

New approaches of weed management in soybean

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Soybean serves the dual purpose for being grown both as an oilseed as well as pulse crop. Soybean seed account for 36% protein and 20% oil content on dry weight basis. The remainder consists of 30% carbohydrates, 9% water and 5% ash. Soybean comprises approximately 90% cotyledons, 8% seed coat or hull and 2% hypocotyl axis or germ. It also contains a good amount of salts, vitamins and health promoting phyto-chemicals. Soybean is an environment friendly grain legume and its cultivation improves soil-health because of its atmospheric nitrogen-fixing ability and deep root system.

Key words: Herbicide, Soybean, Weeds, Weed Management

Globally, soybean is cultivated globally over an area of 156.71 million ha with a production of 353.66 million tonne and having a productivity of 2.39 tonne/ha. In India, soybean is mainly grown in Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. During 2005-06, soybean occupied an area of 7.71 million ha with the production of 8.27 million tonne and 1,073 kg/ha productivity, but now no has increased to 11.61 million ha with production of 8.57 million tonne but production has significantly decreased to 738 kg/ha in 2015-16. The main reasons for this reduction of productivity are mainly due to abiotic and biotic factors. The importance of abiotic stress factors to cause yield or quality loss depends on the environment and thus varies from one agro-ecology to another, one country to another. Abiotic stresses are primarily unavoidable and are the most harmful in relation to growth and productivity of crops, especially under rainfed areas. Similarly, biotic stress are caused by living organisms, viz., weeds, insect pests, diseases, pathogens, nematodes, rodents etc. All these

factors are the largest and most important group affecting all plant parts at different growth stages of soybean.

Among biotic stresses, weeds are major culprit which causes around 37% yield reduction in soybean. If weed management is not done timely or neglected, yield reduction was observed. Henceforth, weed management is an essential agronomic measure to exploit the maximum yield potential of newly developed high yielding varieties.

Weed management strategies in soybean

The effective weed management measures are important for increasing production of soybean. Weed management in soybean crop is the process of minimizing weed infestations so that crops could be grown profitably. Weed free crop is essential to crop for harnessing maximum benefit from the environment. It is important to select the weed management techniques based on the weed diversity present in the field. It is essential to provide the crop weed free condition for longer period during early stages of

the crop. Therefore, use of weed management practices such as preventive measures, cultural, physical or mechanical and chemical methods may be used in increase production of soybean.

Preventive measures

There are those which aims to prevent weeds from being established in a cultivated crop, such as use of weed free seeds for sowing, weed free and well decomposed organic manures, use of cleaned farm machinaries and implements, tolls, keeping irrigation free from weeds, using screen in irrigation channels to avoid long distance travel along with irrigation water.

Cultural method

The agronomical practices necessarily done during crop production are manipulation in the favour of crop rather than the weeds are called cultural agronomical or ecological or non-monetary methods of weed control. These practices play an important role in weed management. Enhancing crop competitiveness against weeds could provide a low cost and safe tool for

Common weeds in soybean (<i>Glycine max</i>)		
Grasses		
<i>Echinochloa colona</i>	<i>Dactyloctenium aegyptium</i>	<i>Digitaria sanguinalis</i>
<i>Dinebra retroflexa</i>	<i>Paspalidium flavidum</i>	<i>Eleusine indica</i>
<i>Cenchrus sp.</i>	<i>Cynodon dactylon</i>	<i>Eragrostis pilosa</i>
<i>Setaria glauca</i>	<i>Setaria verticillata</i>	<i>Setaria faberi</i>
<i>Sida spinosa</i>	<i>Rottboellia exaltata</i>	<i>Rottboellia cochinchinensis</i>
<i>Imperata cylindrica</i>		
Broad-leaved weeds		
<i>Euphorbia geniculata</i>	<i>Alternanthera sesilis</i>	<i>Eclipta alba</i>
<i>Commelina benghalensis</i>	<i>Commelina communis</i>	<i>Cynotis axillaris</i>
<i>Portulaca oleracea</i>	<i>Solanum nigrum</i>	<i>Parthenium hysterophorus</i>
<i>Bidens pilosa</i>	<i>Caesulia axillaris</i>	<i>Trianthema portulacastrum</i>
<i>Phyllanthus niruri</i>	<i>Tridax procumbens</i>	<i>Amaranthus spinosus</i>
<i>Amaranthus hybridus</i>	<i>Amaranthus tuberculatus</i>	
Sedges		
<i>Cyperus iria</i>	<i>Cyperus esculentus</i>	<i>Cyperus rotundus</i>

weed management. Adopt such management measures which provide congenial condition to crop for growth and development and indirectly maintains a crop environment that is detrimental to weeds. Soybean is weak competitors during the early growth stages; thus, early season weed management is more important. Soybean should be grown as a part of rotation in which crops and their cultivation minimize the weed problems progressively. However, some cultural practices in particular stale seed bed, soil solarization, crop rotation, intercropping, crop competition, planting geometry, seed rate, mulching, interculture etc. are used to manage the weed population and crop competition.

Stale seedbed: In this technique, the land is brought to fine tilth by repeated cultivation before the receipt of pre-monsoon showers. This helps to provide favourable conditions to weeds to stimulate initial flush. Later, germinated or emerged weeds are being killed by using harrows (cultivator or disc harrow) or with a flame-weeder or infra-red burner. This is known as 'stale seedbed'. This significantly reduced the weed seed bank which likely to affect the crop. Moist conditions during stale period essentially encourage weed emergence. Generally, the effectiveness depends on occurrence of pre-monsoon showers and if pre-monsoon showers are not received crops and weeds sprouts together resulting in higher weed intensity and severe crop-weed competition.

Soil solarization: Soil solarization for two weeks during hot summer (May and June) is also sufficient to control weeds, but it may be continued to several weeks together for prolonged effect. It may control weeds in crops in the wet season (*kharif*) as well as subsequently in the winter (*rabi*), if crops are grown under zero till condition.

Crop rotation: Monoculture practices i.e. growing of same crop year after year in the same field creates the weed problems in the field. Monoculture leads to increase the infestation of certain crop associated weeds. The proper crop rotations or inclusion of pulse/oilseed crops in rotation is helpful for control of crop associated and parasitic weeds i.e. *Orobanche* in the crop rotation. Changing crops in rotation also changes the weed management option. Crop rotations allows the use of different types of herbicides on the same field in different years and thus prevent the build-up of problematic weeds and help to keep the overall weed population at lower levels. More important, crop rotation and proper selection of weed management in the rotation are key component strategies to reduce weed severity.

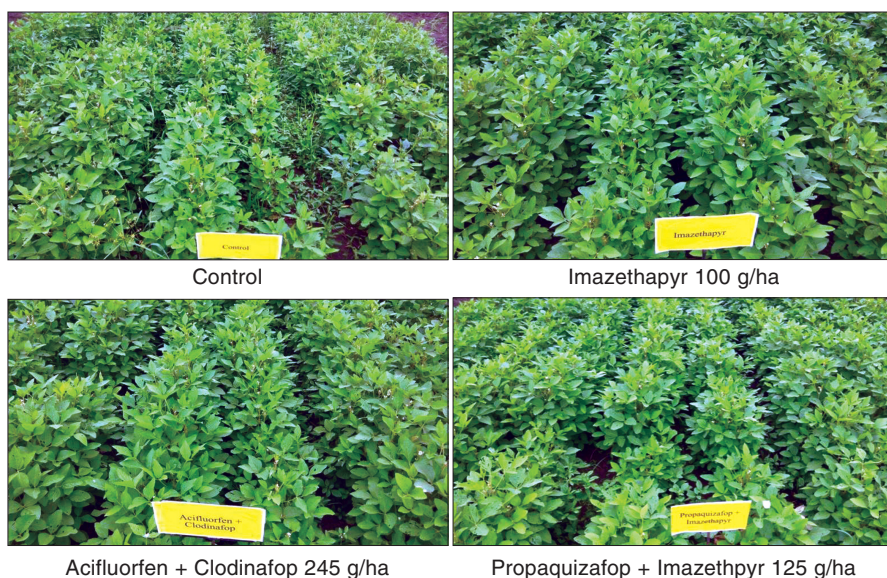
Crop husbandry: Good crop husbandry is one of the most effective, but often one of the most overlooked tools in weed control. A good stand of soybean, which emerge rapidly and shade weeds, is very helpful in reducing weed competition. This involves good management practices such as

choosing a well-adapted variety, weed free seed bed, good fertility, maintaining proper soil pH, adequate plant populations, and using row spacing as narrow as possible. Planting in narrow rows is the most effective means of achieving better weed suppression.

Intercropping: Sowing of short duration crops in between the rows of main crop at different row proportion (additive or replacement series) is very effective tool to reduce weed emergence and also to increase crop competitive ability. Placement of intercrop seeds in between the soybean rows not only restrict the emergence of initial weed flush but also offer competition for utilizing the solar radiation and thus resulting in poor weed stand establishment.

Canopy closure: The basic strategy is to follow practices that result in rapid soybean growth and canopy closure so as to provide maximum shading effect on weeds. Other practices that enhance crop competition with weeds include good seedbed preparation, use of high-quality seed, proper variety selection, early-season disease and nematode management, proper fertilization and liming, and early planting. Utilizing these good management practices is necessary for producing good soybean yields as a result of better weed control.

Cultivation/ inter-culture: Soybean obviously can be grown without cultivation. However, cultivation is effective in controlling weeds growing in inter row spaces. Cultivation is an effective and economical way to supplement weed control through herbicides. Applying herbicides in a band over the row and cultivating the row middles can substantially reduce weed control costs. In fields with a light weed infestation, cultivation alone may be sufficient. Cultivation should be shallow (1 to 2 inches or 2.5 to 5 cm) to avoid crop roots damage, breaking herbicide layer, bringing up untreated soil and weed seeds. To be effective, shallow cultivation must be done when the weeds are small. Weed control is the only benefit received from cultivation except where special soil problems such as crusting or



poor drainage exist.

Mulching/cover crop: Weed may be control by placing mulch materials on soil surface or by growing cover crop. Crop residues and plastics may be potentially utilized as mulch. Placement of these materials on surface, restricts the solar radiation transmission, and also provided physical barrier for emergence of weeds, resulting in lower weed population. Mulching provided control weeds to the extent of 30 to 85%, however, it largely depends on mulch materials.

Population density: In the cultivation of soybean, density of cultivated plants is kept constant in the field while weed density varies with high degree of infestation, which is determined by the soil seed bank richness. Change in seed density per unit area per unit time provided least opportunity to weeds for resource mining, resulting into weak weed plants and ultimately lower weed dry biomass. However, excessive plants of soybean per unit area may not be suitable to achieve potential yield, hence, optimum seeds may be sown.

Row spacing: The adoption of narrow row spacing during the cultivation of soybean has potential for higher yields as compared to the wider row spacing. Soybean should be planted in narrow rows to suppress the initial weed establishment. Higher yields in narrow row spacing are usually attributed to equi-distant

arrangement of crop plants that decreases the intra-species competition for water, nutrients, and perhaps most importantly, light. Besides the potential yield advantages, many producers found that narrow-row spacing has a significant impact on weed populations and their approach to weed management.

Fertilizer application: Placement of fertilizers 2-3 cm below the crop seed played crucial role, as initial placement of fertilizer, provides nutrients only to the crop but not to the weeds. Initial suppression of weeds, resulted in lower weed population and seed production ultimately lowering weed seed bank.

Mechanical method of weed management

Mechanical weed management can be applied as an intervention within the crop and as a preventative measure or as part of pre-season/on season land preparation. This type of primary and secondary tillage, helps to reduce the rate and spread of certain perennial weeds and can also kill emerged weed seedlings. This can also bury weed seeds below the germination zone. Weeding by mechanical methods also include the use of hand hoe and wheel hoe etc. Hand or wheel hoeing is a post-planting intercultural operation and require less manpower than hand weeding. However, line sowing is a pre-requisite for it. Use of rotary hoe and cultivator can be

valuable implements for weed control in soybean, if operated properly and by doing this around 70% weed control can be achieved until weeds are 1-3 leaf stage. An alternative use of herbicides is the mechanical control of weeds. Inter-row harrowing leads to high weed control efficiency and also lowers the risk of crop damage as compared to hand weeding. However, weeds in the intra-row space are not sufficiently controlled by hoeing, and additional tools, such as harrow implements and finger weeders may be used to achieve higher weed control. Further more, precision steering technology (e.g., RTK-GNSS or camera steering systems) could be used to improve the accuracy of the intra-row elements and increase the effective weed control in the intra-row space while simultaneously reducing the risk of crop damage.

Harrowing: Harrowing play an important role in reducing the weed population. Harrowing before planting can also help reduce effect of weed in soybean. Discing kills the weeds that are growing with soybean but also brings weed seed to the surface. It is recommended that perennial weed should be allowed to grow one or two weeks before discing.

Hand weeding: Hand weeding in soybean was recommended where herbicides cannot be used especially in small-scale production. Soybean can be hand weeded 2-3 times to achieve adequate control in area where labour wages are low and labours are easily available in good numbers during peak period of demand..

Interculture with handy tools: As per the availability and suitability interculture operations need to be follow in order to reduce the weed diversity between rows.

Chemical method

Herbicides are potential tool to the farmer for controlling weeds. Application of non-selective herbicides before sowing may control all shot of weeds. Herbicides must be applied within narrow rates of application because at under rate of application, there will be inadequate

and too high rate of application will kill the crop seedlings also. In intercropping system, there is some limitation to use compatible herbicides. Translocated herbicides are readily absorbed by leaves and transported in the symplast; hence effectiveness in controlling perennial weeds and killing underground buds as well as apical meristems is more. Contact herbicides, are not translocated, hence weeds easily regenerate and can only achieve better control of annual weeds. As per the application timings herbicides are classified as pre-plant incorporation, pre-emergence, and post-emergence. Application of pre-plant incorporation in intercropping may increase plant damage and also kill the seedling at early stage. Therefore, for chemical weed control, intensive knowledge is required to know about selectivity of herbicides in different crops and cropping systems. Sometimes, herbicide residues from previous crops can cause problem in soybean cultivation e.g. atrazine applied to a previous corn crop can reduce soybean stand and affect yield. Some herbicides such as metribuzin and bentazon proved effective in the temperate regions but in the tropics either give poor weed control at recommended rates or cause phyto-toxicity. The use of herbicides can curb weed biomass production upto 99% and is therefore the most cost effective measures for weed control. However, a few herbicides are registered for soybean in India. Although new generation herbicides are having wide spectrum weed control ability and can be effectively controlled by a single application or a combination of different herbicides (Table 1).

Pre-plant incorporation: Herbicides applied one week to one day before sowing is called pre-plant incorporation. The herbicide i.e. fluchloralin etc. is applied and incorporated before final land preparation to the surface of the soil with the help of rotavator or disc harrow.

Pre-emergence herbicides: Pre-emergence herbicides are applied one or two days after sowing of a crop but before the emergence of crop.

Table 1. Potent herbicides for control of weeds in soybean

Time of application	Herbicides	Active ingredient	Dose (g/ha)
Pre-plant incorporation	Fluchloralin	45% EC	1,000-1,500
Pre-emergence	Pendimethalin	38.7% CS	682.5
	Metribuzin	70% WP	350-525
	Alachlor	50% EC	2500
	Metolachlor	50% EC	1000
	Oxyfluorfen	23.5% EC	100
	Diclosulam	84% WDG	22-26
	Pendimethalin+ imazethapyr	30% + 2%	1000
Post-emergence	Imazethapyr	10% SL	100
	Fenoxaprop	9.3% EC	80-100
	Quizalofop	5% EC	40-50
	Propaquizafop	10% EC	50-75
	Chlorimuron	25% WP	6-9
	Clomazone	50% EC	750-1000
	Fluazifop-p-butyl	13.4% EC	120-250
	Imazethapyr + Propaquizafop + imazethapyr	35% + 35% WD	70
	Fomesafen + fluazifop-p-butyl	2.5%+3.75% ME	125
	Fomesafen + fluazifop-p-butyl	11.1% + 11.1% SL	313
	Sodium acifluorfen + clodinafop propargyl	16.5%+8% EC	245

Although the emergence of crop is taken into consideration, the emergence of weeds is equally important for designating many pre-emergent herbicides i.e. pendimethalin, oxyfluorfen, metribuzin, metolachlor, etc. Pre-emergence herbicide is preferred because of its better efficiency along with time involvement. Also, it causes no mechanical damage to the crop that happens during manual weeding. Moreover, the control is more effective as the weeds even within the rows are killed, which invariably escape, because of morphological similarity to crop, during mechanical control. Effective weed control depends on the proper selection of herbicides, type of weed flora infesting the crop, time of application and further use of optimum dose of herbicide and suitable nozzle i.e. flat fan or flood jet.

Post-emergence herbicides: The use of post-emergence herbicides alone or in combination may broaden the window of weed management through broad-spectrum weed control. Recently, some new post-emergence herbicides viz. imazethapyr, sodium acifluorfen, quizalofop ethyl, fenoxaprop-p-ethyl, etc. are being marketed with the assurance of selective control of

weeds in soybean. The imazethapyr allowed much flexibility in timing of the applications. Imazethapyr may be applied as pre-plant initiation, pre-emergence or as post-emergences because it can translocate in xylem and phloem both. Although, application of fenoxaprop-p-ethyl at 80 to 100 g/ha effectively controlled the predominant grassy weeds like *Echinochloa colona* and *Paspalum distichum* and recorded significantly lower weed dry matter, higher weed control efficiency and seed yield of soybean. Recently, ready-mix combinations of herbicides are in vogue, which have wider weed control ability and these are being largely used by soybean growers so as to reduce the cost of weed control.

Biological weed control

Biological weed control is the use of natural enemies i.e. fungi, bacteria, virus, insects, birds, fish etc. It is capable in reducing the weeds population and their ability to compete with crop plants. This is maintained by the population balance between the natural enemy and the host plant. Use of plant pathogens to control weeds in soybean was highly successful in temperate agriculture. Currently, one fungus species is registered as bio-herbicide in the United States for use in soybean.

Collego®, based on *Colletotrichum gloeosporioides* f.sp. *aeschynomene*, is used to control *Aeschynomene virginica* (northern joint vetch), a leguminous weed, in soybean and rice crops in Arkansas, Mississippi, and Louisiana. It can be tank mixed with *acifluorfen* to control *Sesbania exaltata*. *Altanaria cassicae* was reported to control sickle pod in soybean. However, in India limited information is available in relation to biological weed control in soybean.

Integrated weed management

Presently, a various weed control methods were found to be effective in controlling weeds in soybean; however, every method has their own advantages and limitations. Single method of weed control may not provide season long and effective weed control. Under such situation, an integrated weed management practice involving preventive, cultural, mechanical and chemical methods could be an efficient tool, as increasing crop density seems to be an alternative to shift crop-weed competition in favour of crop.

Integrating best agronomic practices, timeliness of operations, retaining crop residues on the soil surface, optimum fertilizer and suitable water management practices improve the weed control efficiency of applied herbicides and competitiveness against weeds. After sowing, application of pre-emergence herbicides followed by one hand weeding at 25-30 days after seeding, drastically reduced the weed population, which favour the crops in growth and development. Disregarding the high cost, weed

might be controlled in soybean crop using good management practices of all available methods, combining them in an integrated weed management. Crop rotation is a rather efficient method, since it allows an easy control of the most troublesome weeds. To achieve success on crop rotation, weeds must be managed throughout the soybean growing season. Using full capacity of crop competition is another alternative, yet this tool is often overlooked.

Similarly, combination of cultural (seed rate), mechanical (hand hoeing/ weeding at 25-30 days after seeding and herbicide (pre-mix application of imazethapyr + pendimethalin (1 kg/ha) or pendimethalin at 0.75 kg/ha or metribuzin at 375-500 g/ha, pre-emergence) noticeably reduce the weed density and weed dry weight of soybean resulting in balanced productivity and ultimately profitability. To minimize the production cost, sequential application of pre-emergence followed by post-emergence herbicides need to be adopted, which prevent the initial and later flush of weeds. If at all any weeds left over that may be uprooted manually or localized spray of herbicide. However, as per the abundance of weed type herbicides need to be selected for spray, In the area where more of grassy weeds are present in soybean field, post-emergence application of fenoxaprop-p-ethyl 90 g/ha or quizalofop-ethyl 50 g/ha at 30 days after seeding significantly minimize the grassy weed pressure. In broad leaved weeds abundance fields, chlorimuron at 6-9 g/ha at 25-

30 days after seeding were found effective. However, in presence of wide range of weeds herbicides such as imazethapyr 100 g/ha or tank mix of fenoxaprop + chlorimuron (60 + 9 g/ha) or pre-mix of imazethapyr + imazamox 70 g/ha/propaquizafop + imazethapyr 125 g/ha/ sodium acifluorfen + clodinafop 245 g/ha/ fomesafen + fluazifop-p-butyl 313 g/ha have been found effective for wide spectrum weed control in soybean.

SUMMARY

During rainy season, congenial weather conditions favour weeds to germinate and establish and offers competition to the soybean, resulting 40-60% of loss in productivity. Weeds in soybean can be managed mechanically by low-cost hand tools or inter-row cultivation between 2 and 4 weeks after sowing. Cultural practices such as crop rotation, intercropping, stale seed bed, soil solarization, mulching, weed competitive crop cultivars etc. help in reducing weed problem. However, to combat with the compounded problems due to weeds chemicals weed management such as metribuzin, metolachlor, pendimethalin, imazethapyr, fenoxaprop, chlorimuron (PoE) and some ready mix such as imazethapyr + imazamox, propaquizafop + imazethapyr, fomesafen + fluazifop, acifluorfen+clodinafop was found effective and economical.

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