AGR 301 – Weed Management (1+1)

Theory notes

Weed – Definition:

Weeds are unwanted and undesirable plants which interfere with the utilization of land and water resources and thus adversely affect human welfare.

They can also be referred as plants out of place.

Weeds compete with the beneficial and desired vegetation in crop lands, forests, aquatic systems etc. and poses great problem in non-cropped areas like industrial sites, road/rail lines, air fields, landscape plantings, water tanks and water ways etc.,

Weeds are an important factor in the management of all land and water resources, but its effect is greatest on agriculture. The losses caused by weeds exceed the losses caused by any other category of agricultural pests. Of the total annual loss in agriculture produce, weeds account for 45%, insect 30%, disease 20% and other pests 5%.

Origin of weed and evolution of weed control:

Weeds are no strangers to man. They have been there ever since man started to cultivate crops about 10,000 B.C and recognized as a problem. The concept of weed control is also as old as agriculture. From the beginning of agriculture to the middle of the twentieth centuary, the plough and hoe have been the widely employed means of weed control. As weed infestations began to seriously limit the production of crops, methods were devised viz., manual, mechanical, biological and chemical to combat them.

Classification of weeds:

Weeds can be classified in different groups on the basis of their.

a) Life cycle (ontogeny)
b) Growth characteristics
c) Habitat
d) Ecological affinity to water
e) Origin
f) Plant morphology
g) Plant families
h) Soil reactions
i) Dependence on other hosts
j) Relative position of weeds

a) According to Ontogeny :

Weeds, based on their life cycle can be broadly classified as.

i) Annuals : a) Kharif season annual
b) Rabi season annual

c) Summer season annual
d) Multi season annual

ii) Biennials :

iii) Perennials : a) Simple perennial
b) Bulbous perennial
c) Creeping perennial

i) Annuals : Those weeds which complete their life cycle within a season/year and propagate by seeds. These annuals are sub-divided according to the season of prevalence.

i) Kharif season annual : (June – October)
ex : *Ammania baccifera*
Aeschynomene aspera
Cyperus difformis
Fimbrystyllis miliacea

ii) Rabi season annual : (October – February)
ex : *Chenepodium album*
Phalaris minor
Avena fatua

iii) Summer season annual : (February – June)
ex : *Solanum nigrum*
Trianthema portulacastrum (Saranai)
Argemone mexicana
Portulaca oleracea (Pasalai)

iv) Multi-season annual : (All seasons)
ex : *Echinochloa colonum*
Eclipta alba
Eleusine indica
Phyllanthus niruri

ii) Biennials : Those weeds which complete their life-cycle within two years. They may propagate either by seeds or vegetative parts or by both. Biennials generally do not come up in annual crop fields but they infest perennial crop fields, pastures, lawns and orchards.

Ex : *Daucus carrota*
Zingiber casumunar
Alternenthra echinita
Oxalis carniculata

iii) Perennials: Those weeds which live for three or more years and produce seeds more than once in their life cycle. They may propagate by seeds, vegetative parts or both. Perennials may be of following types.

(i) Simple perennials: These reproduce solely by seeds but when roots or crown are cut, the cut pieces may produce new plant.
ex. *Ipomea carnea*
Lantana camera

(ii) Babous perennial: These propagate by bulbs or bulblets as well as by seeds.
ex: Wild onion and wild garlic.
Allium vineale

(iii) Creeping perennials : These propagate by means of rhizomes, stolons, spreading roots as well as seeds.

ex: *Convovulus arvensis* : Deer's foot
Apropyron repens : Quack grass
Sorghum halepense : Johnson grass

b) According to growth characteristics:

Weeds can be classified on the basis of their growth habit as.

(i) Erect : Stem stands upright
Ex : *Chenopodium album*
Panicum repens

(ii) Prostrate: Some weeds instead of being erect have got short stems with extremely short internodes that give the impression of 'crown of leaves borne on root'.
Ex:. *Eleusine indica*
Portulaca oleracea
Polygonum spp.,

(iii) Twining: In some weeds, stems coil itself round the support in clock wise\anticlock-wise
Ex: *Cuscutta spp*.,
Ipomea quamoclit

(iv) Trailing; Stems of some weeds spread on ground
Ex : *Convolvulus arvensis*
Citrallus Vulgaris

(iv) Runner: In some weeds, stem grow horizontally and there will be formation of special shoots rooting at each nodes.
Ex: *Lippia nodiflora*
Ipomoea biloba

c) According to habitat:

Based on the habit characteristics of weeds, the weeds are classified into;

(i) <u>Weeds of cultivated land</u>

Those weeds which have the tendency to have the life cycle similar to that of the cultivated plant.

Ex: *Amaranthus sp.,*
Euphorbia sp.,

(ii) <u>Weeds of lawns and public parks</u>

The standard lawn grass in various parts of the country is cynodon dactylon. A large number of annual and perennial weeds encroach upon the lawns.

Ex: *Desmodium triflorum*
Imparata cylindrical
Indigofera enneaphylla
Setaria intermedia

(iii) Orchard weeds:

The microclimate of orchards vary in shade, humidity, and excessice soil moisture. Those weed species prefer to the habitat are

Ex: *Cannabis sativa*
Euphorbia geniculata
Imparata cylindrical
Xanthium strumarium
Acalypha indica

(iv) Aquatic weeds:

Aquatic weed habitats include both aquatic environments and those in water saturated soil.

Ex: *Ipomoea reptans*
Exhhornia crassipes
Hydrilla verticillata
Paspalum distichum

(v) Road side weeds

All the 3 types annuals,biennials and perennials are found.

Ex: *Euphorbia sp.,*
Daucus carots
Solanum xanthocarpum

(vi) Weeds of uncultivated land:

Mostly hardy weeds are found in these lands .

Ex. *Digitaria spp.,*
Cenchrus pauciflorus
Tribullus terrestris
Xanthium strumarium

d) According to ecological affinity to water:

(i) weeds of semi-aquatic condition (wet land)

Those weeds which are mostly associated with rice.

Ex. *Echinochloa colonum; E. crusgalli*

(ii) Weeds of garden land:

Ex : *Trianthema porttucastrum*
Digeria arvensis – Koia keerai

(iii) Weeds of dryland:

These weeds are hardy with lengtheier tap root system. It even thrive at very little moisture condition.

Ex. *Euphorbia hirta*- Amman pacharisi.
Celotia argentia

e) Origin of weeds:

(i) Alien: Those weeds which are foreign in origin.

Ex. *Argemone mexicana*
Parthenium hysterophorus

(ii) Apophytes: Those weeds which are introduced by man from one place to another.

Ex: *Phalaris minor*
Corchorus acutangulus

f) According to plant morphology:

(i) Dicot \ Broad-leaved weeds:
Ex: *Cleome viscose;* *Eclipta alba*

(ii) Grasses
Ex. *Echinochloa colonum;* *Cynodon dactylon*

(iii) Sedges:
Cyperus rotundus; *Fimbrystyli miliaceas*

g) According to plant families:

Most of the weeds belong to the families.

(i) Poaceae (Gramineae) : *Eleusine indica*
(ii) Asteraceae (Compositae) : *Tridax procumbens*
(iii) Solanaceae : *Solanum nigrum*
(iv) Euphorbiaceae: *Euphorbia hirta*
(v) Teliaceae: *Corchorus acutangulus*
(vi) Leguminosae: *Melilotus indica*
(vii) Chenopodiaceae: *Chenopodium album*
(viii) Amaranthaceae: *Amaranthus viridii*

h) According to soil reactions:

(i) Saline soils : *Salsola spp*.,
(ii) Alkaline soils: *Cressa erecta*
(iii) Acid soils: *Rumex acetosella*

i) According to dependence on other hosts:

i) Stem parasites — Total ex: *Cuscutta sp*., (Doddar)
Partial ex: *Loranthus sp*., (Mistle toe)

ii) Root parasites — Total ex: Orobanche sp.,
Partial ex. Striga sp., (Witch)

J) According to relative position of weeds:

(i) Absolute weed: is a plant which is not economically desirable but present in a crop field.
Ex. Colonum in rice fields.

(ii) Relative weeds:
A crop plant in an another crop field which is not desirous.
Ex : Cotton in Maize

(i) Rouges: A variety of a crop plant found mixed with another variety of the same crop plant.
Ex: TKM 9 rice in ADT 36 rice.

Characteristics of weeds:

As the weed plants are nourished by nature they bear more tolerant to adverse conditions compared to domesticated crop plants. They bear with it certain special characteristics which help in their Perpetuation , multiplication, dissemination, stabilization and overall adaptation.

(i) Perpetuation:

(a) Weeds perpetuate through seeds \vegetative propagules.

(b) Propagules are produced when weeds experience unfavourable condition.

(c) Seeds are produced at one time or over an extended period of time.

(d) Seeds or vegetative propagules may remain dormant but viable for years when underneath the soil. Eg. Chenopodium sp., for 30 to 40 years.

(ii) Multiplication:

a) No. of seeds\weed plant may sometimes equal to crop plant but seeds produced \unit area exceeds 100 times.

b) Weeds prolify with high fecundity fertile\productive.

(c) Weed will co-exist in crop field or bare field thereby enriching the weed seed population.

(d) Weeds with seed and vegetative propagules multiply enormously.

(iii) Dissemination:

a) The dispersal of seeds or propagules of weeds take place by mobile agents: Man, animals including birds, wind and water.

b) Man is most important for the dissemination of weeds over some distance and in particular direction.

c) Fruits and seeds of some weed species have appendages which enable them to easily carry by wind\water.

d) Most weed seeds have dormancy which estivate unfavourable environment.

e) Some weeds have explosive mechanisms for seed dispersal.

Ex: *Ruellia prostrata*.

(iv) Stabilisation:

i. weeds find their suitable sites and time for establishment by their intrinsic nature which breaks dormancy through the triggering action of edaphic\climatic\biotic factors.

b) Some weeds bear very minute or inconsipicious flowers (ex: *Trianthema portulacastrum*) which often produce mature seeds even before they are recognized as flowers.

c) *E. Colonum* will mature and produce seeds even before the pulling out of seedling for transplanting.

d) Time of maturity of weed seeds coincides with the maturity of the crop plants and get mingled with the crop seeds. Eg. *Phalaris sp*., / *Avena spp*., in wheat.

e) Weeds with radicoid forms easily escape drought, fire, soil erosion, man made modifications or disruptive forces.

Why it is difficult to control weeds?

1. Weeds are prolific with abundant seed production potentialities.
   e.g. *Amaranthus spp*.
2. They Are resistance and persistant to control.
   e.g. *Cyperus spp*.
3. They have long periods of dormancy.
   e.g. *Nelumbium speciosum* – 20 years
   Chenopodium sp. 30-40 yrs.
4. They have deep root system.
   e.g. *Solanum elegnifolium*
5. They can also reproduce by veg. method.
   e.g. *Cynodon*, *Cyperus*
6. Weeds are hardy and resist adverse climatic and soil conditions
   e.g. *Prosopis juliflora*
7. Some weed seeds are similar to crop seeds.
   e.g. Mustard and *Argemone* seeds
8. Weeds have smaller seeds which help in easy dispersa
   e.g. *Amaranthus spp*.
9. One weed seeds gave some appeudages which help in easy dissemination.
   e.g. *Calotropis*, *Acanthospermum hispidum*

Reproduction and Dissemination of weeds:

The knowledge of reproduction of weeds is an essential prerequistle for any planning of their control. Nearly all of them reproduce by means of seeds and a large number of them in addition reproduce vegetatively.

Seed reproduction:

In general weeds produce large number of seeds which have greater viability than crop seeds.

1. *Brassica nigra* (Black mustard) : 58,363
2. *Amaranthus sp*., (Pig weed) : 1,80,220
3. *Solonum nigrum* (Night shade) : 1,78,000
4. *Agrophron repens* (Quack grass) : 11,400
5. *Echinochloa crusgalli* (Barnyard grass) : 7,160

Vegetative reproduction:

Many noxious weeds reproduce and spread vegetatively as well as by seed. The depth to which the root system of such weeds penetrate depends upon the texture of soil, water table, nature of sub soil and species to which they belong.

Medium of weed seed dispersal.

1. Through impure seeds.
2. Through organic manures.
3. Through air\wind.
4. Through cattle.
5. Through agriculture implements.
6. Through birds.
7. Through human beings.
8. Through irrigation and drainage water
9. Through Sewage and sludge.

The depth from which roots and rhizomes regenerate is of importance in its relation to tillage practices and to application of herbicides.

Ex : Quack grass – regenerate from 30 cms

Convolvulus arvensis – regenerate from 120 cms

DISSEMINATION OF WEEDS :

In general, most weeds are good travelers. Though they themselves have no power of locomotion, several agencies like wind, water and animals including man and transport scatter them from place to place. Most weeds have modifications of some kind which adapt them for dissemination by one or more agents.

Eg : Saccate fruits, winged fruits and seeds, comate seeds, parachute fruits, plumed fruits, hook or spiny appendages.

ECOLOGY OF WEEDS:

Ecology is the relationship between plants and environment. The ecology of weeds refers to the growth characteristics and adaptations of weeds in different environments and also their persistence in such conditions. An environment is characterized by climate, edaphic (soil) and biotic factors.

CLIMATE:

Light, temperature, water, wind, humidity and their seasonal variations relates to climatic factors. The light intensity, quality and photoperiod governs the growth, flower and seed production by plants including weeds. Most of the weeds adapt to grow in shade with much competitiveness.

Temperature also plays a very important role in occurrence and distribution of weeds. Soil temperature is particularly concerned with the seed germination, survival of underground parts and similarly early growth of weeds is affected by atmospheric temperature.

Water is one among climatic factor of ecology that determines the occurrence and distribution of plants.

Wind is another effective source for occurrence and distribution.

EDAPHIC

Soil fertility, soil pH, soil temperature, radiation and soil water influence weed population. Soil acidity / alkalinity have considerable influence on weed population.

BIOTIC

Biotic factors include both plants and animals. Crop plants affect the weed population and persistence by competing on the available resources. The root exudates of one plant also influence other plants in their association. Soil found, insect pests, grazing animal and man affect the weed persistence directly/ indirectly.

Weed Adaptations:

Weeds are euryoecious (wide range of tolerance) compared to crop plants which are more stenoecious in nature.

a) Weed seeds have wide range of moisture requirement for seed germination.

b) Weeds can modify their morphology by reducing their leaf area / sending roots deeper and wider.

c) The weeds are quickly responsive to favourable environments after the removal of stress.

d) Some weeds imitate the general appearance, colour, shape or particular feature of another plant and act as a special weapen of defence.

e) Some weed species poses special devices such as thorns, spines, prickles, bristles, stinging hair, glandular hair with poisnous substances, irritating substances, repulsive in smell or disagreeable in odour which help to protect them from natural enemies.

f) Some weeds develop a thick culticle, cork and bark as a defence mechanism.

g) Some weed sp., (*Cyperus* sp. and *Sphaeranthus indicus*) come up during the post harvest period and produce seeds vigorously.

CROP – WEED INTERACTIONS:

The climatic, edaphic and biotic factors of environment determine the distribution of species, their competitive ability, their prevelance and their associations. Apart from natural factors, man-made modifications like management of soil, water, nutrient, crops and pests and crops in sequence also influence the crop-weed interactions. However, weeds with unique characteristics try to shape themselves under any changed situations through acclimatization.

In crop-weed interactions, plant competition is a powerful natural force responsible for the suppression or extinction of weaker plants. There may be intra-plant or inter-plant competitions. Rapidly growing plants with rapid coverage of both below and above ground areas have an advantage over slow growing ones. Density, geometry and architecture of plants have contributing role in competition. Competition is usually most severe when competiting plants are alike in vegetative and reproductive habits.

Weeds compete with crops plants for water, light, nutrients, space, air and the micro-environment. The competition for any one or for all begins when those factors falls below the requirements of both the weed and crop. Also, an abundance of any factor may induce competition for other factors. For example, abundant nutrient supply generate competition for water, light and space.

FACTORS THAT DETERMINE COMPETING ABILITY OF CROP PLANTS

Crop plants and their varieties differ in their competing ability. Rapid and uniform germination, rapid development of foliage and root, tolerance to high density and close canopy etc. are the characteristics of a plant species to be successful in competition. The factors that determine vigorous and uniform stand of crop plants are variety of a crop, soil-water relations. Soil fertility soil reaction, tillage, date of sowing, rate and method of sowing, crop rotation, cropping and cultural system, use of herbicides, inset pest and disease management.

Critical periods:

The chief effect of weed competition on crops is to decrease the yields of crop. The early growth phase of the crop plants are found to be most critical w.r.t competition while on the progress secures competitive ability of the weeds. Those crop plants with rapids and uniform germination, quick development of foliage and root and formation of closed canopy within early stages will have dominating character over weed in the competition. Some crop plants excrete phytotoxins to evict the neighbours and this allelopathic effect is used in competition with needs.

HARMFUL EFFECTS OF WEED

Weeds extend the harmful effects slowly, steadily and inconspicuously and the effect is almost irrevocable.

a) If no restriction is imposed they compete with crop plants and the yield reduction of individual crops varies from 0. to 100% and that of cropping system 5 to 50%.

b) Presence of weeds increases the cost of agriculture and hinders the progress of work.

c) It increases the irrigation requirement.

d) They reduce the valve of produce or otherwise adds the cost of cleaning.

e) Some weeds when eaten (*Cleome viscosa*) by milch animals will produce an undesirable odour in the milk. At times death/disorder/disformity may occur eg: *Datura stramarium*. The fruits and seeds of *Xanthium strumarium* and *Achyranthes aspera* entangle with wool which fetch lower prices.

f) They harbour insect pests, pathogens and parasites

g) They reduce the valve of the land.

h) Their presence will impair the purity of varieties by chance of cross-pollination.

i) Weeds causes health hazards to man and animals.

j) Weeds cause allelopathic effect.

Harmful effect of weed in Non-cropped area:

a) Weeds detracts the beauty of public places.

b) Weeds in non-cropped areas causes fire hazards, accidents and pollution as well as health hazards.

c) Weeds in acquatic environments restrict the movement of water flow there by

   i) loss of water by seepage and
   ii) Poor irrigation efficiency
   iii) Restrict drainage
   iv) Pollute the environment

BENEFICIAL EFFECTS OF WEEDS:

i) Weeds are valued for increasing organic matter content in soil, increasing soil fertility, checking soil erosion, inducing soil formation, food, feed and medicinal values. Eg: *Amaranthus sp*.,, *Trianthema portulacastrum* (Saranai), *Chenopodium album*, are used as greens.

Cynodon dactylon
Echinochloa colonum
Digitaris sanguinalis } Palatable succulent feed.
Eclipta alba
Avena fatua

Centella asiatica } Therapeutic purposes.

Andrographis paniculata

2) Weeds are valued for economic utilization.

Imperata cylindrical *Saccharum munjo*	used for thatching roofs.
Cyperus rotundus *Andropogon squarrosus*	used for making Joss sticks.
Cymbopogan citrates *C. martini*	used for essential oils.

3. Weeds are valued as indicator plants to indicate the incidence of disease, deficiency, disorders etc.,
4. Weeds are valued as source of genetic material for crop improvement.
5. Weeds reclaim problematic soil eg., cynodon & *Argemone mexicana* reclaim alkaline soils.
6. Weeds are valued for protecting bunds, as a host for beneficial organisms, ornamental plants, religious and ritual purposes and for maintenance of biological equilibrium.

Weed management: Principles and methods

Weed management is the application of certain principles and suitable methods that will improve the vigour and uniform stand of the crop at the same time ignore or discourage the invasion and growth of weeds.

Principles of weed management:

Weed have both harmful and beneficial effects. When the harmful effect is greater then their population and growth are to be reduced to such an extent that the damage caused are within permissible limits. At the same time, the cost of weed management should be much less than the expected value of produce lost.

To deal with the problems many methods are adopted based on certain basic principles that relates to.

a) Life cycle of weeds:

eg: The annuals weeds can be easily controlled if they are prevented from seed production.

Similarly, best time to destroy biennials is during the seedling stage of the first year.

Perennials can be checked by repeated destruction of aerial shoots, underground roots etc. by cutting, plugging, digging, drying, flooding etc.

b) Characteristic of weeds:

Prodomiance of a particular group of weeds (such as broadheaved \grasses\sedges) determine the method.

c) Mode of reproduction of weeds.

Number and time of production of propagules, methods of dispersal, dormancy, viability, association with crop plants etc., if known can be useful in determining method to be employed.

d) Habitat, location and season:

The crops and weeds of upland are quite different from low lands, cultural practices and wortability also varies, thus weed might varies.

e) Soil and weather conditions:

Soil texture and moisture are the important factors in selecting suitable method. In light soild flooding cannot be advocated, similarly in heavy soils mechanical method is impeded.

f) Area of weed management:

In localized plots like nurseries hand pulling may be adopted. In larger areas chemical method and in many cases integrated approach is suited.

g) Farming and cultural practices:

Method of weed control varies in

- Grain\seed\fodder production\ Green manure
- Sole\mixed\Inter cropped.
- Direct seeded\ Transplanted.
- Plant crops\Ratoon crops
- Mechanised\Non-mechanised farming.

h) Availability of resources:

The availability of farm labourer, implements power and herbicides determine the method of weed management.

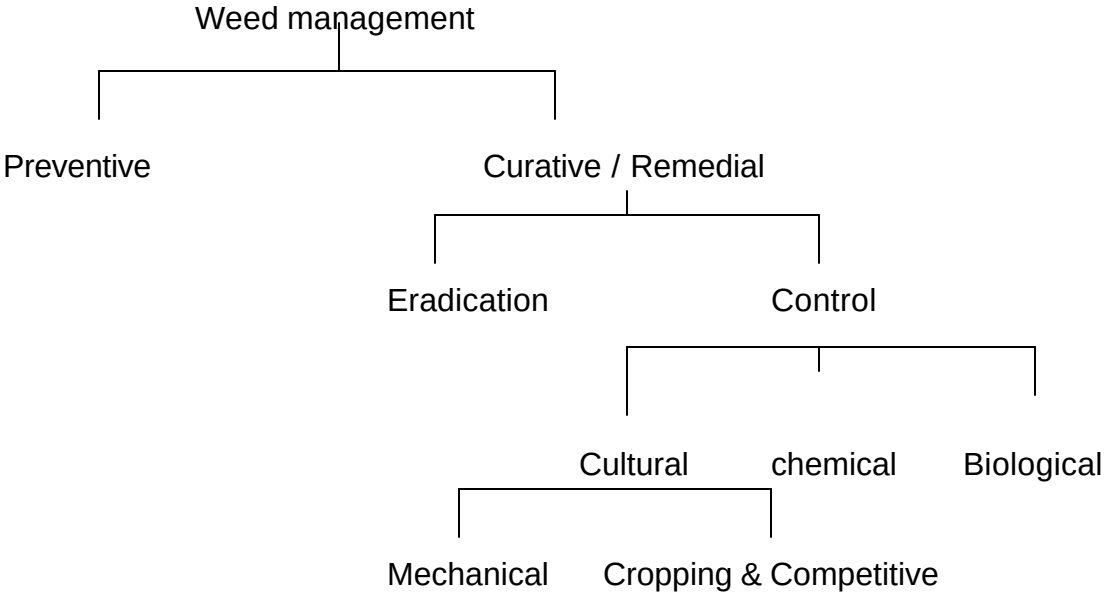
i) Economics of the methods

Even though some methods of weed control, are Profitable, except in some commercial crops, farmers Prefer multi-purpose traditional hoeing.

Methods of weeds management:

Weed control and weed management are the two terms used in weed science. Weed control is the process of limiting infestation of the weed plant so that crops can be grown profitably.

Weed management includes prevention, eradication and control by regulated use, restricting invasion, suppression of growth, prevention of seed production and complete destruction. Thus weed control is one of the aspect of weed management.



Preventive methods:

i) Use pure seed/seedlings.
ii) Avoid feeding hay containing weed seeds without destroying.
iii) Avoid using sand\soil from weed infested area to cultivated area.
ii) Use well rotten\decomposed organic manure.
iii) Avoiding the cattle to move from weed infested area to cultivated area.
iv) Cleaning all implements & tools after use.
v) Keeping irrigation & drainage channel clean.
vi) Keeping fence, roads & bunds clean.
vii) Keeping thrashing yard, granary & compost pit free.
viii) Following legal & quarrentine measures.

Eradication methods:

Eradication can be done by a) destroying the species at the initial stage of introduction. B) Degenerating the buried dormant but viable seeds by fumigation, flooding, heating & other chemicals.

Control methods:

Mechanical methods:

1. Hand pulling
2. Hoeing
3. Tillage
4. Mowing/sickling
5. Flooding
6. Burning
7. Smothering\mulching
8. Digging
9. Cheeling

Cropping & competition:

i. Crop rotation.
ii. Kind of crop.
iii. Use of fertilizers.
iv. Date and rate of planting.
v. Inter cropping
vi. Companion cropping eg. Azolla in Rice
vii. Plant population.

Biological methods.

1. Parasites.
2. Predators.
3. Pathogens.

Ex: i) *Crocidosema lantana* moth on *Lantana camera*

2. Alternaria eichorniae fungi on *Eichhornia crassipes*

3*. Orseoliella javanica* gall midge on *Imperata cylindrica*

4. *Dactylopius tomentosus* cochinelid insect on. *Opuntiadillenii*

5. *Neochetina bruchi* beetle (weevil) on E. Crassiper *N. eichornii*

6. *Tilapia mossambica* fish to control acquatic weeds.

Chemical methods :

I) Selective : a) Foliage & b) Soil applicant

2) Non-selective : a) Foliage b) Soil applicant

Germination stimulants :

Tillage, chemical stimulants like population growth regulators, plant products, responding inhibitors, oxidants, Nitrogenous compounds, anesthetics, etc.

CHEMICAL METHODS:

Employing chemicals for weed control constitutes chemical method, are used for over 85 years. The introduction of Bordeaux mixture in 1896 and subsequent chemicals like sulphuric acid, iron sulphate, copper nitrate, annonium & potassium salts were used for weed control till 1910. During 1930, sodium chlorate, carbon bisulphide, sodium assenate and dinitrophenols are employed. The discovery of 2,4-D in 1940 's revolutionaside the chemical methods.

Benefits of chemical method :

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

Herbicide classification:

Currently there are about 250 herbicides in the world market. The herbicides are classified on the basis of

a) Method of Application: Soil applied
Foliage applied

All herbicides applied at pre-planting and pre-emergence are included in the soil applied group.

Those applied at post-emergence include in the foliage applied.

b) Mode or action:

Based on the physiological and bio-chemical actions of the herbicides they are categorized as

i) Systemic / translocated :
ii) Non-systemic / contact :

c) Chemical affinity and structural similarity:

There are 18 chemical groups\chemical nucleus under which the herbicides having chemical affinity and structural similarity are classified.

	Chemical groups	General structure
1.	Aliphatics	R-COOH
2.	Amides & Acetamides	R1 ------N-c---R3 R2
3.	Arsenicals	R- As – OH
4.	Benzoics & phenyl acetates	--------- COOH
5.	Bipyridiliums (with quaternary ammonium salt)	-------
6.	Carbonates. (Esters of carbanilicacid)	
7.	Dinitroanilines	
8.	Diphyenyl eithers	Derived from phenols

9. Nitrates
10. Phenols OH
11. Phenoxy acids cl--- o—ch2-cooh (2,4-D)
12. Pyridazinones
13. Thiocarbonates (carbonic acid)
14. Triazines
15. Triazoles
16. Uracils
17. Ureas
18. Unclassified

Classification of common herbicides on the basis of mode of application, mode of action and chemical affinity:

Chemical group	Soil applied	Foilage applied systemic	Contact
1. Aliphatic	Allyl alcohol	Dalapon	Acrolein TCA-Trichloro Acetic acid
2. Amides & Acetamides	Alachlor, Butachlor, Metolachlor, Propachlor	Alachlor Butachlor Propanil	Solan- MAA - Methanear-sonic acid
3. Arsenicals	----	MAA MSMA DSMA	Cacodylic acid MSMA
4. Benzoics & phenyl acetates	Chloramben, 2,3,6-TBA	Dicamba 236-TBA	----TBH Trichloru Benzoic acid
5. Bipyeisilliums	----	-----	Diquat, Paraquat, Cyperquat.
6. Carbamates	Chlorbufam, Propham, Terbutol	Asulam, Barban, Propham	------
7. Ditritroanilines	Fluchloralin, Dinitramine, Nitrofluralin, Pendimethalin, Trifluralin	----------	----------
8. Diphenyl	Nitrofen, Nitroflurofen Oxyflurofen	Flurodifen	------
9. Nitrates	Dichlobenil	Bromoxynil	-----
10. Phenols	Dinoseb	---	Dinosed, PCP
11. Phenoxyacides	2,4-D. 2,4-DEP	2,4-D; 2,4,5-T 2,4-DB Dichlorprop MCPA, MCPB	-----
12. Phridazinones	Phrazon Oxyphrazon	Phrazon	----------
13. Thiocarbonates	Benthiocarb, EPTC Butylate	-------	----------

14. Triazines	Atrazine Metribuzin, Propazine, Simazine, Terbutyrin	Metribuzin Terbutyrin	Ametryn.
15. Triazoles	-----	Amitrole	--------
16. Uracils	Bromacil, Isocil	--------	--------
17. Ureas	Diuron, monuron, Fenuron, chlorbromuron Linuron	Chlorbromuron	---------
18. Unclassifed	DCPA, Oxadiazon, cypromid	Glyphosate MH. Picloram	Bentazon.

Pre-Planting : refers to the application of herbicides before the crop is planted.
Pre-emergence : Pre-emergence treatment are applied before a crop\weed have emerged.
Post-emergence : Treatment after the emergence of crop or weed.

Weed control by Germination stimulant:

1. Tillage:

Soil tillage often promotes emergence of weed seedlings due to its effect on soil disturbance. Seed population can be reduced by stimulating their germination by various tillage practices. Inducing the germination of these long lived, dormant seeds is a key to solve long lasting weed problems.

2. Chemical stimulants:

The chemicals that stimulate germination of both viable and dormant seeds include

1. Plant growth regulators (Gibberlins, Cytokinins & Ethylene)
2. Plant products (strigol, Fusicoccin)
3. Respiratory inhibitors(Azide, Cyanide & Hydroxylamine)
4. Oxidants (Hypochlorite, oxygen)
5. Nitrogenous compounds (Nitrate, Nitrite & Thiourea)
6. Anesthetics (Acetone, Ethanol, Chloroformeta)

Of these ethylene, nitrates, strigol and Azide have been tested in the field and used for stimulation of weed seed germination.

Ethylene: is an important tool in the control of *Striga* spp., (witch weed). A single injection of ethylene gas as 1-7 kg ha^{-1} at 20 cm soil depth.

Nitrates: Nitrates are well known to enhance germination of many weed seeds. At the field level, Ammonium Nitrate is known to cause increased emergence of wild oato, *Eleusine indica, E. Colonum*, etc.

ABSORPTION AND TRANSLOCATION OF HERBICIDES:

If a herbicide is to be effective, it must be absorbed by the plant and translocated (except contact) in adequate quantity to the site of action.

Absorption:

Is the process of penetration into the plant tissue.

Absorption of soil applied herbicides:

Herbicide applied to the soil either as pre planting\ pre emergence are usually taken-up by the roots or shoot of emerging seedling.

The water-soluble herbicides as like water and salts are taken-up by the root hairs.

The xylem in the absorbing region is functional and the endodermis at the region will not be lignified to Prevent penetration of solutes.

As shown in the figure from root hair cortex, the molecules migrate via the symplast (Phloem) into the stele where they shift to apoplast (xylem) and ascend into the foliage via the transpiration stream.

A non-polar herbicide can dissolve the Casparian strip and diffuse through it to reach the stele and move symplastically. However, the polar herbicides cannot do this to enter the symplast instead move along the apoplast system.

Besides roots, the soil applied herbicides are also absorbed by young shoots (coleoptiles) and seeds. Eg. EPTC, diallate, eg: atvazine, lineson

Polar compounds: They are either electrically positive as well as negative. They are soluble in polar solvents.

Eg. Water, ch20, Amino acides.

Non-Polar compounds: They are neither strongly positive or negative and soluble in non-polar solvents. Eg: oil, waxes.

Absorption of foliage applied herbicides:

The foliage applied herbicides will have to penetrate the cuticle which is made of 4 different substances1) Cutin 2) Cutin wax 3) Pectin and 4) Cellulose

Cutin (Polumerised long chain fatty acids)
Cutin wax (short chain esters & alcohols)
Pectin (Amorphous long chain acid molecules, Hydrophilic)
Cellulose (Fibrillar, hydrophilic, elastic CH_2O)

to enter into the living cells either by lipoidal route (Non-polar compounds) or by aqueous route (Polar compounds).

Or by both: They also enter into plant through trichomes and stomata. In some cases, herbicide enters into the plant through stem.

TRANSLOCATION:

Once a herbicide is absorbed into the Plant system, it moves either apoplastically/symplastically.

Apoplast : System of Non-living interconnecting cell walls, intercellular spaces, water filled and air filled oxylem elements.

Symplast : System of interconnected protoplasm that is connected from cell to cell by means of plasmodesmata.

Translocation of soil applied Herbicides:

The soil applied herbicides taken up by the roots penetrate into the oxylem and move upward apoplastically in the transpiration stream. Under low moisture\water deficit conditions, a rapid absorption & translocation occurs.

Translocation of Foilage applied Herbicides:

The two main pathways are the phloem and the Oxylem. The herbicides move along with the assimilated using the source to sink principles. A herbicide translocated through phloem can also leak out of the symplast to enter the Oxylem circulation.

FACTORS AFFECTING ABSORPTION AND TRANSLOCATION:

A number of factors affect and modify the absorption and translocation of herbicide.

PLANT FACTORS

a) Branching habit : is very critical for foliage applied herbicides.
b) Plant surface : Hairyness of the surface. Arrangement and shape of leaves cutinization Thickness composing of cuticle (wax)
c) Plant maturity : Herbicides move faster in young plants than in old.
d) Plant species and varieties : Some plant species, some cultivors within the species show differences in A&T of herbicides.

Environmental factors:

a) Temperature & Humidity:
b) Rainfall
c) Wind: has direct effect on ET, could damage the cuticle.
d) Light: Assists herbicide penetration by stimulating stomatal opening, activities, Ps, movement of solutes.

Soil factors:

a) Soil water stress and Temperature: soil water potential affects transpiration, Ps, root permeability etc.,
b) Soil pH : has profound effect on the uptake of herbicides by roots.
c) Soil organic matter and clay type: influence movement, availability and absorption of herbicides.

Chemical factors:

a) Herbicide concentration
b) pH of herbicide
c) Chemical structure
d) Surfactants: are the non-herbicidal compounds, which enhance the absorption by reducing the surface tension between the plant surface and spray particles.
e) Formulation
f) Application

ACTIVITY AND SELECTIVITY OF HERBICIDES:

Herbicide activity is related to the phytotoxic effects of a chemical on the plant growth and development.

Herbicide selectivity is referred to the phenomenon wherein a chemical kills the target plant sp., in a mixed plant population without harming the other plant.

Factors affecting activity & selectivity:

a) Rate of application
b) Plant morphollgy, Thickness of cuticle affects H. Selectivity
c) Stage of plant development
d) Cultivation practices
e) Absorption
f) Translocation
g) Physiological differences
h) Metabolism
i) Environmental factors

MECHANISM OF ACTION OF HERBICIDES:

Herbicides after coming into contact\reaching the site of action will bring about various physiological and bio-chemical effects like.

1. Chlorosis 2. Defoliation 3. Stunting 4. Necrosis 5. Stand reduction 6. Epinasty 7. Morphollogical aberrations 8. Growth stimulation. 9. Cupping of leaves 10. Marginal leaf burn 11. Desiccation 12. Delayed emergence 13. Germination failure etc.

The various physiological and biochemical process are grouped under six broad categories.

1. Respiration and mitochondrial activities
2. photosynthesis
3. Protein and nucleic acid metabolism
4. Hydrolytic enzyme activities
5. Cell division
6. Membrance function

Most of the herbicides affect atleast one or all of these processes.

1. Respiration and mitochondrial activities:

Mitochandria is the cellular organelles, which carry out the cellular respiration. ATP Synthesis and transport of electron & protons. Herbicides affect by uncoupling the reactions responsible for ATP synthesis and interfere in the electron & proton transport.

Eg. Bromoxymil, Dinoseb.

2. Photosynthesis:

Photosynthesis is usually represented by the following equation:

$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

(Glucose)

This takes place in two phases

1. Light reaction \Light phase

$$\text{Water} + ADP + Pi + NADP^+ \longrightarrow \text{Oxygen} + ATP + NADPH + H^+$$

2. Dark reaction \Light phase:

$$CO_2 + NADPH + H^+ + ATP \longrightarrow \text{Glucose} + NADP^+ + ADP + P_i$$

Chloroplasts are the organelles on which photosynthetic activities of the cell are centred.

Herbicides inhibit photosynthesis by

1. Inhibiting \ Blocking the Light reaction and the Production of O_2 from H_2O.
2. Inhibit the transfer of electron from PS II to PS I
3. Removing the electrons from PS I
4. Inhibiting non-cyclic ATP synthesis
5. Inhibitors of photosynthetic pigments

3. Protein and Nuocleic acid metabolism

Protein synthesis is an active and major biological function. Ribosome are particulate where proteins are synthesized. The synthesis of soluble proteins involve in three different stages.

1. Transfer of information from m RNA to the amino acid sequence.
2. Formation of peptide bonds.
3. Release and coiling of polupetide chain.

The Herbicides that are translocated into the plant system either at the early stages or at the grand growth phases will bring a change into protein synthesis, amino acid availability and catalystic enzyme activity.

Eg: Glyphosate, sulfonyl urror

4. Hydrolytic enzyme activity:

One of the major metabolic process that takes place during seed germination is the production of hydrolytic enzymes such as amylases, proteases, lipases, phosphatases, esterases etc., Each of these enzymes degrades the large molecules into subunits for the germinating seed.

Gibberlic Acid $\xrightarrow{GA_3}$ Synthesis of Polyribosomes, Proteins, & Hydrolytic enzymes

An effect of herbicide on any one or more of these events would affect the other events consequently affecting the eventual germination of the seed. A significant number of pre emergence herbicides inhibits these metabolic process.

Eg. Amides & Bio-carbomates

5. Cell division:

'Mitosis' is the process by which cell divides into two identical 'daughter cells'. Cell division has four phases 1) Prophase 2) Metaphase 3) Anaphase 4) Telophase.

In Metaphase of cell division spindle dibres (make up of proteins called microtubules0) are formed. These spindle fibres determined the plane at which cells divide and subsequent organization of new cells.

Some of the herbicides affect the formation of spindle fibre and thereby affect cell division.

Eg: Dinitroainlines, pronomide, propham & chlorpropharm

6. Membrane function:

All plant membranes, even though involved in different cellular functions, have a remarkably similar structure. Membranes are involved in nearly every process that occurs in cell biology. Membranes are very critical to the function of plant cells.

Any herbicides which disrupt the membrane integrity with disrupt the normal plant development. The symptoms of membrane disruption are severe willing and foliage dessication from cell leakage. Herbicides that affect membrane allow the cellular contents to leak into the intercellular spaces.

Eg: Bipyridillium compounds, Dinitrophenols.

PERSISTENCE AND BEHAVIOUS OF HERBICIDES IN SOIL:

'After' a herbicide reaches the soil, through Pre-planting/pre-emergence applications or as foliage run-off, it is subjected to various reactions of soil and environment factors.

Persistence in soils is an important feature of a herbicide as it determines its suitability or otherwise in a particular soil and cropping situation. Herbicides which decompose too readily are less desirable in some situations as they cannot be very effective on the weeds emerging later. In other situations, herbicides which have longer persistence of activity are unsuitable as their phytotoxic residues can injures the sensitive crops grown in rotation. Hence, a knowledge on the persistence and residual effects is essential to use them safely & effectively.

Herbicides reaching the soil become dissipated or removed in the following ways:

1. Uptake and metabolism by plants

Most of the soil applied herbicides are applied at 0.5 to 4.0 kg\ha = 0.5 to 4 ppm in soil of one ha (upto 15 cm depth). Most portion of this herbicide is subjected to dissipation in soil.

In case of post-emergence herbicides, a dose of 1 kg a.i\ha is applied which amount to 100 ppm if the crop yield is 10 ton\ha (assuming all the parts are harvested). This is only theoretical calculation. However, in practice only 0.1 to 1.0 % of the applied herbicide reaches the crop plants.

2. Volatalization:

Volatalization is a process where a condensed phase such as liquid/solid is transformed into vapour by elevation of temperature or reduction of external pressure.

Herbicides with vapour pressure of more than $1x10^{-5}$ mm Hg at 20^{o} c are generally considered volatile.

The volatilization of herbicide from soil\foliar is affected by 1) Air temperature 2) Wind velocity 3) RH 4) Soil temperature 5) Soil moisture 6) VP of the compound 7) concentration 8) solubility in water and 9) its adsorption to soil colloids.

3) Photo-decomposition:

Decomposition by light is an important mechanism of herbicide detoxification in soil under field conditions especially when surface application without subsequent incorporation / rainfall / irrigation.

4) Adsorption and inactivation by soil:

Adsorption by clay colloids is a major factor, which controls the availability of herbicide molecules, movement of herbicides in soil and availability to plants.

Several factors affect the adsorption of herbicides, they are

1. Type of clay colloid.
2. Soil organic matter.
3. Soil p^{H}
4. Moisture content
5. chemical nature of herbicide, and
6. Leaching.

5) Microbial degradation:

The microbial organisms involved in herbicide detoxification include bacteria, fungi, algae, moulds, etc.

Bacteria genera	:	Agrobacterium
		Alcalaginese
		Arthrobactor
		Bacillus
		Pseudomonas
		Nocardia, streptomyces etc.,
Fungi genera	:	Fusarium
		Pencillium

Herbicide combinations, Rotations and Interactions:

Herbicide combinations or mixtures are being increasingly used for effective and economical weed control. Herbicide combinations offer the following advantages.

1. A mixture will broaden the spectrum of herbicidal action in order to kill greater variety of weeds.
2. A mixture will have synergistic/additive effect.
3. In a mixture, one herbicide may prevent rapid detoxification of the other.
4. A mixture offers the possibility of reducing the dose of each herbicides.
5. Less\No devision of resistance in weeds against Herbicides.

Some of the commercial herbicide mixtures currently marketed in the world are:

2, 4-D + 2, 4, 5-T : Glyphosate + 2,4-D
Paraquat + 2, 4-D : Atrazine + Metolachlor.

Herbicide rotations :

In a rotational programme a soil-applied or foliage applied herbicide or both are used in a sequence to take care of annual\perennial weeds.

Herbicide rotation offers the following advantages.

1. It provides most effective weed control for the duration of crop growth.
2. It helps in preventing emergence & occurrence of tolerant weed sp.,
3. It offers high cumulative cost-benefit ratio over the years.
4. It reduces the quantities of herbicides.
5. It aids in reducing the potential for building up of herbicide residue.
6. Avoids shift in weed population.

Herbicide Interactions:

Under the current crop production practices, simultaneous\sequential application of herbicides and other agricultural chemicals like insecticides, fungicides, antidotes, fertilizers etc., are made in a single cropping season. These chemicals when applied as mixture\sequentially undergo a change in physical & chemical characters which could eventually result in enhancement\reduction in the efficacy of one or more compounds.

When two or more herbicides are applied in a mixture or alone as sequential applications they could interact to cause synergistic or antagonistic responses.

Many reports on syngestic responses in herbicide combinations are

1) 2,4 – D and Triazine herbicides.
2) Amitrole and Ammonium Bio-cyanate
3) Paraquat with certain triazines and urea on *Agrophyron repens*.
4) Atrazine and alachlor in corn.

The numerous reports on the antagonistic responses between herbicides are.

1. EPTC with 2,4-D | 2,4,5-T. or Dicamba.
2. Dalapon & Atrazine
3. TCA – 2,4-D
4. TCA – MCPA.

Generally, contact and systemic herbicide combinations show antagonistic response.

Herbicide-Antidote Interactions:

They are always antagonistic in nature.

Eg: Antidotes : 1,8- naphthalic anhydride

N-N- diallyl -2,2- dichloro acetamide.

The seed treatment of these antidotes will prevent the injury of herbicides like Alachlor, EPTC etc.,

Hence, the use of antidotes have tremendous potential in offering.

1. Permit to use of higher rates if herbicides for effective weed control.
2. Using herbicides in case of susceptible varieties adverse weather\soil conditions.
3. Using Non-selective herbicides for selective weeding of field crops.

Herbicide - Fertilizer Interactions:

There is a growing evidence for herbicide plant nutrient interactions. Ammonium ion of fertilizers speed-up the translocation of herbicides and its activity.

Ammonium sulphate 0.5----10% + Glyphosate increased the phytotoxicity.

Aquatic Weeds and their control :

Aquatic weeds are those unwanted plants, which grow in water and completed atleast a part of their life cycle in water.

Many aquatic plants are desirable since they play temporary beneficial sole in reducing agricultural, domestic and industrial pollution. However, some of these aquatic plants are considered weeds when they deprieve the humans at all facets, of efficient use of water.

1. Submersed, emersed and marginal weeds in and along irrigation channels/drainage channels impede water flow, in creases evapotranspiration, Cause damage to annals structures, clog grates, sophons, bridges, pumps etc.,

2. Floating and deep sooted submersed weeds interfere with navigation , prevent boats and steamers from moving

3. Submersed& floating aquatic weeds in farm ponds, village tanks & Qrwe ewawecoiea ewsuxw the water storage .

4. Prevents & impairs the use of inland waters for fishing by creating oxygen deficiency.

5. Aqvatic weeds provide a suitable habitat for mosquitoes causing malaria, filariasis etc.,

6. Aquatic weeds reduce the recreational values of tanks lakes, streams etc.,

<u>Types of Aquatic weeds</u>:

1. Floating weeds (free floating) : *Eicbornial crassipes, pistia stratiotes Azolla, lemboids , selviria*
2. Emergent weeds : *Nymphea, sagittaria*
   (Leaves at orablve water surface)
3. Submerged weeds : *Hydrilla verticillata, Vallisanaria spp.,*
   (Mostly vascular)

4. Marginal weeds : *Typha, Cyperus, Colocasia, Scrpus, Ipomoea.*
5. Algal blooms : *Microcystis, Oscillatory, Anabaena*

Control methods of aquatic weeds :

I. Mechanical methods :

1. Dredging : using bucket and weed fork.
2. Drying : Draioing & drying.
3. Mowing : Shoreline emersed weeds are cut with scythes / swords.
4. Hand cleaning : Men cut using knives & books.
5. Chaining : Using heavy chains on the opposite sides.
6. Burning :
7. Cutting :

II. Biological methods :

1) Fish species like Tillapia, silver carp, common carp, gold fish & silver dollar fish etc.,
2) *Alternaria eichhorniae, cercospora rodmanii* cause diseases in water hyacinth.
3) Flea beette *(Agasiches hydrophilla*) on water hyacinth & salvania is insect control.

III. Chemical methods :

Herbicides to control aquatic weeds have low toxicity to human beings & other warm-blooded animals. Usually spraying is done on only the part of the weed mat

Eg: I) Acrolein (acrylaldebyde) – potent irritant / lachry mator (teargas) at a cone. Of 4to7ppmV.

2) Dalapon @ 15 to 20 k / ha of surface area of weed infestation .

3) Amitrole @ 5 -10 kg /ha (Typha) Amitrole –T - do- (water hyacinth)

4) TCA- Controls phragmites, sorghum halepense

BIO- ASSAY OF HERBICIDES :

In weed research, bio-assays are used to measure the biological response of a living plant to a herbicide and to quantify its concentration in a substrate. Bio-assays are usually conducted with sensitive plant species referred as indicator/ Test plant.

The more commonly used indicator species are cucumber, oats, Barnyard grass, tomatoes, soybean, sorghum etc.,

In bio-assay, an indicator species is grown is herbicide treated soil at different known concentrations along with the same crop grown in untreated soil. This gives responses. Ranging from nil to complete deathas hesbicide conc is increased. The relationship between herbicide dose and plant response (%kill) Can be compared as follows.

The herbicide dose is greatest at a level where the plant produces 50% response and that is known as GR_{50} / ED_{50} / LD_{50}\ID_{50}.

(Growth reduction\Equivalent dose\Lethal dose\Inhibition dose)

The response of an herbicide on two or more plant species can be determined by comparing the ED_{50} values.

The bio-assay studies can be used to determined residue levels of a known herbicide in different fields. The surface soil samples from several areas in the same field are collected and bio-assay test crops are grown in pots under green house conditions. This value can be compared with the standard dose-response curve for estimating the residue. This when continued for time period then the persistence of herbicide can be known.

Adjuvants

Adjuvants are chemicals that improve the herbicidal effects, without being phytotoxic by themselves. Their effects are due to their ability to increase wetting of target surface and enhance penetration. They reduce the energy required to about herbicides across cuticle and exterior leaf membrane barriers.

They are grouped according to the type of action:

Increase H activity--------a. Activator adjuvants (surface, wetting agents, penetrants, oils.)

To reduce drift or --------- b. spray modifier adjuvants (stickers, film formers,
Promote spreading spreaders, spreader, stickers, deposit buildess thicken
And sticking agents foam)

Wider the range of ----- c. Utility modifiers (emulsifiers, dispersants, stabilizing
Cardns under which agents, buffering agents, entifoam agents)
A given formulation is useful.

The common kinds of adjuvants used with herbicides:

Activators:

Wetting agents: also called as surfactants or surface-active agents. Some weed foliage may not get wet by aquepis herbicide sprays (eg. Cyanodos dactylon). When a wetting agent is added to the spray tank, the spray immediately wets the foliage and the herbicide action becomes rapid. (In many commercial herbicide formulation the wetting agents are already provided). Surfactants may be part of the purchased formulation (eg. Glyphosate, or added to spray tank prior to use if recommended (eg. Grammaxane). Even soap surfants acts as a wetting agent. More potent weed against like upher, teepol are mighted in India. Stickers, spreaders, spreader stickers are used in very limited guty with herbicides, but are used mainly with fungicides and insecticides.

Deposit builders: (= filming agents \stickers)

These are added to he herbicide concentrates to hold the toxicant in intimate contact with the plant surface against their otherwise washing away by rain. Many herbicide formulation are pre-provided with deposit builders, otherwise these can be added to the spray tank in areas receiving frequent rains.

Drift control agents:

H spray drifts may post serious hazard to the non-target plants in the neighbourhood. Adjuvants are available that reduce the spray drift possibilities by either (i) increasing the droplet size, (ii) forming a foam, or (iii) making invest emulsion. Drift control agents are particularly necessary in aerial application of HC. Eg:

Stabilising agent:

When an emulsion concentrate is placed in water, it soon tends to oil-out on the surface, unless a suitable stabilizing agent is added to it or it is constantly agitated. It disperses the emulsion concentrate into minute droplets throughout the surface of the water in the tank & maintains this system in this state all throughout the spray work in the field. They are often pre-added in E.C. formulations.

Dispersants \Dispessing agents:

They stabilize the suspension of a weltable power. In its absence the w.p particles tend to settle at the bottom of the tank, unless constantly agitated. They are also pre-mixed with H. powders.

Antifoam agents:

Reduce foam in spray tanks. These agents are usually silicones that are often dispensed in aerosol cans or plastic squeeze bottle. The highest concentrate of antifoam agent needed for climinating foam is about 0.1% farmers often use kerosene or diesel fuel to about 0.1%.

Compatibility agents:

For dispessing emulsifiable H in liquid fertilizers.

Buffering agents:

Minimize the effect of alkaline water acid on spray mixtures of herbicides. Increase the dispersion solubility of H in water.

Activators:

Improve h absorption & or translocation an the target points urea, cm, cl_2 Am nitrate enhance the phytotoxicity of 2,4-D by widening it's entry points in the leaf cuticle.

Paraffinic oils with less than 10% aromatic content are called non-phytotoxicoils (NPO) or phytobland oils. Some of these have been found strong activators of a wide range of shoot-active H, including altrazine, amitrole. Their maximum use has been made to activate atrazhine against established grasses.

Table

HERBICIDE RECOMMENDATIONS, INTEGRATED WEED MANAGEMENT PRACTICES FOR IMPORTANT CROPS

III DIRECT WEED CONTROL METHODS

Sl. No.	Crop	Critical period of weed control	Cultural method of weed control./Mechanical method	Herbicides or chemical weed control	Biological weed control	Remarks
1.	Rice	20-30 DAT	1) Hand weeding 2) Hand pulling 3) Pudding 4) Flooding 5) Weeder (Float)	Butachlor (1-2 kg ai/ha) Alachlor (1-2 kg ai/ha) Thiobencarb + 2, 4D isopropyl (0.75) ester (0.5 kg ai/ha) Metsulfuron methyl (20 WP) (0.008 kg ai/ha) Benthiocarb (1.5 – 2.5 kg ai/ha) Bopanil (2-3 kg ai/ha) (only post-emergence)	1. *Hirsch - manniella* *Spinicaudata* is a rice root nematode which controls most upland rice weeds 2. *Azolla*	I. Substitution and preventive method: a) Stale seed bed technology b) Land preparation c) Water management

2.	Wheat	15 – 30 DAS	a) Hand Hoeing b) Inter cultivation c) Criss-cross sowing	1. 2, 4D (1 – 1.5 kg ai/ha) 2. MCPA (1 – 1.5 kg ai/ha) dissolved in 700 – 800 litres applied at 25 – 30 DAS Efficiency can be increased by mixing urea @ 3% 3. Mixture of Isoproturan (0.75 kg ai/ha) and 2, 4D (0.4 kg ai/ha) during 30-35 DAS		II. Complimentary weed control methods a) Cultivars b) Seedling age / planting method c) Fertilizer management d) Cropping system

Sl.No.	**Crop**	**Critical**	**Chemicals**	**Biological**
3.	Sorghum	21 – 42 DAS	1. Pre-plant application of Atrazine (1 kg ai/ha) + Pre-emergence application of Atrazine (0.5 kg ai/ha) 2. Propazine (1 kg ai/ha) as pre-emergence band	1. Inclusion of cotton crop in the rotation

			application 3. Simazine and 2, 4D have adverse effects 4. Application of paraquat as directed spray effectively controls striga (1-2 litres/ha) 5. Fluchloralin/Alachlor should be used when sorghum is intercropped with any pulses/Groundnut	
4.	Maize	2 to 6 Weeks	1. Pre-emergence application of Atrazine (1-2 kg ai/ha) 2. Combined application of Alachlor (2 kg/ha) and atrazine (1kg/ha) is more effective and have wider spectrum of control 3. Post-emergence application of 2, 4D (1-2 kg/ha) Dinoseb (0.75 to 1 kg/ha) and Dicamba (0.5 to 1 kg/ha) – should be applied at 2-4 leaf stage	
5.	Groundnut	Upto 45 days	1. Alachlor (1-5 kg/ha) – pre emergence application 2. Combination of Alachlor with nitrofen (3-5 kg) or prometryn (1 – 1.5 kg/ha) as pre-emergence 3. For perennial weed control vernolate (2-3 kg) needs to be incorporated before sowing crop seeds	
6.	Sunflower	4-6 weeks	1. EPTC (2 to 3 kg/ha) or Trifluralin (0.5 to 1 kg/ha) are incorporated as per planting	

			2. Alachlor (1-2 kg/ha), Nitrofen (1.5 – 2 kg/ha) as pre-emergence	
7.	Cotton	First 45 days	1. Diuron (0.5 – 1.5 kg/ha), Monuron (1-1.5 kg/ha), Fluchloralin (1-1.5 kg/ha) applied as pre-emergence/preplanting 2. Pre-emergence combination of Trifluralin and diuron (1+1 kg/ha) are most effective and wider spectrum 3. MSMA (2-3 kg/ha) and Dalapon (3-4 kg/ha) as post-emergence directed spray	
8.	Pulses	First 30-35 days	1. Alachlor (1-2 kg/ha), Nitrofen (0.75 – 1.5 kg/ha) Fluchloralin (1-1.5 kg/ha), Trifluralin (1-2 kg/ha) as pre-emergence (preplanting incorp.)	
9.	Tobacco	First 9 weeks	1. Methyl bromide (4 to 8 kg per 100 m2), calcium cynamide (40-60 kg per 100m2) fumigation to sterelise the soil in the nursery before 2-4 days of sowing 2. Fluchloralin (2-3 kg/ha), Pendemethalin (1-1.5 kg/ha) as pre-emergence and vernolate (2-3 kg/ha) and Benefen (1.5 – 2 kg/ha) as pre-planting incorporation in transplanted fields	

10.	Sugarcane	4 to 5 months	1. Pre-emergence herbicides like atrazine (2 to 3 kg/ha) Simazine (2 to 3 kg/ha), Alachlor (1.3 to 2.5 kg/ha) etc., will generally last for 8 to 12 weeks 2. To obtain best results sequential application of pre-emergence and post emergence herbicides or post emergence herbicides like Glyphosate (0.8 to 1.6 kg/ha) Paraquat (0.4 to 0.8 kg/ha), Asulam (3 to 4 kg/ha)	