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A review integrated weed management practices in cotton

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Abstract
The agriculture sector is embracing energy efficient conservation systems and technological innovations to meet the ever increasing demand for food, fibre, and fuel in tune with the rapidly increasing human population. The genetic modification of plants is one of the technological innovations that is adopted rapidly across the world. In cotton, many major producing countries have adopted herbicide-tolerant genetically modified crops. Over-reliance on herbicides for weed management in both genetically modified and conventional systems has led to the rapid evolution of herbicide-resistant weeds. Losses caused by weeds in cotton ranges from 50 to 85 per cent depending upon the nature and intensity of weeds (Prabhu, 2012). 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. 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. 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 different weed management practices and their effect on growth and yield of cotton. Integrated weed management (IWM) can be defined as a holistic approach to weed management that integrates different methods of weed control to provide the crop with an advantage over weeds. It is practiced globally at varying levels of adoption from farm to farm. IWM has the potential to restrict weed populations to manageable levels, reduce the environmental impact of individual weed management practices, increase cropping system sustainability, and reduce selection pressure for weed resistance to herbicides. There is some debate as to whether simple herbicidal weed control programs have now shifted to more diverse IWM cropping systems. Given the rapid evolution and spread of herbicide resistant weeds and their negative consequences, one might predict that IWM research would currently be a prominent activity among weed scientists.

Keywords: Integrated weed management, cotton, genetically modified

Introduction
Cotton is most important commercial crop known as "King of natural fibre" and world over commonly referred as "White gold" which belongs to family Malvaceae and genus *Gossypium.* Cotton crop as commercial commodity plays an important role in the agrarian and industrial activities of the nation and has a unique place in Indian economy and social affairs. It provides employment top about 6 million people. It also provides 65
% raw material to textile industry and contributed 1/3rd of total foreign exchange earning of India (Mayee and Rao, 2002) [7].
India ranks 1st in area and 2nd in production of the cotton. The area covered under cotton crop in India is 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). Whereas the Maharashtra is one of leading cotton growing states in India having 41.46 lakh ha area with the production of 80.00 lakh bales with 329 lint kg ha-1 productivity.
Among the agronomic constraints of cotton production, weed infestations have historically been a major issue. Despite many advances in weed management technology, cotton growers still face significant challenges from weeds. In cotton, weeds cause several direct and/or indirect negative impacts, such as (a) reducing fiber quality,
reducing crop yield, (c) increasing production costs, (d) reducing irrigation efficiency, and (e) 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 and, in some cases, by releasing allelopathic, or growth suppressing, chemicals. However, the degree of damage from weed competition is related to the weed species composition (type of weeds), weed densities, and the duration of weed-cotton competition as related to the lifecycle of the cotton plants. In general, as the weed density in cotton fields increases the damage on fiber yield and quality also increases. This is due to increased competition between the cotton and weeds for available resources such as light, water, and nutrients. It is important to recognize that the direct negative impact from weeds varies significantly throughout the lifecycle of cotton. During the early stages of cotton development (i.e., first 8 to 10 weeks after planting, depending on the location), weeds can out-compete cotton seedlings and cause serious damage by reducing the plant vigor. This often results in a reduction in formation of squares and bolls. However, when the crop has become well-established, the cotton plants will be competitive against weeds and the direct negative impact of the weeds on the crop will be minimal. Therefore, for effective weed management in cotton, growers should concentrate their efforts on weed management in the early part of the growing season. 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. But now days, 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

Herbicides are the dominant tool used for weed control in modern agriculture; they are highly effective on most weeds but are not a complete solution to the complex challenge that weeds present. The overuse of herbicides has led to the rapid evolution of herbicide-resistant (HR) weeds (Beckie 2006; Egan *et al*. 2011; Powles and Yu 2010) [2, 4, 9]. Globally, there are 383 HR weed biotypes among 208 HR weed species (Heap 2012) [5]. Weeds resistant to the most widely used herbicide in the world, glyphosate, have been confirmed in 20 countries (23 species) (Heap 2012) [5]. In addition, multiple herbicide resistance within single biotypes is widespread. Ever-increasing populations of HR weeds, especially those with multiple herbicide resistance, have pressured weed researchers to develop management systems that are less dependent on herbicides (Powles and Matthews 1992) [8]. Present weed issues in and consistent public pressure to reduce overall pesticide use, herbicide alternatives and true integrated weed management (IWM) strategies are urgently required now more than ever.

There are five general weed management strategies: preventive, cultural, mechanical, biological, and chemical. Integrated weed management (IWM) requires a system that integrates these management strategies. However, management strategies must be selected based on the field characteristics because the efficacy of each strategy could vary depending on the local environmental conditions. In other words, an effective management strategy in one location might not be as effective in other locations. Field characteristics such as soil type, soil pH, water conditions, climatic conditions (hardiness zone), rotational crops, and, most importantly, weed species should be considered when selecting effective weed management strategies. Therefore, IWM uses a combination of effective weed management strategies depending on the environmental conditions. Instead of relying on one particular method of weed control, an IWM system uses a combination of methods. By following the principles of an IWM system, we can reduce the use of herbicides and still obtain optimum economic returns. The use of IWM has been shown to be the most economical and sustainable way to manage weeds.

Weed management strategies

Prevention

The most important part of integrated weed management (IWM) is prevention. Growers can prevent weeds from getting into the field by managing weeds in the fencerow or along ditches, controlling weeds before they set seed, planting certified seed, and removing weeds from tillage and harvesting equipment when moving from one field to another. Many of the troublesome weeds, such as field bindweed, Johnsongrass, sandbur, and Palmer amaranth, can be spread from one field to another by harvesting equipment. Preventive management also requires continuous monitoring of the fields for weed problems. Removing weeds the first time they are noticed prevents them from setting seed and spreading to other areas of the field. For example, small populations of recently introduced weed species can be controlled effectively in the “skip” of skip-row cotton, in row-ends, and in turn-rows. The cost of control increases with the size of the weed patch, so it is best to control small weed infestations early and before they become big infestations.

Chemical Control

Though many pre emergence and post-emergence herbicides are available for controlling weeds, the complex weed flora in 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. Successful chemical weed control requires the uniform application of the correct quantity of herbicide(s) over the target area. This makes the application of herbicides a precision operation, and accurate calibrations of sprayers are therefore very important since rates that are too high may injure the crop and rates that are too low may not provide weed control. It is also important to use the chemicals at a time when the crop is at its maximum tolerance, and the weeds are at their maximum susceptibility to the herbicides. The susceptibility of both crops and weeds to herbicides is related to the time of application.

Pre-plant. Registered herbicides for pre-plant application fall into two categories:-

Pre-plant incorporated (PPI) herbicides, such as trifluralin (Treflan) and pendimethalin (Prowl or Acumen), are applied and incorporated into soil 2 to 4 inches deep prior to planting cotton to provide residual weed control. Cotton seed should be planted lower than herbicide incorporation depth to prevent growth retardation.

Pre-plant burndown herbicides, such as thifensulfuron-methyl (Harmony GT XP) and tribenuron methyl (Express with TotalSol), can be applied on emerged weeds prior to planting cotton for a burndown effect. Depending on their chemistry, these herbicides could have residual activity [e.g., flumioxazin (Chateau)] or no residual activity [e.g., glyphosate (Roundup)].

Post-plant. Registered herbicides for post-plant application fall into three categories:

Pre-emergence herbicides are generally applied after planting cotton but prior to weed and cotton emergence for residual weed control. However, some herbicides, such as Diuron (Direx) and pyrithiobac-sodium (Pyrimax 3.2L), have post-emergence activity that can control small seedlings of annual species and also provide residual weed control.

Post-emergence herbicides, such as oxyfluorfen (Galigan 2E or Goal), pyrithiobac- sodium (Pyrimax 3.2L or Staple), sethoxydim (Poast), fluazifop-p-butyl (Fusilade), and clethodim (Select Max or Arrow), are all applied.

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-1and 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.

Mechanical Control

Mechanical weed control is best described as a nonselective control option that is particularly effective against annual weeds. Mechanical control is physical weed removal by tools such as hoes, disks, cultivators, rotary weeders, or mechanical choppers. These devices are designed to cover, uproot, or cut weed seedlings. Mechanical weed control starts with the annual primary and secondary tillage practices. Moldboard plowing of the soil leads to the uprooting and shredding of large weeds that have grown in a field during the fall to the early spring season. Moldboard plowing can also bury the weed seeds deep within the soil where they will not be able to emerge. Secondary tillage, such as disking and harrowing, leads to the shredding of the weed biomass and further dislodging of shallow-rooted weeds. Tillage practices are also useful for incorporating some herbicides into the soil to enhance their effectiveness. Although both primary and secondary tillage often lead to a quick destruction of weeds in a field, they do not provide a lasting solution, especially if weed seeds are still present close to the surface of the soil. Follow up practices using different types of cultivators may be necessary to dislodge and uproot the weeds that emerge after tillage. Mechanical weed control after the planting of cotton is more successful when the weeds are relatively small than when the weeds are large. Therefore, cultivating a cotton field early in the season when the weeds are young will give better results than waiting until later. However, there are some disadvantages that can result from soil disturbances created by tillage and mechanical weed control implements.

Biological Control

Over the past several decades, the concept of biological control of weeds in cotton has received significant interest. A considerable diversity of biological agents has been used to control weeds, including geese, insects, pathogens, and nematodes. However, these biological methods have shown limited successes in effective control of specific weeds in agronomic crops, particularly cotton.

Chinnusamy (2014) [3] 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.

Thomas *et al.,* (2010) [11] 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).

Ali *et al.,* (2013) [1] 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 response to different treatment combinations were either non-significant or significant with very little practical importance.

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