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Integrated Weed Management

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The agricultural growth rate has slowed down in India and increased agricultural productivity is needed to meet the increasing needs of the growing population. Low and stagnant yield per unit area across almost all crops has become a regular feature of Indian agriculture. In this backdrop, the required increase in food production can be realized only through vertical increases in productivity, as the possibilities of horizontal increase i.e., expansion of area are minimal. The vertical increase has got tremendous scope which can be achieved with better genotypes and providing farmer-friendly input technology. One such technology which has a potential to yield substantial increase in the production of food grains is proper weed management as weeds alone are known to account for nearly one third of the losses caused by various biotic stresses.

Economic losses due to weeds

A recent study suggests that nearly one-third of oilseeds, half of the food grains, and an equal amount of pulses produced currently are lost due to weeds and proper weed management technologies if adapted can result in an additional production of 103 million tonnes of food grains, 15 mt of pulses, 10 mt of oilseeds and 52 mt of commercial crops, per annum, which in few cases are even equivalent to the existing annual production. Besides, huge amount of money is spent on controlling the weeds. At a conservative estimate, an amount of Rs. 100 billion is spent on weed management annually in India, in arable agriculture alone. The potential yield losses due to weeds can be as high as about 65% depending on the crop, degree of weed infestation, weed species and management practices. Thus, weed management would continue to play a key role to meet the growing food and fibre demands of increasing population in India.

Environmental impact of weeds

In the agro ecosystems ideal environmental conditions provided for optimal crop productivity are being exploited by the associated weeds. Weeds interfere with crop production through their ability to compete for resources and their impact on product quality. Weeds not

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only cause huge reductions in crop yields but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect-pests, diseases, affect aesthetic look of the ecosystem, native biodiversity, as well as affect human and cattle health and some weeds may also have allelopathic effects.

Herbicide resistance in weeds

Although herbicides have played a vital role in improving crop yields and overall production efficiency, over-reliance and repetitive use of the herbicides belonging to the same class can also led to the development of herbicide-resistant weed biotypes. In India, though herbicides are not used so extensively as in developed countries, but the continuous use of butachlor as well as isoproturon can lead to the development of resistance in *Echinochloa colona* and *Phalaris minor*, respectively, thereby posing a serious threat to the sustainability in rice-wheat system in the country.

Weed flora shift

Changes in input availability and crop sequence have changed the component of weed flora. Increased adoption of resource conservation technologies like zero tillage, bed planting etc., will lead to reduced cost of cultivation, better management of problem weeds like *Phalaris minor* in rice-wheat system. In addition, it may also result in weed flora shift favouring the perennial weeds besides increasing the herbicide use. So proper weed management strategies should be adopted.

Preventive strategies

The preventive measures usually do not offer remedy over the already existing population and diversity of weeds in the crop fields, but they focus on the prevention of further introduction of weeds from different external sources/agents as well as perpetuation of weeds in forth-coming years from the existing stands of weeds in crop fields.

Pure and clean crop seeds and seed certification

Before sowing, thorough sieving should be done in order to sieve out the weed seeds, broken, shrivelled grains and diseased seeds. Check seeds thoroughly and ensure that no weed seed is present. If it is not possible to separate out the weed seeds due to their similar size to that of crop seed, better reject that lot for seed purposes and use certified seed of crops.

Well-decomposed FYM, compost, sewage and sludge

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Use well decomposed FYM where a composting temperature of 65 to 90^{O}C should be maintained for 4-5 months. Treat the FYM with chemicals like acrocyanamide, SMDC (metham), DMTT (mylone) and ammonium thiocyanate (synthetic urea). Sewage and sludge need to be treated properly towards making free from weed seeds before applying to crop fields.

Prevent movement of weeds through machinery etc.

Clean the harvesters, seed cleaners, hey balers and other farm implements before moving them from infested area. Avoid use of gravel, sand and soil from weed infested area.

Keep non crop area clean

Keep irrigation & drainage channel, fence lines, road sides, fence corners and all other non-cropped areas free from weeds. Prevent the dissemination of mature seeds to the main land.

Use vigilance

A farmer should inspect his farm periodically for strange looking new weed. Farmer knows the weed flora in his field. So when a new weed species is seen then prevents its establishment. So that it does not add to existing weed flora.

Physical (Mechanical & Manual) Methods

Hand weeding

Removal of weeds either manually or by using tools like khurpi or sickle, when weeds grown up to some extent and the method is effective against annuals and biennials and controls only upper portion of the perennial.

Hand hoeing

Taking out the weeds with the help of khurpi or hand hoes. Hoeing by cutting the crown part gives proper control. *Convolvulus arvensis* which has shallow root system can be controlled.

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

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It is cutting of uniform growth from the entire area up to the ground level. Effective against erect and herbaceous weeds.

Cutting

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

Mechanical pulling of aquatic weeds along with their roots & rhizomes from the mud.

Chaining

Very big & heavy chain is pulled over the bottom of a ditch with tractors along with embankments of ditch. With rubbing action of chain weeds can be fragmented & collected by nets and hooks.

Flaming

It is the momentary exposure of green weeds to as high as 1000^{o}C from flame throwers to control in row weeds. Flaming is used in western countries for selective weed control in crops like cotton, onion, soybean and fruit orchards.

Soil Solarization

It is effective against weeds which are produced from seeds. It doesn't involve any tillage of the field. 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. Then weeds seeds are desiccated which are present at top 5 cm soil depth.

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. Bring the weed seeds to the soil surface for germination and their subsequent destruction by suitable secondary tillage implements. Incorporation of pre-plant herbicides. Post plant tillage (row cultivation) helps in mixing of manures and fertilizers & control of weeds, soil and water conservation.

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. Polythene sheets, natural materials like paddy husk, ground nut shells, saw

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dust etc. are used as mulching material. 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.

Cultural Methods

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 growth b) addition of FYM or synthetic soil conditioners to very light or heavy soils may improve the soil structure and maintaining better air water relationships and ultimately it improving the crop growth c) manures and fertilizers application of proper kind in adequate quantities improve the crop growth. d) Inoculation of crop seeds with suitable nitrogen fixing and phosphorous solubilising organisms may helps 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. Plough planting (minimum tillage) methods proved to be very useful to reduce early weed 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

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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 favors 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. Wheat-pea and gram break the *Avena* in wheat, grain crop rotation control *Cuscuta.* The *Orobanchae sp.* In mustard can be controlled by crop rotation.

Stale Seedbed

This is achieved by soaking a well-prepared field with either irrigation or rain and allowing the weeds to germinate. These weeds are controlled by using contact herbicides like paraquat and by mechanical methods then sow the crop. Here the advantage is the crop is germinated in weed free environment. In this way, weed seed bank is exhausted.

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 noncompetitive crop. e.g., Cowpea, Lucerne, berseem, millets.

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.

Minimum tillage

Deep and frequent tillage may be useful for some reasons but it serves to bring more of dominant weed seeds and rhizomes to the soil surface Preserve the new weed seeds deep in the soil for the future Zero tillage completely avoids burying of weed seeds and reduces persistence of annual weeds but it induces vigorous growth of perennial weeds.

Summer fallowing

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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 soil born pests, including weeds. Roots, rhizomes and tubers of shallow rooted perennials like Bermuda grass and nut sedge.

History of Herbicide Development

Common salt, ash etc. have been used for centuries to control weeds on roadsides, fence rows & pathways. Selective control of weeds in Agriculture was first conceived in 1896 with the chance observation of French farmer that Bordeaux mixture sprayed on Grape vine to control downy mildew damaged certain broad-leaved weeds. A real breakthrough in selective weed control was achieved in 1945, with the discovery of 2,4-D & MCPA in USA & England independently by P.W. Zimmerman and A. E. Hitchkock. Both 2,4-D and MCPA were found highly selective for cereals and phytotoxic to broad leaved weeds. In Agriculturally developed countries, herbicides form over 45% of the total pesticides used. In India, share of herbicides is only 8% of the total pesticides consumed.

Biological Methods

Utilization of natural living organism, such as insects, herbivorous fish, other animals, disease organisms and competitive plants to limit their growth. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control. The control *Opuntia spp* (prickly pear) in Australia and lantana in Hawai with certain insect bioagents are two spectacular examples of early period biological control of weeds.

Allelopathy as a Weed Management

Allelopathy is a natural technique that may be considered as a tool for biological weed control in crop production. Allelochemicals may be used to develop new tools to combat the evolution of herbicide resistance in weeds. Sunflower extracts completely inhibited seed germination of white mustard (*Sinapis alba* L.). An annuionone isolated from aqueous extract of sunflower (cv. Suncross-42 leaves) reduced the growth of all five selected weed species: *Phalaris minor* Retz., *Chenopodium album* L., *Coronopis didymus* L., *Medicago. polymorpha* L. and *Rumex dentatus* L.

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Integrated weed management is a science-based decision-making process that combinations of the methods of weed control rather than a single method be exercised in coordinated way to bring down weed population below an economic threshold level. This method is more effective because the left-over weeds with one method can be controlled with other method. So this method helps in reducing seed bank status in the field. With the adoption of this method, many problems such shift in weed flora, development of resistance in weed plants can be avoided. Integrated method of weed control is the need of the day and this method must be advocated in order to get long term relief from these undesirable plants. Integrated weed management approach is environmentally friendly as farmers are not entirely dependent on herbicides.

Yield losses due to weeds in some important crops

Crop	Yield loss range (%)	Crop	Yield loss range (%)
Rice	9.1 – 51.4	Sugarcane	14.1 – 71.7
Wheat	6.3 – 34.8	Linseed	30.9 – 39.1
Maize	29.5 – 74.0	Cotton	20.7 – 61.0
Millets	6.2 – 81.9	Carrot	70.2 – 78.0
Groundnut	29.7 – 32.9	Peas	25.3 – 35.5

Different bio-agents used for weed control

Weed	Bio-agent	Reporting Country	Kind of bio agent
Chondrilla juncea	*Puccina chondrillina*	Australia	Plant pathogen
Eupatorium riparium	*Entyloma compositarum*	USA	Plant pathogen
Hydrilla verticillata	*Hydrellia pakistanae*	USA	Shoot fly
Orobanche cernua	*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
Rumex spp.	i) *Uromyces rumicis*	USA	Plant pathogen

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	ii)*Gastrophysa viridula*	USA	Beetle
Tribulus terrestris	*Microlarinus lareynii and M. lypriformis*	USA	Pod weevil
Cirsium arvense	*Septoria cirsii*		Plant pathogen
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

Some Commercial Mycoherbicides 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

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Crop yield losses caused by weeds and other pests in India