluchloralin 0.75 and 1.0 kg/ha preemergence with HW at 30 and 60 DAS and 3 HW at 20, 40 and 60 DAS and 2 IC at 45 and 90 DAS. The weed control efficiency was observed highest under treatment of pendimethalin 1.0 kg/ha+hand weeding at 30 and 60 DAS, followed by fluchloralin 0.75 or 1.0 kg/ha+hand weeding at 30 and 60 DAS and local practices.

Singh and Rathore (2015) reported that highest seed cotton yield was recorded in weed free plots followed by pendimethalin @ 1.0 kg a.i. ha as Pre emergence + quizalofop ethyl @ 50 g a.i. ha post emergence at 2-4 weed leaf stage + one hoeing owing to improved number of bolls per plant and boll weight. Statistically least yield was recorded under weedy check. Weed control efficiency (WCE) was highest under weed free check followed by pendimethalin @ 1.0 kg a.i. ha as Pre. em.+quizalofopethyl @ 50g a.i. ha, at 2-4 weed leaf stage + one hoeing, whereas minimum values were for weedy check. Though net returns were highest for weed free check but higher B:C was observed for pendimethalin @ 1.0 kg a.i. ha as Pre em.+ quizalofopethyl @ 50 g a.i. ha post emergence at 2 - 4 weed leaf stage + one hoeing. Using these herbicides in combination with cultural practices could be the practical solution for economically efficient and effective weed management.

Veeraputhiran and Srinivasan (2015) revealed that application of pre emergence herbicide pendimethalin at 1.0 kg / ha at 3 DAS followed by post-emergence herbicide (quizalofop-ethyl 50 g/ha at 30 DAS) + one hoeing or combined post emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing on 45 DAS recorded lesser weed population and weed dry weight and higher weed control efficiency with lower weed index.

Muhammad *et al.,* (2016) showed that significant differences among the genotypes were present. The correlation study revealed that plant height, number of monopodial branches, number of bolls, boll weight, fiber length and fiber fineness have positive genotypic correlation with seed cotton yield. Path coefficient analysis results showed that days to squaring, number of monopodial branches, and number of bolls, boll weight, and number of nodes, fiber length, and fiber fineness have direct positive effect on seed cotton yield. It was observed that days to flowering, plant height and ginning out-turn (GOT) have direct negative effect on seed cotton yield.

Integrated weed management

To prolong the useful life of herbicides it will be necessary to adopt integrated weed management practices. Integrated weed management incorporates any economic combination of weed control strategies which may include preventative measures, monitoring, crop rotations, tillage, crop competition, harvest weed seed control, the use of different herbicide sites of action in rotation, sequence, and mixtures, herbicide resistant crops, biological controls, crop competition, nutrition, burning, and hand weeding. The key is to vary weed control strategies to destabilize evolution, because history has shown us that any consistent practice to control weeds year after year will result in directed evolution towards their survival.

In the integrated weed management as majority of herbicides available in the market are not broad spectrum herbicides. Hence, depending on the need, we go for combination of herbicides or herbicide mixtures for broad spectrum weed control during which it essential to take care of their compatibility.

Muhammad *et al.,* (2009) stated that pre emergence application of pendimethalin + mechanical weeding recorded higher growth and biometric as well as physical parameters cotton over control. They also found higher yield and yield attribute values with IWM practices over sole application of chemical weed control. G.O.T. (ginning out turn), germination and fibre quality like fibre length and maturity ratio remained unaffected due to IWM treatments. Reverse was held true in respect of net returns and B: C.

Salimi *et al.,* (2010) found that application of different herbicides together was more effective than using of them alone. Trifloxysulfuron sodium + trifluralin, trifloxysulfuron sodium + ethalfluralin and trifloxysulfuron sodium + (440g / kg Fluometuron + 440g / kg prometryn) increased weed control and cotton yield. cultivator + ethalfluralin and cultivator + (440g / kg fluometuron + 440g / kg prometryn) were more effective than cultivator twice at using. Application of trifloxysulfuron sodium as a post emergence herbicide after application of a pre-plant herbicide provided a good control of weeds.

Thomas *et al.,* (2010) state that at the core of integrated weed management lies the principle of using knowledge of organisms and that of the agro-ecosystem and a variety of tools, to provide the needed selection pressure to keep the competitive balance in favor of the crop to the detriment of undesired species. (e.g. weeds).

Vasileiadis *et al.,* (2012) observed that the integration of various planting dates, sustainable herbicide use and inter - row cultivation; tools of great importance in integrated weed management systems. Yield of all cropping sequences (continuous cotton, cotton-sugar beet rotation, and continuous tobacco was higher under moldboard plowing and herbicide treatments. Pre-sowing and pre emergence herbicide treatments in cotton and pre-transplant in tobacco integrated with inter-row cultivation resulted in efficient control of annual weed species and good crop yields.

Ali *et al.,* (2013) suggested that pre-emergence application of Pendimethalin in combination with Inter-culturing+hand-weeding may be used for efficient weed control and higher yields in flat - sown cotton. They also found that Variations in characteristics of fiber quality i.e. % GOT, staple length (mm), and micronaire (micro g inch^{-1}) in responce to different treatment combinations were either non-significant or significant with very little practical importance.

Singh *et al.,* (2013) concluded that effective weed management could be envisaged by herbicides or integrated methods as an alternative measure to the tedious and expensive traditional methods. Diuron @ 0.75 kg a.i./ha as pre emergence coupled with 2 inter culture at one month interval provided satisfactory weed control similar to 2 hand weeding followed by 2 intercultural operations.

Chinnusamy (2014) observed that the crops made resistant to herbicides by biotechnology have consistently been the dominant trait. Thus farmer effectively use reduced or no-tillage cultural practices, eliminate use environmentally suspect herbicides and use fewer herbicides to manage nearly the entire spectrum of weed species in India, the technology of herbicide tolerant crops is in initial stage of field evaluation. Efforts have been made to evaluate and consolidate the agronomic management and advantages of herbicide tolerant transgenic crops.

Madhavi and Ramprakash (2015) reported that herbicide mixture containing pyrithiobac sodium + quizalofop ethyl at 100-125 g/ha can be recommended for broad spectrum weed control in cotton without any phytotoxic effect on cotton and without any residual effect on succeeding crops.

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