Weed Management

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Weed

- Weed is a plant growing where it is not desired.
- Jethro Tull a great British farmer was the first person to refer the word weed and its definition in his famous writing "**Horse Hoeing Husbandry**".
- All weeds are unwanted plants, but all unwanted plants may not be the weeds.
- **Weed science society of America** defined weed as a plant growing where it is not desired.
- **European weed research society** defined weed as any plant or vegetation excluding fungi interfering with the objectives or the requirements of the people.
- **W.S. Blatchley** defined weed as a plant out of place or growing where it is not desired.
- **W.W.Robbins et al**., defined weeds as obnoxious (unpleasant) plants.
- **J.L.Harper** defined weeds as higher plants which are a nuisance.

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Classification of weeds

Weeds are classified

1. Based on morphology – Grasses, Sedges and Broad leaved weeds
2. Based on life cycle – Annuals, Biennials and Perennials
3. Based on nature of stem – Woody, Semi woody and Herbaceous weeds
4. Based on soil types – Acidophile, Basophile and Neutrophiles
5. Based on origin - Indigenous weeds and Exotic/Alien weeds
6. Based on habitat
7. Based on association

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5. Based on origin

- **Indigenous weeds:** Native weeds of the country

Eg. Acalypha indica, Abutilon indicum, Sorghum halepense, Cynodon dactylon and Echinochloa colonum

- **Introduced or Exotic or Alien weeds:** Weeds introduced from other countries.

Eg. Parthenium hysterophorus (North America), Acanthospermum hispidum (America), Eichhornia crassipes (South America-Brazil), Argemone mexicana (Mexico/ North America), Lantana camara (Central America, Mexico) and Croton bonplandianus (South America).

✓ When man aids in its introduction such weeds are called as Anthrophytes.

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6. Based on habitat

Terrestrial weeds

- Crop land weeds: weeds in field. Eg. Echinocloa in rice.
- Non-crop land weeds: weeds in waste lands. Eg. Tribulus terrestris, Xanthium strumarium.
- Grass land weeds: Eg. Vernonia and Rumex spp.
- Weeds of lawns & public parks: Eg. Lippia nodiflora and Eleusine indica.
- Orchard or garden weeds: Eg. Euphorbia geniculata, Imperata cylindrica , Acalipha indica.
- Weeds of plantation crops: Eg. Euphatorium spp. Makania micrantha
- Parasitic weeds: Eg. Loranthus.
- Road side weeds: Eg. Euphorbia, Lantana camera, Hyptis and Prosopis juliflora

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Aquatic weeds

1)Sub merged weeds: Eg. Hydrilla verticillata, Utricularia stellaris.

2) Emerged weeds: Eg. Typha Spp, Nelambium speciosum.

3) Floating weeds: Eg. Eichhornia crassipes, Pistia stratiotes

4) Marginal weeds: Eg. Polygonum, Alternanthera, Ipomea

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7. Based on association

✓ When two plants are living together it is called association. Based on association they are **season bound weeds, crop bound weeds and crop associated weeds.**

- **Season bound weeds:** Sorghum halepense (Perennial) is a summer perennial

  Circium arvense is winter perennial.

  Phalaris minor and Avena fatua are winter season annuals.

- **Crop bound weeds:** Parasitic weeds

1. Root parasites: a. complete root parasite eg. Orobanche (broom rape)in tobacco

b. partial root parasite eg. Striga spp (witch weed) on sorghum

2**. Stem parasites:** a. complete stem parasite eg. Cuscuta (dodder) in lucern & burseem

b. partial stem parasite eg. Loranthus in fruit crops

- **Crop associated weeds:** crop specific due to mimicry, need for specific micro climate and ready contamination with the crops.

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- **Mimicry:** Weeds look exactly like crops morphologically & complete their life cycle.
  - ✓Echinochloa colonum (Jungle rice) mimic the rice crop.
  - ✓Avena fatuva (wild oat) and Phalaris minor (canary grass) both mimic the wheat
  - ✓Loranthus in tea gardens.
  - ✓**Phenotypic mimicry:** Avena fatua (wild oats) tends to grow to the height of winter grains and adjusts its ripening period to the crop over a wide varietal range
- **Need for specific micro climate**

  Cichorium intybus (chicory) and Coronopus didymus (swine cress) requires shady, moist & cool micro climate which is available in lucerne and berseem crops.
- **Ready contamination with the crops**

  If the crop seed mature at the same time & same height of the crop, then it contaminates the crop (also morphologically same) easily
  - ✓ Eg. little seed canary grass (Phalaris minor) with wheat

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Some other terminologies

- **Facultative weeds:** Also called Apophytes. Weeds that grow primarily in wild community and migrated to crop fields. Eg. Opuntia dilleni
- **Obligate weeds:** Occur only on cultivated land. They can't survive and withstand and disappears when the land is not disturbed for 2-3 years. Eg. Convolvulus arvensis
- **Noxious weeds**: Weeds which are undesirable, trouble some & difficult to control. These weeds are also known as special problem weeds.

  Eg. Cyperus rotundus. Cynadon dactylon, Circium arvense, Parthenium, Eichhornea crassipes, Lantana camara, Saccharum spontaneum, Imperata cylindrica and Striga spp
- **Objectionable weed:** It is a noxious weed whose seed is difficult to separate from the crop seed after contamination is called objectionable weeds.
- **Satellite weeds:** Weeds which mature at same time and height as that of crop and have similar size and shape of their seeds as that of crop seeds are easily mixed with crop seed. Eg. Avena fatua and Phalaris minor are such weeds in winter grains. Similarly, Oryza sp. in rice, Cichorium intybus and Cuscuta sp in lucerne.

- **Weed biology** is related to the study of weeds in relation to their geographical distribution, habitat, growth and population dynamics of weed sps and communities.
- **Ecology** is the study of interactions between the plants and their environment.
- **Weed ecology** is the study of interactions between the weeds and their environment.
- **Persistence** is a adaptive measure of a weed that enables it to grow in any environment.
- **Hardiness** refers to its ability to withstand all kinds of natural stresses at a given place. Weeds are both persistent and hardy.

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- **Persistence** of weeds results from their **multifacet mechanisms** such as

1. Prolific seed production
2. Viable seed production
3. Dormancy
4. Vegetative propagation
5. Rapid dispersal
6. Inherent hardiness
7. Evasiveness
8. Self regeneration
9. Selective invasion
10. Weed succession

A weed having more than three multifacet mechanism is called as **Horrible weed**

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Weed dormancy

- **Innate dormancy** is a genetically controlled character. It is due to presence of hard seed coat.

  E.g. Tribulus terrestris, Ipomea sps, Xanthium sps.

- **Enforced dormancy** is due to placement of weed seeds deeper than 5cm in the soils. It is a non-specific character of the seeds and it is caused by the absence of red light.

  E.g. *Xantheum spp*, *Rumex spp*

- **Induced dormancy** results from sudden physiological changes takes place in the seed.

- **Avena fatua** exhibit all the three kinds of dormancy.

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Important points/bits:

- ✓ **Yellow nut sedge** (Cyperus esculentus) does well in subhumid and warm temperate regions, but it does not thrive well in temperate areas with prolonged frost.
- ✓ Purplenut sedge (Cyperus rotundus) thrives well in humid tropics and subtropics.
- ✓ Water hyacinth an important aquatic weed in tropics and subtropics is not yet invaded the temperate waters.
- ❖ Cynodon dactylon seeds retain viability for 2 years.
- ❖ Tribulus terrestris seeds remain alive for 8 years.
- ❖ Cyperus rotundus seeds remain alive for 20 years.
- ❖ Convolvulus arvensis seeds remain alive for 50 years

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- *Tribulus terrestris* possess short spines on fruit.
- *Solanum xanthocarpum* has spines on stem and leaves.
- *Acanthospermun hispidum* has triangular fruit with spines.
- *Mimosa pudica* has short spines on stem.
- *Oxalis latifolia* produces bulbils in roots.
- *Cyperus rotundus* produces tubers.
- *Panicum* produces rhizomes in root.

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Losses due to weeds

- Weeds account for 45% loss of agriculture produce

  Insects – 30%

  Diseases – 20%

  Others (rodents) – 5%

- Weeds compete with crop plants for **moisture, nutrients, space** and **sunlight** and reduce the crop yields.
- **Crop – reduction in yield due to weeds**

  Wheat = 15-30%

  Rice = 30-35%

  Maize, sorghum, pulses, oilseeds = 18-85%

  Bengalgram = 30%

  Redgram = 34%

  Onion = 90.7%

  Potato = 28%

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- ✓ **Ergot of Bajra** pathogen survives on *Cenchrus ciliaris*.
- ✓ Stemborer on rice will survive on ***Echinocloa*** as well as ***Panicum.***
- ✓ Weed infestation in sugarcane leads to **reduction in sucrose** content.
- ✓ **Parthenium** causes **skin rashes.**
- ✓ **Ambrosia *sps.*** causes **heyfever**.
- ✓ If seeds of ***Argemone mexicana*** mixed with mustard seeds cause **blindness.**
- ✓ ***Sorghum halopense (Johnson grass)*** contains alkaloids (HCN) which is fatal to farm animals.

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Uses of weeds:

- Weeds comprise of 2.5 times more N, 1.5 times more P, 3.5 times more K than crop plants.
- Parthenium, *Eichhornea crassipes*, *Eupatorium* are used as compost and also as green manure plants. They should be used before flowering.
- Weeds which are used as food for human beings are *Amaranthus viridis, Celosia argentia (cocks comb weed), Alternanthera sessilis, Portuluca sps, Digera sps, Chromolina odorata.*

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Weed	Use
Centella asiatica	Blood purifier and improves memory power
Phyllanthus niruri	Jaundice
Tylophora indica	Asthma
Solanum nigrum , Solanum xanthocarpum	Asthma, cough and fever
Argemone mexicana oil	Skin treatment
Spirulina sps	Rich in protein
Dicanthium annulatum, Vetiveria zizanoides	Soil binders
Cynodon dactylon	Lawn
Calotrophis, Parthenium, Crotalaria	Reduces nematode population
Jatropha gossypifolia	Biofuel
Lantana camara, Opuntia dellini	Live fences

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CROP WEED COMPETITION or INTERFERENCE

- Acc. to **Muller** competition means that one plant utilizes the necessary growth resources resulting in shortage which is harmful to other plant sharing the same habitat.
- Acc. to **Aldrich** competition is the relationship between two or more plants in which the supply of growth factors falls below their combined demand.
- **Critical period of crop-weed competition** is defined as the shortest time span during the crop growth when weeding is done results in maximum returns. First ¼ - 1/3 of the growing period of many crops is critical period.

Onion (transplanted) – 20-40 DAT

Onion (Direct seeded) – 20-55DAS

Sugarcane – 30-110 DAS

Potato-15-30 DAS

Soybean & Sunflower – 30-40 DAS

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- **Amaranthus viridis** accumulates 3.16% N apart from high levels of potassium (4.51%) in their drymatter.
- Achyranthes aspera and **Digitaria sanguinalis** are 'P' accumulators which contain 1.63% and 3.36% P respectively
- Chenopodium album contains 4.34% K, whereas **Portuluca** contains 4.57% K.
- For producing equal dry matter weeds transpire more water than most of the crop plants.
- **Transpiration coefficient** is the quantity of water (g) necessary for a plant to produce one kg of dry matter.

✓ Cowpea, fieldbean, horsegram, potato, redgram and castor have good weed smothering ability.

✓ Onion, garlic, carrot, maize and sunflower are poor competitors with weeds.

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- Crop-weed competition does not include **allelopathy.**
- **Crop-weed Interference = competition + Allelopathy** (given by Harper)
- Weed competition is always **indirect** but weed **interference** could be **indirect or direct.**
- **Allelopathy** is a direct effect.
- Grassy weeds prove more competitive with cereal crops.
- Broad leaved weeds may put more competition with broad leaved crops.
- Weed density and crop yield have a **sigmoidal** and **fairly inverse relationship** with each other.

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ALLELOPATHY

- The word allelopathy is derived from **greek words**

  Allelo = mutual or each other

  Patho = suffering or to suffer

- The term allelopathy was coined by **Molish** in **1937.**
- **Rice** defined **allelopathy** as any direct or indirect inhibitory effect by one plant including microorganisms on another plant through the production of chemical compounds that escape into the environment.

- Sorghum is allelopathic against Amaranthus hybridus and Setaria viridis.
- Sweet potatoes have allelopathic effect on weeds like Cyperus sps.
- Cucumber is allelopathic against Echinocloa crusgalli and Amaranthus sps.
- Maize is allelopathic against Chenopodium album.
- Euphorbia is having allelopathic interactions on flax.

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- Chenopodium album is having allelopathic interactions on alfalfa, maize and cucumber.
- Parthenium is allelopathic to many weeds.
- Parthenium invades and forms a territoty of its own replacing all the existing weed flora because of allelopathic effect.
- Amaranthus spinosus, Cassia seracia etc. pose a strong allelopathic effect on parthenium.
- **Weed against weeds** allelopathy has enough importance and could be exploited to control some of the poisonous and problematic weeds.
- Parthenium is suppressed moderately (26-50%) by Cassia auriculata, Sida spinosa and Hyptis Suaveolens.
- High suppression (51-75%) of parthenium by Croton bonplandianum, Cassia oxidentalis and Cassia tora.
- **Very high** suppression (76-100%) of parthenium by **Cassia sericea** and Tephrosia purpurea.

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Principles of Weed Management

1. **Prevention**: Prevent the entry and establishment of weeds into uninfected area.
2. **Eradication**: It is complete removal of all live plant parts and seeds of the weed from an area. It may be a field/farm/village/geographical region depending upon the need.
3. **Control** : Weed infestations are reduced but not necessarily eliminated. weed control is done by

   Physical/mechanical,

   Cultural,

   Biological and

   Chemical methods

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BIOLOGICAL WEED CONTROL

- Biological control of weeds simply means controlling the weeds below their **economic threshold level using another organism** like insects, herbivorous fishes, pathogens, competitive plants.
- The first effort at biological control of weeds is to control **cacti in India in 1863 by** cochineal insect known as ***Dactylopius tomentosus***.

➢ **Criteria / Characteristics of successful bio-agent**

1). Host-specific 2. Bioagent hardiness 3. Feeding habit and ease of multiplication

- Bioagent should pass **starvation test.**

❖ Lantana was controlled by "Teleonemia scrupulosa" insect bio-agent. But in India it is likely to damage teak (Tectona grandis) and sesame (Sesamum indicum).

❖ Zygogramma bicolarata is an effective leaf eating bio-agent against Parthenium (carrot grass). But it is found to attack sunflower in India.

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- **Cactoblastis cactorum (moth)** is effective against **Opuntia inermis.**
- **Dactylopius opuntiae** imported from **USA** found effective against **prickly pear.**
- L**antana camara** is a shrub native of **Central America and Mexico.**
- C**rosidosema lantana (moth)** larvae bore through **flowers, fruits, s**eeds and foliage of lantana.
- A**gromyza lantanae** feeds on **seeds** of Lantana camara.
- Z**ygogramma bicolorata** (Mexican beetle) feeds on foliage of parthenium.
- Activity of Mexican beetle is restricted to rainy season and it hibernates in w**inter season.**
- **Epiblema sternuana (gall insect)** is used for control of **parthenium.**
- **Neochetina eichhornae** tunnels petioles and stem of **water hyacinth** (Eichhornea crassipes). **Neochetina bruchi** also controls water hyacinth

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Weed	Bio-agent	Reporting Country	Kind of bioagent
Chondrilla juncea	*Puccina chondrillina*	Australia	Plant pathogen
Cirsium arvense	*Septoria cirsii*		Plant pathogen
Cyperus rotundus	*Bactra verutana*	India, Pakistan, USA	Shoot boring moth
Echinochloa spp. (In rice fields)	i) *Emmalocera sp.* ii) *Tripos spp.*		i)Stem boring moth ii) Shrimp
Eupatorium riparium	*Entyloma compositarum*	USA	Plant pathogen
Hydrilla verticillata	*Hydrellia pakistanae*	USA	Shoot fly
Orobanche cernua	*Sclerotinia sp.*	USA	Plant pathogen
Parthenium hysterophorus	i)*Zygogramma bicolorata* ii)*Epiblema stremuana* iii) *Conotrachelus sp.*	India Australia Australia	Leaf eating beetle Stem galling insect Stem galling insect
Rumex spp.	i) *Uromyces rumicis* ii)*Gastrophysa viridula*	USA USA	Plant pathogen Beetle
Tribulus terrestris	*Microlarinus lareynii and M. lypriformis*	USA	Pod weevil

Bioherbicides

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

CHEMICAL WEED CONTROL

Pesticide	World	USA	India
Herbicides	43%	55%	12%
Insecticides	33%	32%	77%
Fungicides	17%	7%	8%
Others	7%	6%	3%

- Herbicide is derived from two **latin words**

  Herba = plant

  Caedere = to kill

- First herbicide registered and used for selective control of weeds in crops was **2,4-D.**
- Weed control as a science was initiated in 1942.
- The first important discovery in the field of selective weed control was the introduction of **4,6- Dinitro – O - Cresol (DNOC) in France in 1933 is a contact herbicide applied to cereal crops to** control broad leaved weeds.

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- **Pokorng** synthesized 2,4-D in 1940 and described its chemical synthesis in 1941.
- **Zimmerman and Hichcock** too synthesized 2, 4-D in 1942. This event was more highlighted ad taken as first time discovery of 2,4-D.
- **Marthan & Mitchell in 1942 & 1944** from USDA reported its herbicidal activity to selectively control the broad leaved weeds in the lawns.
- **Hammer and Tukey in 1944** observed that 2,4-D successively control weeds in cereals.
- **2,4-D** is first selective organic herbicide in world because of its widespread use in crops mainly cereals all over the world.
- Herbicide is identified with 3 names i.e., common name, chemical name and trade name.

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Trade names of herbicides

Common names	Trade name
Alachlor	Lasso
Anilofos	Aniloguard
Atrazine	Atrataf
Butachlor	Machete
Clomozone	Command
Ethoxysulfuron	Sunrise
Fenoxaprop-p-ethyl	Whipsuper
Glyphosate	Glycel / Roundup
Metolachlor	Dual
Imazethypr	Persuit
Oxyfluorfen	Goal
Oxadiargyl	Raft SC, Topstar WG
Paraquat	Gramoxone
Pendimethalin	Stomp
Pretilachalor	Rifit
Pretilacholar-S	Sofit
Pyrazosulfuron-ethyl	Saathi
Quizalofop-ethyl	Turgasuper
2,4-D	Fernoxone
2,4-DEE	Agrodon
Glufosinate	Basta
Isoproturon	arelon
Propanil	Stam F 34
Thiobencarb	Saturn
Trifluralin	Tip top
Metaxuron	Dosanex
Cinmethylin	Argold, Cinch
Metsulfuron methyl	Algrip
Chlorimuron +metsulfuron methyl	Almix
Chlorimuron -ethyl	Kloben

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Classification of herbicides

I. Based on time of application:

a) **Preplant incorporated:** e.g., Fluchloralin, trifluralin

b) **Pre-emergent herbicide: eg.,** Pendimethalin, alachlor, atrazine, diuron, oxyflourfen, metalachlor, butachlor, isoproturon, pyrazosulfuron ethyl

c) **Post emergent herbicides:**

i) **Early post emergent: (15-20 DAS)** e.g., 2,4-D, Fenoxoprop-p-ethyl, metamfop, cyhalofop-p-butyl.

ii) **Late post emergent:** Applied on foliage of fully grown weeds and they are non selective.

e.g., Glyphosate, paraquat, diquat

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II. Based on selectivity

a) **Selective herbicides:** e.g., Atrazine, butachlor, fenoxoprop-p-ethyl, metolachlor.

Pendimethalin is an excellent herbicide having selectivity to >60 different crops which includes cereals, pulses, oilseeds etc.

However selectivity of any herbicide is **dose dependent and crop dependent.**

b) **Non selective herbicides:** e.g., Glyphosate, paraquat, diquat

III. Based on spectrum of weed control

a) **Narrow spectrum herbicides:** They control a particular group of weed flora.

E.g., 2,4-D is basically a broad leaved weed killer

Diclofop-methyl and fenoxoprop-p-ethyl are grass killers

b) **Broad spectrum herbicides:** They control wider weed flora consisting of broad leaved weeds, grasses and sedges.

E.g., Glyphosate, paraquat, diquat, atrazine, pendimethalin, isoproturon, oxyfluorfen

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IV. Based on site of application

a) **Soil applied herbicides:** They are applied to the soil. They kill germinating and sprouting weed seeds, rhizomes, tubers etc.

- ✓ All pre-emergent herbicides are soil applied herbicides

b) **Foliage applied herbicides:** They are applied on the canopy or the foliage of the weeds. They are applied on the grown up weeds.

E.g., paraquat, glyphosate, 2,4-D

V. Based on residue action in the soil

a) **Residual herbicides:** e.g., Atrazine, 2,4-D, pendimethalin

b) **Non residual herbicides:** e.g., Glyphosate, Paraquat, Diquat

VI. Based on chemical structure

a) **Inorganic herbicides:** e.g., Ammonium sulphate, borate, copper sulphate, sodium chlorate

b) **Organic herbicides:** Most of the herbicides that are in present use are organic

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List of organic herbicide groups

Sl.No	Group	Herbicides
1	**Aliphatic acids**	Dalapon, TCA, Glyphosate, Methyl bromide Cacodylic acid ,MSMA,DSMA
2	**Amides**	Alchlor, Butachlor, Propachlor, Metalachlor, Diphenamide, Propanil
3	**Benzoics**	2,3,6, TBA, Dicamba, tricamba, Chloramben
4	**By Pyridillums**	Paraquat, Diquat
5	**Carbamates**	Propham, Chlorpropham, Barban, Dichlormate, Asulam
6	**Thiocarbamates**	Butylate, Diallate, EPTC, Molinate, Triallate, Benthiocarb, Metham
7	**Dithiocarbamates**	CDEC, Metham
8	**Nitriles**	Bromoxynil, Ioxynil, Dichlobenil
9	**Dintroanilins**	Fluchloralin, Trifluralin, Pendimethalin, Nitralin Isoproturon
10	**Phenols**	Dinoseb, DNOC,PCP

11	**Phynoxy acids**	2,4-D, 2,4,5-T, MCPA, MCPB, 2,4-DB, Dichlorprop
12	**Traizines**	Atrazine, Simazine, Metribuzine, Amytrin, Terbutrin
13	**Ureas**	Monuron, Diuron, Linuron, Metoxuron, Isoproturon, Methabenz thiozuron
14	**Uracils**	Bromacil, Terbacil, Lenacil
15	**Diphenyl ethers**	Nitrofen, Oxyfluorfen, Nitrofluorfen
16	**Aryloxyphenoxy propionate**	Diclopop , Fenoxaprop-p, Quizalofop-p, Haloxyfop-p Fluazifop-p
17	**Cyclohexanedione**	Sethoxydim, Clethodim, Tralkoxydim, Cycloxidim
18	**Imidazolines**	Imazapyr, Imazamethabenz, Imazaquin, Imazamax imazethapyr
19	**Isoxazolidinones**	Clomazone
20	**Oxadiazoles**	Oxadiazon
21	**Oxadiazolides**	Methazole

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22	**N-phenylphthalamides**	Flumiclorac
23	**Phenylpyridazones**	Sulfentrazone
24	**Phthalamates**	Naptalam
25	**Pyrazoliums**	Difenzoquat, Metflurazone
26	**Picolinic acids Pyridine**	Picloram , Dithiopyr, Pyrithiobac, Fluridone, Thiazopyr
27	**Quinolines**	Quinclorac
28	**Sulfonylureas**	Bensulfuron, Chlorimuron, Metsulfuron, Sulfosulfuron Triasulfuron
29	**Triazolinones**	Pyridates
30	**Cineoles**	Cinmethylin
31	**Others**	Pichloram, Pyrazon, Endothal, Oxadiazon, Amitrole, Anilofos

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VII. Based on tranlocation

a. Contact herbicide: kills plants by coming in contact with the plant tissue.

Eg. Paraquat, Diquat, Propanil, Atrazine

b. Translocated/ Systemic herbicide: moves within the plant from the point of treatment to its other parts.

Eg. Glyphosate, Atrazine

VIII. Based on mode of action

a) Cell division inhibitors

i) Microtubule assembly inhibitors: e.g., Dinitroanilines (Pendimethalin, fluchloralin, trifluralin)

ii) Mitosis inhibitors:e.g., Carbamates, thiocarbamates

b) Photosynthesis inhibitors: photo system II. e.g., Triazines, uracils, urea group, Bipyridillium group

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c) Aminoacid/ protein synthesis inhibitors:

1) Blocking or inhibiting EPSP synthase enzyme: 5-Enol Pyruvyl Shikimate 3-Phosphate Synthase enzyme is involved in biosynthesis of 3 aromatic aminoacids such as phenyl alanine, tryptophane and tyrosine.

✓ **Glyphosate** blocks or inhibits the action of EPSP synthase enzyme.

2) ALS synthase enzyme inhibitors: Aceto lactate synthase enzyme is involved in biosynthesis of branched chain aminoacids such as leucine, isoleucine and valine.

✓ **Sulfonyl urea group** of herbicides like chlorosulfuron, Bensulfuron methyl, chlorimuron ethyl, metsulfuron methyl and **imidazolinones** (imazethapyr) inhibit the action of ALS synthase enzyme.

3) Glutamine synthesis inhibitors: Glutamine synthetase enzyme is involved in glutamine synthesis. It plays important role in nitrogen metabolism in plant system.

✓ **Glufosinate** inhibits glutamine synthesis

d) Lipid biosynthesis inhibitors: Acetyl Coenzyme A carboxylase is involved in the biosynthesis of fatty acids.

e.g., Clodinafop-propargyl, Diclofop-methyl, fenoxoprop - pethyl, fluazifop-butyl.

✓ These herbicides are grass killers and have good selectivity for dicotyledonous plants

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Herbicide Formulations

I. Formulations applied after their dilution with water

a) **Emulsifiable concentrates (EC):** EC formulations form an emulsion when added to water before spraying. It appears like milky white.

e.g., Pendimethalin, fluchloralin, alachlor, paraquat, diquat, oxyfuorfen, anilophos, metolachlor

b) **Wettable powders (WP):** It is a finely milled powder which forms a suspension on mixing with water.

e.g., Triazine group, atrazine, simazine, phenyl ureas

✓ EC and wettable powders are the two most popular formulations present in market

c) Soluble liquids(SL)

d) Soluble powders (SP)

e) Dry flowables (DF)

f) Concentrate emulsion (CE)

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II. Formulations applied as such

Granules (G):

- Usually size varies from **0.04 – 1.0 mm.**
- Concentration is usually **< 10%.**
- If size of granules is **< 0.04 mm drift problem will be there.**

e.g., Butachlor (machete – 5% G)-used in **wetland paddy**

- Butachlor is available in both **EC and granular form.**

Degree of toxicity – indicating colour

Extremely hazardous – **Red**

Highly hazardous – **yellow**

Moderately hazardous – **blue**

Slightly hazardous – **green**

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Herbicide application methods

Different Soil Application methods

- Surface application method
- Sub-Surface Layering
- Band Application
- **Soil Fumigation:** (1) by soil injection (chloropicrin)

(2) by releasing it under sealed, plastic covers (methyl bromide) or

(3) by direct soil surface application (Metham).

- Herbigation: Eg. EPTC with sprinkler

Different Foliage application methods

- Blanket Application
- Directed Spraying
- Spot treatment
- Protected Spraying
- D.C.A.(Direct Contact Application)
- Herbicide cloth mulches
- Cut stump method
- Herbicide gloves

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HERBICIDE SELECTIVITY

- ✓ **Selectivity** refers to the phenomenon wherein the herbicide kills the target plant species in a mixed plant population without harming or slightly affecting the other plants.
- ✓ **Selectivity** is considered as the greatest single factor that helped the chemical weed control to succeed since the advent of 2,4-D.

Factors achieving selectivity

1) **Differential absorption of herbicide**
2) **Differential translocation of herbicides**
3) **Differential rate of deactivation of herbicide by the plants**
4) **Difference in specific physiology of crop**
5) **Chronolgical selectivity**

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HERBICIDE MOVEMENT IN PLANTS

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1) Symplastic movement

- ✓ It is source to sink translocation.
- ✓ The herbicides move through **phloem with sugars** or photosynthates produced during photosynthesis.
- ✓ In all foliage applied and post-emergent herbicides the herbicide movement is through symplastic movement.
- ✓ It requires metabolic energy and the movement is **basipetal (apex to base).**

  e.g., Glyphosate, 2, 4-D

2) Apoplastic movement

- The herbicides are primarily absorbed by the roots and move predominantly through **xylem and intercellular spaces** in plants.
- They move along with water (**passive movement) or mineral** nutrient ions (**active movement)**
- In **soil applied or pre-emergent herbicides** the usual basis of herbicide movement is apoplastic movement.

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HERBICIDE MIXTURES

- Herbicides of the **same class or different classes having similar mode of action are not ideal for herbicidal mixture**
- Herbicides having **similar spectrum of weed control should** not be opted for mixing.

Types of herbicide mixtures

1) Factory mix/premix/readymix

Isoguard plus (Isoproturon + *2,4-D)*

Aniloguard plus (Anilophos + 2,4-D)

Primaguard (Atrazine + Metolachlor)

Atlantis (Mesosulfuron-methyl + Iodosulfuron methyl sodium)

Almix (Metsulfuron methyl + chlorimuron ethyl) – used in **rice**

Pursuit plus (Pendimethalin + Imazethapyr)

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2) Tank mix/ field mix herbicide mixtures

It is mechanical mixing of two or more herbicides before their application in the **field.**

e.g., Atrazine + Alachlor

Atrazine + Pendimethalin

Isoproturon + Tralkoxydim

Sethoxydim + Chlorosulfuron

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EFFECTS OF HERBICIDE MIXTURE INTERACTIONS

1) **Synergistic effect:** (AB) > (A) + (B)

Mixture effect of herbicide is more than the effect of herbicide A and B independently.

2) **Antagonistic effect:** The decrease in normal biological activity of one or all component herbicides in a mixture is referred as antagonistic effect.

If (A) > (B) then (AB) < (A)

3) **Additive effect:**. (AB) = (A) + (B)

4) **Enhancement effect: It generally occurs when adjuvant is mixed** with active ingredient in the formulation and it increases the efficacy of herbicide than obtained with active ingredient alone.

e.g., Fenoxaprop-p-ethyl

- Fenoxaprop-p-ethyl is a **grass killer** used in **soybean** under the tradename "**whip super", while same herbicide** is used in **wheat** under **different tradename "pumasuper".**
- The differential action of same herbicide is attributed to different **adjuvants used in the formulations.**

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Adjuvants

- Chemicals employed to improve herbicidal effects are called adjuvants.
- Adjuvants do not act by increasing the innate activity of herbicide.
- Adjuvants enhances the activity of herbicide in the plants where it is needed.
- Kinds:
  1. Surfactants- surface active agents
  2. Stabilizing agents – a. Emulsifiers (for EC) and b. Dispersants (for WP)
  3. Solvents- benzene, xylene, petroleum ether, methyl chloride, alcohols, acetones
  4. Humicants - Glycerol.
  5. Stickers- Several petroleum oils, dupont spreader , stickers, cheveron, citowett
  6. Compatibility agents - Compex
  7. Activators - urea, NH_4Cl, Ammonium thiocyanate, Isoparaffinic and Phytobland oils
  8. Drift control agents - invert emulsions.

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HERBICIDE MIXTURES FOR CROPS

1) Rice:

Anilophos (0.4 kg) + 2,4-DEE (0.5 kg)/ha

Butachlor (1 kg) + Propanil (2.0 kg)

Anilophos (0.3 kg) + chlorimuron (0.004 kg)

Anilophos (0.3 kg) + metsulfuron – methyl (0.004 kg)

Pretilachlor + 2,4-DEE for upland rice

2) Wheat and Barley

Diclofop-methyl (750 g) + Isoproturon (500g)

Isoproturon (750 g) + 2,4-D (250 g)

Clodinafop (60 g) + Isoproturon (500 g)

Fenoxaprop – p- ethyl (120 g) + 2,4-D (500g)

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3) Maize and sorghum

Atrazine (0.5 kg) + Alachlor (1.0 kg)

Atrazine (0.75 kg) + Pendimethalin (0.75 kg)

Atrazine + 2,43-D

4) Soybean

Pendimethalin + Imazethapyr

Metribuzin + Chlorimuron ethyl

Oxadiazin + Metolachlor

5) Sunflower

Fluchloralin + Metolachlor

6) Cotton

Pendimethalin + Diuron

7) Sugarcane

Atrazine + 2,4-D

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FATE OF HERBICIDE IN SOIL

1) Physical processes:

a) Adsorption: Adherence of herbicide molecule on clay colloids and humus and it is unavailable for plant uptake.

b) Leaching

c) Runoff

d) Volatilization: e.g., Fluchloralin

2) Decomposition processes

a) Microbial decomposition: Also called as **biodegradation** process.

b) Chemical decomposition

c) Photodecomposition

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PERSISTENCE OF HERBICIDES

- The length of time that a herbicide remains active in the soil after its initial application is called as **persistence.**

Herbicides	Time of persistence
Phenoxyacid group: 2,4-D Fluazifop-p-butyl Fenoxaprop-p-ethyl Diclofop-methyl	Upto 1 month
Metsulfuron methyl Metolachlor Linuron Prometryne Bromoxynil	1-3 months
Atrazine Simazine Metribuzine Chlorimuron ethyl Alachlor Pendimethalin Oxyfuorfen Oxadiazone Acetachlor	3-12 months
Chlorosulfuron Picloram Bromacil Terbacil	More than 12 months

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Management of herbicide residue in the soil

- Use of optimum dose of herbicide.
- Application of organic manures
- Ploughing
- Use of herbicide safeners
- Frequent irrigation
- Use of **activated carbon**

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Herbicide residue estimation in soil

Herbicide residue in soil can be determined by

1) Biological method/ Bio – assay

2) Chemical method / Analytical method- Chromotography (HPLC)

Indicator plants for herbicides

Atrazine – cucumber, soybean, mustard

Isoproturon/ Diuron – cucumber, barley, sorghum, millets

Alachlor – cucumber

Metolachlor – rice, sorghum and cucumber

Fluazifop-p-butyl – maize

Metribuzin – maize and sorghum

2,4-D – cucumber, cotton, mustard, tomato, soybean

Sulphonyl ureas – sunflower, maize, sorghum, mung bean

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Herbicide resistance

- ✓ The first report of weed resistant to herbicide was noticed in ***Senecio vulgaris*** a biotype resistant to triazine herbicide was noticed in **1968.**
- ✓ In India ***Phalaris minor*** (canary grass) developed resistance to Isoproturon

TYPES OF RESISTANCE

1) Simple resistance: one weed develops resistance to one herbicide.

2) Cross resistance: *e.g.*, *Phalaris minor* develop resistance to isoproturon in course of time gained cross resistance to diclofop-methyl, fenoxaprop-pethyl, clodinafop-propargyl.

3) Multiple resistance: one weed develops resistance to many herbicides different modes of action

e.g., *Lolium rigidum*

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Management of herbicide resistance

- Avoid monocropping and go for crop rotation.
- Abandonment of the herbicide to which the weeds are showing resistance.
- Evaluate alternate herbicides
- Herbicide mixtures use
- Herbicide rotation
- Adoption of integrated weed management practices

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Herbicide Resistant Crops (HRC's)

- Limitations of selective herbicide technology are
  1) Development of weed resistance for herbicides
  2) Residue problem
  3) Pollution
  4) Phytotoxicity
  5) Narrow spectrum activity
- HRC's are **genetically modified crops to which resistance to** certain non selective herbicides such as glyphosate, glufosinate, bromoxynil *etc.* has been conferred through biotechnological tools.
- HRC's were commercially introduced first in **Canada** through **Atrazine resistant canola variety** long back in **1984.**

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HRC	Herbicide	Trade name	Company
Canola	Glufosinate Glyphosate	Liberty Link Canola Roundup Ready Rape	Agr EVO Monsanto
Maize	Glufosinate Glyphosate	Libery Link Corn Roundup Ready Corn	Agr EVO Monsanto
Soybean	Glufosinate Glyphosate Sulphonyl urea	Libery Link Soybean Roundup Ready Soybean STS Soybean	Agr EVO Monsanto Dupont company
Cotton	Glufosinate Glyphosate	Liberty Link Cotton Roundup Ready Cotton	Agr EVO Monsanto

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Problematic weeds and its management

Striga:

- ✓ In striga **phloem is lacking.**
- ✓ Trap crops for striga are **sunflower, castor, linseed, cotton, cowpea, pea, soybean, groundnut, sunhemp.**
- ✓ Striga infestation in sorghum reduced with increase in **soil nitrogen.**
- ✓ Striga can be controlled by preplant incorporation of **fluchloralin @ 0.5-0.75 kg/ha** or by **post emergence application of 2,4-D @ 0.5-1.0 kg/ha.**
- ✓ By spraying some of the natural as well as synthetic stimulants to the soil striga seeds germinate. After germination due to non availability of host plants striga seeds will die. This is called **suicidal germination of Striga.**

Cuscuta: Pre emergent application of trifluralin, pendimethalin and post emergence application of imazethapyr, glyphosate (in non cropped areas)

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Orobanche:

- ✓ **30-70%** yield loss in tobacco due to Orobanche infestation in India.
- ✓ Orobanche has very well developed **xylem and phloem continuity** with tobacco.
- ✓ Trap crops for Orobanche are **garlic, castor, linseed, green gram, cowpea, french bean, soybean, pea.**

Chemical control of Orobanche:

a) Pre-plant incorporation

Imazethapyr @ 50-100 g a.i/ha

Imazaquin @ 100 g a.i/ha

Imazabyr @ 20 g a.i/ha

b) Postemergence

Imazethapyr @ 60 g a.i/ha

- ❖ Orobanche is controlled by the phytophagous insect ***Phytomyza orobanche.***

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Cynodon:

- Bermuda grass can be controlled by grass-selective herbicides like sethoxydim (Grass Getter), fluazifop (Fusilade) or clethodim (Envoy).
- Paraquat and diquat are more suitable under more intensive cropping as they are non residual type.

Parthenium:

- 2,4-D, paraquat provide effective control of weed.
- In non cropped areas 2,4-D esters @2-5 kg/ha or common salt @ 15-20% at actively growing stage.

Cyperus:

- ✓ 2,4 –D & MCPA at 2-5 kg/ha could control this grass
- ✓ Glyphosphate 1 kg/ha is more effective than many foliage applied herbicides.

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Sprayers

Sprayer type	Capacity
Low volume sprayer	150-200 litres/ha
Medium volume sprayer	250-300 litres/ha
High volume sprayer	500-750 litres/ha
Ultra low volume sprayer	5 litres/ha

- **Cone type nozzle, fan type nozzle, flooding jet type nozzle are** different types of nozzles.
- Most suitable type of nozzle is **flooding jet,** reason is uniform application of herbicide application is possible without any gaps.
- In flooding jet different types of nozzles are nozzle no.24, 40, 60, 78.
- With increase in nozzle number droplet size **increases.**
- Nozzle no.24 droplets are very very small or fine.

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Thank you

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