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S Rathika
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India

T Ramesh
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India

R Jagadeesan
Department of Horticulture, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India

Corresponding Author:
S Rathika
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India

Weed management in sugarcane: A review

S Rathika, T Ramesh and R Jagadeesan

Abstract
Sugarcane is a slow growing crop rightly called as "wonder cane". Crop-weed competition occurs during early phase of sugarcane growth. If these weeds are not controlled in the critical period, the yield reduction of sugarcane ranges between 20 to 40 percent. Inefficient weed management is an important threat to sugarcane productivity. The critical period of crop-weed competition has been recorded upto 4 months after planting beyond which the crop smothers the weed flora by itself. It has been estimated that weeds can cause 12 to 72 percent reduction in yield depending on the severity of infestation. Weed infestation is one the most dominant constraints in sugarcane production. If these weeds are not controlled from very beginning the reduction in sugarcane yield may be as high as 10-70 percent. The Indian Institute of Sugarcane Research (IISR), Lucknow developed a technology named "Integrated Weed Management" which checks the weeds with less cost involvement, as weed control is major problem for sugarcane farmers. However, the higher wages of labourers with un-sufficient number of its availability, resulted in poor weed control in cane fields.

Keywords: Sugarcane, weed control, physical method, chemical method, integrated weed management

Introduction
Sugarcane (*Saccharum officinarum* L.) is an important long duration C_4 crop of tropical and subtropical areas which constitutes around 80% of the world's sugar production and 35% ethanol. India is the second largest producer country after Brazil contributing approximately 430.50 million tons production of millable cane from an area 5.09 million hectares with annual average productivity of 8.44 tons ha^{-1} (Anonymous, 2021-22) [3]. The delayed germination, slow initial growth, wide row space and enough supply of nutrients of the crop provides favorable conditions for different weed species infestation. The weed infestation is always a major problem which seriously reduces the yield of sugarcane. Srivastava *et al.* (2005) [24] reported that the extent of yield loss may range from 10% to complete crop failure. Being a long duration crop, it is heavily infested with a variety of weeds. Nearly 150 weed species including annuals, perennials and parasitic weeds have been reported in sugarcane fields in different parts of India. The control of weeds during critical period of crop-weed competition is very important so as to avoid yield loss (Ramesh and Rathika, 2016) [19]. The major weeds reported in sugarcane field were of sedges (*Cyprus rotundus*), grasses (*Cynodon dactlyon, Sorghum halepense, Panicum sp. Dactyloctenium aegyptium, Imperata cylindrica*) and broad leaved weeds (*Chenopodium album, Convolvulus arevensis, Striga asiatica, Portulaca oleraceae, Commelina benghalensis, Trianthema portulacastrum, Amaranthus viridis*). Cultural practices like ploughing, hand weeding and mulching are practiced to control the weeds. However, these methods became cumbersome, time consuming, labour intensive and expensive. Hand weeding is difficult due to non-availability of labour as well as high cost of weeding (Ramesh and Rathika, 2016) [19]. Herbicides are used extensively in Indian agriculture nowadays to control or kill weeds and to have timely weed management (Janaki *et al.,* 2013) [6]. Hence, chemical control of weeds offers a good substitute. It has been estimated that chemical management of weeds in sugarcane is considered as economically feasible one (Oscar *et al.,* 2019) [16]. Use of pre emergence or post emergence herbicides or combination of both essential for reduce crop weed interference (Manisankar *et al.,* 2019) [13].

Weed flora in sugarcane
The major weed flora found in sugarcane field were *Trianthema portulacastrum, Portulaca quadrifida, Corchorus olitorius, Datura fastuosa, Digera arvensis Cyperus rotundus, Cynodon dactylon, Dactyloctenium aegyptium, Chloris barbata* and *Setaria verticillata* (Kalaiyarasi, 2012) [8].

Rathika *et al.* (2013) [20] reported that the weed flora of the experimental field consists of grasses, sedges and broad leaved weeds. Among the grass weeds, *Dactyloctenium aegyptium, Cynodon dactylon, Chloris barbata, Panicum repens* and *Setaria verticiliata* were the dominant ones. *Cyperus rotundus* was the only sedge present. The predominant broad leaved weeds were *Parthenium hysterophorus, Trianthema portulacastrum, Corchorus olitorius, Digera arvensis, Abutilon indicum* and *Datura metel*.

The predominant weeds species in sugarcane crop were *Borreria articularis, Ageratum haustonianum Mill, Setaria palmifolia spp., Dicanthium annulatum, Melochia corchorifolia, Axonopus compressus, Convolvulus arvensis, Sida rhombifolia, Brachiaria amosa, Cyperus pilosus, Commelina spp., and Mimosa invisa*. Out of all these weed species, the problem of *Borreria articularis, Ageratum haustonianum, Mimosa invisa, Cynodon dactylon, Eleusine indica, Digitaria horizontalis, Bidens pilosa, Cyperus rotundus, Solanum nigrum, Panicum maximum, Sataria barbata, Ageratum conyzoides, Paspalum conjugatum, Paspalum urvillei, Paederia foetida, Portulaca oleraceae, Commelina bengalensis, Trianthema portulacastrum, Sorghum halepense, Dactylocterium aegyptium, Dinebra retroflexa and Chenopodium album* which accounts of about 70% total weed population (Mahima and Bordoloi, 2015) [12].

Lokhande *et al*. (2018) [11] reported that the major weed flora were of 60 percent broad leaf weeds and 40 percent grassy weeds. Among broad leaf weeds *viz.*, *Euphorbia geniculata, Parthenium hysteorphorus, Digera arvensis, Merremia emerginata, Alternanthera sessilis, Lactuca runcinata, Portulaca oleracea, Chenopodium album* were found as dominant. While, among grassy weeds *viz., Cynodon dactylon, Brachiaria eruciformis, Cyperus rotundus* were found as dominant. The major weeds reported in sugarcane field comprised of broad leaved weeds (*Commelina benghalensis, Trianthema portulacastrum, Digera arvensis, Amaranthus viridis, Cleome gynandra* and *Ipomea spp*), grassy weeds (*Dactyloctenium aegyptium, Echinochloa colonum* and *Dinebra retroflexa*) and sedges (*Cyperus rotundus* and *Cyperus esculentus*) (Anitta Fanish and Ragavan, 2020) [2]. The major weed flora in sugarcane field were of grassy weeds *viz. Cynodon dactylon* and *Echinochloa crusgalli*, broad leaved weeds *viz., Parthenium hysterophorus* and *Trianthema portulocastrum* and sedge *viz., Cyperus rotundus* (Maurya *et al.*, 2020) [14].

Importance of weed management in sugarcane

Weeds are ubiquitous and insidious tyrants on earth. Their presence in and around the agricultural land results in severe losses. But their menace is ignored because they lack publicity of sudden outbreaks, as in commonly exhibited by several plants. According to an estimate, the total cane yield loss due to weeds in the country per annum is around 25 million tons. The weeds are notorious in being responsible for major part of this loss about 40 percent. Khan *et al.* (2004) [9] reported that cane yield is reduced to the extent of 20-25 percent due to weed infestation.

Zafar *et al.* (2010) [27] have reported that the critical period of crop weed competition in sugarcane ranged between 100 to 105 days. Sugarcane being a long duration crop and due to its initial slow growth it takes longer time for ground coverage. So crop faces tough competition with weeds upto 120 Days After Planting (DAP) which causes yield reduction in cane ranging from 40-67 percent (Kadam *et al*., 2011) [7].

Nature of weed problem

In sugarcane cultivation, the nature of weed problem is quite different from other crops.

1. It is planted with relatively wider row spacing.
2. Its growth is very slow in the initial stages, as it takes about 30 to 45 days for complete germination and another 60-75 days for developing full canopy cover.
3. It is grown under abundant water and nutrient supply conditions.
4. In ratoon crop very little preparatory tillage is taken up, hence weeds that have established in the plant crop tend to flourish well.

Crop-weed competition

In India, the reported cane yield losses ranges from 12 to 72 percent. If weeds are not properly controlled in the initial stages, the yield loss could go upto 17.5 tons/ha. Twining weeds which sprout at later stages and twine around clumps affect cane growth and cause around 25 percent loss in yield. The total cane yield loss in the country per annum is around 25 million tons (equivalent to 2.5 million tons of sugar) valued around Rs. 1500 crores. Weeds harbor certain disease and insect pests that attack sugarcane and thus lead to indirect losses. Bermuda grass (*Cynodon dactylon*), the cogan grass (*Imperata cylindrica*) and other graminacious weeds are known to be alternate hosts to Ratoon Stunting Disease (RSD) of sugarcane. Twining weeds like *Ipomoea spp*. are becoming a problem in many sugarcane growing areas, escalating cost of cultivation besides decreasing cane yields. Climbing weed such as morning glory (*Ipomoea haderacia*) infests the sugarcane crop and causes 20–25 percent reduction in cane yield (Mishra *et al.*, 2016) [15]. The twining weeds also cause serious harvesting problem. *Striga* is creating a great problem in Belgaum, Bagalkot and Bijapur districts and threatening cane cultivation in these areas. Weeds remove four times of N and P and 2.5 times of K as compared to sugarcane during the first seven week period (Anusha and Rana, 2016) [4].

Critical period of weed competition

The period at which maximum crop weed competition occurs is called as critical period which is the "shortest time span in the ontogeny of crop when weeding results in highest economic returns". As a thumb rule, first 1/4 - 1/3 of the growing period in many crops is critical period. The duration of a sugarcane crop is 12-16 months. So, in sugarcane, the initial 120 days can be considered as critical period for crop-weed competition. The length of critical period vary depending on cane types, their competitive ability, variety, soil condition, planting techniques, weed flora composition and extent of weed infestation. The critical period of crop weed competition has been recorded to be 60-120 days after planting in spring cane and 150 days in autumn cane (Singh *et al.*, 2011) [22]. Measures have to be taken before they cause economic damage on cane and sugar yields. Sugarcane being a highly fertilized crop requires frequent irrigations, so weeds grow vigorously and compete with the crop at tillering stage. Weeds in sugarcane need to be controlled at formative stage. Weed control in sugarcane can be achieved by mechanical, chemical, chemical + mechanical methods and trash mulching. Manual hoeing and weeding are costly and labour

intensive. Chemical method of weed management certainly has its merits over the existing methods. Economical weed management in sugarcane is essential for sustainable cane yield (Lokhande *et al.*, 2014) [11].

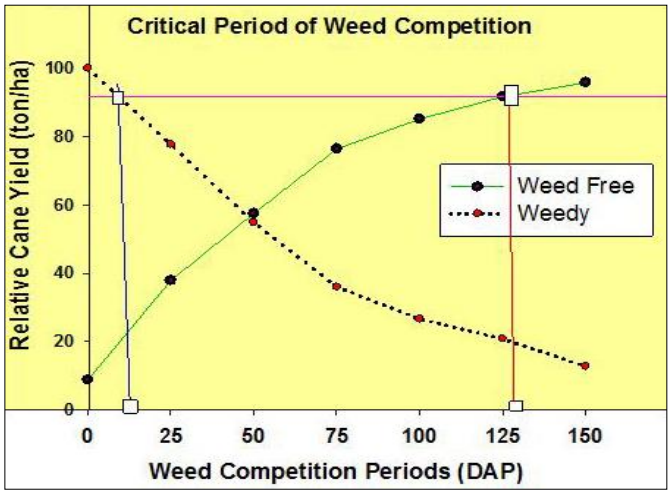

Fig 1: Show the weed competition periods (DAP)

Weed control methods

Weed control is the process of limiting weed infestation so that the crops could be grown profitably and other activities of man conducted efficiently (Anusha and Rana, 2016) [4]. Effective weed control in sugarcane can be achieved by adopting various known approaches of weed management. The various approaches are:

1. Physical methods
2. Chemical method
3. Integrated weed management

Physical method

Sugarcane rows are widely spaced, so shallow rooted weeds can be managed by hoeing with hand tools or with intercultural operations during growing season of crop. Generally, 3-4 hoeing are required after every irrigation during tillering phase of crop to check crop-weed competition. Hoeing has been considered an essential cultural operation for the control of weeds. Physical control of weeds in sugarcane begins with a blind hoeing before the cane sprouts are seen above the ground. Later, during the tillering phase of the crop manual and mechanical row cultivations are done 2-3 times during the season. Finally the crop earthed up, just before it enters the grand growth period. By this time a healthy cane crop can sufficiently smother any new weed seedling. *Ipomoea spp.*, *Convolvulus arvensis* and the trailing weed species, may however still survive by climbing the cane plants. Physical methods work out to be costly. Because of this, farmers face lot of problems in attending to the important operation of timely weeding.

The minimum weed intensity was observed in hoeing at 30, 60 and 90 days after planting (DAP) in the sugarcane field and this treatment also received maximum weed control efficiency (85.15%) (Bhawani and Pramod, 2014) [5]. In sugarcane, the lowest weed density, dry weight of total weeds and higher yield were recorded under the treatment of three hoeing at 30, 60 and 90 days after harvesting (DAH) of main crop (Krishnaprabu, 2020) [10]. Hand weeding was the best to manage weed in sugarcane crop over other treatments (Yadav *et al.*, 2020) [26].

Chemical method

Pre-emergence application of herbicide is essential to control initial weeds. This is done soon after planting as a blanket spray on the third or fourth day. Later on, another application around 35-40 days with a post-emergence herbicide may be required as directed spray on to the foliage of the weeds. Pre-emergence application of triazine compounds (atrazine, simazine etc.) resulted in high mortality of weeds in sugarcane fields. A large number of experiments throughout the country have indicated that for sole crop of sugarcane, atrazine is the most effective herbicide at dosages ranging from 1.25 to 2.0 kg/ha. It controls most of the seed germinated broad leaved weeds and few grasses when applied as pre-emergence spray. Post-emergence application of 2,4-D at 1.0 to 1.5 kg/ha (sprayed on weeds between 40and 60 days) has been found highly effective in controlling most of the broad leaved weeds. Atrazine, Metribuzin and 2,4-D have become a very popular herbicides throughout the state. They give a more or less complete weed free condition for about 50 to 60 days.

For controlling twining weeds such as *Ipomoea spp*. and *Convolvulus spp*., application of atrazine (1 kg/ha) or metribuzin (1 kg/ha) may be done between the cane rows after final earthing up. 2,4-D sodium salt (1-2 kg/ha) can be sprayed on such emerged/grown up broad leaved weeds depending upon their growth stage.

For *Striga* infested cane fields, the same herbicides recommended for controlling twining weeds above, can be used. The trials conducted by UAS, Dharwad on farmers fields have revealed that the herbicide mixtures / combinations of either atrazine + 2,4-D or metribuzin + 2,4-D at 100% or 75% of their recommended doses applied after final earthing up *i.e.* around 100 days after planting (usually when *Striga* starts emerging) and subsequent 2-3 applications at an interval of 30-40 days can effectively control this parasitic weed.

Srivastava *et al.* (2003) [23] reported that the pre emergence use of sulfentrazone at 0.5 kg + atrazine at 2 kg/ha gave better weed control. Singh *et al.* (2008) [21] observed that simazine and atrazine gave best control of weeds in cane fields and increased tillering. Pre emergence application of sulfentrazone at 1200 g a.i/ha for higher weed control efficiency and cane yield of sugarcane with better economic returns (Kalaiyarasi, 2012) [8]. In sugarcane, pre-emergence application of atrazine 1.0 kg a.i/ha on 3 DAP + hand weeding and earthing up on 60 DAP or hand weeding on 30 DAP and earthing up on 60 DAP or halosulfuron methyl 60.0 g a.i/ha at 3-4 leaf stages of *Cyperus rotundus* offered better weed control enhanced yield attributes which resulted in higher cane yield. The test herbicides did not show any phytotoxic effect on succeeding crops even at higher doses (Rathika *et al*., 2013) [20]. Herbicidal treatments were applied to ratoon crop immediately after harvesting of plant crop in the every year under moist conditions. Among different herbicidal treatments, pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 days after ratoon initiation (DARI) was found most effective by recording the lowest weed population and dry weight thus showed highest weed control efficiency (Rajender *et al.*, 2014) [17].

Pre-emergence spraying of metribuzine at 1 kg a.i/ha followed by spraying of 2, 4-D at 1 kg a.i/ha at 45 DARI recorded lesser number of weeds, weed dry weight, higher

weed control efficiency and higher cane yield (Mahima and Chandra, 2016) [12]. Different weed species in sugarcane fields and their control methods on yield and quality of sugarcane were evaluated. Out of them three species belong to the broad leaved perennial weeds (*Convolulus arvensis, Sesbania sesban and Ipomoea cairica*) while six species belong to the broad leaved annual weeds (*Hibiscus trionum, Corchorus sp., Euphorbia geniculate, Portulaca oleraceae, Sida alba, and Datura stramonium*) were observed. The grass perennial weeds were presented by two species (*Cyperus rotundus and Cynodon dactylon*), while only one grass annual weed species were found (*Digitaria sanguinalis*), the efficiency of (Strane, Garlon, Devo, Super Garlon) four herbicides against sugarcane weeds were evaluated. Starane was the most effective herbicides in reducing sugarcane weeds followed by Garlon with no significant differences. Starane was the most effective herbicides in reducing sugarcane weeds followed by Garlon with no significant differences. All the tested herbicides significantly increased the cane yield and the sugar yield compared to the control treatment with no significant differences between the used herbicides. Thus Starane and Garlon could be recommended for the control of weeds in sugarcane fields (Amira *et al*., 2017) [1].

The highest cane yield (t/ha) and CCS yield (t/ha) were recorded with the treatment of Metribuzine 70%WP at 1 kg/ha (POE) along with 2,4-D sodium salt 80 percent WP tank mixed and was found at par with Ametryne 80% WDG at 2.5 kg/ha (POE) and Metribuzine 70% WP at 1 kg ai/ha. (POE) (Waghmare *et al.*, 2018) [25]. Pyrazosulfuron-ethyl + metribuzin + 2,4-D sodium salt WDG (3000 g/ha) recorded significantly higher millable cane yield due to lower weed biomass and higher weed control efficiency (Ramesha *et al.*, 2018) [18]. The lower of total weed density, total weed biomass and the highest weed control efficiency were obtained with post-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} which was reported by Maurya *et al.* (2020) [14].

Integrated weed management

Complete weed control cannot be achieved by using any one method. To have more dependable, economical and desirable weed control without environmental problems, it is advisable to have a proper combination of agronomical, cropping, rotational and biological methods with supplemental use of herbicides. The use of all suitable weed control methods in combination, to keep weed populations below the economic injury level is known as IWM. Being a long duration and widely spaced crop, there is an ample scope of using cultural/mechanical and chemical methods in combination so as to reduce dependence on either of the methods. Application of metribuzin at 0.88 kg/ha at 3 DAH followed by hoeing at 45 DAH followed by 2,4-D at 1.0 kg/ha at 90 DAH of main crop was found most effective treatment for control of weeds in sugarcane ratoon (Waghmare *et al*., 2018; Krishnaprabhu, 2020) [25, 10]. Application of pendimethalin 2.0 kg ha^{-1} + Sesbania (brown manuring) + hand hoeing at 90 DAP recorded minimum number of weeds, weed dry weight, higher weed control efficiency (78.96%), cane yield (100.5 t/ha) and benefit cost ratio (2.72) (Anitta Fanish and Ragavan, 2020) [2].

For popularising it, interaction with the farmers under Institute-Village Linkage Programme was made. The practice involves the use of chemicals along with hoeing and thus reduces the cost on weed control without hamparing the cane yield. Initially, the farmers suspected that use of herbicides may result into less number of millable canes, growth and yield due to adverse effect of chemical on cane but they got satisfied after seeing the research results at the Indian Institute of Sugarcane Research farm. To develop more confidence among the farmers, demonstrations on Integrated Weed Management (IWM) were laid out on their fields. Application of atrazine at 1.0 kg a.i/ha after 2-3 days of sugarcane planting under moist condition controlled weeds up to 40-45 days. To manage broad leaved weeds, application of 2,4-D sodium salt at 1.0 kg a.i/ha with 600 liters of water was done at 60 days after planting. Finally, one manual hoeing at 90 days after planting was also followed. The technology thus, controlled all types of weed in farmers practices, respectively. The input incurred under Integrated Weed Management technology was at par with farmers' practices being followed *i.e.,* two hoeings in sugarcane. Thus, Integrated Weed Management technology controlled the weed resulting higher sugarcane yield. Thus, Integrated Weed Management technology controlled the weed resulting higher sugarcane yield. The farmers of area got impressed with the technology and started to communicate it to others for wide adoption (IISR, Lucknow).

Conclusion

Sugarcane being a long duration crop with wider spacing weeds pose a major problem, which can be effectively controlled by combination of various cultural and mechanical methods along with the chemical methods. Single method of control is not effective. Integrated weed management control the weeds and increase yield. Weed management in sugarcane through intercultural operations has always given good result. In sugarcane, weed density and weed dry matter production were observed minimum in intercultural operations and significantly superior to chemical weed control. The integrated approach to weed management in sugarcane is much more efficient.

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