Exercise – 1. Identification of *rabi* season weeds

Sr. No.	Common Name	English name	Botanical name	Family
1	Gulli danda	Little seed Canarygrass	*Phalaris minor*	Poaceae
2	Jaundhar	Wild oats	*Avena ludoviciana*	Poaceae
3	Rye grass	Poison rye grass/ Ivary	*Lolium temulentum*	Poaceae
4	Loombar gha	Beard grass	*Polypogen monspeliensis*	Poaceae
5	Guien/Buien	Sweet grass/ Annual blue grass	*Poa annua*	Poaceae
6	Milk weed	Perennial sow thistle	*Sonchus arvensis*	Asteraceae
7	Pohli	Wild safflower	*Carthamus oxyacantha*	Asteraceae
8	Kashni	Blue daisy	*Cichorium intybus*	Asteraceae
9	Jangli palak	Sour Dock	*Rumex dentatus*	Polygonaceae
10	Kandiali palak	Dock/ Sorrel	*Rumex spinosus*	Polygonaceae
11	Kaurgandal	Leafy spurge	*Euphorbia simplex*	Euphorbiaceae
12	Piazi	Wild onion	*Asphodelus tenuifolius*	Liliaceae
13	Bathu	Common lambsquarter	*Chenopodium album*	Chenopodiaceae
14	Karund	Nettle leaf	*Chenopodium murale/ Chenopodiastrum murale*	Chenopodiaceae
15	Jangli matar	Grass pea	*Lathyrus sativus*	Fabaceae
16	Dokanni/Pili mattri	Meadow pea	*Lathyrus aphaca*	Fabaceae
17	Rari or rewari (broad leaved)	Vetch	*Vicia sativa*	Fabaceae
18	Rari or rewari (narrow leaved)	Hairy vetch	*Vicia hirsuta*	Fabaceae
19	Maina	Toothed bur clover	*Medicago denticulata*	Fabaceae
20	Maini	Wild fenugreek	*Trigonella polycerata*	Fabaceae
21	Khandi or wild senji	White sweet clover	*Melilotus alba*	Fabaceae
22	Khandi or wild senji	Yellow sweet clover	*Melilotus indica*	Fabaceae
23	Billi booti	Blue pimpernel	*Anagallis arvensis*	Primulaceae
24	Jangli dhania	Corn spurry	*Spergula arvensis*	Caryophyllaceae
25	-	Common Chickweed	*Stellaria media*	Caryophyllaceae
26	Bara takla	Cow cockle	*Saponaria vaccaria*	Caryophyllaceae
27	Chotta takla	Forked catchfly	*Silene conoidea*	Caryophyllaceae
28	Pitpapra	Fumatory	*Fumaria parviflora*	Fumariaceae
29	Satyanasi /Jangli post	Mexican poppy	*Argemone mexicana*	Papaveraceae

30	Jangli halon	Garden cress	*Coronopus didymus*	Brassicaceae
31	Jangli sarson	London rocket/Wild mustard	*Sisymbrium irio*	Brassicaceae
32	Button weed	Little mellow	*Malva parviflora*	Malvaceae
33	-	Green field speedwell	*Veronica agrestis*	Scrophulariaceae
34	-	Stone seed	*Lithospermum arvense*	Boraginaceae
35	-	Wild dogflower	*Antirrhinum orontinum*	Scrophulariaceae
36	-	Purple Cudweed	*Gnaphalium purpureum*	Asteraceae
37	Bhang	Indian hemp	*Cannabis sativa*	Cannabaceae
38	-	Cutleaf evening primrose	*Oenothera laciniata*	Onagraceae
39	-	Goosegrass/ Coachweed/ Catchweed	*Galium aparine*	Rubiaceae
40	-	Thyme-leaf sandwort	*Arenaria serpyllifolia*	Caryophyllaceae
41	-	Cursed buttercup	*Ranunculus sceleratus*	Ranunculaceae

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Exercise – 2. Identification of *kharif* season weeds

Sr. No.	Common name	English name	Botanical name	Family
1	Chirian da dana	Love grass	*Eragrostis tenella*	Poaceae
2	Chirian da dana	Love grass	*Eragrostis pilosa*	Poaceae
3	Chirian da dana	Love grass	*Eragrostis diarrhena*	Poaceae
4	-	Foxtail	*Setaria verticillata*	Poaceae
5	Madhana	Crow foot grass/ Torpedo grass	*Dactyloctenium aegyptium*	Poaceae
6	Makra	Goose grass	*Eleusine indica*	Poaceae
7	Lendhra/ Kutta ghas	Sandbur	*Cenchrus catharticus*	Poaceae
8	Kutta ghas	Sandbur	*Cenchrus biflorus*	Poaceae
9	Takri ghas	Crab grass	*Digitaria sanguinalis*	Poaceae
10	Swanki	Water grass	*Echinochloa colona*	Poaceae
11	Swank	Barnyard grass	*Echinochloa crusgalli*	Poaceae
12	Jangli jhona/ Lal jhona	Wild rice	*Oryza* spp.	Poaceae
13	Gha	Goose grass	*Acrachne racemosa*	Poaceae
14	Bans patta	Running grass	*Brachiaria reptans*	Poaceae
15	Kanki	Wrinkle grass	*Ischaemum rugosum*	Poaceae
16	Ghas	Red sprangletop	*Leptochloa chinensis*	Poaceae
17	Narhi ghas	Knotgrass	*Paspalum distichum*	Poaceae
18	Mothi/ Musadadhi/ Piasa	Hairsedge	*Bulbostylis barbata*	Cyperaceae
19	Ghuien	Grasslike fimbry	*Fimbristylis tenera*	Cyperaceae
20	Rice motha	Common sedge	*Cyperus difformis*	Cyperaceae
21	Mothi	Hedgehog sedge	*Cyperus compressus*	Cyperaceae
22	Itsit/chupatti	Horse purselane	*Trianthema portulacastrum*	Aizoaceae
23	Bhambola	Ground cherry	*Physalis minima*	Solanaceae
24	Makoh	Black nightshade	*Solanum nigrum*	Solanaceae
25	Shamkanamole	Yellow berried nightshade	*Solanum xanthocarpum*	Solanaceae
26	Datura	Jimson weed	*Datura stramonium*	Solanaceae
27	Halda	-	*Vicoa indica*	Astereceae
28	Churislot	Worm weed	*Artemisia scorpia*	Astereceae
29	Gutpatna	Cockle bur	*Xanthium strumarium*	Astereceae
30	Daryaibooti	Erect horseweed	*Conyza stricta*	Astereceae
31	Jalbhangra	False daisy	*Eclipta alba*	Astereceae

32	Gumma	Common leucas	*Leucas aspera*	Lamiaceae
33	Hulhul	Spider flower	*Cleome viscosa*	Brassicaceae
34	Gulabi	Rattlepod/ Rattlebox	*Crotalaria medicaginea*	Fabaceae
35	Patasabel	Snoutbean	*Rhynchosia capitata*	Fabaceae
36	Chibber	Wild melon/ Native gooseberry	*Cucumis callosus*	Cucurbitaceae
37	Puthkanda	Prickly chaff flower	*Achyranthus aspera*	Amaranthaceae
38	Chulai	Smooth pigweed	*Amaranthus viridis*	Amaranthaceae
39	Kandiali chulai	Spiny pigweed	*Amaranthus spinosus*	Amaranthaceae
40	Tandla	False amaranth	*Digera arvensis*	Amaranthaceae
41	Salara	Plumed cockscomb	*Celosia argentea*	Amaranthaceae
42	Salari	Globe amaranth	*Gomphrena celosioides*	Amaranthaceae
43	Bari dodak	Pill pod spurge/ Snake weed	*Euphorbia hirta*	Euphorbiaceae
44	Chhoti dodak	Shrubby spurge	*Euphorbia microphylla*	Euphorbiaceae
45	Dodak/Chandni/ Umbrella milkweed	Sun spurge	*Euphorbia helioscopia*	Euphorbiaceae
46	Chhoti dodak	Chickenweed	*Euphorbia thymifolia*	Euphorbiaceae
47	Hazardani	Leafflower	*Phyllanthus niruri*	Euphorbiaceae
48	Jangli mirch	Common spurge	*Croton sparsiflorus*	Euphorbiaceae
49	Bhakhra	Puncture vine	*Tribulus terrestris*	Zygophylaceae
50	Jangli jute	Wild jute	*Corchorus tridens*	Tiliaceae
51	Lunak	Purslane	*Portulaca oleracea*	Portulaceae
52	Lunak	Purslane	*Portulaca quadrifida*	Portulaceae
53	Lunak	Purslane	*Portulaca meridiana*	Portulaceae
54	Kaonmakki	Day flower	*Commelina benghalensis*	Commelinaceae
55	Bel	Blue morning glory	*Ipomoea nil*	Convolvulaceae
56	Bel	Tiger foot morning glory	*Ipomoea pestigridis*	Convolvulaceae
57	Oonthchra	Heliotrope	*Heliotropium eichwaldii*	Boraginaceae
58	Bhang	Indian hemp	*Cannabis sativa*	Cannabaceae
59	Ghrilla	Pink node flower	*Caesulia axillaris*	Asteraceae
60	Khatti booti	Indian sorrel	*Oxalis corniculata*	Oxalidaceae
61	Khatti booti	Pink wood sorrel	*Oxalis martiana*	Oxalidaceae
62	Sani	Goose weed	*Sphenoclea zeylanica*	Sphenocleaceae
63	Jhone da motha/ Chhatri wala motha	Rice flat sedge	*Cyperus iria*	Cyperaceae

64	-	Little ironweed/ Ash-coloured fleabane/ Goat weed	*Vernonia cinerea*	Asteraceae
65	-	Sand herbage	*Gisekia pharnaceoides*	Molluginaceae
66	Safed nali	Wild buckweed	*Polygonum glabrum*	Polygonaceae
67	Chakavat/ Chakunda	Coffee weed/ Sickle pod	*Cassia tora*	Fabaceae
68	-	Shrubby senna	*Cassia sericea*	Fabaceae
69	Kesudo	Coffee senna	*Cassia occidentalis*	Fabaceae
70	Bekario	Creeping indigo	*Indigofera linnaei*	Fabaceae
71	-	Aligator weed	*Alternanthera philoxeroides*	Amaranthaceae
72	-	Lesser rice-field flatsedge	*Cyperus microiria*	Cyperaceae
73	-	Small knotweed	*Polygonum plebeium*	Polygonaceae
74	Char patia	Water fern	*Marsilea quadrifolia*	Marsileaceae
75	Ilaichi motha	Club-rush/ Bulrush	*Scirpus roylei*	Cyperaceae
76	-	Arrowhead	*Sagittaria sagittifolia*	Alismataceae
77	-	Frogfruit	*Lipia nodiflora*	Verbenaceae
78	-	Hairy slitwort	*Lindernia ciliata*	Scrofulariaceae
79	-	Green fox tail	*Setaria glauca*	Poaceae
80	-	Bristly foxtail/ Hooked bristle grass	*Setaria verticillata*	Poaceae
81	-	Blistering ammannia/ Red stem	*Ammannia baccifera*	Lythraceae
82	-	Carpet weed	*Mollugo nudicaulis*	Molluginaceae
83	-	Purple spikerush	*Eleocharis atropurpurea*	Cyperaceae

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Exercise – 3. Identification of perennial, lawn and aquatic weeds

Sr. No.	Common name	English name	Botanical name	Family
1	Baru	Johnson grass	*Sorghum halepense*	Poaceae
2	Khabal grass	Bermuda grass	*Cynodon dactylon*	Poaceae
3	Kans or Kahi	Tiger grass/ Kans grass	*Saccharum spontaneum*	Poaceae
4	Sarkanda/ Munj/ Kana	Pin reed grass	*Saccharum munja*	Poaceae
5	Dab or Kusa ghas	Halfa grass/ Big cordgrass/ Salt reed-grass	*Desmostachya bipinata*	Poaceae
6	Palwan gha	Marvel grass	*Dicanthium annulatum*	Poaceae
7	Siru/ Dhabi/ Bharavai	Congo grass/ Lalang grass	*Imperata cylinderica*	Poaceae
8	Deela or Motha	Nut grass	*Cyperus rotundus*	Cyperaceae
9	Pahari akk	Blush morning glory	*Ipomoea carnea*	Convulvulaceae
10	Lehli or hirankhuri	Field bind weed	*Convolvulus arvensis*	Convulvulaceae
11	Amar bel (on zizyphus)	Dodder	*Cuscuta reflexa*	Convulvulaceae
12	Amar bel (on Lucerne)	Dodder	*Cuscuta chinensis*	Convulvulaceae
13	Aak	Maddar root	*Calotropis procera*	Asolepiadaceae
14	Roadsided Itsit/ Biskhapra	Spiderling	*Boerhavia diffusa*	Nyctaginaceae
15	Chhittar thor	Prickly pear	*Opuntia dillenii*	Cactaceae
16	Jal khumbi	Water hyacinth	*Eichhornia crassipes*	Pontederiaceae
17	Panja phulli	Lantana	*Lantana camara*	Verbinaceae
18	Leh	Canada thistle	*Cirsium arvense*	Asteraceae
19	Jangli gobhi	Bold-leaf launeae	*Launaea nudicalis*	Asteraceae
20	Gajar Ghas	Wild carrot weed	*Parthenium hysterophorus*	Asteraceae
21	-	Alyce-clover	*Alysicarpus vaginalis*	Fabaceae
22	-	Kidney weed	*Dichondra repens*	Convolvulaceae
23	-	Goat weed	*Ageratum conyzoides*	Asteraceae
24	-	Canada fleabane	*Erigeron canadensis/ Conyza canadensis*	Asteraceae
25	Jortor	Common reed	*Phragmites karka*	Poaceae

26	Narha	Giant cane	*Arundo donax*	Poaceae
27	Sarson banda/ Sarson da mama	Egyptian broomrape	*Orobanche aegyptiaca*	Orobanchaceae
28	Dhaul phulli	Witch weed	*Striga lutea*	Serophulariaceae
29	Svetbarela	Mallow	*Sida rhombifolia*	Malvaceae
30	-	Black jack/ Spanish needle	*Bidens pilosa*	Asteraeceae
31	Narhi ghas	Dallis grass/ Paspalum	*Paspalum dilatatum*	Poaceae
32	-	Caesar's weed	*Urena lobata*	Malvaceae
33	-	Water lettuce	*Pistia stratiotes*	Araceae
34	-	Common duck weed	*Lemna minor*	Araceae
35	-	-	*Hydrilla verticillata*	Hydrocharitaceae
36	-	-	*Vallisneria spiralis*	Hydrocharitaceae
37	-	Pond weed	*Potamogeton pectinatus*	Potamogetanaceae
38	-	Pond weed	*Potamogeton crispus*	Potamogetanaceae
39	Dib	Cat tail	*Typha latifolia*	Typhaceae
40	Kamal	Lotus	*Nelumbo lutea*	Nymphaceae
41	Boor	Great duck weed	*Spirodela polyrhiza*	Lamnaceae
42	-	Water fern	*Salvinia molesta*	Salviniaceae
43	-	Pond weed	*Potamogeton perfoliatus*	Potamogetanaceae
44	-	Hornwort	*Ceratophyllum demersum*	Ceratophylaceae
45	-	Bullrushes	*Scirpus maritimis*	Cyperaceae
46	-	Water fern	*Azolla pinnata*	Salviniaceae
47	Brahmi booti	Indian pennywort	*Centella asiatica*	Umbelliferae
48	Brahmi booti	Thyme leaved gratiola	*Bacopa indica*	Scrophulariaceae
49	Sanghara	Chinese water chestnut	*Trapa natans*	Trapaceae
50	-	Water speedwell/ Blue speed well	*Veronica anagallis-aquatica*	Plantaginaceae

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Exercise 4. Preparation of weed herbarium

Objective

1. To enhance the understanding of students regarding weed identification at different growth stages.

Materials required

1) Knife / scalpel

2) Plant press

3) Scrap book/Herbarium sheets

Procedure

Herbarium (plural: herbaria) is a collection of plants that are dried, pressed and preserved on herbarium sheets and arranged in sequence in accordance of specific purpose for future reference, record and study.

Herbarium collection

1) Collect the plant material at different growth stages.

2) Maintain all the plant parts intact (leaf, stem, flowers, fruits)

3) Collect fresh part of the plant.

Herbarium pressing and drying

- The weed plant should be pressed with wooden press board.
- Collected specimen should be placed in between the folds of newspaper for blotting. Ensure that plant is intact.
- To dry out the specimen, keep it for 24 hrs. This is called as Sweating period.
- Ensure that the specimen is spread properly in the newspaper folds.
- The large specimens are to be cut in parts according to convenience and the cut parts are to be arranged on same sheet.
- If the foliage is very thick, it has to be pruned assuring that the portion of the cut parts are identified.
- The newspaper should be changed after 12 hrs in first instance and there after 24 hrs, 48 hrs and 72 hrs is done till the specimen is dried completely. This is called Natural drying.
- In artificial drying, after sweating period specimens can be dried in hot air oven by maintaining 62^0C.

Herbarium mountings

- Thick herbarium sheets are used for mounting.
- Keep the specimen in centre and spread properly.
- Fix the specimen to the mounting sheet with glue / gum / tape.

Herbarium labeling

- Label the specimen in the space provided on lower left side of the herbarium sheets.
- The label information should contain botanical name, local name, english name, family and habitat.
- Write the index for it.

Things to do

1) Collect 100 weeds.

Exercise: Write botanical name of following weeds.

Common name	Botanical name
Hulhul	
Gutputna	
Oonthchara	
Kaonmakki	
Bans patta	
Baru	
Jangli hallon	
Takri ghas	
Pitpapra	
Kanki	
Pohli	
Maina	
Chirian da dana	
Gajar ghas	
Water hyacinth	
Hazardani	
Daryai booti	
Piazi	
Chotti dodak	
Jangli dhania	

Exercise – 5. Weed survey in crops and cropping systems

Objective

1. To apprise the students regarding association of weeds with crops under different environments.

Purpose of a weed survey

- To collect information on weed biology and ecology, including location and acreage infested, growth requirements, spread patterns and rates.
- Use of data for developing weed management programmes.
- Establishing a historical site specific database.
- Evaluation of the progress of a weed management program.
- Increase public awareness and support for the program.

Protocol for weed survey/surveillance

- The districts and or agro-climatic zone in each state or area of jurisdiction of state agricultural universities should be divided into five parts and route should be fixed for each part for weed survey/surveillance.
- Survey should be conducted twice in a year during both main seasons of summer *(kharif)* and winter *(rabi).*
- Stoppage should be made at 10 km for each survey and the survey spot should not be near any building or permanent structure. One should walk at least 100 metre deep in the field for survey.
- The minimum area under a particular crop should be one acre or more for recording observations on weeds and quadrat of 50 cm × 50 cm should be placed randomly at four spots in a field moving diagonally.
- Survey spot should also include non cropped area and garbage area.
- At each field, the GPS data for longitude, latitude and height above mean sea level should be recorded.
- Information from the farmer should be collected on following:
    - Crop rotation for last three years.
    - Herbicide/weed control method used for last three years.
    - His/her experience with applied herbicide/weed control measures.
- The observations on weeds should be recorded on:
    - Individual count of all weeds from each quadrat
    - Record of any new weed encountered
- Climate data should be taken form nearest weather station for the month in which survey is conducted and mean data for temperature, relative humidity, rainfall and sunshine hours should be reported. Ambient CO_2 concentration should also be recorded, if possible.
- The each spot fixed through GPS should be surveyed again after 5 years to monitor shift in weed flora, if any.

- **Work out the following from the weed count data**

$$\textbf{Density/m}^2\textbf{=} \frac{\text{Total no. of individuals of sp. A in all the quadrats}}{\text{Total no. of quadrats plotted}}$$

Number of individuals per 50 cm × 50 cm quadrat should be multiplied by 4 to obtain the density/m^2

$$\textbf{Relative Density (RD) (\%)=} \frac{\text{Density of sp. A}}{\text{sum density of all species}} \times 100$$

$$\textbf{Frequency (\%) =} \frac{\text{No. of quadrats where the species A occurred}}{\text{total no. of quadrats plotted}} \times 100$$

$$\textbf{Relative Frequency (RF) (\%) =} \frac{\text{Frequency of sp. A}}{\text{Sum frequency of all species}} \times 100$$

Importance Value Index (IVI) = Relative Density + Relative Frequency

The results should be presented in the following way:

Route of survey: A——B——C——D (name of village or city)

Table: Weed flora of crop in the district (——)

(GPS data for the range of latitude, longitude and height above MSL for the district)

Weed species (Total No.)	Relative Density (%)	Relative Frequency (%)	IVI
Grasses 1 2 3 4			
Broadleafs 1 2 3			
Sedges 1 2 3			

Others

(Only dominant weed species (about 10) should be listed and rest should be included in others which may be mentioned in text)

Weather parameters (for the period of survey)

District/ Month	Temperature (°C)		RH (%)	Rainfall (mm)	Sunshine hours (hrs.)	Ambient CO_2 (ppm)
	Min	Max				
District-A (Month)						
District-B (Month)						

Important points

- The GPS data for each spot should be kept secured to be used at the time of second cycle of surveillance which help in locating the spot
- Any important information like invasion of some new weed, new emerging wed problem, shifts in weed flora, reduced efficacy of any herbicide against a particular weed/or weeds should be reported and highlighted in the text.
- During interpretation of the results, RD will tell about the comparative status of the population strength, RF will tell about the status of distribution and IVI will tell about the overall dominance status of each species in the surveyed area.
- Each year there should be 20% overlapping of the spots form the previous year.
- Information on road side and waste lands should also be recorded.

Exercise

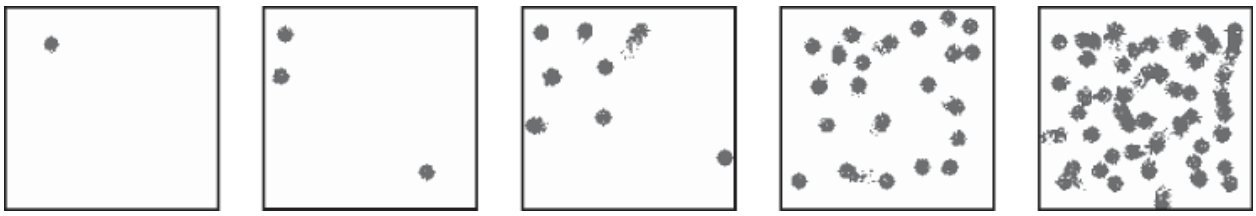
In survey, total no. of plotted quadrats (of 100 cm × 100 cm size) was 20. Total no of individuals of sp. A, B and C in all quadrates were 32, 25 and 13, respectively. Number of quadrate where species A, B and C occurred was 17, 10 and 5, respectively. Calculate IVI of A, B and C.

There is another system for interpreting the results of weed survey of noxious weeds, known as "Dominance Rating"

1. It can be found by searching in and around other species. A dominance of "1" is not obvious.
2. It can be seen only by moving through the vegetation or by searching for it while standing on one place. A patchy pattern observed by moving through the vegetation rates a dominance of "2".
3. It is easily seen by standing in one place and glancing around, but it is not an obvious dominant. In a mixed stand, several species may fall into this category.
4. It is at least a co-dominant. It shares dominance relative to cover or is considered slightly subordinate to other species, native or introduced
5. It dominates the site. It is dominant in the sense that it provides essentially total cover when viewed casually.

Rough Sketches of Dominance Categories

1 = one plant 2 = few 3 = easily seen 4 = >50% coverage 5 = >90% coverage



Diagnosing a Herbicide Resistance Problem:

1. All other causes of herbicide failure have been eliminated. (Herbicide properly applied: Rate? Timing? Placement? Incorporation? Appropriate weed growth stage? Favorable weather during/following application? Adequate reaction time?)
2. Other weed species on herbicide label (than the suspect weed spp.) were controlled effectively?
3. Field has history of continuous use of same herbicide or herbicides with same mode of action?
4. The weed species that now demonstrates potential resistance was controlled effectively in the past by the herbicide?

Exercise 6. Crop-weed competition studies

Objectives

1. To study the weeds associated with different crops
2. To acquaint the students with the critical period of crop weed competition for different crops
3. To estimate the critical period of crop-weed competition under field conditions

Procedure

Crop-weed associations are primarily due to similarity in climatic needs, seed sizes, seed germination, tillage needs, cropping and harvest practices.

Season bound weeds: They are seen in a particular season, irrespective of crop. These are either summer annuals or winter annuals.

Summer annuals: eg *Echinochloa, Eleusine*

Winter annuals: eg *Phalaris, Avena, Rumex*

On the basis of vegetative growth, perrenials are further classified into two catagories- *Sorghum halepense* is summer perennial and *Circium arvense* is winter perennial.

Crop bound weeds: Weeds which usually parasite the host crop partially or fully for nourishment i.e parasitism. These weeds are also called as parasitic weeds. Crop bound weeds are of two types.

1. Root parasites
   a. Complete root parasite eg *Orobanche* (broom rape) on tomato, mustard
   b. Partial root parasite eg *Striga* spp (witch weed) on sugarcane
2. Stem parasites
   a. Complete stem parasite eg *Cuscuta* (dodder) in lucerne and berseem
   b. Partial stem parasite eg *Loranthus* on fruit crops

Crop associated weeds: These are crop specific due to

1. Mimicry: These weeds morphologically look like crops. eg *Echinochloa crusgalli* resemble the rice plant. *Avena ludoviciana* and *Phalaris minor*, both mimic wheat plants.
2. Need for specific micro climate: Requires shady, moist & cool micro climate and which is available in lucerne and berseem. eg *Cichorium intybus* and *Coronopus didymus*
3. Ready contamination with the crops: If the crop seeds mature at the same time and plant have same height as that of the crop plant having similar seed size and shape, then it easily contaminates the crop. eg *Phalaris minor*

Crop-weed competition

Competition is mutual adverse effect of two organisms utilizing common resources, that are essential for their growth and development, which are in short supply. Competition between crop and weeds is mainly for nutrients, soil moisture, light and space etc. The basic requirements of crop and weed plants are the same and competition will start only when the supply of any one or more factor (s) is in short supply. The principle of plant competition is that the first plants to occupy any area of soil, small or large, tend to exclude others.

Types of competitions: There are two types of competition.

A. Intra specific competition – It is the competition between the plants of same species, which may

be of crop or weed. As the plants (of crop and weeds) grow in age, due to mutual competition their number per unit area decreases which may be due to self-induced competition.

B. Inter specific competition – It is competition between two or more plants belonging to different species. In other words, it is competition of crop with associated weeds and it has more bearing on agricultural crops.

Weed-crop interference – It is interaction among the plant species of the same nature or of the different nature. This term includes competition, as well as, the possible allelopathic interferences which may be negative, positive or neutral.

Critical period of crop-weed competition (CPWC) – The period in the life cycle of the crop during which there is maximum loss in grain yield, due to competition by weeds. In general, initial growth stages of crops are very sensitive to competition by weeds and there is maximum loss to the crop if weeds are not removed during this period.

CPWC is that part in the life cycle of a crop plant when weeding results in highest economic returns. Usually, CPWC ends when crops cover 80 per cent of the soil. The length of CPWC depends on the nature of crop, its competitive ability, cultivar and growing condition. In the case of quick growing crops such as maize, sorghum and sunflower-critical period of weed competition is short; whereas in crops where the initial growth is slow such as sugarcane, potato and cotton, critical period of competition is longer.

Estimation of critical period under field condition– Specific information on beginning and end of the critical period of competition is possible by carrying out research experiments. To determine the extent of weed competition and yield losses of crop in the field, experiments are conducted with the following treatments.

Exercise 1: Let a crop is of about 75 days duration. Arrange the treatments as follows.

Weedy for the x days	**Weed free for the x days**
T_1 - 0 Days	T_7 - 0 Days
T_2 - 15 Days	T_8 - 15 Days
T_3 - 30 Days	T_9 - 30 Days
T_4 - 45 Days	T_{10} - 45 Days
T_5 - 60 Days	T_{11} - 60 Days
T_6 - 75 Days	T_{12} - 75 Days

The treatments are to be imposed in the field duly observing the randomization, replication, local control. The recommended packages of practices for the crop selected are to be followed.

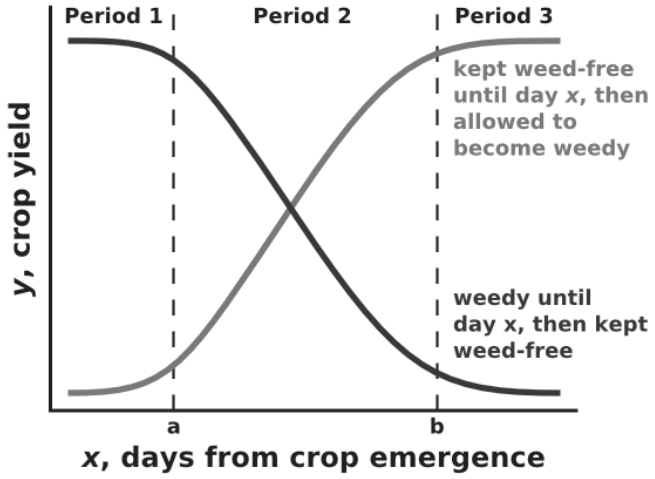


Figure: Weeds that emerge with the crop must be removed before the end of Period 1 (maximum weed-infested period) to prevent them from reducing crop yield. The crop must be kept clean throughout Period 2 (the critical period for weed-crop competition). Later emerging weeds (Period 3) have little effect on crop yield. In practice, many vegetable growers endeavor to keep crops weed free throughout Periods 1 + 2, the minimum weed free period, sometimes called the "critical weed-free period." Figure credit: Ed Zaborski, University of Illinois (adapted from Altieri, 1995).

Exercise 2: Study the table and find the critical period of crop-weed competition.

Treatment	Yield (q/ha)
Weedy upto 20 DAT then weed free	27.5
Weedy upto 40 DAT then weed free	18.8
Weedy upto 60 DAT then weed free	13.5
Weedy upto 80 DAT then weed free	12.7
Weed free upto 20 DAT then weedy	19.4
Weed free upto 40 DAT then weedy	27.0
Weed free upto 60 DAT then weedy	27.7
Weed free upto 80 DAT then weedy	27.9
Season long weedy	28.1
Season long weed free	12.1
LSD (p=0.05)	1.2

Exercise 3: Students will visit research farm of the department along with teacher in-charge and will record observations on weeds growing in the crop, raised with the adoption of different agronomic practices. e.g.

A. Infestation of *P. minor* in rice-berseem as compared to rice-wheat rotation.

B. Role of wheat cultivars for smothering weeds.

C. Growth and development of *P. minor* as influenced by dates of sowing of wheat.

D. Role of planting pattern on growth of weeds.

E. Growth and development of weeds as influenced by seeding density.

F. Status of weeds in zero/normal till wheat.

Exercise 7. Calculation of herbicide doses and method of application of herbicides.

Objectives

1. To familiarize the students with various methods of applying herbicides
2. To acquaint the students with herbicide dosage calculations

Procedure

Herbicide are applied as broadcast and as spray (pre-plant, pre-emergence, post-emergence)

Pre-plant: Application of herbicides after seed bed preparation but before sowing the crop. All volatile herbicide are applied as pre-plant soil incorporation e.g. use of triallate (Avadex BW) in wheat for the control of wild oats.

Pre-emergence: It is application of herbicide before the germination (emergence) of crop and weeds e.g. use of pendimethallin (Stomp 30 EC) in pulses and other crops.

Post-emergence: Application of herbicide on the emerged crop and weeds e.g. use of 2,4-D in wheat for the control of broad leaf weeds.

Broadcast application: This method is adopted for applying herbicides in transplanted paddy after mixing in sand or fertilizer.

Blanket application: It is overall application of herbicide over the entire field, starting from one corner and ending at the other corner of the field.

Band application: It is application of herbicide only on crop rows and leaving inter-row area as unsprayed. It is applicable only in wider row sown crop e.g. use of atrazine in maize at 10 DAS.

Lay by application: Application of herbicide in between the rows of the crop.

Directed application: It is application of herbicide only on weeds growing in crop rows. e.g. use of paraquat (Gramoxone 24 WSC) or glyphosate (Roundup 41 SL) in maize, cotton or sugarcane.

Spot application: It is not overall application of herbicide on the entire field but only weed infested spots are treated. Prepare required solution of recommended weedicide before going for spot application.

Rate of application: It is the amount of active ingredient or acid equivalent of herbicide applied to a unit area of land or water body. It is usually given in terms of kg a.i. or a.e. / ha.

Active ingredient (a.i.): A chemical in commercial product that is directly responsible for its herbicidal effect is called active ingredient. The ingredient may be as per cent by weight or volume. eg. Herbicide concentrate 50 % w/v contains 500 g of active ingredient per litre of the liquid product.

1) For crops

$$\text{Dose of Commercial product kg ha}^{-1} = \frac{\text{Recommended dose in kg a.i. or a.e. ha}^{-1}}{\text{Percent concentration in the product}} \times 100$$

Acid equivalent (a.e.): refers to that part of a formulation that theoretically can be converted to the acid. Some herbicide structures are active organic acids and some are not dissolved in water. eg. Phenoxyalkanoic acid. They are prepared in the form of their salts and esters for the ease of their field application.

For instance, 2, 4-D in acid form is water insoluble then we have to use its sodium and amine salts and esters. The acid equivalent (a.e.) of sodium salt of 2, 4-D is 92.5%. It indicates that 2, 4- dichloro phenoxy acetic acid is 92.5% in sodium salt of 2, 4-D.

Liquid formulations may indicate both per cent active ingredient and acid equivalent as weight per liter. In such cases, the concentration in terms of acid equivalent may be considered.

A commercial formulation of 2,4-D containing 580 g of diethanolamine salt per litre would have a concentration of a.i. 58 per cent, but the concentration in terms of acid equivalent will be

$$\frac{58 \times \text{Molecular weight of 2,4-D acid}}{\text{Molecular weight of 2,4-Diethaianolamine}} = \frac{58 \times 221}{326} = 39.32 \text{ per cent}$$

The acid equivalent (a.e.) of a concentrate is always less than its content of active ingredient (a.i.).

2) For aquatic weeds

For controlling aquatic weeds, herbicides are applied on weight basis (of water body).
Wt. of water (in lbs) = Volume × 62.3
Volume= L×B×D
Where
L-length of water body in feet
B-breadth of water body in feet
D-average depth of water body in feet
One cubic feet of water weighs 62.3 lbs.

$$\text{lbs of herbicides in a.i./ a.e./ha} = \frac{\text{Weight of water (lbs)} \times \text{Recommended dose of herbicide (ppm)}}{1000{,}000}$$

Then work out dose of commercial product as above.

Exercise

Q1. Calculate the amount of commercial product (Saturn 50 EC) of pre-emergence herbicide thiobencarb required for 4000 m^2 area to control weeds in rice. The recommended rate of application is 1.25 kg a.i./ha.

Q2. Calculate the amount of commercial product (Atrataf 50 WP) of pre-emergence herbicide atrazine required for 500 m^2 area to control weeds in maize. The recommended rate of application is 1.00 kg a.i./ha.

Q3. Calculate the amount of commercial product (Sencor 70 WP) of pre-emergence herbicide metribuzin in sugarcane needed to cover one hectare area. The recommended rate of application is 0.7 kg a.i./ ha?

Q4. Calculate the amount of commercial product (Stomp 30 EC) of pre-emergence herbicide pendimethalin required for 1000 m^2 area to control weeds in green gram. The recommended rate of application is 0.750 kg a.i./ha.

Q5. Calculate the amount of commercial product (Nominee Gold 10 SC) of post emergence herbicide bispyribac sodium recommended to control grasses and sedges in rice to cover 5000 m^2 area at recommended application rate of 0.025 kg/ha.

Q6. A pond measuring 30 ft length, 20 ft breadth and 5 ft average depth is infested with water hyacinth. Calculate the amount of sodium salt of 2,4- D required for spraying the pond with recommended dose of 10 mg/kg.

Q7. **Calculate doses:**

Chemical a.i. kg/ha	**Product name with formulation**	**Dose for 2.5 acres**
Atrazine 0.50		
Trifluralin 1.2		
Pendimethalin 1.0		
Butachlor 0.75		
Bispyribac 0.02		
Clodinafop 0.06		
Pretilachlor 0.75		
Glyphosate 1.50		
Isoproturon 0.9		
Sulfosulfuron 0.025		

Exercise 8. Estimation of weed indices

Objectives:

1. To compute the weed indices.
2. To enhance the understanding of students regarding the use of weed indices in explaning the results of weed control studies.

Materials required

- Quadrat of 0.5m × 0.5m size or any other size.
- Observation note book.

Procedure

It is necessary to know the number and nature of weeds competing with the crops. The weed density gives the biological stress that the crops are subjected to.

Measurement of weed density:

There are two methods normally adopted for the measurement of weed density.

1. **Counting method:** Here different species of weeds are counted by using the quadrat in a crop field.
2. **Dry matter method:** By this method, the weeds are cut at the base and record the fresh weight immediately and the dry weight, after drying in an oven are taken to compute the weed density.

In weed control experiments, apart from recording observation on crop, observations on weeds are also recorded. Weeds intensity is recorded as

A) Intensity based on weed count

1. Throw a quadrat measuring 30 cm × 30 cm or 50 cm × 50 cm or 1 m × 1 m or of any other size randomly in a plot.
2. Count the total weeds present in the quadrat. These weeds can be counted accordingly to their type or species depending upon the nature of study.
3. Repeat it 3 to 4 times in a plot.
4. Convert the weed population into number of weeds per square metre before reporting.

B) Intensity based on dry matter of weeds

1. Select randomly at least two/three places from a given plot and remove above-ground portion of all the weeds from the known quadrats.
2. Depending upon nature of study, different categories of weeds can be made according to their species.
3. Sun dry the samples.
4. Then place the samples in oven at 55^0 C till complete dryness.
5. Weigh the samples and calculate the dry matter production in kg ha^{-1} or gm^{-2}.

Sometimes the magnitude of loss due to weeds is not depicted clearly from weed count or dry matter of weeds. So, following studies are sometimes very useful.

1. **Weed Index (WI) :** It is a measure of the efficacy of particular treatment when compared with weed free treatment and is expressed as percentage of yield potential under weed free. Higher weed index means greater loss due to weeds:

$$\text{Weed Index} = \frac{X - Y}{X} \times 100$$

X – Crop yield from weed free

Y - Crop yield of particular treatment

2. Weed Control Efficiency (WCE)

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

DMC- Dry matter of weeds in control (unweeded) plot

DMT- Dry matter of weeds in a treatment

3. Herbicide Efficiency Index (HEI)

$$HEI = \frac{\frac{YT\text{-}YC}{YC} \times 100}{\frac{DMT}{DMC} \times 100}$$

YT – Crop yield from treatment

YC – Crop yield from control (unweeded) plot

DMT – Dry matter of weeds in a treatment

DMC – Dry matter of weeds in control (unweeded) plot

Precautions

1. The weed count should be taken after the emergence of weeds but at the initial stage of crop growth itself to facilitate the placement of quadrat.
2. Take care to note the name and number of weeds immediately.
3. Select at random, the location (or) site for placing quadrat in different places of the crop field.

Exercise

Q1 Calculate.

Treatments	Yield (q/ha)	Weed DMA (g/m^2)	Weed index
Clodinafop	55	2	
Isoproturon	40	25	
Weedy	25	33	
Weed free	57	0	

Q2 Calculate.

Treatments	Yield (q/ha)	Weed DMA (g/m^2)	WCE
Clodinafop	55	2	
Isoproturon	40	25	
Weedy	25	33	
Weed free	57	0	

Q3 Discuss the salient results of a weed control experiment on the basis of weed indices in wheat with the following data which was recorded at the time of harvest.

Treatments	No. of *P. minor* plants m^{-2}	Dry matter of *P. minor* (kg ha^{-1})	Plant height (cm)	Effective tillers per m row length	Grain yield (q ha^{-1})
Clodinafop 60 g ha^{-1}	0	0	110	72	55.7
Sulfosulfuron 25 g ha^{-1}	0	0	108	70	54.9
Isoproturon 0.94 kg ha^{-1}	107	1430	109	69	40.6
Metribuzin 0.25 kg ha^{-1}	2	40	110	64	51.5
Weed free	0	0	111	70	56.7
Control	257	4270	112	55	24.9
C.D. at 5 %	35	390	NS	4.1	6.8

Results & Discussion:

Conclusions:

Exercise 9. Preparation of spray solutions of herbicides for high and low volume sprayers.

Objectives

1. To acquaint the students regarding spray technology for achieving herbicide efficacy.
2. To prepare proper spray solutions for spraying different formulation of herbicides.

Procedure

Spray Volume : According to the volume of spray applied per unit area, pesticide spraying techniques are broadly classified as High Volume (HV), Low Volume (LV) and Ultra Low Volume (ULV). These terms describe the volume of water used as a carrier. Initially high volume spraying technique was used for pesticides application but with the advent of equipment improvement in the technique of producing smaller droplets the trend is to use minimum amount of carrier or diluent liquid and this leads to the usuage of low volume and ultra low volume technique. Besides the most common classification of HV, LV and ULV at times, intermediate classifications like Medium Volume (MV) and Very Low Volume (VLV) is also adopted. MV is intermediate to HV and LV whereas VLV is intermediate to LV and ULV. Whatever may be the volume of water in HV, MV, LV, VLV or ULV, the quantity of pesticide per unit area remains the same.

1. HV : High Volume = More than 150 l/ha. Suitable for insecticides, fungicides, herbicides. It can be done with knapsack sprayers, tractor mounted sprayers.
2. LV : Low Volume = Approx. 10-150 l/ha. Suitable for insecticides, fungicides. It can be done with motorized knapsack sprayer, air craft, low r.p.m. spinning disc appliances.
3. ULV : Ultra Low Volume = Approx. 1-5 l/ha. Suitable for insecticides. It can be done with high r.p.m. spinning disc appliances, motorized knapsack sprayer fitted with special spinning disc and air craft.

Spray Droplets : Herbicides are mostly applied on the target in the form of spray droplets. Droplets produced by hydraulic nozzle are not uniform in size. Sprays contain both fine and coarse droplets. They are defined in term of their diameter and density on the target.

Coarse droplets	**Fine droplets**
• Narrow swath	Wider swath
• Less under leaf coverage	More under leaf coverage
• More spray volume is required	Less spray volume is required
• Particles coalesce and run off	Particles do not coalesce and run off
• Poor penetration into the crop	Good penetration into the crop
• Less loss due to wind, thermal current	More loss due to wind, thermal current
• Poor biological efficacy	Good biological efficacy
• Spray pattern like rain	Spray pattern like mist

To understand how spray application equipment delivers pesticides to a target, it is necessary to know a little about the physical properties and behaviour of droplets. Droplet size and density (number of droplets per unit area of target) are two important factors for effective spraying. Knowledge of droplet diameter and density is important for efficient use of pesticides. The droplets diameter of a given spray can be measured as the median of either the number or volume of droplets.

The Number Median Diameter

The Number Median Diameter (NMD) is the droplet diameter where the number of droplets

above the NMD is equal to the number of droplets below the NMD. The NMD is usually smaller than the VMD because most pesticide sprays usually contain a large number of very small droplets. The VMD is affected by relatively few large droplets whereas the NMD is more influenced by small droplets. The more uniform the size of droplets, the closer the ratio of VMD and NMD approaches.

The Volume Median Diameter

The Volume Median Diameter (VMD) is defined as that droplet diameter which divides the volume of spray into two equal parts i.e. the volume of spray with droplets of a diameter less than VMD equals the volume of droplets with a diameter greater than the VMD. These droplets are classified according to their Volume Mean Diameter (VMD) as follows:

Aerosol	=	below 50 micron
Mist	=	below 100 micron
Fine spray	=	101-200 micron
Medium spray	=	201-400 micron
Coarse spray	=	Over 400 micron

Optimum Droplet Size

Optimum droplet size for application of pesticide are generally specified within a range of droplet diameter. More precise definition of optimum droplet size in application of herbicide may not be possible, due to biological complexity of target. Besides this, the fate of droplets from the time of their formation by a nozzle until their deposition onto a target is influenced by several factors such as: velocity of droplet ejection, gravitational force, wind velocity, air turbulence caused by thermal movement, volatility of the spray liquid and characteristics of target surface

Droplet size is most important for efficient application with minimum contamination of environment. A 500 micron droplet will contain 1000 times the lethal dose of a 50 micron droplet. To reduce wastage, narrow range of droplet spectrum is essential. Coarse droplets are largely influenced by gravitational force and relatively unaffected by turbulence. Fine droplets will be influenced by wind and turbulence and have a tendency to drift. Droplet sizes more than 300 microns are lost by drip whereas the droplet sizes less than 100 microns are lost by drift. Loss of spray by drip and drift are more prominent in HV and ULV spraying technique respectively.

In a normal course, the spray droplets are in a spherical shape. To understand the mathematical logic and for simplicity in calculations, the droplets may be considered in the shape of a cube and not a sphere. Imagine that the ideal spraying has been carried out which has produced all droplets of same size in cube shape having all sides of equal dimensions say 2 mm. The volume of a droplet is the sum arrived at after multiplication of length, breadth and height i.e. a cubic relation. If the droplet size is reduced from 2 mm to 1 mm, number of droplets produced will increase by 8 times from the same volume. The area occupied by the droplets is the sum arrived at after multiplying length and breadth i.e. a square relation.

Similarly, when the size of a droplet is reduced, the contact area of droplets on the target increases. Thus by reducing the droplet size from 2 mm^3 to 1 mm^3, double contact area can be achieved from the same amount of spray volume. Conclusively, if the droplet size is reduced from 2 mm^3 to 1 mm^3, in other words by a factor of two, from the same volume of pesticide: Eight times more droplets can be produced i.e. spray droplets density will be eight times more. This means number of droplets increase by the cube of the factor of size reduction. Double contact area of droplets on targets can be achieved. This means the contact area increases by the same factor of size reduction.

Preparation of spray solution

A. Dose calculations: Herbicides are recommended on a.i. or a.e. basis but in the field they are used on the basis of commercial product which are available in the market and their dose can be calculated as under.

$$\text{Dose of Commercial product kg ha}^{-1} = \frac{\text{Recommended dose in kg a.i. or a.e. ha}^{-1}}{\text{Percent concentration in the product}} \times 100$$

B. Calibration of the pump: Select any spraying equipment by keeping in view size of the farm, time of application of herbicide, facilities available, type of the soil, moisture holding capacity of soil etc. Let us assume Knap-sack spray pump has been selected for applying herbicide fitted with either flat fan or flood zet nozzle. Measure a small area and pour measured quantity of water into the containor of the pump. Spray the plot with water and measure the left out water and work out the amount of water used for spraying a unit area. Then calculate the amount of water required for spraying one acre. Do not change pump operator or nozzle while applying herbicide in the field.

C. How to prepare spray fluid: Thoroughly mix the calculated dose of herbicide in small quantity of water and then make the volume of solution (spray fluid) up to calibrated amount in a big containor. Use hand gloves and gas masks while preparing the solution and at the time of its application in the field. Stir the spray fluid thoroughly before each filling. Alternatively, stock solutions (number of litres equivalent to number of spray pumps required for spraying one acre) can be prepared in a small containor. Pour one litre of stock solution into the pump and make the volume up to 15 litre by adding water. Put one or two litres of water before pouring stock solution in the containor.

D. Spray technology: Before starting the spraying operation, check the nozzle by spraying plain water on a pucca floor. If wetting of the floor is not uniform, change the nozzle or nozzle tip. The person who has done calibration, should be deputed for spray in the field. Start spraying from one corner of the field in a band and second band should be parallel to the first with slight overlapping. Keep the nozzle at the height of 50 cm from the ground or canopy level. Spray should be as uniform as possible. The left over solution should not be resprayed but must be discarded on a barren land. Do not move the nozzle to and fro. Always spray at right angle to the direction of wind and do not spray along or across the direction of wind. Postpone spray, if wind velocity is high. Wear full sleeve shirt, trouser, shoes, hand gloves and gas mask, while spraying. Do not spray with empty stomach and also do not eat while spraying. After spray operation is complete, take bath with soap and change your clothes.

Exercise :

I. Do calibration of Knap-sack sprayer

II. Prepare spray fluid (solution) for one acre

III. Demonstrate proper spraying technology with different nozzles.

Exercise 10. Use of various types of spray pump and nozzles and calculation of swath width.

Objectives

1. To study the different sprayers and functions of different parts of equipment.

2. To calculate correct amount of spray liquid discharged per unit area for different types of nozzles.

Procedure

Herbicides are largely applied as spray. Several types of sprayers are available from small hand operated to large ground and aerial sprayers.

Major components of sprayers: The important components of a sprayers are (i) pump (ii) power source (iii) tank (v) agitator (vi) distribution system and (vi) pressure regulator.

(i) Pump: Any spray liquid must be atomized before it leaves the spray nozzle. A pump provides the necessary pressure for this purpose. Two kinds of pumps are generally used in herbicide sprayers.

(ii) Source of power: A source of power is needed to run the sprayer pumps this source of power may be (a) manual (b) battery (c) motor or (d) tractor engines.

(iii) Spray tank: A sprayer has either a built in tank or separate tank to carry the spray liquid. Depending upon the kind of sprayer, the tank size varies from 25 to 2250 liters and sometimes even more. A tank is provided with a large opening, fitted with strainer and a cap to fill the spray liquid. Small tank opening can make filling and cleaning of the tank difficult.

(iv) Agitator: The agitator keeps the spray liquid components in homogenous mixture. It may be either a mechanical or hydraulic type. The mechanical agitators are usually made in the shape of metal rod with a fan or rings at its distant end. Hydraulic sprayers are provided only in large, tractor-mounted spray tanks. Agitators are most essential for the application of herbicide emulsions and suspensions.

(v) Distribution system: A distribution system of sprayer includes nozzles, spray lance, spray boom and delivery hose.

a) Nozzle: The nozzle performs four basic functions : 1. atomizes liquid into droplets, 2. disperses the droplets in a specific pattern, 3. meters liquid at a certain flow rate, 4. provides hydraulic momentum.

The Nozzle tip is one of the most important and least expensive part of a spraying system. Nozzles are identified by their (1) droplet size, (2) delivery and (3) spray pattern that they produce. Of the three characteristics, the spray pattern is fixed for a given nozzle (except triple action nozzle).

There are two major types of nozzles in use for the application of herbicides. These are (a) flat-fan nozzle (b) flood-jet nozzle. The droplet size and delivery of the nozzle will vary with the pump pressure. In general, smaller the spray droplet size, more is the herbicidal phytotoxicity.

The "Flat fan" nozzles are available in two spray patterns viz. the tapped edge pattern and rectangular pattern. Tapped edge pattern is to apply pre and post emergence herbicide spary, while rectangular pattern for the pre emergence application of herbicides. Flat fan nozzles with numbers of 80 800 or 110 900 can be used whose discharge rate varies from 80- 100 l/ acre where 80^{O} and 110^{O} are the spray angles and 800 mm and 900 mm are theoretical coverage

by spray keeping spray height at optimum level.

The flood-jet nozzles with numbers of Wide Spray Nozzle (WSN) produce medium droplet sprays, reducing their drift hazard potentials. Flood jet nozzle with WSN 24 number can also be used for post-emergence application as its discharge rate is less. Always use flood jet nozzles with WSN 78 or WSN 62 numbers for pre-emergence application whose discharge rates are higher.

b) Lance: It is a brass rod, about 90 cm long, attached to delivery hose of the sprayer and fitted at its free-end with a replaceable nozzle. In many cases the spray lance is bent at the nozzle end to form a goose neck. At the hose-end it is provided with various types of trigger mechanisms to shut-off the flow of the liquid. For specific purposes, the spray lance may be fitted with plastic shields at its nozzle end to prevent spray drifts.

c) Boom (or spray bar): A boom is essentially a horizontal pipe with two to several nozzles on it. Usually, these nozzles are spaced 50 cm apart. The boom length (distance between nozzles at the two ends of the boom) may vary from 1 m to 15 m. Short booms with 2 or 3 nozzles are used with manual sprayers, while the longer ones are attached to the tractor-mounted sprayers. A spray boom covers a wider spray swath in each trip than a lance.

Spray swath is the total width of land wetted by a boom. It is slightly more than the boom length. The vertical height of the boom and nozzle spacing on the boom can be adjusted to obtain uniform overall spray, or a directed spray, or a band spray of the herbicide, as per requirement.

d) Delivery hose: A hose is a flexible hollow tube designed to carry fluids from one location to another. Hose are also called as pipe which usually refers to a rigid tube.

(vi) Pressure regulator: Power-driven sprayers are usually fitted with a pressure regulator so as to push the liquid at a constant, desired pressure. Without a pressure regulator, a nozzle will deliver more liquid at one time and less at the other, in the same trip. Moreover, some herbicides are prescribed to be applied at specific pressures to obtain best results.

Kinds of sprayer

1. Knapsack sprayers: Knapsack sprayers are carried on the back of the worker during the operation. Usually they carry metallic tanks, but these are also available with plastic tanks to reduce weight, though plastic tanks are prone to damage by rats. Three types of knapsack sprayers are: (i) hydraulic sprayers, (ii) pneumatic sprayers, and (iii) motorized pneumatic sprayers.

(i) **Hydraulic knapsack sprayers:** A hydraulic knapsack sprayers is a manually operated sprayer which works under hydraulic pressure. Its tank capacity is up to 15 litres, with provision for mechanical agitation of the spray liquid. The worker uses his left hand to operate the lever handle of the sprayer as the lever maintains constant pressure. The output is usually 0.4 ha per man day, but it is possible to obtain higher output by replacing the lance with a 2-3 nozzle boom.

The hydraulic knapsack sprayer is primarily a high volume sprayer, unless special low volume nozzles are fitted to it. It can develop a pressure of up to 12 kg cm^{-2}, but with practice one could spray at 3 to 4 kg cm^{-2} pressure to prevent a possible spray drift.

Hydraulic knapsack sprayer is a low cost, easy to maintain, and a small holding farmer sprayer.

It is particularly satisfactory for spot treatment, band application of herbicides but blanket application cab be done if it is provided with boom.

The main drawback of a hydraulic knapsack sprayer is its three way tiring action on man, viz, a load on the back, one hand engaged in operating the pump, and the other one in directing the lance.

(ii) **Pneumatic or compressed system knapsack sprayers:** Pneumatic knapsack sprayers are comparatively easy to work with since they are pressurized before loading on the back of the worker. This allows a free hand to the operator. The tank is first filled to about 2/3rd capacity with the spray liquid with either a built in pump, separate charge pump or CO_2 cylinders.

A big drawback of pneumatic sprayers: undesirable for herbicide spray as spray pressure reduced after some time. This may cause uneven spray. Also, the mouth of these sprayers is small which makes cleaning of the tank cumbersome.

The pneumatic knapsack sprayers are useful tools to spray herbicides in limited situations like paddy fields and water banks.

(iii) **Motorized pneumatic sprayers (= Blowers):** A motorized pneumatic sprayer is a low volume sprayer suitable for spraying concentrated spray liquids. The blast of air acts as carrier of the herbicide concentrates in these sprayers, which are, therefore, also called blowers. The air is forced-through the spraying jet of the delivery hose of the blower and a nozzle tube ejects the spray liquid in this blast. The air blast atomizes the spray liquid into fine droplets. Faster the air is pumped into the spraying jet, more vigorous is the atomization. The equipment is fitted with petrol engine of about 1.2 H.P.

2. **Foot operated sprayers:** The pump in the foot sprayer consists of a pump barrel and a pressure chamber. The plunger with a suction cup or piston drives into the pump barrel, thus sucking the liquid into the pressure chamber and expelling it through the discharge line. It has provision of 1-2 long delivery hoses. Its potential spray pressure is 17-21 kg/cm^2 and output with lance is 1ha/day.

3. **Tractor mounted sprayers:** with spray pressure of 1.4 to 2.8 kg cm^{-2} and fitted with multi nozzle boom are very useful in herbicide application for large holding of farmers. Tractor mounted sprayer fitted with booms are used to spray road side vegetation. Tractor run sprayers have : (i) high uniformity of sprayers, (ii) high working efficiency and (iii) full utilization of tractor during idle time.

4. **Aerial sprayers:** Herbicide application from air is limited to treat aquatic weeds like water hyacinth, paddy fields, large sugarcane plantation. Presence of obstacles like trees and diversified farming in India are bottle necks in its use.

Calibration of Knap-sack sprayer

Pattern of spray mainly depends upon kind/type of nozzle and diameter of orifice. Efficiency of the applied herbicide is governed by its application technology. In general, foliar uptake herbicides needs less spray volume i.e. mist type spray whereas root uptake herbicides needs more spray volume i.e. coarse droplets. Uniformity of herbicide application depends upon the width of spray boom i.e. more uniformity in wider spray boom and vice versa.

Herbicides are mainly applied by the farmers with backpack Knap-sack sprayer with tank capacity

of 15 litres. To this pump, spray lance with single, double or triple nozzles can be attached. Apart from this equipment, herbicides can also be sprayed with power sprayers, which are operated with small power engine or tractor.

To determine the exact quantity of water required for an area, following steps are required for calibration:

1. Prepare the sprayer

Check the sprayer and its parts and ensure that it is in good working condition. Fill the sprayer tank with a known quantity of water (let 5 litre.).

2. Mark area for spray

Mark out area (let 10 m × 2 m) in the field. The land surface used for calibration of sprayer must be similar to the field to be sprayed.

3. Computation of spray solution for one hectare

Work the lever of the hydraulic sprayer a few times and develop enough pressure. During spray, keep the height of nozzle at about one and a half ft (half metre) from the ground or foliar surface. Always maintain constant nozzle height while spraying. Walking must be at a comfortable pace while spraying, and this speed must be maintained throughout calibration, and later in actual spraying. The spraying should be done at constant pressure which should be between 1.5 to 2.0 bars (1 bar = 1.02 kg/cm^2 = 10^5 pascal).

Spray should be done in bands (straight strips) by keeping the spray lance straight. Second band of spray should be in parallel to the first band with overlapping depending upon nozzle (for flat fan nozzle: 20- 30 % and for flood zet nozzle: 50 %). When specified area is completely sprayed, measure quantity of water left in the tank and subtract it from the original quantity (5.0 litre) taken, and compute exact amount of water consumed for spraying.

$$\text{Volume of spray solution required (l/ha)} = \frac{\text{Volume sprayed (l)}}{\text{Area sprayed (ha)}}$$

4. Calculate the number of sprayer loads required for one ha.

$$\text{Number of sprayer loads/ha} = \frac{\text{Volume of spray solution required (l)}}{\text{Sprayer capacity (l)}}$$

To ensure uniform application of herbicides, following points should be taken into consideration while spraying:

I. Choice of herbicide

Choose the herbicide out of the recommendations of PAU depending upon the weed flora of a crop and type of soil. Do not purchase unrecommended herbicide.

II Selection of nozzles

For the spray of herbicides always use flat fan/flood zet nozzles and do not use cone type nozzle, as its spraying pattern is not uniform.Further for only foliar uptake herbicides like clodinafop, fenoxaprop-p-ethyl, 2,4-D etc. use of flat fan nozzle is more beneficial due to smaller size of droplets which will be retained more effectively by the plant foliage. For root uptake herbicides, flood zet / flat fan nozzle can be used.

III Method of spray

Spray should be done in bands (straight strips) by keeping the spray lance straight. When you reach at the end of the field, stop spraying and second band of spray should be parallel to the first band with slight overlapping. Keep the height of nozzle about one and a half feet (0.5 m) from the ground/foliar surface. Do not move the nozzle to and fro while spraying. Stir the solution before each filling.

Exercise: Spray of herbicide with different nozzles will be demonstrated to the students and they will record the following observations.

Type of sprayer/spray lance	Spray swath (cm or m)	Time required for spraying one acre (hours)	Volume of water required for one acre (litres)
A. Knap-sack sprayer fitted with flat fan nozzle			
B. Knap-sack sprayer fitted with flood zet nozzle			
C. Knap-sack sprayer fitted with cone type nozzle			

Exercise 11. Economics of weed control

Objective

1. To study the economics of weed control treatments.

Procedure

The BC ratio is the ratio between gross/net return (₹/ha) obtained from any activity and the costs/ expenditure (₹/ha) that are incurred for obtaining the said gross return. The benefit cost ratio (BC Ratio) is obtained by the given formula.

$$\text{Benefit Cost ratio} = \frac{\text{Gross/Net Return (₹/ha)}}{\text{Gross expenditure (₹/ha)}}$$

Gross return is obtained by multiplying the quantity of output and the MSP (Minimum Support Price). Gross cost/expenditure is the cost of cultivation of that particular crop. Variable cost of cultivation can be worked out based on the existing price of the inputs. The fixed cost may not be taken into account. Net returns (benefit) is calculated as the difference between gross returns and variable cost.

Let your net returns be N = G-E where G is gross returns and E is expenditure. The ratio N/E = (G/E)-1. So you can use either N/E or G/E because they are closely related. But your decision rule will be different. If you use G/E then the project passes the test of acceptability if G/E > 1. If you use N/E then the project passes the acceptability test if N/E > 0. In either case you are using the rule that a project passes the acceptability test if G-E>0. (Munro Alistair, Professor, National Graduate Institute for Policy Studies, Japan)

Illustration showing the calculation of Benefit cost Ratio in Onion

Here a comparison is made between the farms those who apply herbicides in combination with manual labourers and those farms whom are using only manual labourers for the control of weeds in onion crop. Now, the benefit cost ratio is obtained as the ratio between the gross return and the gross expenditure.

S. No.	Particulars	Unit	Herbicide Applied Farms	Manually weeded Farms
a.	Gross Expenditure	₹/ha	101160	112660
b.	Yield	kg/ha	20395	17525
c.	Price of Onion	₹/kg	15.00	15.00
d.	Gross Return	₹/ha	305925	262875
	Benefit cost ratio (d / a)		**3.02**	**2.33**

Exercise

Q1 Calculate B:C ratio of weed control treatments and find the economical method. Three herbicides (H1, H2 and H3) were tested against unweeded (UW). MSP of produce: ₹ 1200/q.

Treatments	Grain yield q/ha)	Variable cost (₹)	Gross returns (₹)	Net returns (₹)	B:C
H1	70	25000			
H2	65	28000			
H3	67	32000			
UW	15	18000			

Q2 Calculate economics of different weed control treatments in turmeric.

Treatments	Dose (g/ha)	Variable cost (₹ 000/ha)	Rhizome yield (t/ha)	Gross returns (₹ 000/ha)	Net returns (₹ 000/ha)	B:C
Metribuzin fb 2 hoeings at 30 and 60 days	70	52807.8	10.8			
Metribuzin fb PSM 9 t/ha fb HW	70	51785.3	18.2			
Pendimethalin fb 2 hoeings at 30 and 60 days	1000	53255.1	12.0			
Pendimethalin + PSM 9 t/ha fb HW	1000	52232.6	12.0			
Atrazine + PSM 9 t/ha fb HW	750	52386.0	16.8			
Weed free check (Repeated hoeings)	-	68729.7	17.1			
Weedy check	-	46097.6	4.2			

MSP of turmeric : ₹ 20000/t

Exercise 12. Herbicide residue analysis in plant and soil

Objectives

1. To famlirise the students regarding standard methodology followed for residue analysis.
2. To acquaint the students regarding various instrumentation technique used for analysing herbicide residue.

Procedure

The three basic phases involved in herbicide residue methodology are:

1. Collection and sample preparation
2. Extraction and cleanup
3. Detection and quantitation

1. Collection and sample preparation

This involves 3 processes (i) sample collection, (ii) transportation and (iii) sample preparation.

(i) Sample collection: Sample can be in form of soil, whole plant, foliage, straw, grain and water.

Soil Sample: Sample must be drawn at least from 6-8 places from each plot up to a depth of 15 cm (plough layer zone), sub soil samples (14-45 cm) should also be taken.

Plant Sample: Eight to ten foliage samples should be taken from each treatment and replicate plots It would be desirable to take samples of lower, middle and top leaves which can later on be mixed.

Grain: Grain is stable food, it would be better to have minimum grain per plot. Collect at least 2-5 kg of grains per plot.

Water sample: Collect in amber color bottle and preserve with sodium sulfite and store at 4^0C.

(ii) Transportation: Some sample need to be transported from one places to another. In such cases, sample should be properly frozen in dry ice and packed.

(iii) Preparation of samples: The collected samples should be brought to the laboratory mixed and chopped up in suitable sizes. Samples for residues analysis should be made through quartering techniques.

The principal objectives of sample preparation for residue analysis are; isolation of the analytes of interest from as many interfering compounds as possible, dissolution of the analytes in a suitable solvent and pre-concentration. Sample preparation in most of the analytical procedures, takes 50-75% of the total time of the analysis.

The bulk sample is made by uniting and mixing the primary samples. The bulk sample should if possible constitute the final sample. If the bulk sample is too large, the final sample may be prepared from it by a suitable method of reduction.

2. Extraction and cleanup

This involves 4 processes (i) extraction, (ii) cleaning, (iii) concentration of extracts, (iv) storage of extracts.

(i) Extraction process: The residues of herbicide are present in minute quantity in substrate. The

first step in residue analysis is therefore to transfer this very small amount from a relatively large proportion of biological materials on or in which it is found into a solvents. This process is known as the extraction process.

The method of extraction and the type of the solvent or solvent combination will be dependent on the solvent combination, physical and chemical properties of the pesticides to be extracted, the type of substrate from which it will have to be quantitatively removed and the final method of analysis. Extraction should be done by solvent in which as particular herbicide has a maximum solubility. If the solubility of the solvent is less, a multi solvent extraction would be desirable.

The choice of extracting solvent, polar, non polar or mixture of both will depend on the nature of the solvent and polarities of the pesticides to be extracted. But it has been seen that mixed solvent are generally better than a single solvent.

Sample should be sub divided as finely as possible so that the surface of solvent penetration is as greater as possible. Sufficient contact time must be allowed for solvent penetration. Moisture content of the sample is critical and air dried sample should be avoided.

Extraction can be done with surface rinsing, macerating or blending with solvents, soxhlet extraction, solid phase extraction (SPE) etc.

(ii) Clean up of extracts: Cleanup is a term, which is used in residue methodology for the isolation of a pesticide from interfering extraneous extractives or solvents. If an extract is to be analyzed by a method in which nearly any organic material would interfere, the cleanup procedure must be extensive.

As a general rule, it is usually best to cleanup an extract only as much as necessary since even the most satisfactory methods tend to remove some pesticides. The analyst must choose the cleanup procedure or combination of procedure that will be most practical in terms of cost, time and availability.

Co-extractives like pigments, fats and oils etc. can interfere with the method of analysis and hence must be removed by any one or more of the following methods: partition distribution, steam distillation, oxidation, saponification, precipitation method, adsorption chromatography, thin layer chromatography etc.

(iii) Concentration of extracts: The temperature chosen for concentration of extract through evaporation should be such that it does not degrade the compound.

(iv) Storage of extracts: As far as possible, storage must be avoided and samples after extraction must be analysed as soon as possible. Storage should not be encouraged beyond 15 days. Degradation will be minimum if stored at -20^0C in deep freezer.

3. Detection and quantitation

Well established residue analyses methods published in standard journal and books and perceived by appropriate body should be chosen for determining herbicides residues. Residues should preferably be estimated by GC, GCMS, HPLC or LCMS. However other methods like TLC, HPTLC, bioassay

and enzyme inhibition methods available be used for determination. It is desirable that residues are determined by any two methods and results compared. Various instrumentation technique in herbicide residue analysis are:

- Colorimetry and UV Spectrophotometer
- Thin layer chromatography
- Gas liquid chromatography (GLC)
- High performance liquid chromatography (HPLC)

Exercise 13. Bioassay of herbicides residues

Objectives:

1. To familirise the students regarding need of bioassay method of herbicide residue analysis.
2. To familirise the students regarding procedures for conducting bioassay studies.

Procedure

In spite of rapid developments in analytical methods, bioassay remains a major tool for qualitative and quantitative determination of herbicides. A major advantage of the bioassay is the assurance that the phototoxic activity of the herbicide molecule is being measured. A secondary advantage is that it is not generally necessary to extract the herbicides form the substrate. Bioassay procedures are usually more economical, less difficult to perform and do not require as much expensive equipments as in chemical analytical methods.

Bioassay procedures have been used to investigate many practical aspects of herbicide behaviours in the environment. The different methods and approaches in herbicide research based on bioassay are outlined below:

A) Soil effects:

The effect of soil factors on herbicidal activity may be determined by bioassay and correlate phytotoxicity with relevant soil physical and chemical characteristics.

B) Dissipation from soil surface:

Bioassays have been used in experiments dealing with the process of dissipation from soil surface especially volatilization and photodecomposition.

In volatility studies, a source and a sink for herbicide vapors may be set up in a closed container or treated soil may be exposed to an air flow. The bioassay measures the concentration of herbicide remaining in the soil and from this, the amount of herbicide volatilized is computed.

Photodecomposition can be induced experimentally by irradiation of herbicides in soil solution or on artificial surfaces or on soil with UV lamps or natural sunlight. The herbicidal activity is measured by bioassay after certain period of exposure and compared with non exposed treatments.

C) Movement in soil:

Various bioassay methods have been developed for studying the movement of herbicides in soil. In field experiments, soil samples may be taken from different depths and assayed. In laboratory, leaching studies using soil columns can be conducted. Various methods have been used to assess the movement of compounds. Bioassay techniques to examine upward and lateral movement of herbicides are also developed.

D) Degradation and persistence:

Soil samples at different depths may be collected from the herbicide applied plots and assayed in the laboratory. A similar procedure has been used to follow dissipation of herbicides in water.

E) Residual effect:

The residual effect of herbicides on succeeding crop can be assessed using bioassays.

Indicator Species

There are various procedures for conducting the bioassay studies. The choice of a particular procedure will depends upon the herbicide and its phytotoxicity to bioassay species. At the same time, the bioassay must also satisfy certain requirements. In an effective bioassay, the indicator species

should be sufficiently sensitive to detect even small amounts of herbicides and should express the response with increasing herbicide concentrations.

Various organisms can serve as an indicator for a given herbicide and conversely, many herbicides though belong to different chemical groups, can be tested by the same organism. Microorganisms also have been used in some bioassays. The indicator species should be sensitive to minute amounts of the chemical and should respond by clear, easily observable and measurable symptoms. Herbicide bioassays are usually conducted with sensitive plant species referred as indicator / test species. Cucumber, sorghum, mustard, soybean, oat and minor millets are some commonly used indicator plants in herbicide bioassays.

Bioassay materials used for various groups of herbicides

Selected herbicide families	Bioassay/Indicator species
Aliphatic halogenated acids e.g. dalapon	Oats, millets, cucumbers, barley, wheat rice
Acetamides	Crab grass, oats, barley, ryegrass, pig weed
Acetanilide e.g. Alachlor, metolachlor	Cucumber, ryegrass, crab grass
Benzoic acid	Cucumber, oats, foxtail, pig weed
Dicamba	Beans, sorghum, cucumber
Chlorpropham	Cucumber, oats, rye grass
Diphenly ether	Cucumber, crab grass
Phenoxy derivative e.g. 2,4-D	Cotton, pig weed, tomato, mustard
Substituted Ureas e.g. Diuron, Monuron, IPU	Cucumber, ryegrass, oats, barley, millet, sorghum
Thiocarbamates e.g. EPTC	Ryegrass, oats
Dinitroanilines e.g. trifluralin, fluchloralin	Oats, sorghum, rice, cucumber
Triazines e.g. Atrazine, simazine	Oats, cucumber, sugar beet.

Assessment Parameter:

The response of indicator plants to herbicides can be evaluated in various ways.

A) Germination Tests: Many herbicides strongly inhibit the germination of sensitive species but few tests have been based simply on germination number. Sub lethal concentrations frequently produce an inhibition of radical or shoot elongation which is dose related in a range sufficiently large to allow valid measurements. Typically, the root or shoot elongation is observed after a period of 24 – 96 hours. Cucumber, sorghum and oat are the main species used in germination tests but they are not sensitive to photosynthetic inhibitors.

B) Assessment of Plants: Determination of dry weight is most common assessment used in bioassay. Generally, the tops only are weighed since the separation of roots from soil is laborious. Observation based on fresh weight and dry weights generally give good estimations.

For many photosynthesis inhibitors shoot growth is reduced before the appearance of the injury symptoms. Measurement of plant height or leaf length provide an assessment of herbicidal activity which may replace weighing. While leaf length is easily measured on monocots, other measurement may be considered on the other species. For instance, the petiole of the first trifoliate leaf of legumes gives dependable estimation.

Observation of plant height generally give similar results. However, with herbicides inducing deformation in the shoot, the plant height values should be used with care, It was found that

with thiocarbamates, the height reduction was greater than weight reduction. Recording both the parameters is useful in experiments including different type of herbicides. Visual estimation of relative development or of injury intensity is often use.

C) Physiological and Morphological Effects: The physiological, bio-chemical and structural modifications of plants induced by herbicides can be used for bioassay assessment. Reduction of photosynthetic activity by photosynthesis inhibitors has been measured or leaf discus. Chlorosis may be evaluated by determining chlorophyll content through spectrophotometer. Estimation of decrease in viability of root tissue with a modified tetrazoltum test can be done.

D) Symptoms: Symptoms which are typical of a certain group of herbicides or of a given compound can be used for qualitative assay and if the intensity of symptoms are dose related, it can also be used for quantitative determinations. Ex. Epinasty of cotton have been used to measure the effect of 2, 4-D.

Exercise 14. Visit to weed control experiments.

Objectives:

1. To familiarize the students regarding the basic needs of weed control experiments.
2. To familiarize the students with the weed control experiments being conducted in the Department.

Procedure:

The conduct of a weed control experiment is just similar to the other agronomic trials with the exception that only weed control measures are variable. Planning and execution of weed control experiments is made depending upon the objectives of the study. The only basic need of these experiments is that the population of the target weed (s) should be present in the field selected to conduct weed control experiment. Also it must be ensured that proper ecological conditions must be provided for the proper growth and development of this target weed.

An ideal herbicide is that herbicide which provides effective control of weeds i.e. target plants without showing any phyto toxic effect on the crop. Important criteria of a good herbicide are:

I. Economical to use and adequately cheap which should be within the purchasing power of a average farmer.

II. Safe to man and his animals.

III. Safe to rotation crops.

IV. Free of any interaction with herbicide applied to soil during the previous season.

V. Resistant to change in weather condition.

Depending upon the nature of herbicide, it is evaluated at variable levels and at different times during the initial growth stage of the crop. Finally after three years of experimentation the level of herbicide along with its time of application showing satisfactory control of target weed (s) is selected and also it should be ensured that it is safe (non-phytotoxic) to the crop. This treatment is compared with the already recommended herbicide treatment/hand hoeing practice for controlling weeds. Latter on selected dose is tested on the field of the farmers under variable agro- climatic conditions. If the results are consistent then this practice is approved for its inclusion in the package of practices. However for testing brand formulations of the already recommended herbicides, only single year testing at research farm and at farmer's field is made only at one level i.e. the recommended one.

Exercise 1:

Students will visit herbicide evaluation trial and would record the following observations on crop and weeds for the new herbicides, which are under the process of evaluation and compare these treatments with the already recommended treatment (standard).

A. On crop

Treatments	Plant height (cm)	Tillers/ m^2	LAI	Visual condition of the crop	Remarks
Standard treatment (Recommended)					
New herbicide treatments					
Control (unweeded)					

B. On target weeds

Treatments	Weed count m^{-2}	Dry matter weeds (g m^{-2})	Observations regarding other weeds
Standard treatment (Recommended)			
New herbicide treatments			
Control (unweeded)			

Exercise 2: Identification of recommended herbicides

S. No.	Name of herbicide	Formulation	Colour of formulation	Solubility in water	Colour of solution in water
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

Excercise 3:

Give your comments/suggestions regarding the conduct of following experiments along with soil type, other needs of the experiment and details of treatments.

I Control of *Rumex spinosus* from wheat.

II Cultural methods for the control of *P. minor* in wheat.

III Control of *Caesulia axillaris* from transplanted paddy.

IV Efficacy of herbicides in relation to variable pH of soil.

V Control of *Cyperus rotundus*.

Exercise 4: Write the trade name of the recommended herbicide and its dose for the following situations.

Malva in wheat	
Cyperus iria and *Echinochloa* in DSR	
BLW in transplanted rice	
Cyperus rotundus in sugarcane	
Trianthema in cotton	
Brachiaria in maize	
Resistant *P. minor* in wheat	
Annual weeds in green gram	
Annual weeds in turmeric	
Annual weeds in GSL-2	

Exercise 5: Write one herbicide chemical/brand name each:

PS II inhibitors	
PS I inhibitors	
ALS inhibitors	
ACCase inhibitors	
EPSP inhibitors	
Systemic herbicide	
Contact herbicide	
Pre-plant incorporated herbicide	
Mitotic poison	
PPO inhibitors	

Exercise 6: Write salient findings of the weed control experiments which you have visited.

PRACTICAL MANUAL

FOR

AGRON. 503

PRINCIPLES AND PRACTICES OF WEED MANAGEMENT

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