Weed Control – Management

Weed control and management are the two terms often we use in weed science. Weed control is the process of limiting infestation completely so that crop can be grown successfully or other operations can be done efficiently. The objective of weed management is to limit the weed population by providing favourable environment to the crop plants with the intension that vigorous crop can suppress the weeds.

The extent to which any weed growth to be limited will depend upon the cost of weed management and the benefits anticipated from the operation. The weed population at which the cost of weed management equals the additional profits represents the Threshold level of weeds.

The aim of weed management is to manage the vegetation on land and water bodies in such a way it will encourage the growth of beneficial plants of our interest at a particular place and time and will suppress the remaining relatively unwanted plants.

Various methods adopted for weed management are

a) Prevention b) Eradication c) Control / management

A. PREVENTION

It encompasses all measures taken to prevent the introduction and/or establishment and spread of weeds. Such areas may be local, regional or national in size. No weed control programme is successful if adequate preventive measures are not taken to reduce weed infestation. Following preventive control measures are suggested for adoption wherever possible & practicable.

1. Clean cultivation
2. Use of weed free clean and certified seeds
3. Keeping seed beds free from weeds
4. Avoid feeding r material containing weed seeds to the farm animals
5. Avoid adding weeds which set seeds to the manure pits.
6. Clean the farm machinery thoroughly before use
7. Keep irrigation channels, fence-lines, and un-cropped areas clean
8. Use vigilance. Inspect the farm frequently for any strange looking weed seedlings. Destroy such patches of a new weed by digging deep and burning the weed along with its roots.
9. Quarantine regulations deny the entry of weed seeds and other propagules from one country to another at airports and shipyards
10. Remove / destroy weeds before they attain reproductive stage or setting seeds
11. Prevention by weed Laws

Weed laws are important in reducing the spread of weed species and increase the use of high quality certified crop seeds. There are no weed laws in India except in Karnataka which declared Parthenium as a noxious weed.

Weed laws largely prohibit seeds of noxious weeds passing through mislabeled or contaminated seeds.

B. 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 ha., a few thousand m_2 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.

C. Weed Control / Management

It encompasses those processes where by weed infestations are reduced but not necessarily eliminated. Weed control aims at only putting down the weeds present by some kind of physical or chemical means while weed management is a system approach where in advance planning is done to minimize the invasion of weeds in aggressive forms and give crop plants a strongly competitive advantage over the weeds.

Weed control / management methods are grouped into cultural, physical, chemical and biological. Every method of weed control has its own advantages and disadvantages. No single method is successful under all weed situations. Many a time, a combination of these methods gives effective and economic control than a single method.

Physical or Mechanical weed control / management

Mechanical or physical methods of weed control are being employed ever since man began to grow crops. The mechanical methods include tillage, hoeing, hand weeding, digging cheeling, sickling, mowing, burning, flooding, mulching etc.

1. 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.Tillage also buries weeds and also exposes weed seeds to the soil surface for solar scorching. Tillage operation includes ploughing, discing, harrowing and leveling. In case of perennials, both top and underground growth is injured and destroyed by tillage.

Tillage operations are broadly grouped as pre plant and post plant / inter-cultural operations which are aiming for different purposes viz., soil moisture conservation, aeration, incorporating the manure and indirectly promote the crop growth for subsequent suppression of weeds.

2. Summer tillage: 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. Initial tillage before cropping should encourage clod formation. These clods, which have the weed propagules, upon drying desiccate the same. Subsequent tillage operations should break the clods into small units to further expose the shriveled weeds to the hot sun.

3. Hoeing: Hoe has been the most appropriate and widely used weeding tool for centuries. It is however, still a very useful implement to obtain results effectively and cheaply. Hoeing is particularly more effective on annuals and biennials as weed growth can be completely destroyed. In case of perennials, it destroy the top growth with little effect on underground plant parts resulting in re-growth.

4. Hand weeding: It is done by physical removal or pulling out of weeds by hand or removal by implements called khurpi. It is probably the oldest method of controlling weeds and it is still a practical and efficient method of eliminating weeds in cropped and non-cropped lands. It is very effective against annuals, biennials and controls only upper portions of perennials. The major set back here is the labour availability, time consumption and ideal soil condition.

5. 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. This can be done using pickaxe or guddali or crow bar.

6. Cheeling: It is done by hand using a cheel hoe, similar to a spade with a long handle. It cuts and shapes the above ground weed growth. It is useful on annuals and biennials and widely used in plantation crops.

7. Sickling: Sickling is also done by hand with the help of sickle to remove the top growth of weeds to prevent seed production and to starve the underground parts. It is popular in sloppy areas where only the tall weed growth is sickled leaving the root system to hold the soil in place to prevent soil erosion.

8. Mowing: It is the cutting of weeds at uniform height and used o restrict seed production and check excess weed growth. It is a machine-operated practice mostly done on roadsides and lawns.

9. Burning or Flaming: Burning or firing is often an economical and practical means of controlling weeds. It is used to (a) dispose of vegetation (b) destroy dry tops of weeds that have matured (c) kill green weed growth in situations where cultivations and other common methods are impracticable.

Flaming is the exposure of green weeds to a very high temperature (up to 1000°C) using flames from burning petroleum gas. Flames are directed towards weeds in between crop rows with a hood cover.

10. Flooding: Flooding is successful against weed species sensitive to submergence in water. Flooding kills plants by reducing oxygen availability for plant growth. The success of flooding depends upon level and period of submergence of weeds.

11. Dredging and Chaining: These methods are adopted for aquatic weeds. Removing of weeds along with their roots and rhizomes with the help of mechanical force is called dredging. The floating aquatic weeds are removed by chaining. High strength chain is pulled over the water bodies to collect weeds.

Merits of Physical or Mechanical Method

1) Oldest, effective and economical method
2) Large area can be covered in shorter time
3) Safe method for environment
4) Does not involve any skill
5) Weeding is possible in between plants
6) Deep rooted weeds can be controlled effectively

Demerits of Mechanical Method

1) Labour consuming
2) Possibility of damaging crop
3) Requires ideal and optimum soil condition

CULTURAL METHODS OF WEED CONTROL / MANAGEMENT:

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. They should, therefore, be used in combination with other methods. In cultural methods, tillage, fertilizer application and irrigation are important apart from selection of variety, time of sowing, cropping system, cleanliness of the farm etc., in controlling the weeds.

1. Field preparation: The field has to be kept clean and weed free. Flowering of weeds should not be allowed. This helps in prevention of build up of weed seed population. Field operations must be planned in such a way that field is kept weed free.

2. Varieties: Short stature, erect leaved varieties permit higher light compared to tall and spreading type of varieties. Weeds continue to germinate for longer time in dwarf varieties resulting to higher infestation.

3. Sowing / Planting methods: Sowing / planting should be taken with in three days of rainfall or irrigation. Weeds present in soil start germinating with in 2 – 3 days and suppress the crop plants if we delay the sowing.

Sowing with seed drill followed by passing blade harrow in between the rows to cover seeds will disturb weeds which are already germinated. Transplanting is another operation which reduces the weed growth as the crop has an advantage of age.

4. Time of planting: Optimum time of planting crops seems also best season for emergence of weeds. Attributing to the availability of photo-insensitive varieties, in field with a bad history of weeds, crops can be sown / planted either little earlier or later than the normal planting. This helps to avoid first flush of weeds.

5. Optimum plant population: Lack of adequate plant population is prone to heavy weed infestation, which becomes difficult to control later. Therefore practices like selection of proper seed, right method of sowing, adequate seed rate etc. are very important to obtain proper and uniform crop stand which are capable to offer competition to the weeds.

6. Crop rotation: The possibility of a certain weed species or group of species occurring is greater if the same crop is grown year after year. In many instances, crop rotation can eliminate or atleast reduce difficult weed problems. The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation. Cotton - sorghum crop rotation to control striga.

7. Smother or 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. Smother crop germinates quickly and develop large canopy with deep roots. They suppress weeds by excluding light and utilizing large portion of nutrients, water in the soil.

8. Mulching: Mulch is a protective covering of material maintained on soil surface. Mulching has smothering effect on weed control by excluding light from the photosynthetic portions of a plant and thus inhibiting the top growth. It is very effective against annual weeds and some perennial weeds like *Cynodon dactylon.* Mulching is done by dry or green crop residues, plastic sheet or polythene film.

9. Solarization: This is another method of utilization of solar energy for the desiccation of weeds. In this method, the soil temperature is further raised by 10-12 °C by covering a presoaked fallow field with thin transparent polyethylene sheet during hot summer months. The polyethylene sheet checks the long wave back radiation from the soil and

prevents loss of energy by hindering moisture evaporation. Solarization kills the weeds through desiccating the weed seeds, suffocation through ceasing gas exchange, scorching of the sprouted seeds and microbial disintegration / desiccation of weeds seeds.

10. Stale seedbed: A stale seedbed is one where initial one or two flushes of weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. At this stage a shallow tillage or non- residual herbicide like paraquat may be used to destroy the dense flush of young weed seedlings. This may be followed immediately by sowing. This technique allows the crop to germinate in almost weed-free environment.

11. Fertilizer and water management: Plants differ in their ability of responding to applied fertilizer and water. Application of fertilizer and irrigation water at appropriate time, method and depth will improve the crop vigour through their efficient use and suppress the weeds.

Merits of Cultural Method

1. Low cost for weed control
2. Easy to adopt
3. No residual problem
4. No damage to crops

Demerits of Cultural Method

1. Immediate and quick weed control is not possible
2. Weeds are kept under suppressed condition
3. Perennial and problematic weeds can not be controlled

BIOLOGICAL WEED CONTROL /MANAGEMENT

It is the control or suppression of weeds by the action of one or more organisms through natural means or by manipulation of weed, organism or environment.

Use of living organism's viz., insects, disease causing organisms, herbivorous fish, snails or even competitive plants for the control of weeds is called biological control. 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.

Qualities of bio-agent

1. Host specific: The bio-agent must feed or affect only on the targeted host
2. It must be free of predators or parasites.

3. It must adapt readily to the environment conditions.
4. Must be capable of seeking out itself to the host.
5. It must kill the targeted host or atleast prevent its reproduction rapidly
6. It must reproduce / multiply rapidly.

Mode of action:

Insects kill the weeds by boring into the plant to weaken / collapse the plant part and through consumption / destruction of vital plant parts

Pathogenic organisms damage the host plant through

a) Enzymatic degradation of cell constituents
b) Production of toxins
c) Disturbance of hormone system
d) Obstruction in translocation of food materials and mineral nutrients
e) Malfunctioning of physiological processes

Effects of biological agents in weed management depends on

1. **Choice of Bio-agent:** The selected organism must be able to kill the weed or prevent its reproduction. It must locate host plant and should have high reproductive capacity sufficient to maintain the required population.

2. **Aggressiveness:** It is the competitive ability of bio-agents on weeds.

3. **Climatic conditions:** Climate affects the adoptability of the bio-agent and inturn the weed suppression.

Biological control agents

Insects :

Weed	Bioagent
1. *Lantana camera*	Larvae of *Crocidosema lantana* (flowers & fruits) Larvae of *Agromyza lantanae* (berries) Larvae of *Theclea echion* and *T. barochi* Lacewingbug.: *Teleonemia scrupulosa.*
2. *Opuntia* sp.	*Cactoblastis cactorum* *Dactylopius opuntiae* *Dacylopius tomemtosus* *Dactylopius indicus*
3. *Hypericum perforatium* (Europe, USA, Newzealand)	*Chrysalis hyperici* *Agrilus hyperici* *Chrysalis gameliata*
4. *Cuscuta* sp.	*Melanogromyza cuscutae* *Smicronyx cuscutae*
5. *Cyperus rotunudus*	*Bactra vermosana*

6. *Imperata cylindrica*	*Orseoliella javanica* or *seoliella javanica*
7. *Eichornia crassipes*	*Neochetina bruchi* *Neochetina eichhorni*
8.*Parthenium hysterophorus*	*Zygogramma biocolorata*

Plant pathogens: Disease causing pathogens viz., Fungi, Bacteria, Virus offer greater promise for use as bio-herbicides. Bio-herbicides are the biological agents applied similar to the chemical herbicides in controlling weeds. The active ingredient in bio-herbicide is a living organism or its metabolites and is applied in moderate doses. Fungi are the most commonly used agents and hence, bio-herbicides are some time called as myco-herbicides.

Sl. No	Product	Content	Target weed
1	Devine	A liquid suspension of fungal spores of *Phytophthora palmivora* causes root rot.	Strangle vine (*Morrenia odorata*) in citrus
2	Collego	Wettable powder containing fungal spores of *Colletotrichum gloeosporoides* causes stem and leaf blight	Joint vetch (*Aeschyomone virginica*) in rice, soybean
3	Bipolaris	A suspension of fungal spores of *Bipolaris sorghicola*	Jhonson grass (*Sorghum halepense*)
4	Biolophos	A microbial toxin produced as fermentation product of *Steptomyces hygroscopicus*	Non-specific, general vegetation

Fish : Common / grass carp (*Cyprimus carpio*) feed on grasses in the aquatic eco-system.

Mites: A spider mite (*tetranychus sp*) is found to be useful in controlling prickly pear.

Plants: Cowpea sown in between sorghum / pigeon pea rows effectively reduces the growth.

Mammels / animals: Many animals which feed weed as a fodder.

Merits of Biological agents

1) Least harm to the environment
2) No residual effect
3) Relatively cheaper and comparatively long lasting effect
4) Will not affect non-targeted plants and safer in usage

Demerits of Biological agents

1) Multiplication is costlier
2) Control is very slow
3) Very few host specific bio-agents are available at present
4) No absolute guarantee of safety

CHEMICAL WEED CONTROL

The use of chemicals generally referred as herbicides, for the control of weeds is called chemical weed control offers greater potential in modern agriculture.

The word herbicide is derived from latin word 'Herba' meaning 'Plant' and 'caedere' meaning 'kill'.

The selectivity exhibited by certain chemicals to cultivated crops in controlling its associated weeds without affecting the crops forms basis for the chemical weed control. Such selectivity may be due to differences in the morphology, differential absorption, differential translocation, differential deactivation etc.

History of herbicides

Common salts, ash etc have been used for centuries to control weeds on road side, fence rows and path ways.

Selective control of weeds in agriculture was observed in 1896 with the invention of bordeux mixture in France which is sprayed for control of downy mildew in grapes. It has damaged certain broad leaved weeds because of the presence of $CuSO_4$.

Between 1896 and 1908, several inorganic salts and acids were tried in small grains. The compound tested are sulphuric acid, carbon bisulphide, sodium arsenate, kaolinite, calcium cyanamide etc.

Between 1930 and 1940, some boron compounds, thiocyanates, dinitro phenols, ammonium sulphate and other mineral salts were tried for weed management.

A real break through in selective chemical weed control was observed in 1941-45 with the discovery of 2,4-D (2,4-Di Chloro Phenoxy Acetic Acid) and MCPA (4-Chloro, 2-Methyl Phenoxy Acetic Acid) in USA and England respectively. These were found highly selective to cereals and phytotoxic to the broad leaved weeds. Also, they are non-corrosive, non-flammable and non-explosive.

Consequently, TCA, Dalapon, Chloro-Propham were discovered in 1945.

Today more than 300 herbicides in the world which were produced by about

100 companies.

Objective and Scope of herbicide usage

Commercialization, industrialization and subsequent urbanization forced labour scarcity to agriculture sector. Indiscriminate use of inputs in the name of green revolution favoured the multiplication of weeds rapidly. Further, swelling cost of hired labour, limited fuel & investment for mechanization, non-adoptability under extreme soil & climatic conditions for cultural & mechanical means are the reasons for introduction of herbicides in large scale. Hence, herbicides offer wider scope in weed management. However, herbicides are not aimed to substitute the physical, cultural or biological methods. Practical weed control is a combined effect of good cultural practices, herbicides and other techniques.

Merits

1) Herbicide can be recommended for adverse soil and climatic conditions, as manual weeding is highly impossible during monsoon season.
2) Herbicide can control weeds even before they emerge from the soil so that crops can germinate and grow in completely weed-free environment at early stages.
3) Weed which resemble like crop in vegetative phase may escape in manual weeding. However, these weeds are controlled by herbicides.
4) Herbicide is highly suitable for broadcasting in closely spaced crops where interculture is impractical.
5) Controls the weeds without any injury to the root system of the associated standing crop especially in plantation crops like Tea and Coffee.
6) Reduces the need for pre planting tillage
7) Controls many perennial weed species
8) It is profitable where labour is scarce and expensive
9) Suited best under minimum & zero tillage condition
10) Highly economical

Demerits

1) Pollutes the environment and affects the soil micro flora and fauna
2) It requires technical knowledge for calibration
3) Some herbicide is highly costlier
4) Suitable herbicides are not available for mixed and inter-cropping system.

CLASSIFICATION OF HERBICIDES

1) Based on Placement

i) **Soil applied herbicides**: Those herbicides which are applied on soil. They are mostly pre-emergence or pre-planting herbicides Eg. Butachlor, Fluchloralin

ii) **Foliage applied herbicides**: Those herbicides, which are applied on the foliage of

weeds. They are mostly post-emergence herbicides. Eg. 2,4-D, Glyphosate, Paraquat

2) Based on Selectivity

i) Selective herbicide: A herbicide is considered as selective when in a mixed growth of plant species, it kills some species (weeds) without injuring the others (Crop). These are also called as Narrow spectrum herbicides. Eg. Atrazine

ii) Non-selective herbicide: It destroys majority of treated vegetation irrespective of crop and weed. These are also called as Broad spectrum herbicides Eg. Paraquat

3 Based on Mode of action / translocation

i) **Contact herbicide**: A contact herbicide kills those plant parts with which it comes in direct contact Eg. Paraquat

ii) **Translocative / systemic herbicide**: Herbicide which tends to move from treated part to untreated areas through xylem / phloem depending on the nature of its molecule. The entire plant is poisoned and killed. Eg. Glyphosate

4) Based on Time of application

i) Pre-plant incorporation (PPI): Application of herbicides before the crop is planted or sown. Soil application as well as foliar application is done here. For example, fluchloralin can be applied to soil and incorporated before sowing rainfed groundnut while glyphosate can be applied on the foliage of perennial weeds like *Cyperus rotundus* before planting of any crop.

ii) **Pre-emergence :** Application of herbicides soon after sowing before a crop or weed has emerged. In case of annual crops application is done after the sowing of the crop but before the emergence of weeds and this is referred as pre-emergence to the crop while in the case perennial crops it can be said as pre-emergence to weeds. For example soil application by spraying of atrazine on 3rdDAT to sugarcane can be termed as pre-emergence to cane crop while soil application by spraying the same immediately after a rain to control a new flush of weeds in a inter-cultivated orchard can be specified as pre-emergence to weed.

iii) Post-emergence : Herbicide application after the emergence of crop or weed is referred as post-emergence application. When the weeds grow before the crop plants have emerged through the soil and are killed with a herbicide then it is called as early post-emergence. For example spraying 2,4-D Na salt to control parasitic weed striga in sugarcane is called as post-emergence while spraying of paraquat to control emerged weeds after 10-15 days after planting potato can be called as early post-emergence.

5. Based on the persistence / residual toxicity

i) Residual herbicide: A residual herbicide maintains its phytotoxic effect in soil for more than 3-4 weeks. Ex. 2,4-D

ii) Non-Residual herbicide: These are inactivated in the soil with in 3-4 weeks. Ex. Paraquot

Based on chemical structure

a) **Inorganic herbicides:** These herbicides do not contain carbon atoms in their molecules. They are further classified into different groups based on their chemical nature

b) **Organic herbicides:** These herbicides contain carbon atoms in their molecules. They may be oils or non-oils. Diesel oil, xylene type of aromatic oils, polycyclicaromatic oils are oil type of organic herbicides. Organic acids and salts as well as oil type of herbicides are not in use now. Majority of the present day herbicides are organic compounds, which are non-oils.

HERBICIDE FORMULATIONS

Herbicides in their natural state may be solid, liquid, volatile, non-volatile, soluble or insoluble. Hence these have to be made in forms suitable and safe for their field use. Such forms are called as Herbicide formulations.

An herbicide formulation is prepared by the manufacturer by blending the active ingredient with substances like solvents, inert carriers, surfactants, stickers, stabilizers etc. herbicides are formulated for easy handling and controlled activity on the target plants

Need for preparing herbicide formulation

i) To have a product with physical properties suitable for use in a variety of types of application equipment and conditions.
ii) To prepare a product which is effective and economically feasible to use
iii) To prepare a product which is suitable for storage under local conditions

Types of formulation

I. **Emulsifiable concentrates** (EC): A concentrated herbicide formulation containing organic solvent and adjuvants to facilitate emulsification with water. emulsifier helps in uniform distribution of the chemical in water and no stirring is necessary while spraying. Eg. 2,4-D ester, Nitrofen, Diallete

Adjuvants: Adjuvants are any substance either added in a herbicide formulation or added to the spray tank that modifies herbicidal activity or application characteristics, such as better mixing and handling, increasing droplet coverage, spray retention and droplet drying, increasing herbicide cuticle penetration.

ii. **Wettable powders** (WP): When the herbicides materials are of low solubility in water, they can be ground into finepowder for suspension in water. This type of formulations is called wettable powders. They require continuous agitation to prevent their settling and to give uniform concentration of the herbicides in the entire spray solution. Eg, Atrazine 80% WP, Simzine 50%WP, Diuron 80%WP, lsorproturon 70%WP.

iii. **Granules** (G): The inert material (carrier) is given a granular shape and the herbicide (active ingredient) is mixed with sand, clay, vermiculite, finely ground plant parts (ground corn cobs) as carrier material. eg., Alachlor granules.

iv. **Water soluble concentrates** (WSC) Herbicide formulations that are in the form of soluble liquids are called water-soluble concentrates. E.g. 2,4-D amine, Dicamba, Diquat, Paraquat

v. **Soluble powders (SP):** These are water-soluble powders. They form a homogenous solution when dissolved in water, which can be applied by spraying. Salts of most herbicides are soluble in water. Eg. Sodium salts of 2,4-D, TCA, Endothal, Dalapon.

vi. **Liquid suspension (LS):** If the active ingredient is not soluble in water, it is solubilised in organic solvents. When the product of active ingredient and solvent is added to water for spraying, it forms a liquid suspensions. These chemicals are comparatively cheaper than emulsifiable concentrates but require constant agitation during spraying to avoid setting. Eg : Atrazine, Cyprazine, Nitraline.

METHODS OF APPLICATION

Factors influencing the methods of application are

a. Weed-crop situation
b. Type of herbicides

c. Mode of action and selectivity d. Environmental factors

e. Cost and convenience of application

Soil Application of Herbicides

a. Surface application : Soil active herbicides are applied uniformly on the surface of the soil either by spraying or by broadcasting. The applied herbicides are either left undisturbed or incorporated in to the soil. Incorporation is done to prevent the volatilization and photo-decomposition of the herbicides. Eg. Fluchoralin – Left undisturbed under irrigated condition and Incorporated under rainfed condition

b. Subsurface application: It is the application of herbicides in a concentrated band, about 7-10 cm below the soil surface for controlling perennial weeds. For this special type of nozzle is introduced below the soil under the cover of a sweep hood. Eg. Carbamate herbicides to control *Cyperus rotundus.* Nitralin herbicides to control *Convolvulus arvensis*

c. Band application: Application to a restricted band along the crop rows leaving an untreated band in the inter-rows. Later inter-rows are cultivated to remove the weeds. Saving in cost is possible here. For example when a 30 cm wide band of a herbicide applied over a crop rows that were spaced 90 cm apart, then two-third of the cost is saved. This method is useful where labour is expensive and inter-cultivation is possible.

d. Fumigation: Application of volatile chemicals in to confined spaces or in to the soil to produce gas that will destroy weed seeds is called fumigation. Herbicides used for fumigation are called as fumigants. These are good for killing perennial weeds and as well for eliminating weed seeds. Eg. Methyl bromide, Metham

f. Herbigation: Application of herbicides with irigation water both by surface and sprinkler systems. In western countries application of EPTC with sprinkler irrigation water is very common in Lucerne.

Foliar Application

i. Blanket spray: Uniform application of herbicides to standing crops without considering the location of the crop. Highly selective herbicides are applied in this method. Eg. Spraying 2,4-Ethyl Ester to rice three weeks after transplanting

ii. Directed spray: Application of herbicides on weeds in between rows of crops by directing the spray only on weeds avoiding the crop. This could be possible by use of protective shield or hood. For example, spraying glyphosate in between rows of tapioca using hood to control *Cyperus rotundus*.

iii. Protected spray: Applying non-selective herbicides on weeds by covering the crops which are wide spaced with polyethylene or metallic covers etc. This is expensive and laborious. However, farmers are using this technique for spraying glyphosate to control weeds in jasmine, cassava, banana.

iv. Spot treatment: It is usually done on small areas having serious weed infestation to kill it and to prevent its spread leaving the weed free gaps untreated. This can avoid possible wastage and reduces the cost. Rope wick applicator and Herbicide glove are useful here.

Methods of treating brush and trees

Brush weeds and unwanted trees are treated with herbicides with different methods depending on the situation.

1. Foliage treatment : is the most common method of treating the brush where the foliage is drenched with suitable herbicide. The treatment is best done when the brush leaves are fully expanded and growing actively.

2. Bark treatment : here the chemical is applied to the stem near the ground. It may be

a) Broadcast bark treatment: Application of herbicide to the entire stem area of the plant . This is adopted when small woody plants having thick stem. Oil mixed phenoxy herbicides are applied in this method.

b) Basal bark treatment : here the herbicides are applied to the stem base of 30-40 cm above ground, here selective trees can be killed without injuring other trees.

3. Trunk injection : Trunk injection often help the herbicide to penetrate through the bark. The trunk injections are made by frilling or notching with an axe or tree injector.

a) Frill treatment : Here the herbicide is brushed or squirted to the cutting edge around the tree that are too large for bark treatment.

b) Notching : The tree trunk may be notched with an axe for every 15 cm of the trunk circumference.

4. Stump treatment : Stumps of many species may sprout immediately after cutting. Here the trees are cut to the ground surface and concentrated herbicides / pastes are applied to the stump of cut surface.

SELECTIVITY OF HERBICIDES AND PRECAUTIONS IN THEIR USE

The differential response of plants (Crops and Weeds) to herbicides is called as selectivity of herbicides. In other words, herbicides harm or kill weeds where as crop plants are unaffected due to the selectivity. The fundamental principle of herbicide selectivity is that more toxicant reaches the site of action in active form inside the targeted plants. This may be due to the difference in absorption, translocation, deactivation, carbon metabolism and resistance of protoplasm. The selectivity of herbicide may be due to one or combination of these processes. The difference in these processes is due to

a) Morphological and physiological differences observed between crop and weeds.
b) Man induces selectivity either by time or method of herbicide application or by

other management practices.

c) Absorbents & antidotes may be used to prevent herbicide absorption by non-target plants.

d) Herbicides and their formulations may differ in their ability to contact the non-target plants.

e)

I. Difference in absorption :

a) Foliage active herbicides : The absorption of foliar applied herbicides primarily depends on retention of herbicide fluid on vegetation. The retention in turn depends on leaf properties like orientation, waxiness, pubescence, corrugation, ridges, depressions etc. In cereals like rice and wheat, have erect orientation than horizontal orientation of broad leaved weeds. Further, the active growing point is hidden in leaf whorls till booting stage where as dicotyledonous weeds have their sensitive growing points exposed to herbicides.

b) Soil active herbicides: The difference in uptake of soil applied herbicides is often based on differential interruption or availability. When herbicide is sprayed on the soil surface, it spreads into thin layer in the top 2-3 cm. most of the weeds germinate from shallow layer. The soil applied herbicides are toxic when they are absorbed by roots. Because of the bigger sized crop seeds, they are generally placed to a depth of 4-5 cm or more and roots develop deeper than 5 cm where there is no herbicide. As weeds germinate from the top layer they come in contact with herbicide and get killed. This type of selectivity is often called as depth protection.

c) Induced selectivity: Selectivity can be created or induced by using absorbents and antidotes. Absorbents are the materials which have the capacity to absorb the active chemical molecule which are placed near the crop seeds to prevent the effect of chemicals. Activated charcoal adsorbs herbicides like 2,4-D, 2,4,5-T, Propham, butachlor etc. Germinating crop seeds and seedlings that are surrounded by a layer of activated charcoal are safe against these herbicides. Absorbents can be applied by different methods like applying over the seed row, in the seed hole, dipping the roots in charcoal-water mixture or seed pelleting.

Antidotes or safeners are the substances capable of antagonizing specific herbicide phyto-toxicity to plant. Some of the antidotes are NA (1,8-Nepthalmic anhydride) & R-25788 are proven effective antidotes of EPTC etc.

II. Differential translocation

There are instances where equal amounts of herbicides absorbed by plants, but translocated at different rates. The selectivity between sugarcane (Tolerant) and beans (Susceptible) to 2,4-D is due to low translocation in sugarcane and rapid translocation in beans. This selectivity further depends on water status and activity of the plants.

III. Differential protoplasmic resistance

Application of herbicides causes deficiency of certain vitamins, amino acids or other constituents. Protoplasm of certain plants can resist the deficiency and tolerate to herbicides. For instance, plants that show tolerance to dalapon can withstand Pentothenic acid deficiency in their tissue and also resist precipitation of their cell proteins.

IV. Differential rate of deactivation

The differential deactivation of herbicide in the plants induces selectivity. The deactivation may be due to metabolism, reverse metabolism or conjugation.

a) **Metabolism:** Breakdown of herbicide inside the plant into non-toxic metabolites is known as metabolism of herbicides. Selectivity of terbacil between tolerant peppermint and susceptible morning glory is due to differential rates of breakdown. Peppermint metabolises terbacil rapidly at the cost of photosynthesis while herbicide persist long time in morning glory due to poor metabolism of terbacil.

b) **Reverse metabolism:** In some of the metabolic reactions of herbicides, the intermediate chemical substances are more toxic than their parent compound. The herbicides 2,4-DB & MCPB are not phytotoxic originally and metabolism of these compounds through enzymatic β-oxidation form a toxic compound which is not found in leguminous plants and are resistant to these compounds.

c) **Conjugation:** Coupling of intact herbicide molecules with some of the plant cell constituents in living plant is known as conjugation. Conjugation takes the toxic herbicide concentration out of main stream of activity in plants. Chloramben is rapidly conjugated in roots of tolerant soybean with glucose molecule to form N -glucosyl chloramben. In susceptible plants, conjugation is slow and herbicide enter to the site of action. Tolerance of grasses to 2,4-D is also due to conjugation

V. Differential carbon metabolism

Herbicides affect carbon metabolism and metabolic activity differently in different plants. Chlorofenprop methyl decrease the reducing sugars gradually in wild oats while barley is not affected.

Precautions in storage and handling of herbicides

1. Store the herbicides away from fertilizers, seeds, food, feed and children in cool and ventilated place. The left over herbicide must be retained in originally labeled container. The container must be airtight to avoid caking, oxidation, fuming etc.
2. Transportation of herbicides should be done with trolley and not with bare hand / body.

3. Prepare the herbicide dilutions in open spaces away from the source of irrigation water. Wear rubber gloves, a pair of eye glasses and cover the nose with a cloth.
4. Mix the solution with a stick and not by bare hand. Bury the empty containers deep in any waste land
5. Keep fresh water and soap handy to meet any emergency
6. Don't smoke or eat during and in between the spray intervals. Also don't use mouth to blow the clogged nozzles.
7. Take bath and wash the cloths thoroughly as soon as the spray is over.
8. In case of accidental oral intake, induce quick vomiting by any local methods.
9. Avoid herbicide drifts from reaching the non-target plant and animals.

ALLELOPATHY

Allelopathy is the detrimental effects of chemicals or exudates produced by one (living) plant species on the germination, growth or development of another plant species (or even microorganisms) sharing the same habitat.

Allelopathy does not form any aspect of crop-weed competition, rather, it causes Crop-Weed interference, it includes competition as well as possible allelopathy.

Allelo chemicals are produced by plants as end products, by-products and metabolites liberated from the plants; they belong to phenolic acids, flavanoides, and other aromatic compounds viz., terpenoids, steroids, alkaloids and organic cyanides.

ALLELOPATHIC EFFECT OF WEEDS ON CROPS

(1) Maize:

- Leaves & inflorescence of *Parthenium* sp. affect the germination and seedling growth
- Tubers of *Cyperus esculentus* affect the dry matter production

(2) Sorghum:

- Stem of *Solanum spp* affects germination and seedling growth
- Leaves and inflorescence of *Parthenium* affect germination and seedling growth

ALLELOPATHIC EFFECT OF CROP PLANTS ON WEEDS

- Root exudation of maize inhibits the growth of *Chenopodium album*
- The cold water extracts of wheat straw when applied to weeds reduce germination and growth of *Abutilon* sp.

ALLELOPATHIC EFFECT OF WEEDS ON WEEDS.

- Extract of leaf leachate of decaying leaves of *Polygonum* contains flavonoides which are toxic to germination, root and hypocotyls growth of weeds like *Amaranthus spinosus*

- ❖ Inhibitor secreted by decaying rhizomes of *Sorghum halepense* affect the growth of *Digitaria sanguinalis* and *Amaranthus* sp.
- ❖ Exudates of *Cassia spp* affect germination & growth of *Parthenium hysterophorus*

INTEGRATED WEED MANAGEMENT (IWM)

Any single method for weed management mayn't be effective in controlling weeds. Integration of different methods like sanitation, mechanical, cultural, biological and chemical means kept the weeds under check at an economic cost. IWM uses a variety of technologies in a single weed management with the objective to produce optimum crop yield at a minimum cost taking in to consideration ecological and socio-economic constraints under a given agro-ecosystem.

IWM is a system in which two or more methods are combined to control a weed.

Need for IWM

a) No single weed management practice is effective in controlling wide range of weed flora

b) Continuous use of same herbicide creates resistance or causes shift in the flora.

c) Indiscriminate herbicide use and its effects on the environment and human health.

Good IWM should be

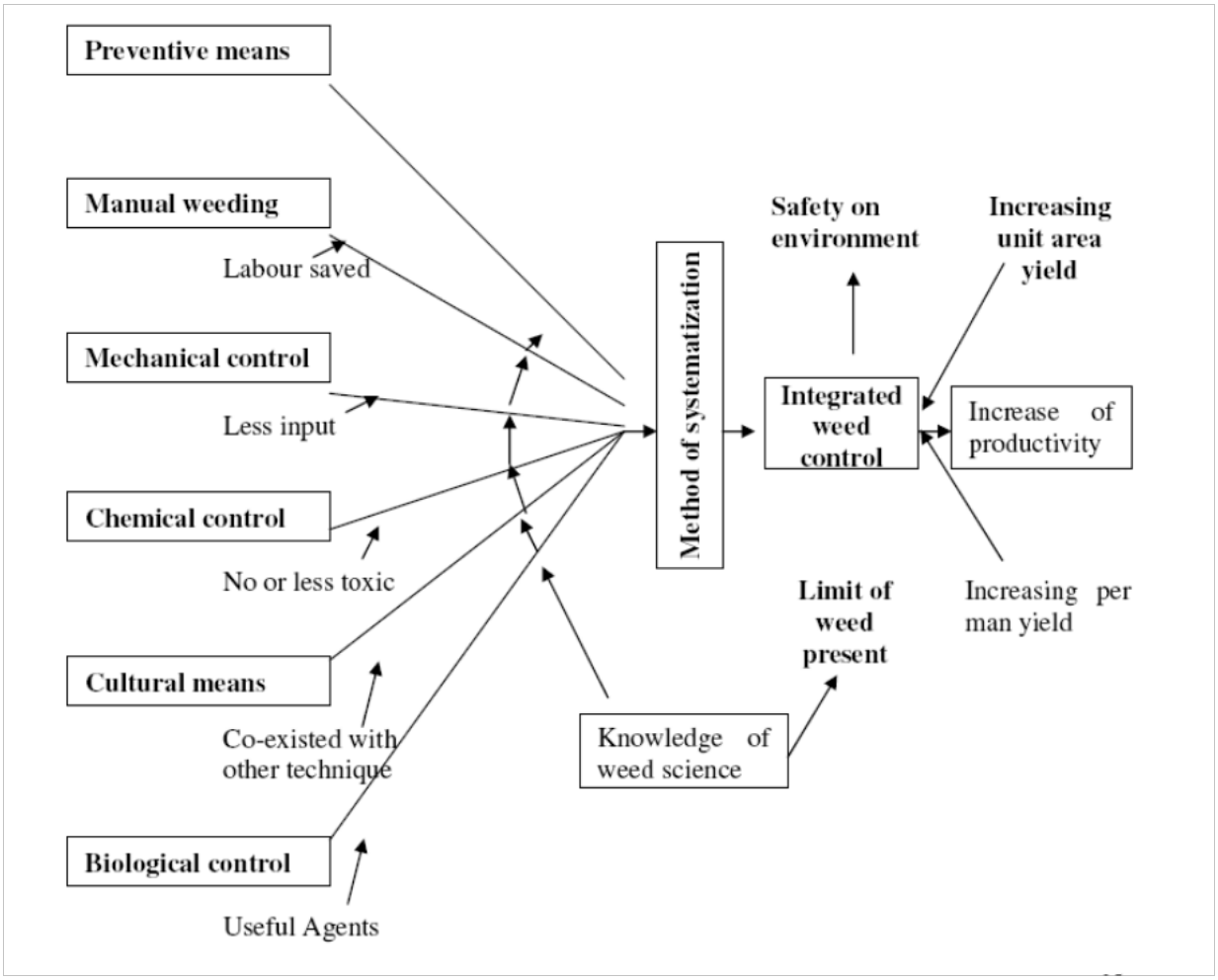
a. Flexible enough to incorporate innovations and practical experiences of local farmers.

b. Economically viable and practically feasible.

Advantages of IWM

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

A conceptual model of IWM developed by Noda is given below



IWM for Different Crops

RICE: initial 30-35 days in transplanted & 60 days in direct seeded crop is critical.

Nursery

a) Soaking seeds in salt water to remove weed seeds

b) Keep a thin film of water and avoid drainage.

c) Application of Pre-emergence herbicides viz., Butachlor, Thiobencarb, Pendimethalin, Anilofos on 8thday after sowing to control weeds in the lowland nursery.

Transplanted Main field

1) Hand weeding: 20-25 & 40-45 DAS or transplanting.

2) Interculture: Passing rotary weeder in transplanted paddy after 25 DAT.

3) Submergence: in low land paddy water level is maintained at 2.5 - 5 cm.

4) Chemical method: There are 4-5 important herbicides available in market.

Pre-emergent: Butachlor @ 1.5 kg a.i per ha or Pendimethalin @ 3 lit ai ha^{-1} or Anilophos @ 0.5 lit. ai/ha at 3-4-DAT

Post-emergent: 2,4-D Ethyl Esters or 2,4-D sodium salt @ 1.5 kg ai/ha or propanil

@ 3 lit ai/ha at 35 -40 DAS.

Application of Pretilachlor @ 1.25 l ha^{-1} in fields infested with *Cyperus* and Pyrazosulphuron @ 250 g ha^{-1} in *Echinocloa* infested plot.

MAIZE – First 25-30 days are critical

1) Hand weeding at 25-30 DAS

2) Interculture - Earthing up is the most used weed control method.

3) Chemical - Atrazine / Simazine as pre-emergent @ 0.75 kg ai/ha.