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4. Integrated Weed Management – A Step towards Sustainability

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Abstract:

Integrated Weed Management (IWM) represents a pivotal stride towards sustainability in modern agriculture. Weeds, unwanted plants competing with crops, have long vexed farmers, prompting the excessive use of chemical herbicides, with adverse environmental and economic consequences. IWM seeks to redress this by offering a holistic approach that integrates various weed control techniques, acknowledging the complex dynamics of agricultural ecosystems. IWM methods encompass cultural practices, biological control, mechanical weed removal, and judicious herbicide use. By diversifying tactics, IWM diminishes the likelihood of herbicide-resistant weeds, preserving the effectiveness of vital chemical options. Furthermore, IWM fosters soil health, reduces erosion, and enhances biodiversity. This multifaceted approach not only safeguards crop yields but also upholds the ecological balance and ensures the long-term sustainability of agricultural systems. Crucially, IWM aligns with the principles of sustainable agriculture, mitigating the environmental footprint while securing food production. As our world grapples with food security and environmental degradation, Integrated Weed Management stands as a compelling strategy to harmonize the needs of the present with the imperatives of the future.

4.1 Introduction:

An integrated weed management may be defined as the combination of two or more weed-control methods at low input levels to reduce weed competition in a given cropping system below the economical threshold level. It has proved to be a valuable concept in a few cases, though much is still to be done to extend it to the small farmers' level. Integrated Weed Management (IWM) approach aims at minimizing the residue problem in plant, soil, air and water.

An IWM involves the utilization of a combination of mechanical, chemical and cultural practices of weed management in a planned sequence, so designed as not to affect the ecosystem.

The nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation, the standard of crop husbandry, and the ready and timely availability of any method and the economics of different weed-management techniques are some of the potent considerations that determine the success for the exploitation of the IWM approach.

4.2 Why Integrated Weed Management:

The continuous use of the same method leads to the buildup of tolerant weeds. Therefore, the suitable combination of different weed control methods or integrated weed management (System Approach) should be practice for minimizing the losses caused by various weeds.

Herbicides have become one of the most important components in weed control because of use of high yielding varieties which created economic incentive for farmer to reduce weed.

4.3 Concept of Integrated Weed Management:

Uses a variety of technologies in a single weed management with the objective to produce optimum crop yield at a minimum cost taking into consideration economic and socio economic constrains under a given agro ecosystem.

4.4 Components of Integrated Weed Management:

The goal of IWM is to incorporate different methods of weed management into a combined effort to control weeds.

Just as using the same herbicide again and again can lead to resistance, reliance on any one of the methods below over time can reduce its efficacy against weeds.

Two major factors to consider when developing an IWM plan are

- Target weed species
- Time, resources, and capabilities necessary to implement these tactics

Advantages of Integrated Weed Management:

- It shifts the crop weed competition in favour of crop
- Prevents weed shift towards perennial nature
- Prevents resistance in weeds to herbicides
- No danger of herbicide residue in soil or plant
- No environmental pollution
- Gives higher net return.

Principles of Integrated Weed Management:

- IWM place the crop in competitive advantage over the weeds by manipulating the crop habitat by utilizing some biological differences between crop and weeds.
- In IWM measures should be directed to reduce the survival mechanism of weeds in the soil.
- Crop cultural practices should be incorporated to discourage the establishment of the perennial and parasitic weeds.
- Any individual element of the weed management should be friendly and it should not be harmful to the environment.
- IWM practices should be flexible according to the need

4.5 Methods of Weed Management:

For designing any weed control programme in an area one must know the nature and habitat of the weeds in that area, how they react to each environmental changes and how they respond to herbicides.

Managing weeds in three different ways:

- **Prevention**
- **Eradication**
- **Control**

4.5.1 Preventive strategies:

Prevention of introduction and spread of weeds in an entirely new locality is termed as preventive method. It is essential to know that how weeds disseminate. By taking following measures weed spread can be prevented from entering into a new locality.

Sowing of weed free clean seed: The seed contaminated with weed seed is a good source of spread of weeds. It becomes hard to separate the weed seed from the crop seed. For example, cruciferous crops like radish, cauliflower, cabbage, broccoli etc. are well mixed with the seed of Satyanashi (*Argemone mexicana*). Such impure seed should be discarded for sowing.

Use of clean implements: While operating agricultural implements like cultivator, harrow, and seed drill etc. in weed infested field, care must be taken that multiplication part of weed like rhizome, bulb, tubers, stem is not being carried along. The agricultural implements should be cleaned properly. Only then these should be used in other fields. This helps in controlling spread of the weeds.

Removal of weeds along canal and irrigation channel: Weed seed get transported through water and reach the field. Removal of weeds growing along the sides of canal or irrigation channel is necessary.

Care in transplanting of seedling: Many horticultural plants like all transplanted vegetables, flowers, and fruits are transplanted in the field with soil attached to their root. Infestation of soil with weed may contaminate a new field.

Use of well rotten manure: Weed seeds have good viability. The seed of hirankhuri (*Convolvulus arvensis*) remain viable for as long as 50 years. Doob (*Cynodon dactylon*) and motha (*Cyperus rotundus*) seed viability lasts for two and five years, respectively. For making manure the cowdung is generally heaped. If the heaping period is short, the seed do not lose its viability and grows in the field wherever manure is applied. So only well rotten manure should be used.

Avoiding passing of cattle from weed infested area: Grazing in weed infested field followed by allowing passage of cattle in new field favours dissemination of weed seed. The weed seeds after passing through alimentary canal of the animal come out through dung, where it gives rise to weed. Some weed seeds also stick to the legs and skin of the animals and get transported to some other place where it germinate and grow as a weed.

Crop management practices. All such practices which favour the growth of main crop only disfavour the growth of weed. The following management practices have smothering effect on weed and must find place in crop land to prevent weed spread:

- Proper crop rotation prevents establishment of weeds.
- Higher plant population per unit area smothers the growth of weed.
- Proper placement of fertilizer in the root zone of the seed favours the growth of crop only. The weeds deprive of nutrients and their growth is restricted.
- Fast and vigorous growing varieties by virtue of their larger leaf canopy cause smothering effect on the growth of weed. Such crops should receive preference to prevent spread of the weed.

Enforcement of weed Laws: In India, many noxious weeds grow in the fields and pose great economic and health hazard. Noxious weeds are those perennial weeds which are reproduced by seeds, stem, roots, and other reproductive parts as well and are very difficult to control. *Parthenium hysterophorus, Striga* sp., *Cyperus rotundus*, *Cynodon dactylon* etc. are noxious weeds that grow in many horticultural crops. In India , no weed laws are in force except in Karnataka where Parthenium has been declared as a noxious weed.

Quarantine Laws: Quarantine laws impose legal restrictions on the movement of the agricultural material. If there were adequate quarantine laws, the *Parthenium* and *Argemone* which widely grows in vegetable and flower field may not have entered India. Creating isolation between widely weed infested area and new area is essential by enforcing and observing quarantine properly.

Use of pre-emergence herbicides: Herbicides which are used before the emergence of weeds either before or after planting of crop, is a good preventive measure for preventing weed infestation. Such herbicides either inhibit seed germination or kill young seedlings before they get established.

Eradication: It infers that a given weed species, its seed & vegetative part has been killed or completely removed from a given area & that weed will not reappear unless reintroduced to the area. Because of its difficulty & high cost, eradication is usually attempted only in smaller areas such as few hectares or few thousand m2 or less.

Eradication is often used in high value areas such as green houses, ornamental plant beds & containers. This may be desirable and economical when the weed species is extremely noxious and persistent as to make cropping difficult and economical.

4.5.2 Weed Control Methods:

Weed control is the process of limiting infestation of the weed plant so that crops can be grown profitably. Thus, weed control is one of the aspects of weed management.

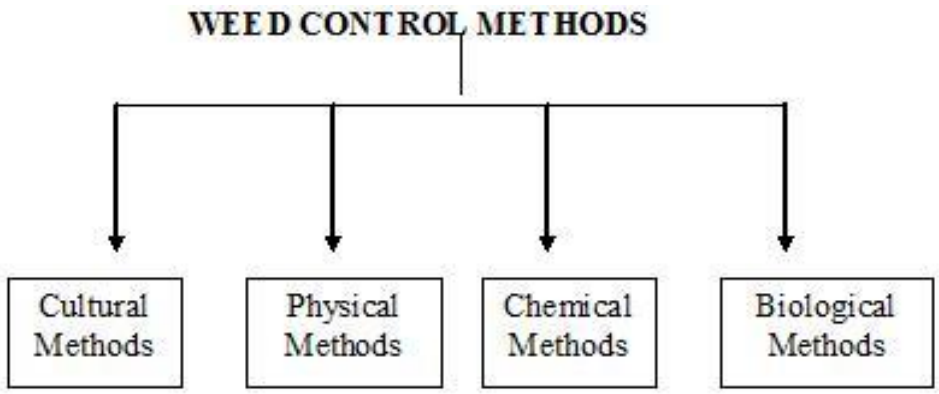


Figure 4.1: Weed Control Methods

4.5.3 Cultural Methods of Weed Control:

Several cultural practices like tillage, planting, fertilizer application, irrigation etc., are employed for creating favourable condition for the crop. These practices if used properly, help in controlling weeds. Cultural methods, alone cannot control weeds, but help in reducing weed population.

Proper crop stands and early seedling vigour - Lack of adequate plant population is prone to heavy weed infestation, which becomes, difficult to control later. Therefore, practices like

a. Selection of most adopted crops and crop varieties
b. Use of high viable seeds
c. Pre plant seed and soil treatment with pesticides, dormancy breaking chemicals and germination boosters
d. Adequate seed rates are very important to obtain proper and uniform crop stand capable of offering competition to the weeds.

Selective Crop Simulation:

Vigorous crop plants compete better with weeds as they close the ground very quickly. Selective simulation can be achieved by

a. application of soil amendments like gypsum or lime may correct the soil conditions in favour of crop.
b. manures and fertilizers application of proper kind in adequate quantities improve the crop growth.
c. Inoculation of crop seeds with suitable nitrogen fixing and phosphorous solubilising organisms may help in selective simulation of some crops e.g. Legume crop and non legume weed. Selective simulation in wide row crops like maize, sugarcane, cotton can be achieved by foliar application of nutrients.

Proper Planting Method:

Any planting method that leaves the soil surface rough and dry will discourage early growth. In summer, furrow planting of crops reduces the weed problems. Because in this method irrigation water restricted initially to the furrow only. In transplanted crops farmers get opportunity to prepare weed free main field.

Planting Time: Peak period of germination of seasonal weeds coincides with crop plants. So little earlier or later than normal time of sowing is beneficial by reducing early crop weed competition. For example, using photo insensitive varieties we can make adjustments with regarding to time of planting.

Crop Rotation: Growing of different crops in recurrent succession on the same land is called as crop rotation. Monocropping favours persistence and association of some weeds. Crop rotation is effective in controlling of crop associated and crop bound weeds such as *Avena fatua* in wheat and *Cuscuta* in lucerne. The *Orobanchae* sp. In tobbaco can be controlled by crop rotation.

Stale Seedbed: Stale seedbed is one where initial 1 to 2 flushes of weeds are destroyed by harrowing before planting or sowing of the crop. This is achieved by soaking a well-prepared field with either irrigation or after receiving rain and allowing the weeds to germinate.

Smother Crop / Competitive Crop: This crop germinates very quickly and develop large canopy, capable of efficient photosynthesis within short period. They possess both surface and deep roots. Competitive crop covers the ground quickly than non-competitive crop. e.g., Cowpea, Lucerne, berseem, groundnut and sun hemp.

Growing of Intercrops: Inter cropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of weed management. Many short duration pulses viz., green gram and soybean effectively smother weeds without causing reduction in the yield of main crop.

Summer Fallowing: The practice of summer tillage or off-season tillage is one of the effective cultural methods to check the growth of perennial weed population in crop cultivation. In the month of April, May and June farmers expose their lands to sun in order to control many soils born pests, including weeds. Roots, rhizomes and tubers of shallow rooted perennials like Bermuda grass and nut sedge.

Field Preparation:

- The field has to be kept weed free. Flowering of weeds should not be allowed. This helps in prevention of buildup of weed seed population in the fields.
- Irrigation channels are the important sources of spreading weed seeds. It is essential, therefore, to keep irrigation channels clean.
- Deep ploughing in summer, exposes underground parts like rhizomes and tubers of perennial and obnoxious weeds to scorching summer sun and kills them.
- Conventional tillage which includes 2 to 3 ploughings followed by harrowing decreases the weed problem.
- Running blade harrows cuts weeds and kills them.
- In lowland rice, puddling operation incorporates all the weeds in the soil which would decompose in course of time.

Planting Method:

- Sowing of clean crop seeds without weed seeds should be done. It is a preventive method against introduction of weeds.
- Sowings are taken up one to three days after rainfall or irrigation depending on soil type. Weeds already present in the soil start geminating within two or three days.
- Sowing operation with seed drill removes some of the germinating weeds.
- Transplanting is another operation which reduces weed population. Since, the crop has an additional advantage due to its age.

Solarization:

Method of heating the surface by using plastic sheets on moist soil trap the soil radiation. In this method the soil temperature is further increased by 5 to 100^{c}. Israel has so far made maximum use of this technique. However, this is costly technique.

4.6 Use of Fertilizers or Selective Crop Stimulation:

The band (near to crop roots) of nitrogen for cereals, sugarcane, and suagrbeet etc. is said to resulted in their vigorous growth that carries them beyond weed competition. Some fertilizers like calcium cyanamide and ammonium sulphate directly destroy the delicate weeds. **Irrigation and Drainage**

- Depending on the method of irrigation, weed infestation may be increased or decreased.
- Frequent irrigation or rain during initial stage of crop growth induces several flushes of weeds.

- In lowland rice, where standing water is present most of the time, germination of weeds is less.
- Continuous submergence with 5 cm water results in reducing weed population whereas under upland situation, weed population and weed dry matter is very high

Varieties:

Short stature, erect leaved varieties permit more light compared to tall and leafy traditional varieties. Weeds continue to germinate for long time in 'dwarf varieties resulting in high weed growth.

4.7 Physical (Mechanical & Manual) Methods of Weed Control:

Physical force either manual, animal or mechanical power is used to pull out or kill weeds. Depending on weed and crop situation one or combination of these methods are used.

Hand-weeding:

- Pulling out weeds by hand or uprooting weeds by using small hand tool is known as hand weeding.
- Two aspects are important in hand weeding: the number of hand weedings to be done and the interval between two hand weedings.
- The number of hand weedings to be done depends on crop growth, weed growth and critical period of crop-weed competition.
- The number of hand weedings range from 2-4 for most of the field crops.
- The interval between two weedings depends on the quickness of weed growth which interferes with crop growth. Generally, it is 15-20 days

Hand hoeing:

- The entire surface soil is dug to a shallow depth with the help of hand hoes, weeds are uprooted and removed.
- After hand hoeing, the field is subjected to drying to avoid re-establishing of uprooted weeds.

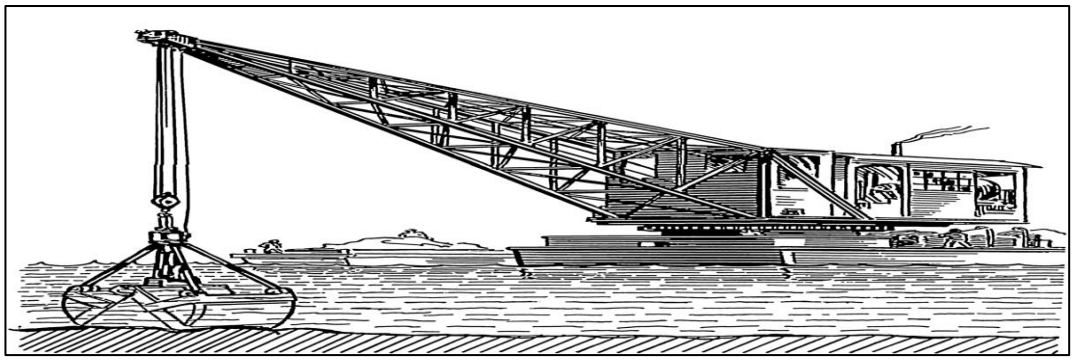
Digging: Digging is very useful in the case of perennial weeds to remove the underground propagating parts of weeds from the deeper layer of the soil. They can be eliminated by digging with crowbar or Pick axe etc.

Mowing and cutting:

Mowing is cutting of uniform growth from the entire area up to the ground level. Cutting is the topping/cutting of the weeds little above ground level. It is done with help of axes and saws. It is mostly practiced against brushes and trees.

Dredging and Chaining:

Mechanical pulling of aquatic weeds along with their roots & rhizomes from the mud is known as dredging. In case of chaining, a very big & heavy chain is pulled over the bottom of a ditch with tractors along with embankments of ditch.



Burning and Flaming:

It is cheapest method to eliminate the mature unwanted vegetation in non-cropped areas and range lands. Flaming is used in western countries for selective weed control in crops like cotton, onion, soybean and fruit orchards. It is the momentary exposure of green weeds to as high as 1000oC from flame throwers to control in row weeds.

Soil Solarization:

It is effective against weeds which are produced from seeds. Covering the soil with transparent, very thin plastic sheets of 20-25 mm polyethylene (PE) film during hottest part of summer months for 2-4 weeks. This increases the temperature by 10-12 0 C over the un-filmed control fields.

Tillage:

Tillage removes weeds from the soil resulting in their death. It may weaken plants through injury of root and stem pruning, reducing their competitiveness or regenerative capacity: Pre plant tillage helps in burying the existing weeds.

Mulching:

The mulch provides a physical barrier on the soil surface and must block nearly all light reaching the surface so that the weeds which emerge beneath the mulch do not have sufficient light to survive. E.g.- Polythene sheets, natural materials like paddy husk, ground nut shells, saw dust etc. The efficiency of polythene sheet is more (more polythene) if it is applied in continuous sheet. It is effective against annual weeds and perennial weeds.

Flooding:

Flood kills weeds by excluding oxygen from their environment. Flooding is a worldwide crop husbandry method of controlling weeds in rice fields. It helps in controlling weeds like Kans *Cyperus spp.* (*Saccharum Spontaneous*) which grows luxuriantly in heavy ill- drained soils during rainy season.

4.8 Biological Methods of weed control:

Insects, herbivorous fish, other animals, disease organisms, and competitive plants are all used to inhibit their growth. Weeds cannot be eradicated using biological management methods, although the number of weeds can be controlled. This strategy does not work for all sorts of weeds. The best targets for biological control are introduced weeds. Two significant examples of early period biological weed control are the control of Opuntia spp. (prickly pear) in Australia and lantana in Hawaii with particular insect bioagents.

Table 4.1: Different bio-agents used for weed control:

Weed	Bio-agent	Reporting Country	Type of Bioagent
Chondrilla juncea	Puccina chondrillina	Australia	Plant pathogen
Eupatorium riparium	Entyloma compositarum	USA	Plant pathogen
Hydrilla verticillata	Hydrellia pakistanae	USA	Shoot fly
Orobanche cornea	Sclerotinia sp.	USA	Plant pathogen
Parthenium hysterophorus	i)Zygogramma bicolorata ii)Epiblema strenuana iii) Conotrachelus sp.	India Australia Australia	Leaf eating beetle Stem galling insect Stem galling insect

Weed	Bio-agent	Reporting Country	Type of Bioagent
Rumex spp.	i) Uromyces rumicis ii) Gastrophysa viridula	USA USA	Plant pathogen Beetle
Cyperus rotundus	Bactra verutana	India, Pakistan, USA	Shoot boring moth
Echinochloa spp. (In rice fields)	i)Emmalocera sp. ii) Tripos spp .	-	i)Stem boring moth ii) Shrimp
Tribulus terrestris	Microlarinus lareynii and M. lypriformis	USA	Pod weevil

Table 4.2: Some Commercial Bioherbicides used in weed control

Product	Content	Weed controlled
De-Vine	A liquid suspension of fungal spores of Phytophthora palmivora. It causes root rot in the weed.	Strangler-vine. (Morrentia odorata) in citrus orchards.
Collego	Wettable powder containing fungal spores of Colletotrichum gloesporiodes Sub sp. aeschynomone	Joint vetch (Aeschynomone sp). In rice fields. The bioherbicide causes stem and leaf blight in the weed.
Bipolaris	A suspension of fungal spores of Bipolaris sorghicola.	Johnson grass (Sorghum halepense)
Biolophos	A microbial toxin produced as fermentation product of Streptomyces hygroscopicus.	Non-specific, general vegetation
Luboa-2	Colletotrichum gloesporiodes Spp. Cuscuta	Cuscuta

4.9 Allelopathy as a Weed Management:

Allelopathy is a natural process that can be used in crop production as a tool for biological weed management. Allelochemicals could be utilised to develop new methods to tackle weed resistance to herbicides. White mustard seed germination was entirely suppressed by

sunflower extracts (*Sinapis alba* L.). *Phalaris minor* Retz., *Chenopodium album* L., *Coronopus didymus* L., *Medicago polymorpha* L., and *Rumex dentatus* L. were all inhibited by an annuionone derived from aqueous extract of sunflower (cv. Suncross-42 leaves).

4.10 Chemicals Methods of Weed Control:

Chemicals that are used to kill plants or weeds are called herbicides. Chemical weed control functions on the basis that certain chemicals are capable of killing some plants weeds without significantly affecting other plants or crops.

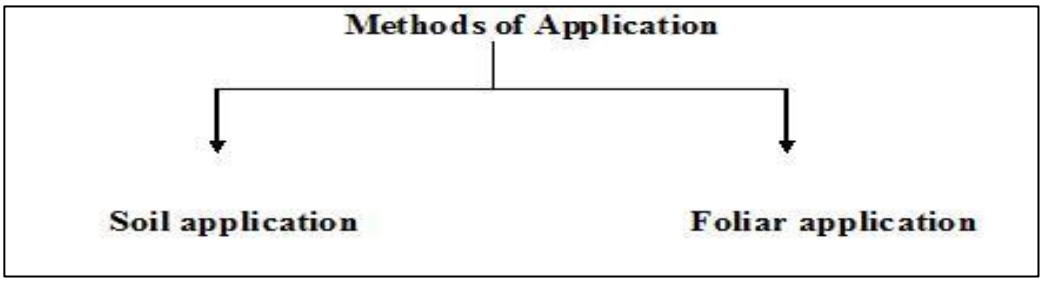


Figure 4.2: Methods of Application

4.10.1 Soil Application:

A. Soil Surface Application:

Herbicides are usually applied to soil surface to form a uniform herbicide layer. The applied herbicides, due to their low solubility may penetrate only few centimeters into the soil. Weeds germinating in the top layers are killed due to incidental absorption of herbicides. eg. triazines, ureas and anilide.

Soil incorporation: Some herbicides are applied to soil surface and incorporated into the soil either by tillage or irrigation for their effectiveness. eg. volatile herbicides *viz*., aniline and carbamate

Sub-surface application: Perennial weeds like *Cyperus rotundus* and *Cynodon dactylon* are controlled by injecting herbicides to the lower layers of the soil at several points.

B. Foliar Application:

Band application: Herbicides are applied as narrow bands over or along the crop row. The weeds in between the crop rows can be controlled by intercultivation or band application of herbicide. This method is useful where labour is expensive and intercultivation is possible. eg. Weeds in maize can be controlled effectively by spraying atrazine on seed row at the time of sowing.

Blanket application: Application of herbicide over the entire leaf area. Selective herbicides are applied by this method.

Directed Application: Herbicide are applied directly to weeds between crop rows, avoiding the crop foliage. Care is taken to avoid spray fluid falling on the crop. eg. Late weeds in cotton can be controlled by spraying non selective herbicide by directed spray.

Spot application: Herbicides are applied or poured on small patches of weeds, leaving the relatively wee free patches untreated. It minimizes the herbicide usage per unit area.

Benefits of chemical method:

- Herbicides can be applied for weed control in crop rows and where cultivation is impossible.
- Pre-emergence herbicides provide early season weed control.
- Cultivation & manual methods of weed control may injure the root system.
- Herbicides reduce the need for pre-planting tillage. They are extremely useful in minimal\zero tillage.
- Herbicides can control many perennial weeds which cannot be controlled by other methods. Eg: *Cyperus* sp.,

4.11 Conclusion:

Integrated weed management is a science-based decision-making approach that includes multiple weed control methods rather than relying on a single method to reduce weed populations below an economic threshold. This strategy is more effective since any weeds that are left over from one method can be controlled with another. As a result, this technique aids in the reduction of seed bank status in the field. Many difficulties, such as shifts in weed flora and the development of resistance in weed plants, can be prevented by using this strategy. The requirement of the day is for an integrated weed control strategy, and this method must be promoted in order to achieve long-term respite from these unwelcome plants. Integrated weed management approach is environmentally friendly as farmers are not entirely dependent on herbicides.

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