International Journal of Plant & Soil Science

Volume 35, Issue 24, Page 66-74, 2023; Article no.IJPSS.108791
ISSN: 2320-7035

A Review on Weed Management Techniques

Janak Raj [a++*], Pradeep Kumar [b++], Sarita Jat [a#] and Anuradha Yadav [a]

[a] Department of Agronomy, SKNAU, Jobner, Rajasthan, India.
[b] Department of Agronomy, NAU, Navsari, Gujarat, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i244298

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/108791

Review article

Received: 14/09/2023
Accepted: 22/11/2023
Published: 26/12/2023

ABSTRACT

Weeds in the crop field were found to be a major concern. Weeds engage in competition with the primary crop for essential resources such as nutrients, water, space, and sunlight. Utilizing the nutrients that are given to the primary crop, weeds can occasionally completely overtake it. Some weeds are extremely poisonous and dangerous to both people and animals. Herbicide use to manage weeds clearly shows that it has a adverse effect on the ecosystem, water quality, and soil quality. Studies conducted in the field of weeds clearly show this. Furthermore, weeds become resistant to a herbicide when it is used consistently. Numerous techniques, such as mechanical, cultural, chemical, and biological ones, can be used to control weeds. But the application of several herbicides in chemical. control is now so pervasive. Chemical fertilizers should not be used excessively as this lower's environmental quality and damages soil health. As a result, a brand-new strategy known as Integrated Weed Management (IWM) was developed, in which all existing strategies are combined to cut down on the use of herbicides alone.

[++] Ph. D Research Scholar;
[#] M.Sc.;
**Corresponding author: E-mail: 1997janakraj@gmail.com;*

Keywords: Weed control; cultural approaches; mechanical methods; biological methods; chemical methods; IWM advancement.

1. INTRODUCTION

Weeds have persisted since time immemorial, representing plants that either do not belong to cultivated crops or are intentionally sown in the primary field alongside crop plants. These opportunistic plants not only coexist with the primary crop but also actively vie for essential resources, including food, space, sunlight, and nutrients. This competitive interaction results in notable agricultural production losses, as observed by Das in [1]. The complete eradication of weeds from the main field proves to be an elusive goal due to their diverse modes of propagation, encompassing vegetative propagules, dormant seed dissemination, and other methods [2]. The effectiveness of weed control is intricately tied to the overall success of agriculture [3]. Weeds play a crucial role in the agricultural system, consuming a significant portion of the resources allocated for plant growth, as highlighted by Oerke in [4]. Improper weed management or failure to control weeds at the failure to harvest crops at the appropriate time leads in a considerable decrease in agricultural productivity and an increase in production expenses [5]. Weeds can diminish output by up to 90%, and they can cause crop failure. Previously, crop rotation, seed cleansing, tillage practices, and other methods were used to eliminate weeds. Cultural control involves implementing modifications to the cropping system to mitigate the influence of weeds on the primary crop, as discussed by Dubey in [6]. However, biological control options are constrained, leading to limited adoption. In physical control, manual techniques such as hand weeding or hoeing are employed, while chemical control relies on the use of herbicides, making this method widely favored among farmers. The excessive use of chemical fertilizers and its repercussions on soil and the environment has emerged as a global concern. Throughout history, farmers have implemented various measures to manage weeds, including practices such as seed cleaning, maintenance of clean farm equipment, and ensuring the cleanliness of irrigation channels. Below is a description of different weed control methods:

2. CULTURAL/ ECOLOGICAL/ AGRO-NOMICAL METHODS

It is known as crop management practices. Various cultural practices, including tillage, planting, fertilizer application, and irrigation, play a crucial role in establishing favorable conditions for crops. When employed effectively, these practices contribute to weed control by aiding in the reduction of weed populations. While cultural methods may not independently achieve complete weed control, they complement other techniques. Key components of cultural methods include tillage, fertilizer application, and irrigation. Additionally, factors such as the choice of crop variety, sowing timing, cropping system, and farm cleanliness are instrumental in weed management (Kumar *et al.,*2014).

Fig. 1. Field preparation

3. FIELD PREPARATION

It is imperative to maintain a weed-free field by preventing the flowering of weeds. This practice is crucial for inhibiting the accumulation of weed seeds in the area.

4. SUMMER TILLAGE

Engaging in summer tillage or off-season tillage proves to be an effective cultural method in restraining the proliferation of perennial weed populations during crop cultivation. The initial tillage preceding cropping is designed to promote clod formation. These clods, containing weed propagules, desiccate upon drying. Following tillage operations are then aimed at breaking these clods into smaller units, intensifying exposure of the withered weeds to the sun's heat. Badiyala et al. [6].

5. CROP DENSITY

Regarded as a pivotal factor in suppressing weed growth, achieving an optimal plant population in the field is essential. This is because an adequate plant density creates competition against weeds, hindering their growth by either occupying space or utilizing available nutrients, as highlighted by Meena et al [7].

6. FERTILIZER APPLICATION

Applying fertilizer in the appropriate quantity, at the right time, and in the right location proves instrumental in weed reduction. This practice ensures that the main crop receives all the necessary nutrients, as emphasized by Dubey in [8].

7. MAINTAINING ON OPTIMUM PLANT POPULATION

Insufficient plant population is susceptible to intense weed infestation, posing challenges for later control. Hence, critical practices such as selecting suitable seeds, employing proper sowing methods, using an appropriate seed rate, and safeguarding seeds from soil-borne pests and diseases are crucial. These measures are vital for establishing a proper and uniform crop stand capable of effectively competing with weeds, as emphasized by Kumar et al. in [9].

Fig. 2. Crop rotation

8. CROP ROTATION

The likelihood of a particular weed species or group persisting increases when the same crop is cultivated continuously. Crop rotation proves to be a valuable strategy in addressing, if not entirely eliminating, challenging weed issues. Managing troublesome weeds, such as Cyperus rotundas, may involve incorporating lowland rice into the crop rotation, as suggested by Das et al. in [1]. For instance, rotating crops like wheat, maize, or soybean has been shown to reduce the prevalence of weeds, as observed in studies such as Teasdale et al. in [10]

9. TIME OF SOWING

Initiating early sowing of crops offers a competitive advantage against weeds, as highlighted by Sindhu et al. in [11]. This is because crops emerge before weeds, depriving the latter of sufficient space, nutrients, or light for growth, as observed in studies such as Cici et al. in [12]. For instance, planting rice crops during the monsoon not only results in optimal yields but also reduces the prevalence of weeds.

10. METHODS OF SOWING

The choice of sowing methods plays a crucial role in reducing weed populations, as emphasized by Dev et al. in [13]. In the context of wheat crops, zero tillage has been identified as particularly effective in weed control, concurrently leading to increased yields, as demonstrated by Jat et al. in [14].

11. GROWING OF INTERCROPS

The practice of intercropping demonstrates superior weed suppression compared to sole cropping, offering an opportunity to employ crops as tools for weed management. Certain short-duration pulses, such as green gram and soybean, have proven effective in smothering weeds without adversely affecting the yield of the main crop, as noted by Shah et al. in [15].

Additionally, this strategy contributes to a reduction in weeding costs, leading to an enhanced net income by lowering input expenses. For example, intercropping legumes, cucurbits, sweet potatoes, and similar crops not only suppress weed growth but also assist in mitigating the risk of soil erosion.

12. STALE SEEDBED TECHNIQUE

A stale seedbed refers to a prepared field where the initial one or two weed flushes are eradicated before crop planting. This is accomplished by saturating the well-prepared field with either

irrigation or rain, prompting weed germination. At this stage, shallow tillage or the application of a non-residual herbicide, such as paraquat, can be employed to eliminate the dense flush of young weed seedlings, as suggested by Singh in 2014. Subsequently, sowing can take place immediately. This technique creates an environment nearly free of weeds, allowing the crop to germinate successfully, as noted by Sindhu et al. in 2010.

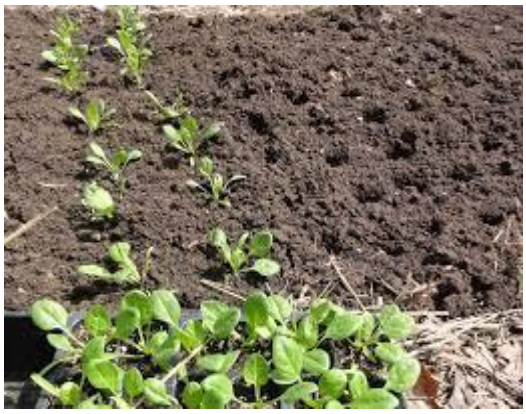

Fig. 4. Uses of stale seedbed approach

12.1 Blind Tillage

The process of tilling the soil after sowing a crop, but before the emergence of the crop plants, is referred to as blind tillage. This technique is commonly used to reduce weed intensity, particularly in drill-sown crops where the emergence of crop seedlings may be impeded by the formation of a soil crust due to rainfall or irrigation shortly after sowing.

12.2 Merits of Cultural Methods

1. Cost-effective weed control method
2. Simple and easy to adopt
3. Absence of residual problems
4. Minimal technical skill required
5. No harm to crops
6. Efficient in weed control
7. Maintenance of the crop-weed ecosystem

12.3 Demerits of Cultural Methods

1. Immediate and rapid weed control is not achievable
2. Weeds are maintained in a suppressed condition
3. Ineffective for controlling perennial and troublesome weeds
4. Practical challenges in adoption

12.4 Mechanical/ Physical methods

Mechanical or physical methods of weed control have been employed since the inception of agriculture. These methods encompass various techniques such as tillage, hoeing, hand weeding, digging, cheeling, sickling, mowing, burning, flooding, mulching, and more.

Fig. 5. Tillage operations

Fig. 6. Hand weeding technique

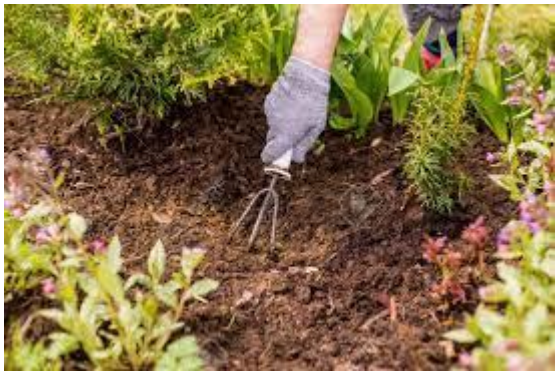

Fig. 7. Hand hoeing

12.4.1 Tillage

Tillage serves to eliminate weeds from the soil, leading to their demise. This process may

weaken plants by causing injuries to roots and stems, reducing their competitiveness and regenerative capacity. Additionally, tillage buries weeds, disrupting their growth. Tillage operations, including plowing, discing, harrowing, and leveling, are employed to promote soil turnover, weed germination, and the exposure of seeds to sunlight, facilitating their effective destruction later on. In the case of perennial weeds, both above-ground and underground growth are harmed and eliminated through tillage [16].

12.4.2 Hand weeding

This method involves the manual removal or pulling out of weeds by hand or by using implements like khurpi, which resembles a sickle. Likely one of the oldest weed control methods, hand weeding remains a practical and efficient approach for eliminating weeds in both cultivated and uncultivated areas. It is particularly effective against annuals and biennials and is limited to controlling the upper portions of perennial weeds, as noted by Angiras et al. in [17].

12.4.3 Hand hoeing

The hoe is considered one of the most suitable and extensively used weeding tools, offering quick and cost-effective results. It is often added to the cultivator for tending to row crops. Hoeing is particularly effective against annuals and biennials, as it can completely destroy their weed growth. However, when dealing with perennials, hoeing primarily targets the top growth with minimal impact on underground plant parts, leading to the possibility of re-growth

12.4.4 Sickling

Sickling, a manual process employing a sickle, is utilized to remove the top growth of weeds by hand. The aim is to prevent seed production and starve the underground parts of the weeds. This method is particularly prevalent in sloped or hilly areas, where only the tall weed growth is sickled, leaving the root system intact to anchor the soil and prevent soil erosion, as highlighted by Gupta O.P. in [18].

12.4.5 Digging and Cheeling

Digging proves to be highly beneficial, especially in the case of perennial weeds, as it targets the removal of underground propagating parts from the deeper layers of the soil. Cheeling is a manual process carried out using a cheel hoe, which resembles a spade with a long handle. This technique involves cutting and shaping the above-ground growth of weeds.

12.4.6 Mulching

Mulch refers to a protective covering of material maintained on the soil surface. Mulching has a smothering effect on weed control by preventing light from reaching the photosynthetic portions of plants, thereby inhibiting their top growth [19]. This method is highly effective against annual weeds and certain perennial weeds such as Cynodon dactylon. Mulching can be achieved using dry or green crop residues, plastic sheets, or polythene film. For optimal effectiveness, the mulch should be thick enough to prevent light transmission and eliminate photosynthesis [20].

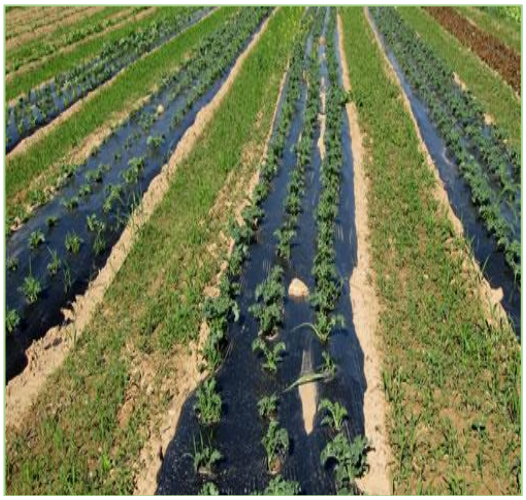

Fig. 8. Mulching in agriculture

12.4.7 Mowing and Slashing

Mowing is primarily employed in non-crop settings such as canal bunds, farm roads, parks, and lawns, while slashing may find application in both cropped and non-cropped situations (Senarathne et al., 2011). Occasionally, mowing using sickle mowers or rotary mowers is recommended for weed control in widely-spaced fruits and plantation crops. It proves effective in managing tall annual weeds, but not perennial weeds, as mowing and slashing cut only the top growth and do not address the horizontal, prostrate, and underground growth of perennial weeds. Das T.K. [21].

12.4.8 Burning and Flaming

Burning is a cost-effective method for eliminating mature, unwanted vegetation in non-cropped

areas such as range lands, field bunds, roadsides, and ditch banks. This technique is employed to (a) dispose of vegetation, (b) eradicate the dry tops of matured weeds, and (c) eliminate green weed growth in situations where cultivations and other common methods are impractical. Flaming involves the momentary exposure of green weeds to high temperatures (up to 1000°C) through the flames emanating from burning liquid petroleum gas. A hood cover directs the flames onto weeds between rows, killing the cell protoplasm of plants [2]. Flaming is commonly used in various Western countries for the selective control of inter-row weeds in crops like onions, soybeans, sorghum, etc.

Fig. 9. Flooding in the field

12.4.9 Flooding

Flooding proves effective against weed species that are sensitive to prolonged submergence in water. This method kills plants by reducing the availability of oxygen necessary for their growth. The success of flooding depends on the complete submersion of weeds for extended periods. Flooding is an efficient weed control method, particularly for some perennial weeds such as Cyperus spp., *Cynodon dactylon*, and *Convolvulus arvensis.*

12.4.10 Chaining and Dredging

Chaining and dredging are methods employed against aquatic weeds. Chaining involves pulling a heavy chain through the bottom of a ditch, utilizing two tractors moving on either bank of the ditch. The heavy chains cut and uproot the roots, causing them to float to the surface, where they are then collected. On the other hand, dredging is the mechanical removal of weeds along a channel, encompassing their roots and rhizomes covered in mud. This technique is utilized for the removal of both submerged and emerged aquatic weeds. Rana *et al*.,[22].

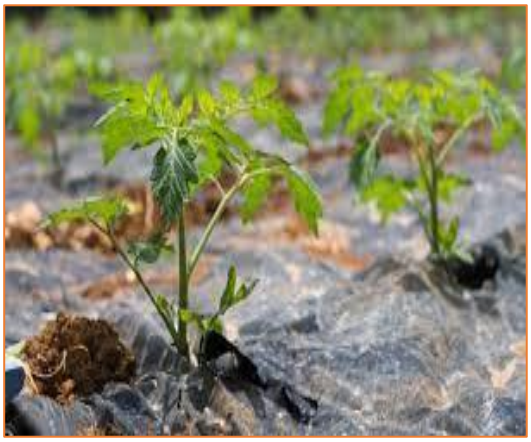

Fig. 10. Biological control of Weed

13. SOIL SOLARIZATION

This method involves harnessing solar energy for weed desiccation in fallow fields during hot summer months. The concept is based on the idea that light from the sun, in the form of short electromagnetic waves, easily penetrates colorless translucent polyethylene films (20-25 mm). This light reaches the soil, raising its temperature by 10-12°C within 2-4 weeks and reaching up to 55-60°C. This elevated temperature is effective in controlling most weed species whose seeds are present in the top 5 cm of the soil layer [23].

13.1 Merits of Mechanical Methods

1. Oldest, efficient, and cost-effective method
2. Allows coverage of large areas in a shorter time
3. Environmentally safe method
4. Requires no specialized skills
5. Enables weeding in between plants
6. Effectively controls deep-rooted weeds

13.2 Demerits of Mechanical Methods

1. Labor-intensive
2. Potential for crop damage
3. Requires specific and optimal conditions

13.3 Biological Control

Biological control involves the utilization of natural living organisms, such as insects,

Table 1. Promising bioagents of weeds

Weed	Bioagent	Reporting country	Kind of bioagents
Chondrilla juncea	*Puccinia chondrillina*	Auatralia	Plant pathogens
Cirsium arvense	*Septonia cirsii*	-	Plant pathogens
Cyperus rotundus	*Bactra vendana*	India, USA	Shoot boring moth
Hydrilla verticillata	*Hydrilla pakistanae*	USA	Shoot fly
Orobanche cernua	*Sclerotinia spp*	USA	Plant pathogenes
Parthenium hysterophorus	*Zygogramma bicolarata*	India	Leaf eating insect
	Epiblema strenuana	Australia Australia	Stem galling insect Stem galling insect
	Conotrachelus spp		
Rumex spp	*Uromyces rumicis*	USA	Plant pathogens
	Gastrophysa viridula	USA	Beetle
Tribilus terrestris	*Microlarinus lareynii*	USA	Pod weevil

herbivorous fish, other animals, disease organisms, and competitive plants, to limit the growth of weeds. While it may not eradicate weeds entirely, it can significantly reduce weed populations. This method is not universally effective for all types of weeds, and it is particularly useful for controlling introduced or invasive weed species [24]. Notable examples include the control of Opuntia spp. (Prickly pear) in Australia and lantana in Hawaii using specific insect bioagents [25]. Biological control is an eco-friendly method and is generally cost-effective. In India, this method is commonly employed to control Parthenium hysterophorus [16].

13.4 Merits of Biological Control

1. Causes minimal harm to the environment
2. No residual effect
3. Relatively cost-effective with a comparatively long-lasting impact
4. Does not affect non-targeted plants and is safe to use
5. Highly effective in controlling weeds in non-cropped areas
6. Some fish, snails, and other animals can convert weed vegetation into a food source

13.5 Demerits of Biological Control

1. Multiplication is expensive
2. Control is slow
3. Limited success in control
4. Availability of very few host-specific bio-agents at present

13.6 Chemical Methods

Herbicides or inorganic chemicals are employed to destroy weeds in this weed control method.

Herbicides can be sprayed on leaves or applied to the soil. Farmers have increasingly turned to chemical solutions since the Green Revolution to suppress weed growth and boost their profits. Herbicides, while often effective in weed control, come with several drawbacks, as they can harm the environment and soil. They become weed-resistant as a result of their prolonged use. Therefore, their ideal application is good, but using these chemicals extensively harms the ecosystem, raising alarms of impending danger.

13.7 Integrated Weed Management (IWM)

The primary challenge for agricultural and weed scientists is developing a technique that is cost-effective, highly efficient, time-efficient, and requires minimal labor Riemens *et al*., [26]. Weeding operations have an extremely high production cost since they must be done by hand, which raises the overall cost of production Kewat *et al*., [27]. The country loses a lot of money every year as a result of poor weed management techniques Das and Yaduraju [28]. The cost of manufacturing can be reduced by employing effective weed management strategies [28]. Developing a labor-free weed control strategy is essential for achieving sustainable crop production goals Elzein *et al*., [29]. In this context, a new approach called Integrated Weed Management (IWM) has been developed, combining two or more weed management techniques Kruidhof *et al*., 2008 [30]. IWM is an efficient, low-input weed management method that has become a crucial component of agricultural systems Kumar *et al*., [31]. This approach can be seen as a long-term weed management strategy that integrates chemical, biological, mechanical, and cultural techniques Mohler *et al*., [32]. For instance, utilizing manual weeding in addition to pre- and post-emergence herbicides on wheat crops produced the best results when compared to using pesticides on their own Verma *et al*., [33]. Farmers should adopt integrated weed management as it is environmentally friendly and involves the use of inorganic chemicals in

minimal amounts Yadav *et al*., [34]. This approach ensures the optimal use of chemicals in combination with cultural and mechanical methods for weed control.Although chemical weed control methods are effective, ideal, and practical, it is essential to consider integrated weed management for a more sustainable and balanced approach to weed control in agriculture Angiras and Rana [35].

14. ADVANTAGES OF IWM

1. Shifts the balance of crop-weed competition in favor of the crop
2. Prevents the transition of weeds toward perennial nature
3. Helps prevent the development of resistance in weeds to herbicides
4. Eliminates the risk of herbicide residue in soil or plants
5. Minimizes environmental pollution
6. Leads to higher net returns in agriculture

15. CONCLUSION

Weeds pose a significant biotic constraint to production in various cropping systems. Relying on a single method of control is often insufficient for long-term weed management and may lead to the development of resistance. Despite the application of specific control methods, weeds continue to cause substantial yield losses. To address this challenge and feed the growing global population, there is an increasing need to minimize yield losses through the development and implementation of effective and sustainable Integrated Weed Management (IWM) programs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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