E-Publication (NBP-14-02)

Judicious use of pesticides in sustainable crop production and PGR management

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Introduction

The global population has placed an order to farmers to produce food for an estimated 9.1 billion people expected to inhabit the earth by 2050. To feed the world, food production has to be scaled up by 70% and this may be achieved through proper utilization of available plant genetic resources in development of high yielding varieties of crops, improved crop production and protection technologies. Pesticides are the major tool to contain the insect-pests and save the crops from their damage. About 20-30% agricultural produce is lost annually due to insect-pests, diseases, weeds and rodents, which in monetary term equals to Rs. 1,00,000 Crore. Therefore, judicious use of pesticides plays a major role in plant protection.Their use for sustainable crop production was also advocated by the Nobel Peace Prize winner the late Dr. N. E. Borlaug. No doubt pesticides are reliable source to keep the pest population below economic threshold but if used injudiciously, they may pose serious health hazards to human beings, domestic animals, natural enemies of crop pests and other forms of life through unwanted contamination of food, feed, water bodies and environment. Development of resistance in insect-pests against pesticides, pest resurgence, secondary pest out-break and increase in cost of production due to high cost of pesticides are other disadvantages associated with injudicious use of pesticides. In view all these, the sensible approach suggested and generally accepted in increase crop production is for a judicious and safe use of pesticides. In India, a total 248 pesticides and biopesticides have been registered as per Insecticide Act of 1968 as on 20.05.2014.

PGR management activities and judicious use of pesticide

Plant genetic resources including the reproductive (true seed) or vegetative propagating material of the cultivated varieties (cultivars) in current use and newly developed varieties, obsolete cultivars, primitive cultivars (land races), wild and weed species, near relatives of cultivated varieties and special genetic stocks (including elite and current breeders' lines and mutants). PGR management activities involved identification, preservation and documentation of potentially valuable plant genetic resources, their propagation in field; evaluation against different stresses and utilization in crop improvement programme; collection of seed stock or vegetative propagating material (ranging from tissue cultures to whole plants) held for long-term security in order to preserve the genetic variation for scientific purposes and as a basis for plant breeding and safe exchange of PGR. Plant genetic resources are vulnerable to a number of insect-pests, diseases, nematodes and weeds. Hence protection of PGR from these biotic stresses in an effective and eco-friendly way through judicious use of pesticide is almost necessary in order to their healthy harvest, pest free conservation and used them in breeding stress tolerant and high yielding cultivar.

Pesticide consumption trend in India and the World

India’s pesticide consumption of 600 g/ha is far below its major Asian peers -17 kg/ha in Taiwan, 13 kg/ha in China and 12 kg/ha in Japan. Low consumption can be attributed to fragmented land holdings, lower level of irrigation, dependence on monsoons, low awareness

among farmers about the benefits of usage of pesticides etc. The domestic market has immense growth potential because of the low level of pesticide consumption. Consumption of pesticide in major countries is given in Table 1.

Table 1: Per capita consumption of pesticide in major countries

S. No.	Name of country	Pesticide consumed (Kg/ha)
1.	Taiwan	17.0
2.	China	13.0
3.	Japan	12.0
4.	USA	7.0
5.	Korea	7.0
6.	France	5.0
7.	UK	5.0
8.	India	0.6

Source: Industry reports, Analysis by Tata Strategic (FY 12)

From the above table it is noted that in India pesticide consumption is far less vis-à-vis other countries. However, we have the problem of pesticide residue in food products and our consignments have been rejected at foreign ports many times. In our country the residue problem in food products is mainly due to use of persistent pesticide as well as non-judicious use of pesticides *i.e.* indiscriminate use of chemical pesticides, non-observance of prescribed waiting period, use of sub-standard pesticides, improper advice and supply of pesticides to the farmers by pesticide dealers, effluents from pesticide manufacturing units, improper disposal of left-over pesticides, treatment of fruits and vegetables with persistent and non-recommended pesticides etc. To minimize the misuse of pesticides we have to follow the "Good Agricultural Practices" exercising a thorough understanding about the use of various pesticides in an effective and eco-friendly way.

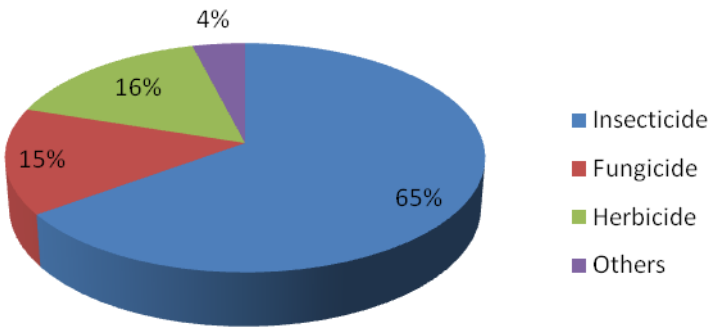


Fig. 1: Share of different pesticides in India, FY-2012 (Source: Industry reports, Analysis by Tata Strategic)

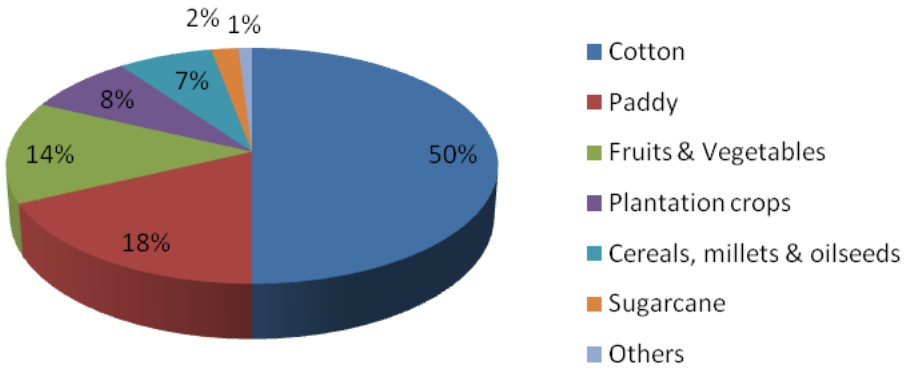


Fig. 2: Crop-wise pesticide consumption in India, FY-2012 (Source: Industry reports, Analysis by Tata Strategic)

Types of pesticides

Pesticides are specific in their action. Based on their activity, pesticides are categorized in to several types. Various types of pesticide is summarized in Table 2.

Table 2: Different types of pesticides

Types of pesticide	**Activity**
Algaecides	Control algae in lakes, canals, swimming pools, water tanks and ot her sites.
Antimicrobials	Kill microorganisms that produce disease.
Attractants	Attract specific pests using natural insect chemicals
Pheromones	Confuse the mating behavior of insects.
Avicides	Control pest birds.
Bactericides	Destroy bacteria.
Bio-pesticides	Naturally occurring substances with pesticidal properties.
Biocides	Kill microorganisms.
Disinfectants and saniti zers	Kill or inactivate disease-producing microorganisms on inanimate objects.
Fumigants	Produce vapors or gases to control air- or soil borne insects and diseases.
Fungicides	Destroy fungi that infect plants, animals, or people.
Herbicides	Control noxious weeds and other vegetation that are growing or competing with a desired species.
Insect Growth Regulators (IGRs)	Accelerate or retard the rate of growth of insects.
Insecticides	Control or eliminate insects that affect plants, animals, or people.
Miticides (Acaricides)	Kill mites that live on plants, livestock, and people.
Molluscicides	Kill snails and slugs.
Nematicides	Kill nematodes, which are microscopic wormlike organisms that live in the soil and cause damage to food crops.
Ovicides	Control insect eggs through the application of low-sulphur

	petroleum oils to plants and animals.
Predacides	Control vertebrate pests.
Repellents	Repel pests such as mosquitoes, flies, ticks, and fleas.
Rodenticides	Control mice, rats, and other rodents.

Decision to use a pesticide

Prevention is always the best way to manage a pest problem. Use of pesticide should be a last resort because they are costly and if used in an injudicious way then they may be hazardous to human beings, domestic animals, natural enemies of crop pests and other forms of life. Farmer should exercise some other possible ways to manage the pests other than pesticide. A number of cultural practices are helpful in minimizing the pest population below the harmful level. Use of resistant/tolerant cultivars will minimize the pest population below economic threshold level. Other cultural practices include sanitation, crop rotation, proper tillage, inter-cropping with less susceptible cultivar, optimum use of irrigation and fertilizer. Physical removal of infected parts of crop plants, play an important role in minimizing pest population. In case of many defoliators, female insect lay thousand of eggs in bunches on the leaves of host plant in few pockets of the field and first instar larvae after hatching start feeding on that particular leave in group which can easily be noticed during regular visit of field. At this stage few leaves with all population of insect from the entire field can be easily removed physically before dispersing the insects into the entire field during their advance stage. Mustard aphid, *Lipaphis erysimi* (Kalt.) first appeared on the plants in border row. The infested twig can be easily removed at regular interval to prevent further multiplication. In sugarcane, borer infestation can be minimized by removing infested shoot physically at regular interval. Pheromone traps are used to catch up the adult population and/ or adult insects of one sex which will certainly reduce the further multiplication of those insects. Change the conditions which may favour the pest to become a problem. Each specific pest organism has optimum environmental conditions for causing damage. For instance, powdery mildew in many plants is favoured by shade. Sometimes providing plants with a sunny location, opening up canopies to provide air circulation and avoiding excessive fertilizing and irrigation will keep the insect-pests and disease from becoming serious.

However, cultural control methods are preventive rather than curative as they are dependent on long-range planning based on detailed knowledge of the bio-ecology of the crop-pests-natural controls-environmental relationships. In the past, such methods were poorly understood and the results were very variable and often it was very difficult to evaluate their effectiveness. Hence, farmers were eventually switched over to more reliable and less knowledge and skill dependent toxic chemical solution.

Before using any pesticide, be sure whether damage to the crop is done by insect-pests and diseases or by other abiotic factors. Damage can also be the result of other factors such as incorrect irrigation, poor drainage, herbicide toxicity, or physical damage. For this, expert advice must be taken from plant protection specialists of nearby Block, Krishi Vigyan Kendra, Agricultural Research Station, District Agriculture and Extension Authority, Agricultural Colleges or Universities and ICAR institutes. Sometimes it has been observed that farmer is unable to understand the real cause of damage to the crop. In such cases they take decision on their own and approach the local dealers or distributors of pesticides and buy any pesticide suggested by him and use it. This results in loss of money to the farmers and cause unnecessary contamination of the environment. This is the big lacuna in our country that sale of pesticides is not channelized through professionally qualified persons. These things compound the pesticide contamination in the environment, undesirable residue build up in food and feed commodities, increase in cancer cases and other mysterious diseases,

rejection of our food commodity consignments at foreign ports, though India is using very low quantity of pesticide per unit area in comparison to some other developed countries like Japan and USA but our way of use is faulty. An expert advice is must therefore be taken before deciding on a pesticide option.

Verify that the pest you seek to control is really going to cross the economic threshold level (ETL). Economic threshold level is the pest density at which control measures should be applied. How many pests are there and will a pesticide spray be justified? Some times crop is attacked by few insects-pests in certain pockets of field and sufficient number of natural enemies of that pests are active or pest has done the economic injury to the crop and farmer takes the decision to use a pesticide. In both the conditions, the decision to use a pesticide shall be uneconomical and result in unnecessary stockpiling the pesticide load in to the environment. A wise thought is that first quantify the damage caused by a particular pest using economic threshold level of that pest. Economic threshold level for some important insect-pests and diseases is given in Table 3.

Table 3: Economic threshold level of some crop pests

Crops	Pests	Economic threshold level
Paddy	Stem borer	5-10% dead heart in vegetative stage or 2% white ears or 1 moth or 1 egg mass/sq. m in ear head bearing stage
	Leafhoppers	10-15 insects/hill (vegetative stage)
	Brown Plant hopper	5-10 insects/hill (vegetative stage)
	Gall midge	1 Silver shoot (gall)/sq. m
	Rice leaf folder	1 freshly damaged leaf/hill or 10% damaged leaves
	Rice gandhi bug	1-2 insect/hill
	Rice root weevil	2 grubs/hill
	Blast	5-10% disease severity (vegetative stage)
	Bacterial leaf blight	2-5% disease severity (vegetative stage)
	Sheath blight	5% affected tillers
Wheat	Aphid	10 aphid/ear head during vegetative stage
	Armyworm and American pod borer	4-5 larvae per metre row
	Nematode	7-8 eggs or larvae/g soil for cyst nemetode
	Rodents	25 live burrows/ha
Pearl millet	Stem borer	10% plants with damage symptoms
	White grub	1 grum/m^2 area
	Downey mildew	10% incidence at 30 days after transplanting
	Nematodes	1-2 nematodes/gm soil
Sorghum	Shoot fly i) after 1 week of	1 egg/plant or presence of eggs on 5% plants

	germination ii) after 2 week of germination	Dead hearts in 15% plants
	Stem borer	Dead hearts, shot holes in leaves and unfilled ear heads in 10% plants
Sugarcane	Early shoot borer	Dead hearts in 15-20% tillers
	Top borer	5 % dead hearts in 2nd brood (June end)
	Gurdaspur borer	Death of 10% canes
	Pyrilla	3-5 insects/leaf
	Black bug	25 insects/plant
Cotton	Pink bollworm	10% infested fruiting bodies with live larvae
	American & spotted bollworm	5% infested fruiting bodies or 1 larva/plant
	Whitefly	5-10 nymphs or adults/leaf before 9 AM
	Jassid	2 nymphs/leaf
	Aphid	10% infested plants counted randomly
	Thrips	5-10 thrips/leaf
	Spodoptera	1 egg mass or skeletinized leaf/10plants
	Nematode	1-2 larvae/g of soil
Rapeseed-Mustard	Mustard aphid	13-29 aphid/plant
Sunflower	Whiteflies	8-10 adult/leaf
	Jassids	15-20 jassids/plant
	Capsule borer	5-6 moth/pheromone trap
	Spodoptera	5-6 moth/pheromone trap
Groundnut	White grub	1 grub/m^2
	Leaf miner	2-3 larvae/plant
	Jassids	15-20 jassids/plant
	Spodoptera	2 larvae/plant
Chick pea	Gram pod borer	2-3 eggs/plant or 2 early instar or a matured larva/plant
	Cut worm	1 larvae/meter row length
	Wilt and root rot	5-10% infested plants
Okra	Jassid	2-5 nymphs/leaf
	Whiteflie	4 adult/leaf
	Fruit & shoot borer	1 infected plant/metre row
	Red spider mite	2 mite/leaf
Cucurbetaceous vegetables(Cucumber, Pumpkin, Bottle-gourd, Bitter- gourd, Sponge- gourd,	Spotted leaf beetle	1 adult/m^2
	Leaf hoppers	2-3 nymphs/leaf
	Root knot nematode	1-2 larvae/g of soil

Snake- gourd, Ash - gourd, Squash)		
Cruciferous vegetables (Cabbage, Knol-khol, Radish, Cauliflower)	Sawfly and diamond back moth	1 larva/plant
	Root knot nematode	1-2 larvae/g of soil
Tomato	Fruit borer	1 larva/plant
	Whiteflies	4 adult/leaf
	Root knot nematode	1-2 larvae/g of soil
Chilly	Thrips	6 thrips/leaf
	Red spider mite	5-10 mites/leaf
	Fruit bore	1 larva/plant
Citrus	Whiteflies	5-10 nymphs/leaf on mandarin 25-30 nymph/leaf on citrus and orange
	Aphid	25% infested shoot
	Mealy bug	5-10% infested fruits in summer and 15% in autumn
	Fruit fly	40-5- adult/trap/week (orange)

Source: Package and Practices adopted by Directorate of Plant Protection Quarantine & Storage, Faridabad, ICAR and State Agricultural Universities (www.ppqs.gov.in)

If the use of a pesticide is finally decided, use it in an integrated pest management (IPM) program that includes use of non-chemical methods also. In almost all cases, a combination of measures may provide the most satisfactory and long-term pest control.

How to choose the right pesticide?

First of all farmer should take the expert advice as described earlier. The first step in choosing a pesticide is to identify the organism correctly (e.g., the specific insect, weed, or plant disease) causing the problem. It is well known that insect-pests and diseases are associated with the crops and cause damage in various ways right from the sowing till harvest and even in godowns after harvest. Some diseases are seed born and seed treatment for these diseases with a particular fungicide is necessary before sowing. Insects may damage the crop in various ways. They may cut seeds, roots of plants, underground stem tubers, tunnel in stem or branches, defoliate the plant, suck the cell sap from leaves, inflorescence, stem and fruits and transmit various viral diseases in the plants. Some times more than one insect species and diseases may be associated with the crop. To fight against such a situation, different kinds of pesticides may be required. Many insecticides are effective to kill only the larval stage and ineffective against eggs or pupae. Many fungicides are preventive treatments and will not eliminate infections that have already started although they may slow their spread. For an insect-pest a common insecticide may solve the problem while in infestation of insect-pests and diseases a combination of two insecticide or combination of insecticide and fungicide may be necessary. Similarly, pre-emergence herbicides are effective against germinating weeds while post-emergence herbicides are effective against actively growing weeds. Some herbicides kill only grasses while others kill broadleaf weeds. It is, therefore, essential for an individual involved in pest control to know all these things precisely before selecting a proper pesticide. Select those pesticides which create least risks to human health, non target species and the environment. The use of same pesticide should not be repeated every time to avoid

resistance development in the pest. Avoid the use of a pesticide that complicate other pest problems *i.e.* use of synthetic pyrethroids induce the resurgence of sucking pests in cotton. It is better to change the pesticide before the resistance actually appears. Restricted use pesticides must be only in those situations where they are recommended. A list of restricted pesticides with the type of restriction imposed and banned pesticides is given in Table 4 and 5 respectively.

Table 4: List of pesticides restricted for use in India

S. No.	Name of Pesticides	Type of restriction(s) imposed
1.	Aluminium phosphide	The Pest Control Operations with Aluminium phosphide may be undertaken only by Govt./ Govt. undertakings/ Govt. Organizations / pest control operators under the strict supervision of Govt. Experts or experts whose expertise is approved by the Plant Protection Advisor to Govt. of India except [1]Aluminium phosphide 15 % 12 g tablet and [2]Aluminum phosphide 6 % tablet. The production, marketing and use of Aluminium phosphide tube packs with a capacity of 10 and 20 tablets of 3 g each of Aluminium phosphide are banned completely.
2.	DDT	Use of DDT in agriculture is banned. In very special circumstances warranting the use of DDT for plant protection, the state or central government may purchase it directly from M/s Hindustan Insecticides Ltd to be used under expert government supervision. Use of DDT for the public health programme up to 10,000 metric ton per annum except in case of any major outbreak is restricted. The export of DDT to Parties and State non-Parties is strictly in accordance with the paragraph 2(b) article 3 of the Stockholm Convention (1972) on Persistent Organic Pollutants (POPs).
3.	Methyl bromide	It's use is restricted as fumigant for insect control in storage and to be sold only to government organizations and to be used under the strict supervision of government expert or pest control operators whose expertise is approved by the plant protection adviser to the government of India. Phasing out of production and consumption of Methyl bromide shall take place by 2015 as per Vienna Convention for the protection of Ozon layer and Montreal protocol on substance that deplete the Ozon layer.
4.	Methyl parathion	Use of methyl parathion 50% EC and 2% DP formulation is banned in fruits and vegetables and permitted in other crops where honey bees are not acting as pollinators.
5.	Sodium cyanide	Use of sodium cyanide is restricted for fumigation of cotton bales under expert supervision approved by plant protection adviser to the Govt of India.
6.	Monocrotophos	Use of monocrotophos in vegetable is banned but allowed to use in other crops.
7.	Fenitrothion	Use in agriculture is banned but allowed for locust control and insect-pests of public health importance.
8.	Diazinon	Use in agriculture is banned but allowed for household purposes.

9.	Fenthion	Use in agriculture is banned except for locust control, household and public health.
10.	Dazomet	Not permitted for use in tea crop.
11.	Methoxy ethyl mercuric chloride	Use in agriculture is banned except for seed treatment of potato and sugarcane.
12.	Captafol	The use of Captafol as foliar spray is banned. Captafol shall be used only as seed dresser. The manufacture of Captafol 80 % powder for dry seed treatment (DS) is banned for use in the country except manufacture for export.
13.	Cypermethrin	Cypermethrin 3 % smoke generator, can be used only by Pest Control Operators and not by the General Public.

Source: www.cibrc.nic.in

Table 5: Pesticides banned for manufacture, import and use in India

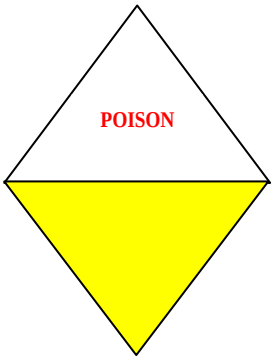
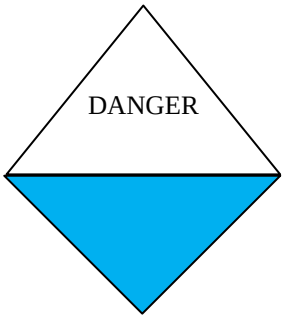
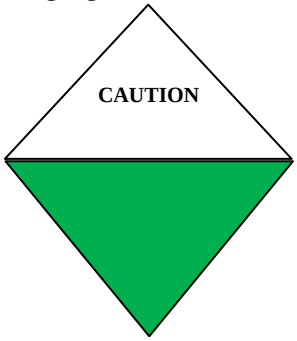
S. No.	Name of Pesticides	S. No.	Name of Pesticides
1.	Aldicarb	19.	Heptachlor
2.	Aldrin	20.	Maleic hydrazide
3.	Benzene hexachloride (BHC)	21.	Menzona
4.	Calcium cyanide	22.	Methomyl 12.5% L formulation
5.	Captafol 80% powder (for export only)	23.	Methomyl 24% formulation
6.	Carbofuran 50% SP formulation	24.	Metoxuron
7.	Chlorbenzilate	25.	Nicotine sulphate (for export only)
8.	Chlordane	26.	Nitrofen
9.	Chlorfenvinphos	27.	Paraquat dimethyl sulphate
10.	Copper acetoarsenite	28.	Pentachloro nitrobenzene (PCNB)
11.	Dibromochloropropane	29.	Pentachlorophenol (PCP)
12.	Dieldrin	30.	Phenyl mercury acetate (PMA)
13.	Endrin	31.	Phosphamidon 85% SL formulation
14.	Endosulfan	32.	Sodium methane arsonate (MSMA)
15.	Ethylene dibromide (EDB)	33.	Tetradifon
16.	Ethyl mercury chloride	34.	Toxaphene
17.	Ethyl parathion	35.	Trichloro acetic acid (TCA)
18.	Lindane (Gamma-HCH)		

Source: www.cibrc.nic.in

The label of pesticide should be read before purchase and be sure that the pesticide purchased is recommended for the target pest and crop. The label and leaflet is a legal document mandatory for every pesticide registered in India. Some of the information that is contained on the label includes: Trade name or brand name, active ingredients and their percentage, types of plants or sites where pesticide may be used, pest targeted, quantity to be used, method and time of application, signal colour and word defining toxicity to people, first aid, proper storage and disposal of empty containers. Any application not consistent with the label is considered illegal. Pesticide label provide critical information how to safely handle and use pesticide products. Pesticides are classified in to several categories based on their toxicity. The toxicity of a pesticide is its ability to cause injury or harm to a person/animal. The toxicity of a pesticide is determined by LD_{50} (lethal dose 50) or LC_{50} (lethal concentration 50) to a test animal. Pesticides with high LD_{50} are the least toxic while

pesticides with low LD_{50} are highly toxic to human-being. A summarised information on classification of pesticides based on toxicity has been given in Table 6.

Table 6: Classification of pesticides based on toxicity

Degree of toxicity	LD_{50} mg/kg		Colour on label, Symbol & signal word on the label	Lethal oral dose for a man	Pesticides
	Oral	Dermal			
Extremely toxic	1-50	1-200	Bright red, Skull& Cross bones and Poison 	A taste to a grain	Methyl parathion. Monocrotophos, Phosphamidon, Methomyl, Zinc phosphide, Aluminium phosphide, Phorate, Carbofuran, Bromodiolone
Highly toxic	51-500	201-2000	Bright yellow & Poison 	A pinch to 1 teaspoonful	Diclorvos, Dimethoate, Imidacloprid, Chlorpyriphos, Acetamiprid, Oxy-demeton methyl, Carbaryl, Fipronil, Propiconazole, Tricyclazole, Profenophos, 2,4-D
Moderately toxic	501-5000	2001-20000	Bright blue, Danger 	1-2 teaspoonful	Malathion, Thiamethxam, Acephate, Alphamethrin, Thiram , Herbicides *i.e.*Pedimethalin, Butachlor, Thiobencarb, Diclofop methyl, Metoxuran, Metribuzin,
Less toxic or safe	>5000	>20000	Bright green, Caution 	28-560g	Mancozeb, Captafol, Hexaconazole, Pretilachlor, Fenoxaprop-p-ethyl, Sulfosulfuron, Many Botanicals

How to choose the right dose?

Always use the recommended dose of pesticides to get effective and safe pest control. The use of higher dose than the prescribed one, will not control the pest any faster and resulted wasting of the pesticide, time and money and potentially causing plant injury (phytotoxicity) and contaminating the environment with excess chemicals that is also detrimental to other form of life *i.e.* human being, domestic animals, aquatic fauna, parasitoids, predators, pollinators etc. A sub-lethal dose also leads to a poor pest control and development of resist In India, ance in pest organism against pesticides.

How to choose the least toxic alternatives ?

Pesticides are used to kill or control the target pest. "Selective" pesticides kill only a few closely related organisms. The broad spectrum pesticides kill a range of pests and non target organisms also. Most pesticides cause negative impacts on the environment *i.e.* some insecticides having low toxicity to humans may have high toxicity to beneficial insects like parasitic wasps or other desirable organisms like honey bees, earthworms, or aquatic invertebrates. Most herbicides selectively kill some weeds but could also kill other desirable plants if not used properly. Pesticide persistence in the environment is also a factor in the safety of pesticides. Pesticides that break down rapidly usually have less negative impact on the environment but are more difficult to use because they do not leave toxic residues that would kill pests arriving hours or days after the application. Such pesticides must be applied precisely when the most vulnerable stage of the pest is present.

Hence it is best to choose the least toxic chemical pesticide which can kill the target pest without much disturbing the other form of life. Several plant-based pesticides *i.e.* neem seed kernel extract, neem oil, certain azadirachtin based commercial formulations of neem are being used against several crop pests. Several macrobial and microbial pesticide could also be used to control a number of insect-pests and diseases of crop. Some bio-agents i.e *Trichogramma* sp. are important egg parasitoids developing on large scale by a number of bio-control laboratories in India and being used successfully to control the borer insect-pests of cotton, sugarcane, gram, tomato etc. Coccinelids and *Chrysoperla carnea* are major predators feeding on aphid and other soft bodied insects infesting a number field crops. Several fungi like *Trichoderma* sp., *Metarhizium* sp., *Beauveria bassiana, Verticillum lecanii* etc are being mass cultured in laboratories and used commercially against a number of crop pathogen and insect-pests. *Tetrastichus pyrillae,* an egg parasitoid and *Epiricania melanoluca* a nymphal and adult parasitoids of sugarcane *Pyrilla,* have checked effectively several epidemics in past caused by this insect in sugarcane growing states of the country. Several commercial formulations of a number of strains of *Bacillus thuringiensis* (Bacteria) and Nuclear Polyhedrosis Viruses are available in the market to control a number of dreaded insect-pests of different crops. These bio-pesticides are very host specific, safe to other forms of life and may control those pests successfully who have already developed resistance against chemical pesticides. *Zygogramma bicolorata* beetle has been used on large scale to control the Congress grass, *Parthenium* weed. The weevil, *Neochitina eichorniae* and *N. bruchi* are proving to be the effective bio-agents against water hyacinth weed in our country.

Among the chemical pesticides, select a pesticide which is effective, comparatively safe to non-target species having a short residual action in the environment. Pest control with recommended pesticide in some important crops is summarised in Table 7.

Table 7: Pest control with recommended pesticides in different crops

Crops	Pests	Recommended Pesticide
Paddy	Stem borer	Apply granules of cartap hydrochloride 4G @ 1.0 kg a.i./ha
	Green leaf hopper & Plant hopper	Spray of monocrotophos 36SL @ 0.5 kg a.i./ha or imidacloprid 17.8 SL @ 25 g a.i./ha
	Leaf folder	Spray monocrotophos 36SL or chlorpyriphos 20EC @ 0.5 kg a.i./ha
	Gall midge	Root dip of seedlings in chlorpyriphos 20EC @ 0.02% or apply granules of carbofuran 3G @ 1.0 kg a.i./ha
	Blast	Spray of carbendazim 50WP @ 0.1% or tricyclazole 75WP @ 0.06%
	Bacterial leaf blight and sheath blight	Spray validamycin 3L @ 2 ml/litre of water or propiconazole 25EC @ 0.1%
	False smut	Spray chlorothalonil 75WP or propiconazole 25EC @ 2 ml/litre of water
	Weeds	Apply butachlor 50EC @ 1.25-2.0 kg a.i./ha or anilophos 30EC @ 0.4-0.5 kg a.i./ha or thiobencarb 50EC @ 1.5 kg a.i. /ha or pretilachlor 50EC @ 0.5-0.75 kg a.i./ha as pre-emergence herbicides within 4-6 days after transplanting
Wheat	Termite	Seed treatment with chlorpyriphos 20EC @ 4 ml/kg seed
	Foliar aphid	Spray imidacloprid 200SL @ 0.4 ml/litre of water on border row
	Army worm and American pod borer	Spray carbaryl 50WP @ 750-1000 g a.i./ha
	Loose smut	Seed treatment with carboxin 75WP @ 2.5g/kg seed or tebuconazole (Raxil 2 DS) @ 1.0 g/Kg seed
	Karnal bunt	Spray propiconazole 25EC @ 0.1 % (1 ml in 1 litre of water) at ear head emergence stage
	Rusts and powdery mildew	Spray with propiconazole 25EC @ 0.1%
	Weeds	Pre-emergence spray (3-5 days after sowing) of pendimethalin 30EC @ 1kg a.i./ha or post emergence (30-35 days after sowing) spray of sulfosulfuran 75WG @ 25g a.i./ha or metribuzin 70WP @ 0.175-0.210 kg a.i./ha or isoproturon 75WP + 2,4-D 80WP @ (750+500) g a.i./ha effectively control both grassy and broad leaved weeds
	Rodents	Apply 2.5% (1:40) zinc phosphide bait preceded by one day prebaiting
Pearl millet and Sorghum	Grass-hopper	Spray chlorpyriphos 20EC @ 0.5 kg a.i./ha
	Stem borer and Shoot fly	Application of Phorate 10 G or Carbofuran 3 G @ 1.0 kg a.i./ha
	Earhead bug and midge	Spray carbaryl 50WP @ 1kg a.i./ha

	Downey mildew	Spray mancozeb 75WP @ 2 kg/ha
	Ergot	Spray od copper oxychloride @ 0.25% at the time of flowering
	Weeds	Pre-emergence spray of Atrazin 50WP @ 0.5%
Cotton	Bollworms	Spray neem products (1500 ppm) @ 2.5 litre/ha or NPV @ 250 LE/ha or chlorpyriphos 20EC @ 500-700g a.i./ha or profenophos 50EC @ 1000-1250g a.i./ha or indoxacarb 14.5SC or spinosad 45SC @ 75g a.i./ha
	Aphid/jassid/thrips/ whiteflies	Spray neem seed kernel extract (NSKE) @ 5% or neem products (1500 ppm) @ 2.5 litre/ha or imidacloprid 17.8SL or thiamethoxam 25G @ 25 g a.i./ha
	Cotton leaf curl virus	Control the whiteflies
	Weeds	Pre-emergence spray of pendimethalin 30EC @ 0.75-1.025 kg/ha or alachlor 50EC @ 2.0-2.5kg a.i./ha or pre-plant incorporation of fluchloralin 45EC @ 0.9-1.2 kg a.i./ha control both grassy and broad leaved weeds effectively
Gram and Lentil	Gram pod borer	Spray NPV @ 250 LE + 0.5% jaggery + 0.1% tinopal/ha at the appearance of 1st instar larvae or eggs. Spray of *Bacillus thuringiensis* var. kurstaki @ 0.75-1.0 kg/ha or 5% NSKE at pre-flowering stage is also effective. Among the chemical pesticide - spray chlorpyriphos 20EC @ 500g a.i./ha or deltamethrin 2.8EC @ 10-12.5 g a.i./ha.
	Cut worm and termite	Spray of chlorpyriphos 20EC @ 500 g a.i./ha Seed treatment with chlorpyriphos 20EC @ 15-20 ml/kg seed
	Wilt and damping-off	Seed treatment with *Trichoderma viridi* 1% WP @ 9 g/kg seeds or combination of Carbendazim with carbosulfan @ 0.2%
	Weeds	Pre-emergence spray (3-5 days after sowing) of Pendimethalin 30EC @ 1 kg a.i./ha
Black gram and green gram	Hairy caterpillar and pod borer	Spray NPV @ 250 LE/ha or chlorpyriphos 20EC @ 500g a.i./ha or deltamethrin 2.8EC @ 10-12.5 g a.i./ha.
	Whiteflies, Jassids, Thrips,	Spray monocrotophos 36SL @ 0.5 kg a.i./ha. It also reduces the incidence of yellow vein mosaic virus.
	Stem fly	Soil application of Phorate 10 G or Carbofuran 3 G @ 1.0 kg a.i./ha
Sugarcane	Termite, white grub, root borer and early shoot borer	Application of chlorpyriphos 20EC @ 5 litre/ha at the time of planting or at 35-40 days after planting along the furrow followed by irrigation is effective against termite, white grub, root borer and early shoot borer (whorl application)
	Top borer	Application of phorate 10G or carbofuran 3G @ 25 kg/ha in the last week of June along the furrow near root zone
	Pyrilla and scale insect	Spray malathion 50EC @ 0.05% concentration

	Black bug	Spray monocrotophos 36SL @ 1 ml/litre of water
	Mealy bug	Spray monocrotophos 36SL or chlorpyriphos 20EC @ 2 ml/litre of water
	Red rot and smut	Sett treatment with thiophanate methyl 70WP @ 0.2%
	Weeds	Pre-emergence spray (3-5 days after sowing) of Atrazine 50 WP @ 1 kg a.i./ha provide an effective weed control upto 5-6 weeks.
Rapeseed-mustard	Aphid	Spray of NSKE @ 5%, use dimethoate 30EC or oxy-demeton methyl 25EC @ 1 litre/ha if pest crosses ETL
	Painted bug	Seed treatment with imidacloprid 70 WS @ 5 g/ha or dust the crop with quinalphos 1.5% dust @ 20-25 kg/ha or spray the crop with imidacloprid 17.8 SL @ 40 g a.i. per ha
	Sawfly	Spray of malathion 50EC @ 500ml/ha
	White rust	Seed treatment with metalaxyl @ 6 g/kg or spray mancozeb 75WP @ 2 kg/ha
	Black spot and downey mildew	Spray mancozeb 75WP @ 2 kg/ha
	Powdery mildew	Spray wettable sulphur 80WP @ 2 kg/ha
	Sclerotenia rot	Seed treatment with carbendazim 50WP @ 2 g/kg or spray @ 0.1%
	Weeds	Pre-sowing soil incorporation of fluchloralin 45EC @ 1 kg a.i./ha or pre-emergence spray (1-2 days after sowing) of pendimethalin 30EC @ 1 kg a.i./ha
Groundnut	White grub	Soil application of phorate 10G or carbofuran 3G @ 1.0 kg a.i./ha
	Spodoptera and hairy caterpillars	Spray NPV @ 250 LE/ha or *Bacillus thuringiensis* @ 1.0 kg/ha, in severe infestation spray quinalphos 25EC @ 1250 ml/ha
	Leaf spot and rust	Spray carbendazim 50WP@ 375g a.i./ha
	Weeds	Pre-emergence spray of oxyflourofen 23.5EC @ 0.15-0.25 kg a.i./ha
Soybean	Stem fly and Girdle beetle	Soil application of phorate 10G oe carbofuran 3G @ 1 kg a.i./ha
	Defoliators	Spray NSKE (5%) or *Bacillus thuringiensis* @ 1.0 kg/ha, in severe infestation spray quinalphos 25EC @ 1000 ml/ha
	Sucking insects (Aphid, whiteflies, thrips, jassids)	Spray NSKE @ 5%, In severe infestation, spray dimethoate 30EC @ 0.03%
	Rust	Spray with propiconazole 25EC @ 0.1%
	Sclerotium stem rot	Spray carbendazim 50WP @ 0.1%
	Weeds	Pre-sowing soil incorporation of fluchloralin 45EC @ 1 kg a.i./ha
Sunflower	Capsule borer	Spray NSKE (5%) or NPV @ 250 LE/ha or *Bacillus thuringiensis* @ 1.0 kg/ha, in severe infestation spray

		fenvalerate 20EC @ 0.005%
	Defoliators (Tobacco and Bihar hairy caterpillar)	Spray NSKE (5%) or NPV @ 250 LE/ha or *Bacillus thuringiensis* @ 1.0 kg/ha, in severe infestation spray quinalphos 25EC @ 1250 ml/ha
	Sucking insects (Jassids whiteflies, thrips,)	Spray NSKE @ 5%, In severe infestation, spray dimethoate 30EC @ 0.03%
	Downey mildew	Seed treatment with metalaxyl 35 WP @ 6g/kg of seed
	Alternaria blight	Seed treatment with thiram @ 2g/kg of seed Spray mancozeb 75WP @ 2 kg/ha
Cucurbetaceous vegetables and fruits (Cucumber, Pumpkin, Bottle- gourd, Bitter- gourd, Sponge- gourd, Snake- gourd, Ash -gourd, Squash, musk-melon, water-melon)	Spotted beetle and red pumpkin beetle	Spray *Beauvaria bassiana* fungus powder formulation @ 1 kg/ha, in severe infestation spray carbaryl 50WP @ 1 kg/ha or chlorpyriphos 20EC @ 1 ml/litre of water
	Fruit fly	To destroy the adult kept poison bait @ 10 ml/polythene bag at 25 places/ha. Bait is made by mixing of methyl eugenol and malathion 50EC in (1:1)
	Sucking insects (aphid and whiteflies)	Spray NSKE @ 5% In severe infestation, spray dimethoate 30EC @ 1 ml/litre of water
	Wilt	Seed treatment with *Trichoderma viride* @ 3 g/kg of seed or with thiram @ 2 g/kg of seed
	Anthracnose and Downey mildew	Spray mancozeb 75WP @ 2 kg/ha
	Powdery mildew	Spray dinocap 48EC @ 300 ml/ha
	Root knot nematode	Seed treatment with *Trichoderma viride* @ 3 g/kg of seed was found effective
Brinjal	Brinjal fruit and shoot borer	Spray of *Bacillus thuringiensis* var. kurstaki @ 500 g/ha Spray carbaryl 50WP @ 4 g/litre of water at the time of flowering and fruiting
	Sucking insects (aphid, jassid and whiteflies)	Spray NSKE @ 5% In severe infestation, spray dimethoate 30EC @ 0.03%
	Alternaria leaf spot	Foliar spray of carbendazim 50WP @ 300 g a.i./ha
	Weeds	Pre-planting soil incorporation of fluchloralin 45EC @ 0.9-1.35 kg a.i./ha control both grassy and broad leaved weeds effectively
Okra	Fruit and shoot borer	Spray NSKE @ 5% or any neem based pesticides (1500 ppm) @ 2 ml/litre of water at the time of flowering and fruiting, if population crosses ETL then apply carbaryl 50WP @ 4 g/litre of water
	Red spider mite	In severe infestation spray wettable sulphur 80 WP or Dinocap 48EC or dicofol @ 0.05%
	Jassid and whiteflies	Spray NSKE @ 5%
	Leaf blight	Spray mancozeb 75WP @ 2 kg/ha
	Yellow vein mosaic	Control whiteflies

	Weeds	Pre-planting soil incorporation of fluchloralin 45EC @ 0.9-1.20 kg a.i./ha control both grassy and broad leaved weeds effectively
Tomato	Fruit borer	Spray NPV @ 250 LE/ha or *Bacillus thuringiensis* var. kurstaki @ 500 g/ha at the time of flowering and fruiting If population is crossing ETL then spray profenophos 50EC @ 2 ml/litre of water
	Whiteflies	Spray NSKE @ 5% In severe infestation, spray dimethoate 30EC @ 0.03%
	Root knot nematode	Soil application of carbofuran 3G @ 1 kg a.i./ha
	Leaf curl virus	Control whiteflies
	Leaf blight	Spray mancozeb 75WP @ 2 kg/ha
	Weeds	Pre-emergence spray of metribuzin 70WP @ 0.525 kg a.i./ha effectively control both grassy and broad leaved weeds
Cabbage, Knol-khol, Radish, Cauliflower,	Sawfly and aphid	Given in rapeseed-mustard
	Diamond back moth	Spray *Beauvaria bassiana* fungus powder formulation or *Bacillus thuringiensis* var. kurstaki @ 500 g/ha
	Head borer	Spray NSKE @ 5% at the head initiation stage
	Damping off and black rot	Seed treatment with *Trichoderma viride* @ 2 g/100g of seed was found effective
Chilly	Thrips	Spray NSKE @ 5%
	Red spider mite	Spray NSKE @ 5%, in severe infestation spray dicofol @ 0.05%
	Fruit borer	Spray NPV @ 250 LE/ha or *Bacillus thuringiensis* var. kurstaki @ 500 g/ha at the time of flowering and fruiting
	Damping off	Seed treatment with *Trichoderma viride* @ 4 g/kg of seed
Mango	Mango hopper	Three spray of carbaryl 50WP @ 0.15% or monocrotophos 36SL @ 0.04% at initiation of penicle formation, full stage of penicle formation and fruit set at pea stage.
	Mealy bug	Spraying of monocrotophos 36SL @ 0.05% or carbaryl 50WP @ 0.2% is effective
	Fruit fly	Adult fruit fly can be controlled by poison bait through hanging of bottle trap containing 100 ml emulsion of methyl eugenol @ 0.1%+malathion @0.1% at a suitable height on the trees.
	Powdery mildew	Spray twice wettable sulphur 80WP or Dinocap 48EC @ 2g/litre of water at 15 days interval
	Dieback	Spray copper oxychloride @ 0.3% just after appearnce of disease and repeat the same after 20 days
Guava	Fruit fly	Same as in mango
	Fruit borer	Adult can be controlled by spraying of carbaryl 50WP @ 0.1% at the beginning of fruiting season and before the ripening of fruits

	Mealy bug	Spraying of monocrotophos 36SL @ 0.05% is effective
Pomegranate	Anar butterfly	Spray fenvalerate @ 0.005% at the time when more than 50% fruits have set
	Stem borng beetle	Inject 5-10 ml diclorvos @ 0.25% per hole into the tree trunk
	Thrips, whiteflies and aphid	Spray NSKE @ 5% In severe infestation, spray dimethoate 30EC @ 0.06%
	Leaf spot and fruit spot	Spray thiophanate methyl @ 1 ml/litre of water
Pineapple	Fruit rot and root rot	Prophylactic spray (drenching) of copper oxychloride @ 0.3%
Citrus	Citrus psylla, Aphid, Thrips and Whiteflies	Spray NSKE @ 5% or neem product (1500 ppm) @ 2.5 litre/ha, if population is crossing ETL then spray monocrotophos 36SL @ 0.1%
	Fruit fly	Adult fruit fly can be controlled by poison bait using methyl eugenol @ 0.1%+malathion @0.05%
	Lemon butterfly	Spray monocrotophos 36SL @ 0.04%
	Citrus canker and Anthracnose	Spray copper oxychloride @ 0.3%

Source: Package and Practices adopted by Directorate of Plant Protection Quarantine & Storage, Faridabad, ICAR and State Agricultural Universities (www.ppqs.nic.in,)

Names of pesticide

Many pesticides have difficult names that reflect their chemical structure. Therefore, they are often given a shorter name, called common name, to make them easier to identify. These common names are often based on the name of the active ingredient in the pesticide. For example: carbaryl is the common name for 1-naphthyl methyl carbamate, and glyphosate has a chemical structure called N-(phosphono methyl) glycine. The active ingredient (abbreviated as a.i.) is the compound that is used to control the harmful organism. Its ability to kill, harm or deter a certain pest or disease has been proven and its use for this purpose is authorized through a registration process. Farmers and extension agents need to remember that different companies produce pesticides that contain the same active ingredient, which are sold under several trade names. Usually, the common or chemical names are printed on the products (labels) to enable users to identify the different products that contain the same active ingredient. For example, cypermethrin 10EC is the active ingredient in the following insecticides - Cyperforce, Balathrin 10EC, Globathrin 10EC, Cymbush 10EC, Delthrin 10EC, Suraksha 10EC, Superthrin 10EC, Cyperkil 10EC, etc.

Suitable pesticide formulation

One has to select a suitable pesticide formulation since a single pesticide is often sold in different formulations. Different formulations of the same ingredient behave differently. Pesticide formulation may be liquid (emulsifiable concentrate, suspension concentrate, low concentrate liquid, flowable liquids etc.), dry (dust, granules, wettable powder, soluble powder, dry flowable, water-dispersible granule, baits etc), ULV, aerosols etc. While choosing a formulation few things *i.e.* cost, site to be treated, locations (dry, hill, plain, agricultural, forest, urban etc.), habit of the pest, danger of drift or runoff, type of applicators available etc. must be taken in to account. Different abbreviations used for different pesticide formulations are given in Table 8.

Table-8: Abbreviations used for different pesticide formulations

Abbreviations	Name of formulations	Abbreviations	Name of formulations
A	Aerosol	MTF	Multiple temperature formulation
AF	Aqueous flowable	P	Pellets
AS	Aqueous suspension	PS	Pellets
B	Bait	RTU	Ready-to-use
C	Concentrate	S	Solution
CM	Concentrate mixture	Sc	Sprayable concentrate
CG	Concentrate granules	SD	Soluble dust
D	Dust	SG	Soluble granule
DF	Dry flowables	Sn	Active solution
DS	Soluble dust	SP	Soluble powder
EC	Emulsifiable concentrate	ULV	Ultra low volume
F	Flowable (liquid)	ULW	Ultra low weight
G	Granules	W	Wettable powder
GL	Gel	WDG	Water-dispersible granules
L	Liquid (flowable)	WP	Wettable powder
LC	Liquid concentrate	WS	Water soluble concentrate
LV	Low volatile	WSG	Water-soluble granules
M	Microencapsulated	WSL	Water-soluble liquid

Points for consideration while using pesticides:

a) Calculate the right dose of pesticide based on pesticide formulations

Before application or purchase of pesticides, it is always necessary to calculate the right dose of insecticides or herbicides or fungicides required for application. This would unable the farmers to purchase and use only the required amount of pesticides. Several methods for calculating the pesticide dose with some example are given herewith.

If recommended as g a.i./ha:

Rate of pesticide is given mainly in terms of a.i./ha

$$\text{Quantity of material required per hectare} = \frac{\text{Rate of application}}{\text{Active ingredient in \%}} \times 100$$

Example: Find out the quantity of Dimethoate 30EC to be sprayed in one hectare area if rate of application is 300g a.i. /ha

Quantity of Dimethoate 30EC/ha =300/30 x 100 = 1.00 litre

For the calculation of this type we must know the a. i. present in the commercial product.

If recommended as per cent concentration:

By Formulae

$$\text{Amount of pesticide} = \frac{\text{Volume of spray solution (liter)} \times \text{Per cent strength of pesticide solution to be sprayed}}{\text{per cent strength (a.i.) of pesticide given}}$$

Example: Calculate the amount of malathian 50 EC per ha when applied as 0.05 per cent solution and volume of spray solution required is 500 litre per ha

$$\text{Amount of malathian 50 EC/ha} = \frac{500 \times 0.05}{50}$$

$$= 0.5 \text{ litre}$$

b) Pesticide's shelf life

The shelf life of a pesticide refers to the period for which a particular pesticide can be used or stored without any considerable deterioration in its quality or period after which it becomes un-usable even if stored properly. All pesticides have a limited shelf life and accordingly the expiry period is written on the labels of the products. The expired pesticide should never be used for pest control programme because the product may loose its activity resulting in poor pest control and secondly it may prove phytotoxic to the crop due to change in its chemical composition over a period of time.

c) Waiting period for pesticides

Waiting period refers to the time gap to observe between the last application of insecticide and the harvesting for consumption. It may be vary from pesticide to pesticide, crop to crop and place to place depending upon the residual toxicity of pesticide and environmental conditions. The leaflets supplied along with pesticides normally contains these information about different crops. At least 15 days waiting period should always be observed with commonly recommended insecticides.

d) Follow the compatibility chart

The term compatibility refers to the criteria whether a chemical can be mixed with a particular chemical without any adverse effect on the toxicity. Many time farmers try to mix insecticide and fungicide together to control insects and diseases or mix pesticide with fertilizers like urea most often. Therefore, it is advised to go through the recommendations given on the leaflet precisely for compatibility if any exists between those chemicals to avoid crop damage by the phytotoxic action of such incompatible mixed product.

e) Pesticide application equipments

Various types of pesticide application equipments are required for pesticide application depending upon the treatment site and choice of pesticide. The selection of right equipment for pesticide application is important for successful pest control. Generally the equipment used for this work are, hand sprayers and atomizers (for smaller area of kitchen gardening), hand compression and knapsack sprayers, hand carried dusters and granule applicators (suitable for small and marginal farming), motorized knapsack mist blower and various kinds of power sprayers, dusters (for large scale pest control work or spraying on taller crop/trees etc), ultra low volume or controlled-droplet applicators (suitable for specially designed formulations or pest control in dry areas), injectors and fumigation equipment (for household and storage pest control), aerial application through aircrafts (for large scale coverage and difficult terrain). Always keep the separate sprayer for herbicide application and label it "WEEDS ONLY" otherwise herbicide residue in the sprayer may injure plants if

the same sprayer is used for applying another type of pesticide or fertilizer. If it is not possible at all then the sprayer should be thoroughly washed with clean water thrice to remove any unwanted residue of previously used chemical herbicide. The use of proper nozzles is key factor in getting proper bio-efficacy results. Many times it is observed that farmers use the same nozzle with sprayer for all kinds of pesticides whether it is insecticide, fungicide and or herbicide. This will give a improper coverage of pesticide on the target area resulted in poor pest control. It is advisable to use jet nozzle for spraying of herbicides and hollow cone nozzle for spraying of insecticides and fungicides.

f) Minimizing Environmental Contamination

Use spot treatments where the pest is most prevalent and avoid widespread applications of the pesticide in whole crop if not infested equally at all places. For spot treatments, mix the pesticide according to label instructions, and apply the mixture only to the affected area. Wick or shielded applicators for some herbicides should be used to avoid environmental contamination. Bait for rodents and ants and tree trunk treatments for certain insects are other ways of limiting environmental exposure.

SUMMARY

It is necessary to save our important plant genetic resources from the pests and 20-30 per cent agriculture produce lost annually at various stages right from cultivation to storages due to ravages of insect-pests, diseases, weeds, rodents etc. Pesticides are an important and reliable tool in integrated pest management programme (IPM) to contain the pest problem and losses caused by them. But in the past, their indiscriminate use has polluted the environment by harmful accumulation in food, feed, soil, water bodies, air etc. A sensible approach to save the genetic resources from pests and increase the crop production with the use of pesticides is that they may be judiciously used in Integrated Pest Management programme. Therefore, it is necessary to be aware of economic threshold of pests, selection of right pesticide, dose and formulation keeping in view their safety to the environment. The precautions adopted right from purchase of pesticide to various stages of their application and use are well addressed. The tactics of safe and effective use of pesticide will certainly achieve the target of sustainable agricultural production and PGR management set before us in an environment friendly way.