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Management of weeds in food legumes

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Abstract

Weeds are one of the major constraints in sustainable production of all crops including food legumes. The food legumes are mostly grown under rainfed/dry land conditions and hence do not receive the best management practices that are required for maximization of crop productivity. Crops, particularly grown during rainy season or under irrigated conditions are more heavily infested with weeds and hence experience heavy losses in crop yields if weed management is not adequately done. The crops are infested with such diverse weed flora that integration of different methods of weed management is needed for realizing the full potential of the crop. The major weeds associated with food legumes are *Trianthema portulacastrum* and *Echinochloa colona* during rainy season, *Pluchea lanceolata, Convolvulus arvensis, Carthamus oxycantha*, *Vicia sativa* and *Asphodelus tenuifolius* (in dry lands), *Cichorium intybus, Medicago hispida, Chenopodium album, Phalaris minor* and *Avena ludoviciana* (in irrigated lands) during winter season. Parasitic weed *Cuscuta* spp. is a serious problem in lentil, greengram and blackgram especially in rice-fallows. Broomrape (*Orobanche* spp.) is a great menace in several food legumes and is particularly very serious in faba bean and lentil in the Mediterranean region. Cultural, mechanical and manual methods are the principal methods used in the management of weeds in food legumes in many regions. However, perennial weeds *viz*., *Cyperus rotundus, Sorghum halepense* and *Cynodon dactylon* are not controlled due to their re-emergence. The effectiveness of manual or mechanical methods of weed removal could be enhanced by their timely application at the field level. Herbicides are an effective alternative particularly in places

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where labour is expensive or in short supply although, their use is limited in much of the less developed countries due to a variety of reasons. The herbicide use in soybean is, however, very extensive mainly in the USA, Brazil and other developed countries. Most recently transgenic crops resistant to non-selective herbicide like glyphosate provides producers the flexibility to control a broad spectrum of weeds including parasitic and difficult-to-control weeds with minimal crop damage. Despite growing criticism, herbicide tolerant soybeans occupied 48.4 million hectares, representing 60% of the global transgenic crop area of 81.0 million hectares for all crops in the year 2004.

Introduction

Weeds are a major constraints in crop production in general, and more so in food legumes due to their slow initial growth, and short stature. Often these crops are restricted to poor and marginal lands hence do not receive adequate inputs and modern crop production technologies including the ones meant for management of weeds. Weed problems vary according to crop, agro-climatic region and the season when it is grown. Most of the area under food legumes is rainfed/dryland. Weeds compete with the crop plants for soil moisture, solar radiation, space and nutrients. When improved agricultural technologies are adopted, efficient weed management becomes even more important, otherwise the weeds rather than the crops benefit from the application of costly inputs. Ali and Lal (1989) reported that among various production inputs, weed management was found to be the most important one contributing about 31% in pigeonpea, 110% in urdbean and 60 % in mungbean towards total productivity. In chickpea, weed management contributed the most followed by fertilizer use and insect pest and disease control.

Major Weeds

Food legumes are grown throughout the year, hence weed flora also vary depending upon the season. The magnitude of weed problem varies with the agro-ecological conditions and the level of management. Crops grown in rainy season are more heavily infested with weeds than the crops grown in winter and spring season due to adequate soil moisture and congenial growing conditions.

In India *Trianthema portulacastrum* is the most serious weed in food legumes grown during monsoon and spring/summer seasons. During winter season under rainfed conditions, *Pluchea lanceolata* and *Carthamus oxycantha* are very serious weeds. *Pluchea* is a deep-rooted perennial weed in rainfed chickpea, lentil etc., particularly in light soils. It defies all cultural, mechanical and manual methods of removal. Its chemical control options too are limited.

The seeds of *Lathyrus aphaca, Vicia sativa* and *V. hirsuta* are such in shape and size that their separation from lentil, chickpea and peas is difficult. These weeds hence pose a serious problem in seed production and processing of these crops. *Saccharam spontaneum* and *Asphodelus tenuifolius* are also posing serious threat in chickpea and lentil cultivation in light and dry soils in Bundelkhand region, South Haryana, Northern and Central M.P. *Cichorium intybus, Medicago denticulata* and *Convolvulus arvensis* are also the emerging problem weeds in winter legumes.

Parasitic weeds *Cuscuta campestris* in mungbean and urdbean in rice-fallows in coastal Andhra Pradesh, Tamil Nadu and in chickpea and lentil in parts of Madhya Pradesh and Chattisgarh are a huge problem. *Orobanche* spp. a total root parasite infests over 16 mha cropland worldwide with major hosts including sunflower, food & forage legumes, vegetable crops, tobacco, etc. It is most severe on chickpea, fababean, lentil and peas in the Mediterranean countries, Europe, Asia and America. *O. crenata* and *O. foetida* are the common species infesting food legumes the world over. The infestation in fababean is particularly serious in Morocco, Tunisia, Algeria, and Egypt. In morocco, an estimated 133,000 ha of fababean is reported to be experiencing 12-33% loss in yield. About 45% of the cropped area in Tunisia is affected with a yield loss ranging from 50-80%. Similarly, about 30% of the cropped area in Egypt is infested with *Orobanche* of which 50% is considered very serious. *O. ramosa* is a serious weed of beans and peas in Egypt, of chickpea and lentil in the Near and Middle East and of several legumes in Italy. *O. minor* is quite problematic in beans and peas in Egypt, legumes in Czechoslovakia, Italy, Egypt, Australia and Hungary. The planting of beans and peas has been abandoned in some areas of Malta, Morocco and Sicily due to severe infestation of crops with *O. ramosa.* The growth of parasitic plant biomass below ground is so vigorous at times that it may weigh several times more than the crop to which it is attached.

Bromus rigidus, Lolium rigidum, Avena strerilis, Phalaris spp etc. are some of the other major weeds in the Near and Middle East.

Critical Period of Crop-Weed Competition

One of the major principles of crop-weed competition is that the plants established in the field earlier smother another species of plant coming at later stages. Food legumes are very slow in seedling growth and they do not have much canopy in terms of branching and leaf size during initial growth to stand up to weed competition. Emergence of weeds in food legumes begins simultaneously with the crops leading to severe competition between weeds and the crop right from the very early stage. But weeds on account of their better adaptation and survival mechanism under adverse conditions grow faster and outgrow crop plants easily. The degree of loss depends upon the nature and magnitude of weed infestation. This period varies in different pulse crops. In rainy season, weeds keep emerging almost throughout the crop season because of favorable temperature conditions and frequent rains. The degree of yield loss depends on the nature of weeds and the stage and duration of weed crop competition (Table 1). Therefore, the weed free requirement of different food legumes is of utmost importance to make weed management practices more effective and economical.

Weeds compete with crop plants for various production resources such as nutrients (Table 2), moisture, sunlight and space and consequently reduce yield and quality of produce. Food legumes being poor competitor to weeds especially during initial growth stages suffer considerable yield loss. The potential yield loss varies from 18-90% depending upon the growing conditions, crop species and management practices. Weeds also reduce the yield potential indirectly by serving as alternate host to a number of crop pests e.g., *Vicia sativa* in chickpea provides shelter to *Helicoverpa armigera*, a major pest of chickpea (Chauhan *et al.*, 1991).

Table 1. Effect of different weed free periods on seed yield (kg ha^{-1}) of different pulse crops

Treatment	Mungbean*	Urdbean*	Lentil*	Chickpea*	Peas**
Weed free up to first					
15 DAS	512	621	-	-	-
30	890	868	1635	1533	820
45	899	899	-	-	1310
60	877	923	2271	1967	1280
75	-	-	-	-	1280
90	-	-	2365	1917	-
Weed free up to harvest	894	947	2292	2050	1420
Weedy up to harvest	243	219	797	1217	645
LSD (P=0.05)	60	72	142	232	185

*Singh, (1993), **Singh *et al.* (1991).

Table 2. Nutrient removal (kg ha^{-1}) by weeds and legume crops

Crops	Nitrogen		Phosphorus		Potassium		Reference
	Crop	Weed	Crop	Weed	Crop	Weed	
Mungbean (rainy season)	12.4	132.2	5.3	17.6	10.3	130.1	Yadav *et al.* (1985)
Mungbean (summer season)	55.6	79.1	10.2	19.8	49.1	79.1	Kundra *et al.* (1991)
Urdbean	73.4	76.3	-	-	-	-	Kumar *et al.* (1985)
Pigeonpea	-	28.4		23.7		14.2	Singh *et al.* (1980)
Chickpea	32.3	54.6	5.0	7.7	47.3	72.4	Dadhich and Mali (1991)
Peas	30.6	71.6	5.8	14.4	33.1	105.0	Ahlawat *et al.* (1983)
Soybean	-	53.2	-	9.3	-	-	Chhokar *et al.*, (1997)

Weed Management

The weed management in food legumes requires an integrated approach wherein elements of effective cultural, mechanical, biological, ecological and chemical methods are required to be incorporated into the crop production system with due consideration of economic, environmental and sociological consequences. Different methods of weed management are briefly discussed below.

Cultural Management

Despite the great progress made in agriculture, manual and mechanical methods continue to be important weed management practices in many regions of the world. Cultural methods are used to complement manual and mechanical methods. Cultural practices such as method and time of sowing, crop density and geometry, crop species and varieties, method and time of fertilizer application, mulching, crop rotation and intercropping, time of irrigation, soil-solarisation etc., have pronounced effect on crop-weed interference. Cultural practices are manipulated in such a way that they become more favourable for crop growth and less to weeds. They are not only eco-friendly but are cost effective as well. However, their impact is substantial only when they are practiced collectively.

Sowing Time

Planting time considerably influences the occurrence and manifestation of weed species. In timely sown chickpea, the weed population by 30 days is generally quite high to attract manual weeding whereas in late sown chickpea the build up of adequate weed flora is only after 45 days. Delayed sowing of lentil and chickpea is also reported to reduce the infestation of *Orobanche* – a root parasite (Linke and Saxena, 1989). Malik *et al.* (1988) reported that in chickpea, the maximum emergence of most competitive weed, *Chenopodium album* L. occurred when crop was sown on November 5 and declined gradually with delay in sowing. However, in most winter pulses this can not be a viable approach as delayed sowing invariably results in reduced yield. Sinha *et al.* (1988) reported that early sowing (10 August) and closer row spacing (30 cm) reduced the weed growth and increased the dry matter accumulation, LAI, NAR, CGR and grain yield of irrigated pigeonpea at Kalyani (West Bengal).

Planting Geometry

Planting density and pattern modify the crop canopy structure and in turn influence weed-smothering ability. Narrow row spacing will bring variation in micro-climate viz., light intensity, evaporation and temperature at soil surface. Increased shading at soil surface will smother weed growth. Narrow row spacing are known to suppress the weed growth (Sinha *et al.*, 1988), however, degree of suppression varies greatly. In *Phaseolus vulgaris*, (Tesadale and Frank, 1983) found that closer row spacing suppressed weds effectively than wider row spacing.

Intercropping

In wide spaced food legume crops such as pigeonpea, intercropping of short duration and quick canopy forming crops is a common practice, which besides covering risk will reduce weed infestation. Patel *et al.* (1983) found that intercrops suppressed the weeds and increased the total productivity.

Crop Rotation

Rotation among crops having drastically dissimilar life cycles or requiring different management practices is useful in disrupting weed cycle. Sankaran and Chinnamuthu (1993) found that *Paspalum dilatum* was nearly eliminated after three crops of rice-maize-mung bean, whereas *Digitaria ciliaris* became dominant. In rice-rice-urdbean system, a 70 per cent increase in *Cyperus rotundus* population has been reported (Laesino, 1980). Crop rotation is one of the most effective and practical ways of management of parasitic weeds such as *Cuscuta* and *Orobanche.* However, this strategy is not acceptable to many farmers as this has to be continued for many years for complete elimination of these weeds due to the presence of long seed dormancy. One of the better options is to rotate with trap crops, which induce germination of parasitic weed seeds, but they themselves are not parasitised. The suggested trap crops for *O.crenata* include sorghum, barley, clover, flax and coriander (Goldwasser and Kleinfeld, 2004).

Nutrient Management

The role of phosphatic fertilizers in food legumes is well recognized. They increase root development and nitrogen fixing capacity of root nodules. Kumar *et al.*(1996) reported that weed number and biomass were reduced significantly due to increased levels of phosphorus.

Competitive Cultivars

Cultivars differ in relative growth rate, spreading habit, height, canopy structure and inherent competitive character and accordingly differ in their weed suppressing ability. A quick growing and early canopy-producing cultivar would be expected to be better competitor against weeds than crops lacking these characters. Malik (1990) reported that whitebean cultivars varying in growth habit differed in their ability to compete with weeds. Mishra and Bhan (1997) found that pea cultivar JP 885 was quite effective in suppressing weeds and recorded better seed yield over cultivar JM-1. This approach could only be successful provided plant breeders identify weed suppression traits as important ones for inclusion in their breeding programs.

Mechanical Methods

Mechanical weed control involves removal of weeds with various tools and implements including manual removal by hand weeding. Inter-cultural operations are performed primarily to destroy the weeds present in the field and create favourable soil conditions for growth of food legumes. Hand hoeing and manual weeding are the common practices followed in almost all food legumes crops in many countries. One or two hand weedings at critical crop-weed stage provide satisfactory control of weeds in most of the food legumes. Extra weeding may be required if crops are infested with perennial weeds. In pigeonpea, two mechanical weedings, one at 25-30 DAS and another at 45-50 DAS have been found to be as effective as complete weed free conditions. In soybean, mungbean and urdbean, two hand weedings at 25 and 45 DAS are found effective in controlling weeds. In winter season legumes *viz.*, chickpea, peas, lentil, frenchbean and fababean, two weedings one at 30 days and another at 60 days after sowing provide an effective control of all the weeds. Although widely practiced, effective weed control is dependent on the timeliness of weed removal. Further, adverse soil conditions and higher labour costs may limit their use in many regions.

Chemical Control

Weed control through manual/mechanical methods is not always efficient or cost effective. Unavailability of labour during peak period, high labour cost, unfavourable environment particularly in rainy season etc often limit adoption of manual or mechanical methods of weed control.. Under such conditions, use of herbicides is advantageous and economical. In the use of herbicides for weed control important considerations that have to be kept in mind are; herbicides should not be harmful to the beneficial soil microflora, the harvested produce should not contain any herbicide residue that may prove detrimental to the health of human beings and livestock and herbicides should not leave any residues in soil which would injure crops grown in rotation. The most promising herbicides are listed in Table 3. However, it may be remembered that a single herbicide will not control all weeds and continuous use of a herbicide may lead to shift in the weed flora or development of herbicide resistance in weeds. Therefore, it is desirable to integrate other non-chemical methods of control along with chemical method.

Table 3. List of promising herbicides with their rates and mode of application for different food legumes

Crop	Herbicides	Dose (kg ha^{-1})	Time of application
Pigeonpea, mungbean and urdbean	Alachlor	1.0-1.5	PE
	Fluchloralin	1.0-1.5	PPI
	Metolachlor	1.0-1.5	PE
	Metribuzin	0. 25	PE
	Oxyfluorfen	0.10-0.15	PE
	Oxadiazon	0.50-0.75	PE
	Pendimethalin	1.0-1.5	PE
	Trifluralin	1.0-1.5	PPI
Cowpea	Alachlor	1.0-1.5	PE
	Fluchloralin	1.0-1.5	PPI
Pea, chickpea and lentil	Fluchloralin	0.75-1.0	PPI
	Linuron	0.75-1.0	PE
	Metribuzin	0.25	PE
	Oxyfluorfen	0.1-0.15	PE
	Pendimethalin	1.0-1.5	PE
	Clodinafop	0.060	30-35 DAS
French bean	Oxyfluorfen	0.20	PE
	Pendimethalin	1.0	PE
Lablab bean	Fluchloralin	1.0-1.25	PPI
	Metolachlor	0.75	PE

PE = Pre-emergence, PPI = Pre-plant Incprporation, DAS = Days after sowing

Effect of Herbicides on Nodulation

Most herbicides at their recommended rate and time of application are not known to adversely affect the soil microflora. If at all there is some effect, it is considered to be transient and reversible. Praharaj and Dhingra (1995) observed that application of pendimethalin 0.50 kg/ha neither had any adverse effect on the nodulation and nitrogenase activity nor it influenced the efficiency of rhizobial inoculants in terms of biological nitrogen fixation (BNF) in soybean. *Rhizobium* inoculation irrespective of the method of weed control (chemical or manual) enhanced the BNF and fixed an additional 66.1-74.7 kg N/ha over uninoculated control.

Integrated Weed Management

Considering the diversity of weed problem, no single method of weed control, whether manual, mechanical or chemical could provide the desired level of efficiency under all situations. The most recognized approach to weed control is based on combination of manual, cultural and mechanical methods with herbicides. Herbicides could be used as a supplement at as low a rate as possible. Judicious combination of cultural and chemical methods of weed control is considered appropriate from the stand point of sustainability and safety to environment. In rainy season, because of the continuous rains many a times, early weed removal may not be possible and the use of pre-emergence herbicides for removing early weed competition and supplementary hoeing or hand weeding for removing later emerging weeds may form a package of weed control practices. Integration of lower rates of pre-emergence herbicides with one hand weeding or hoeing at 30-40 DAS provides excellent control of weeds in most situations.

Orobanche Control

Considering the importance of this parasitic weed a separate discussion on its control is given in this section. Amongst the control methods of *Orobanhce,* crop rotation systems involving trap crop, catch crops and non-host crops are considered important. Theoretically, repeated planting with non-host plants for many seasons should deplete the parasitic weed seed bank in the soil. However, this may not be considered as a practical approach because of very long seed dormancy of *Orobanche* seeds in the soil (Goldwasser and Kleifeld, 2004). However, growing trap crops that stimulate the germination of *Orobanche* seeds but they themselves are not parasitized is considered highly useful in depleting soil seed bank. Some of the important trap crops for *O. crenata* are sorghum, barley, vetch, fababean, clover, flax and coriander (Goldwasser and Kleinfeld, 2004). Similarly, planting 'catch crops' i.e. an *Orobanche* host crop, which will be destroyed after inducing parasite seed germination and attachment, would be similarly effective. In this case, vigorous and densly planted host crop is preferred such as faba bean (*Vicia alba*) for *O. crenata.*

Soil Solarization is a promising technique in the management of *Orobanche.* By covering of soil with transparent polythene sheet, the soil temperature is increased to the level lethal for weeds. Soil temperature increases to the tune of 8-12 °C by soil solarization over corresponding non-mulched soil. Sauerborn *et al.* (1989) reported an excellent control of *Orobanche* in fababean and lentil with 20-50 days of solarisation treatment (Table 4). Although the technology is very promising it has limited application due to its high cost.

Improving soil fertility effects the ability of the host plant to cope with the parasitism primarily on sites that are located on poor soils. Adding nitrogen fertilizers is reported to

Table 4. Duration of solarisation on broomrape infestation in fababean and lentil

Days solarised	Broomrape			
	fababean		lentil	
	No. (m^{-2})	Dry wt. ($g\ m^{-2}$)	No. (m^{-2})	Dry wt. ($g\ m^{-2}$)
0	115	152	61	33
20	57	122	32	37
30	33	65	25	35
40	26	57	22	29
50	13	41	4	4

have a positive effect on reducing *Orobanche* infestation and damage, while no effect was achieved by adding potassium or phosphorus (Linke, 1999).

Although several chemicals have been found effective against *Orobanche*, not many could be used successfully due to a variety of reasons. Soil applied herbicides are either non-selective to the crop or may not reach the depths where it is required. The weed emerges quite late in the season but defeating any post-emergence application of herbicides. Repeated post-emergence application of glyphosate (at 60-80 g/ha) has been found to be successful in controlling *O. crenata* in fababean, pea and lentil in several countries (Goldwasser and Kleinfeld, 2004). The small parasitic tubercles attached to the host roots, were sensitive to the low doses of the herbicide, which is otherwise non-selective to many crop plants. It is worth investigating this performance of glyphosate in chickpea. Similarly, imidazoline herbicides, which are selective to many food legumes, also appear promising control. Garcia Torres *et al.* (1998) reported selective control of *O. crenata* in fababean by pre-emergence and post-emergence applications of imazethapyr, imazapyr and imazaquin. However, no published information is available of their use in chickpea.

Development of genetically engineered herbicide resistant crop varieties offer new possibilities of *Orobanche* control in many host crops including chickpea. For greater discussion an *Orobanche* control, readers are directed to recent review by Goldwasser and Kleinfeld (2004).

Herbicide Resistant Crops

Imparting herbicide resistance to normally herbicides susceptible crops to produce herbicide-resistant crops has been the most extensively exploited area of plant biotechnology. During the last eight years (1996 to 2003), global adoption rates for transgenic crops have been unprecedented and reflect grower satisfaction with the products that offer significant benefits ranging from more convenient and flexible crop management, higher productivity or net returns/hectare, and a safer environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. Despite the growing controversy the area under transgenic crops is increasing at a faster rate. The transgenic crops resistant to non-selective herbicide like glyphosate introduced recently provide producers the flexibility to control a broad spectrum of weeds with minimal crop damage.

Herbicide tolerant soybean occupied 48.4 million hectares, representing 60% of the global transgenic crop area of 81.0 million hectares in the year 2004. The first use of herbicide resistant soybean was in 1994 with the introduction of STS (Sulfonylurea tolerant) soybean varieties, glyphosate (Roundup Ready) and glufosinate (Liberty Link) resistant soybean are now commercially available. Glyphosate resistant (Roundup Ready) soybean varieties have been widely adopted for planting by the American farmers since its introduction in 1996.

Conclusion

Weed management in food legume crops is a challenging task due to emergence of weeds in flushes, unpredictability of rains, non-workable soil conditions and non-availability of timely labour, non-availability of broad spectrum herbicides etc. Considering the diversity of weed problem, no single method of weed control, whether manual, mechanical or chemical would be sufficient to provide season-long weed control under all situations. Integrated weed management system as a part of integrated crop management system would be an effective, economical and eco-friendly approach for weed management in food legumes. Combination of pre-emergence herbicides with manual or mechanical weeding would be required for effective weed management. Sequential application of pre and post-emergence herbicides may provide broad-spectrum weed control. Parasitic weeds *viz*., *Cuscuta* and *Orobanche* are becoming serious threats to food legume cultivation in many parts of the world and their control as on now is unsatisfactory. There is a need for effective herbicides and bioagents for their control. There is an urgent need for developing mycoherbicides for the management of parasitic weeds and for using biotechnology and molecular techniques to improve the efficacy of plant pathogens. Similarly, efforts must be intensified in identifying the sources of resistance to *Orobanche* for their incorporation in to crop plants. Glyphosate resistant (Roundup Ready) soybean varieties have found instant success in the USA and other major soybean growing countries of the world. Considering the several advantages of using the herbicide resistant soybean, it is worthwhile exploring their possible use under Indian conditions.

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