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Efficient weed management in pulses for higher productivity and profitability

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ABSTRACT

India is the largest producer, consumer and importer of pulses. There is a huge shortage of pulses in the country to meet the domestic demand of predominant vegetarian population. The low production and productivity of pulses is mainly due to several biotic and abiotic constraints. In general, the pulse crops are more susceptible to these stresses including weeds. An estimate shows yield losses due to weeds are more than either insect-pests or diseases. Pulses are mostly grown by poor farmers on marginal rainfed lands with low or no inputs. Further, these crops are treated on low priority compared with rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.). Little attention has been given in past by researchers also for developing strategies for weed management in pulses. A few herbicides are registered in India for use in pulses, and that too only as pre-emergence or pre-plant incorporation. Due to these reasons, most weed-management recommendations in pulses involve application of pre-emergence herbicide followed by manual weeding. But due to implementation of different development programmes in the country, shortage of labour is realized in agricultural operations, especially for weeding. Therefore, development of alternative methods including use of post-emergence herbicides has become necessary in pulses. At present, area under conservation agriculture is increasing in the country which mainly focuses on crop diversification with pulses. Thus, there is need to develop long-term strategic research for weed management in pulses.

Key words: Conservation agriculture, Crop–weed competition, Herbicide, Nutrient loss, Parasitic weeds, Soil solarization, Weed management

INTRODUCTION

Pulses are the second most important group of foodgrain crops after cereals in India. These are essential for nutritional security, soil health and sustainable agriculture. Developing countries contribute about 74% to the global pulses production, and the remaining comes from developed countries. India, China, Brazil, Canada, Myanmar and Australia are the major pulse-producing countries, with relative share of 25, 10, 5, 5 and 4% respectively. In 2013, the global production of pulses was 81 million tonnes from an area of 73 million ha. Dry beans contributed 31.7% to global pulses production, followed by chickpea (17.9%), dry peas (15.1%), lentil (6.8%) and pigeonpea (6.5%). About 90% of the global pigeonpea, 75% of chickpea and 37% of lentil area falls in India (FAOSTAT, 2009). We are the largest producer and consumer of pulses in the world, contributing around 25–28% of the total global production.

PULSES IN INDIAN AGRICULTURE

A large number of pulse crops (grain legumes) are grown in India including chickpea (*Cicer arietinum* L.), pigeonpea [*Cajanus cajan* (L.) Millsp.], mungbean [*Vigna radiata* (L.) R. Wilczek], urdbean [*Vigna mungo* (L.) Hepper], cowpea [*V. unguiculata* (L.) Walp.], lentil (*Lens culinaris* Medikus ssp. *culinaris*), lathyrus (*Lathyrus sativus* L.), French bean (*Phaseolus vulgaris* L.), horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.], field pea (*Pisum sativum* L.), mothbean [*Vigna aconitifolia* (Jacq.) Marechal] and a few others. The relative coverage under major pulse crops is: chickpea (39.4%), pigeonpea (15.5%), mungbean (15.4%), urdbean (11.9%), lentil (5.6%) and field pea (3%). Presently, total production of pulses is 19.3 million tonnes from an area of 25.2 million ha, with productivity of 764 kg/ha (Fig. 1). The stagnant growth of pulse production over the years and continuous increasing human population in the country led to decline in per capita consumption of pulses from 67 g/day/person during 1951 to 35 g/day/person during 2010 (against the recommendation of 65 g/day/person by the Indian Council of Medical Research). The pulses deficit has remained to the tune of 4–5 million tonnes for long period, which was mainly compensated by import from other countries. However, encouraged by the accomplishments of the last few years and tremendous opportunities available for vertical and horizontal expansion, the future seems to be promising towards achieving self-sufficiency in pulses. In

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order to ensure self-sufficiency, the pulse requirement in the country is projected to be about 50 million tonnes by 2050 which necessitates an annual growth rate of 4.2% (IIPR, 2013).

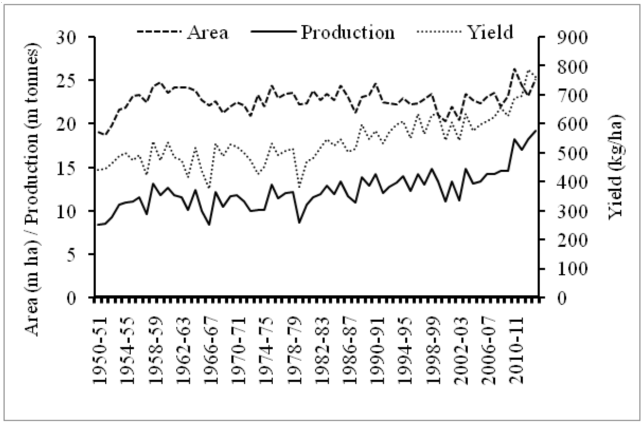

Fig. 1. Area, production and yield trends of total pulses in India

Chickpea continues to be the largest consumed pulse crop, followed by pigeonpea, urdbean, mungbean and field pea. The major pulse-producing states in the country are: Madhya Pradesh (26.4%), Maharashtra (16.2%), Rajasthan (12.8%), Uttar Pradesh (8.9%), Andhra Pradesh including Telangana (8.0%) and Karnataka (7.6%), while remaining 20% is contributed mainly by Gujarat, Chhattisgarh, Bihar, Odisha, Jharkhand and Tamil Nadu (Table 1). Nearly 84% pulses are grown under rainfed condition, also in combination with other non-legume crops, and encounter many types of biotic and abiotic stresses. Further, these crops are grown in almost all types of soil with minimal inputs and care.

Production of pulses has remained almost stagnant over the years since green revolution in the country due to various kinds of biotic and abiotic stresses. Weeds are the principal biotic constraint in production of pulses. It is estimated that out of total annual losses of agricultural produce from various pests, weeds alone account for 37% loss, which is higher than insect-pests or diseases (Kumar *et al*., 2013a). Besides direct reduction in crop yields, weeds also render other farm operations difficult and serve as alternate host for many diseases and insect-pests. Thus, effective weed control in pulses is essential to maximize seed yield and quality, and also to reduce weed competition in following crops. An yield increase of 31–110% in rainy season (*kharif*) pulses like pigeonpea, mungbean and urdbean; and 26–45% in winter season (*rabi*) pulses like chickpea, field pea and lentil has been recorded owing to effective weed management (Chandra, 1982; Ali and Lal, 1989). Most of the weed-control recommendations in pulses involve application of pre-emergence herbicide followed by manual weeding (Balyan and Malik, 1996; Chaudhary *et al*., 2011). Although weed management through manual weeding is effective, it is uneconomical due to higher cost involved. Moreover, non-availability of farm labourers on time for manual weeding calls for use of

Table 1. Per cent share of major states in area and production of pulses in India (2013–14)

State	Area	Production
Madhya Pradesh	21.52	26.41
Maharashtra	15.54	16.19
Uttar Pradesh	16.64	12.82
Andhra Pradesh (including Telangana)	9.14	8.87
Karnataka	6.62	8.04
Rajasthan	9.76	7.63
Gujarat	3.22	3.84
Chhattisgarh	2.25	2.96
Bihar	2.10	2.70
Odisha	3.19	2.44
Jharkhand	3.49	2.28
Tamil Nadu	3.15	2.18
West Bengal	1.04	1.30
Haryana	0.61	0.67
Others	1.74	1.66
All India	100.00	100.00

Source: DAC (2014)

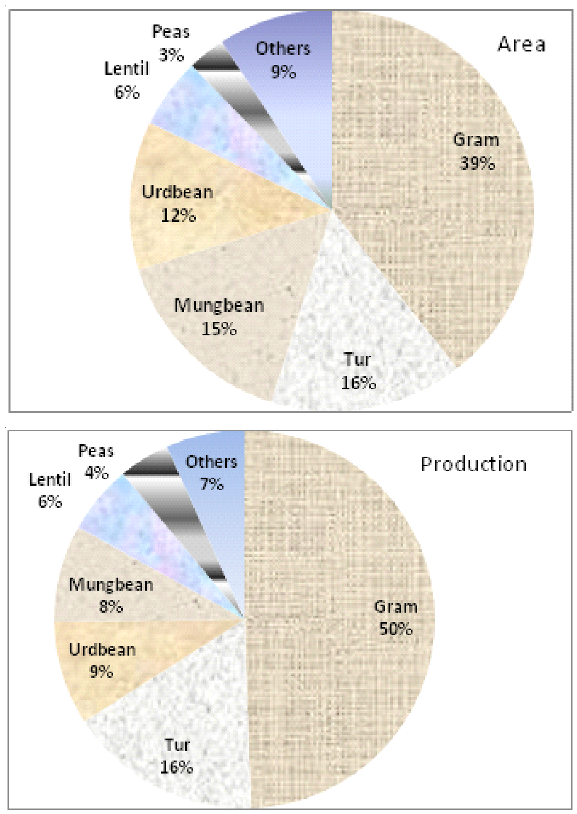

Fig. 2. Per cent share in area and production of different pulses in India

post-emergence herbicide for season-long weed control in pulses.

MAJOR WEED FLORA

Intensity of weed infestation in pulses varies with the agro-ecological condition and cultural practices followed. Various types of weed flora including narrow-leaf (monocots, grasses), broad-leaf (dicots) and sedges are found in different pulse crops (Table 2). The reduction in growth and yield depends on the kind of weed flora and their infestation in the field. Productivity of pigeonpea + sorghum intercropping was affected more due to narrow-leaf weeds and sedges than dicot weeds (IIPR, 2009).

In the rainy season, carpet weed (*Trianthema portulacastrum* L.; syn. *T. monogyna* L.) grows profusely in semi-arid regions. It is also a major weed in summer pulses in Indo-Gangetic Plains. Day flower (*Commelina benghalensis* L. and false amaranth [*Digera muricata* (L.) Mart.] are of secondary importance. *Echinochloa colona* (L.) Link, *makra* [*Dactyloctenium aegyptium* (L.) Willd.], *Digitaria sanguinalis* Scop. and guinea grass (*Panicum maximum* Jacq.) are the major grassy weeds which invade the crops heavily during the rainy season. Nut grass (*Cyperus rotundus* L.) is most common in the summer and rainy season, and offers the rhizospheric competition through its chain of underground tubers. *Kans* (*Saccharum spontaneum* L.) and Johnson grass [*Sorghum halepense* (L.) Pers.] are perennial grasses, which reproduce through underground rhizomes. Quail grass (*Celosia argentea* L.) occurs in the rainy-season pulses in light-textured soils of northern and Bundelkhand regions, and heavy soils of central and southern parts of the country.

In winter season, lamb's quarters (*Chenopodium album* L.), scarlet pimpernel (*Anagallis arvensis* L.) and *Fumaria parviflora* Lam. are found in irrigated as well as in rainfed pulses. *Asphodelus tenuifolius* L. emerges in different flushes and poses problem in rainfed chickpea and lentil throughout northern and central India under light soils (Kumar, 2013). Wild safflower (*Carthamus oxyacantha* M. Bieb.) and prickly poppy (*Argemone maxicana* L.) are troublesome weeds in field pea and other winter pulses, as harvesting and threshing becomes difficult due to their spiny nature. Similarly, deer's foot (*Convolvulus arvensis* L.) binds the plants of chickpea, pea and lentil in northern and central India and renders harvesting difficult (Kumar and Yadav, 2013). Small canary grass (*Phalaris minor* Retz.) and *Avena fatua* L. are the major grassy weeds in winter pulses growing in irrigated condition. Common vetch (*Vicia sativa* L.) has emerged as a major weed in rainfed winter pulses in Bundelkhand region of Uttar Pradesh and Madhya Pradesh. Similarly, *Lepidium didymum* L.; syn. *Coronopus didymus* L. is becoming serious in winter pulses in many parts of India due to its resistance against almost all herbicides and fast-spreading nature due to production of a large number of minute seeds.

Table 2. Major weeds associated with pulse crops

Season / type of weeds	Weed species
Rainy-season pulses	
Broad-leaf weeds	*Celosia argentea, Cleome viscosa, Commelina benghalensis, Cucumis trigonus, Digera arvensis, Eclipta alba, Euphorbia hirta, Phyllanthus niruri, Trianthema monogyna, Convolvulus arvensis*
Narrow-leaf weeds	*Cynodon dactylon, Dactyloctenium aegypticum, Digitaria sanguinalis, Echinochloa colonum, Echinochloa crus-galli, Eleusine indica, Eragrostis tenella, Fimbristylis* spp., *Panicum maxima, Setaria glauca, Saccharum spontaneum, Sorghum halepense*
Sedges	*Cyperus difformis, Cyperus iria, Cyperus rotundus*
Winter-season pulses	
Broad-leaf weeds	*Ageratum conyzoides, Anagallis arvensis, Argemone maxicana, Asphodelus tenuifolius, Carthamus oxycantha, Chenopodium album, Convolvulus arvensis, Coronopus didymus, Fumaria parviflora, Gnaphalium indicum, Lathyrus aphaca, Launaea nudicaulis, Medicago denticulata, Melilotus alba, Rumex dentatus, Solanum nigrum, Spergula arvensis, Vicia hirsuta, Vicia sativa*
Narrow-leaved	*Avena ludoviciana, Phalaris minor, Lolium temulentum, Poa annua, Polypogon monspeliensis*
Sedges	*Cyperus rotundus*
Summer-season pulses	
Broad-leaf weeds	*Amaranthus viridis, Chenopodium album, Eclipta alba, Physalis minima, Polygonum plebejum, Portulaca quadrifida, Solanum nigrum, Trianthema monogyna*
Narrow-leaf weeds	*Cynodon dactylon, Dactyloctenium aegypticum, Digitaria sanguinalis, Eleusine indica, Panicum maximum, Setaria glauca*
Sedges	*Cyperus rotundus*

Source: Adapted from IIPR (2009)

CROP–WEED COMPETITION

Weeds compete with crop plants mainly for nutrients, moisture, light and space. Many weeds secrete toxic allelo-chemicals which adversely affect the growth and development of crops. The competition becomes severe due to smothering effect when weeds emerge earlier than the crop. The initial growth of some pulses like pigeonpea, chickpea and lentil is slower than weeds. Thus, severe problem of crop–weed competition is observed in these pulses. Sometimes total crop failure is also observed due to heavy infestation of diverse weed flora in the rainy season. Maintaining weed-free environment throughout the growth period is difficult and uneconomical. In fact, near maximum yield can be achieved through effective weed control during critical period of crop–weed competition. However, the weeds which emerge later may not reduce the yield but produce large number of seeds for next season. The critical period of crop–weed competition of short-duration pulses like urdbean and mungbean is up to 30 days, while for long-duration crops like pigeonpea, chickpea and French bean, it is up to 60 days.

YIELD AND NUTRIENT LOSSES DUE TO WEEDS

The extent of crop–weed competition for these limited resources and reduction in crop yield are dependent on type and intensity of weed flora present in the field. Ali and Lal (1989) reported 23.6% reduction in yield in pigeonpea, 52.4% in urdbean and 38.3% in mungbean (Table 3). The contribution of weed management in chickpea yield enhancement was observed to be 26.3%, which was maximum than any other factor contributing to yield (Chandra, 1982). In a multi-location study, considerable yield reduction due to weeds was recorded in pigeonpea (46.7%), urdbean (55.4%), chickpea (48.1%), lentil (58.8%) and field pea (47.1%) (Table 4). The variation in yield reduction was mainly due to weed intensity, crop management and agro-climatic conditions (Table 5).

Table 3. Seed yield (kg/ha) of rainy-season pulses as influenced by different inputs

Production factor	Pigeonpea	Mungbean	Urdbean
Control (C)	911	490	412
Fertilizer (F)	953	654	645
Weed control (WC)	1,193	794	865
Insect-pest / disease control (IDC)	913	667	565
Fertilizer + WC	1,344	884	1,054
Fertilizer + IDC	1,244	791	683
WC + IDC	1,291	860	928
F + WC + IDC	1,519	1,071	1,140

Source: Ali and Lal (1989)

The level of weed infestation is directly related to nutrient depletion by weeds, and it was observed to be as high as the nutrient uptake by crop plants under unweeded check (Table 6).

WEED MANAGEMENT

Weeds should be managed in such a way that will encourage the growth of crop plants beneficial to our interests and suppress the remaining unwanted plants (weeds). There are many approaches by which weeds can be effectively and economically controlled in pulses.

Preventive measures

For successful weed management, it is most important to prevent the distribution of weed seeds from one field to another, and from infested to uninfested areas. Weed seeds are dispersed by several mechanisms like wind, water, farm machinery, animals etc. National and international trade of crop seeds contributes to the seed dispersal over long distances. Use of clean crop seed is the most effective preventive method of weed management. It is also important to recognize and eradicate the invasive weeds in a newly infested field to prevent build-up of the weed population. Hand-pulling and burning of weeded plants is necessary to prevent the reproduction of thousands of seeds. In fact the basic principle of managing annual weeds, which reproduce mostly from seeds, lies in killing them before flowering, so as to prevent seed setting and their infestation in the next season.

Crop rotation

Selection of good crop rotation is must to prevent development of diverse weed population in pulses. Growing of sesame (*Sesamum indicum* L.) during the rainy season reduces the weed population including *Cyperus* in winter pulses. Puddling in rice (*Oryza sativa* L.) also helps in minimizing *Cyperus rotundus* in the following chickpea. Similarly, *Phalaris minor* and *Chenopodium album* in chickpea can be minimized by following puddling in rice (IIPR, 2009). Inclusion of pulses in the rainy season can reduce the infestation of *Phalaris minor* and *Avena fatua* in winter crops. Crops like mungbean and urdbean which grow fast and compete with the weeds should be included either as sole cropping or intercropping.

Intercropping

Pulses are normally gown under inter- or mixed cropping in rainfed agro-ecosystems of India. Intercropping has been found to suppress the weeds through formation of good canopies due to competitive planting pattern. The suppression of weed growth in intercropping system is mainly due to increased leaf area and light interception.

Table 4. Yield loss due to weeds in important pulses

Crop	No. of locations	No. of trials	Mean seed yield (kg/ha)		Loss (%)
			Weed free	Weed infestation	
Pigeonpea	16	21	1,573	774	46.7
Urdbean	15	18	1,001	474	55.4
Chickpea	10	13	1,545	767	48.1
Lentil	6	8	1,709	755	58.8
Field pea	9	13	2,094	1,054	47.1

Source: Yaduraju (2002)

Table 5. Yield loss due to weeds in different pulses

Crop	Yield loss (%)	Reference
Pigeonpea	31.0–52.8	Singh and Sekhon (2013)
Chickpea	77.8	Patel *et al*. (2006)
Urdbean	43.3	Choudhary *et al*. (2012)
Mungbean	38.6	Kumar *et al*. (2016)
Lentil	37.7	Yadav *et al*. (2013)
Field pea	50.0	Singh *et al*. (2016)
Rajmash	49.5	Kumar *et al*. (2014)
Lathyrus	46.1	Pramanik *et al*. (2014)
Mothbean	30–40	Bathar *et al*. (2005)

Table 6. Nutrient removal by pigeonpea and weeds under different weed-management practices

Treatment	Seed yield (kg/ha)	Nutrient uptake by pigeonpea (kg/ha)			Nutrient depletion by weeds (kg/ha)		
		N	P	K	N	P	K
Unweeded check	789	59.10	5.88	20.13	26.89	4.11	23.94
Two hand-weedings	1,513	116.99	11.58	41.12	4.72	1.10	5.30
Fluchloralin (1.0 kg/ha as ppi)	1,249	94.93	9.12	32.56	14.70	3.73	11.55
CD (P=0.05)	32	1.02	0.72	0.91	0.37	0.33	0.46

Source: Rana *et al*. (1999)

Inclusion of short-duration and quick-growing intercrops in between the rows of long-duration and tall-growing crops has been found to suppress the weed infestation (Table 7). As a result of considerable reduction in weed weight due of inclusion of intercrops in long-duration wide-spaced crops, the weeding requirements have been found to be reduced substantially (Ali, 1988). In pigeonpea-based intercropping, fast-growing short-duration pulses like cowpea, urdbean and mungbean suppress weed flora by 30–40% compared with 22% by sorghum [*Sorghum bicolor* (L.) Moench] (IIPR, 2009). Critical period for weed control in intercropping systems is slightly longer than that for sole crops. In a long-duration pigeonpea + sorghum system, the critical period of crop–weed competition was extended up to 8–9 weeks (Ali, 1991). In central and peninsular India, pigeonpea + sorghum has been found to be the most productive system on Vertisols, whereas on Alfisols and Entisols, pigeonpea + pearlmillet [*Pennisetum glaucum* (L.) R. Br.] proved to be the ideal system (Ali and Singh, 1997). Talnikar *et al.* (2008) found that weeds caused 79.9% reduction in pigeonpea seed yield if weeds were allowed to grow till harvest. However, the yield losses were only 38.2% in pigeonpea + soybean [*Glycine max* (L.) Merr.] intercropping system. Similar effect was also reported in chickpea + wheat (Banik *et al*., 2006) and chickpea + mustard [*Brassica juncea* (L.) Czernj. & Cosson] (Kaur *et al*., 2014) intercropping systems.

Soil solarization

Soil solarization is a novel technique of management of soil-borne pests and weeds through heating of surface soil by using plastic sheets placed on moist soil to trap the solar radiation. Yaduraju and Ahuja (1990) reported reduction in population of grassy and broad-leaf weeds due to soil solarization. By this method the soil temperature in-

Table 7. Weed-smothering efficiency (WSE) of important cropping system

Intercropping systems	WSE (%)
Pigeonpea + urdbean	32.8
Pigeonpea + mungbean	31.0
Pigeonpea + cowpea	39.1
Pigeonpea + sesame	36.6
Pigeonpea + pearlmillet	50.8
Maize + urdbean	17.3
Maize + pigeonpea	16.4

Source: Ali (1988)

creased by 8–10°C over the corresponding non-mulch soil and thereby most of the annual and perennial weeds belonging to genera *Amaranthus, Anagallis, Avena, Chenopodium, Convolvulus, Digitaria, Eleusine, Fumaria, Lactuca, Phalaris, Portulaca, Solanum* and *Xanthium* were effectively controlled. However, weeds such as *Cyperus rotundus* (tubers), *Melilotus* spp. (hard seed-coat) and *Cynodon dactylon* (rhizomes) are not controlled by solarization (Patel *et al*., 2005). The solarization effect diminishes with soil depth and the weeds which are capable of putting up growth from deeper layers, survive the treatment. This technique is however applicable to nurseries and high-value crops like vegetables, and cannot be followed for large-scale cultivation of field crops because of cost considerations.

Mechanical measures

Mechanical methods involve removal of weeds with various tools and implements, and include tillage, hoeing, mulching, burning etc. Intercultural practices are performed with implements used by hand, bullocks or tractor to create favourable conditions for the growth of crops. One or two hand-weedings provide satisfactory weed control in all pulses if done at critical stages. Although herbicides are fast replacing other weed-management practices, mechanical methods are very much needed to make weed control more effective, manageable and economical. Location-specific small hand tools which enhance the working efficiency, and reduce the drudgery and cost have been developed in different crops and regions. The old practice of stale seedbed (Gopinath *et al*., 2009) and summer deep ploughing are also followed for weed management in pulse-production systems.

Weed control through herbicides

Herbicides are chemicals used to kill or inhibit the growth of weeds without affecting crop plants. Weed management through herbicides is gaining popularity due to scarcity of labour for weeding on time. Further, manual weeding is also expensive, less efficient and cannot be performed under adverse soil and weather condition. Therefore, herbicides can be used as an alternative of manual or mechanical weeding. Previously, weed control through herbicides was considered a costly proposition. However, in recent times availability of low-dose, high-potency, non-residual, broad spectrum herbicides has provided great opportunity to accomplish effective weed control at much lower cost than mechanical methods. The efficiency of these herbicides depends largely on their nature and agro-climatic conditions in which they are used. Many herbicides have been tested and recommended for weed control in pulses as pre-emergence or pre-plant incorporation.

Pendimethalin is the most popular herbicide used in all pulse crops. However, it is not effective in controlling all kinds of weeds for long periods. Imazethapyr, a post-emergence broad spectrum herbicide, has been recommended for use in rainy-season pulses like pigeonpea, urdbean and mungbean. However, in winter-season pulses like chickpea, lentil and field pea, it has shown toxicity even at lower dose of 15 g/ha (Kumar *et al*., 2013a). Clodinafop and quizalofop-ethyl can also be used as post-emergence in most pulse crops if only the grassy weeds are present in the field. Research is underway to develop imazethapyr and metribuzin-tolerant chickpea (Gaur *et al*., 2013;

Table 8. Herbicides recommended for mungbean, urdbean and pigeonpea

Herbicide	Dose (g/ha)	Application time	Remarks
Alachlor	2,000–2,500	0–3 DAS	Annual grasses and some BLWs
Fluchloralin	750–1,000	Pre-planting	Annual grasses and some BLWs
Oxadiazon	250	0–3 DAS	Broad spectrum weeds
Oxyfluorfen	100–125	0–3 DAS	Broad spectrum weeds
Pendimethalin	750–1,000	0–3 DAS	Annual grasses and some BLWs
Fenoxaprop	50–70	15–20 DAS	Annual grasses
Quizalofop-ethyl	100	15–20 DAS	Annual grasses
Imazethapyr	50–100	20–25 DAS	Broad spectrum weeds
Pendimethalin *fb* imazethapyr	1250 + 100	0–3 and 20–25 DAS	Broad spectrum weeds

DAS, Days after sowing; *fb,* followed by; BLWs, broad-leaf weeds
Source: Adapted from Dixit and Varshney (2009)

Chaturvedi *et al*., 2014), and lentil and field pea (Parihar *et al*., 2016). Some of the commonly used herbicides in pulses and their time of application are listed in Tables 8 and 9.

Herbicides for intercropping systems involving pulses

Pulses are commonly grown under inter/ mixed cropping systems. Several pulse-based intercropping systems are prevalent in India. The herbicide which is working in sole crop may not work in intercropping systems due to diverse nature of intercrops. Hence, different strategies for weed management need to be followed in pulse-based intercropping systems.

Herbicides recommended by researchers in different pulse-based intercropping systems are mentioned in Table 10.

INTEGRATED WEED MANAGEMENT

Exclusive reliance on a single method of weed control is not possible, practical and economical; and therefore, all the available methods should be employed in an integrated manner to ensure effective weed management and higher crop productivity. Preventive measures are a pre-requisite for weed control, and the mechanical and cultural weeding should be employed in pulse crops as per their suitability to the local conditions. Pre-emergence herbicides are effective for controlling the first-flush weeds after sowing up to about a month of crop growth. Post-emergence herbicides like imazethapyr and quizalofop-ethyl can be used in specific pulse crops, but they do not provide broad-spectrum weed control. In fact, no suitable herbicide is available for post-emergence application for control of broad-leaf weeds in pulses. In the central parts of India, chickpea is heavily infested with *Medicago hispida* Gaertn., *Rumex dentatus* L., *Cichorium intybus* L., *Vicia sativa, Lathyrus sativus* etc. despite application of pendimethalin as pre-emergence application. Manual weeding being not cost-effective and herbicide not available for controlling these weed species; the farmers are in fact leaving chickpea cultivation in this region. In view of the above, integrated weed management approach involving pre-emergence herbicide application followed by me-

Table 9. Herbicides recommended for chickpea, lentil and field pea

Herbicide	Dose (g/ha)	Application time	Remarks
Fluchloralin	750–1,000	Pre-planting	Annual grasses and some BLWs
Metolachlor	1,000–1,500	0–3 DAS	Annual grasses and some BLWs
Metribuzin (in peas only)	250	0–3 DAS or 15–20 DAS	Annual grasses and some BLWs and some sedges
Oxyfluorfen (in peas only)	100–125	0–3 DAS	Broad-spectrum weeds
Pendimethalin	750–1,000	0–3 DAS	Annual grasses and some BLWs
Quizalofop-ethyl	50–100	15–20 DAS	Annual grasses
Clodinafop	60	25–30 DAS	Annual grasses
Pendimethalin *fb* quizalofop-ethyl	1,250 + 100	0–3 and 20–25 DAS	Broad-spectrum weeds

DAS, Days after sowing; *fb,* followed by; BLWs, broad-leaf weeds
Source: Adapted from Dixit and Varshney (2009)

Table 10. Suitable herbicides for weed control in pulse-based intercropping systems

Intercropping	Weed management	References
Pigeonpea + mungbean	Pendimathalin 1.0 kg/ha	Venkateswarlu and Ahlawat (1986)
Pigeonpea + soybean	Fluchloralin 0.5–0.75 kg/ha or alachlor 2.0 kg/ha	Venkateswarlu and Ahlawat (1986)
Groundnut + pigeonpea	Fluchloralin 1 kg/ha	Venkateswarlu and Ahlawat (1986)
Maize + urdbean	Butachlor 1.25 kg/ha	Reddy and Reddi (2003)
Chickpea + linseed	Pendimethalin 1.0 kg/ha or oxadiazon 0.50 kg/ha	Tewari *et al.* (2009)
Chickpea + mustard	Pendimethalin 1.25–1.5 kg/ha *fb* quizalofop-ethyl 60 g/ha	Kumar *et al*. (2015)
Lentil + linseed	Pendimethalin 1.0 kg/ha	Tewari *et al.* (2009)
Wheat + chickpea	Pendimethalin 1 kg/ha *fb* quizalofop-ethyl 100 g/ha	Authors experience
Mungbean + pearlmillet	Butachlor 1 kg/ha	Reddy and Reddi (2003)
Pigeonpea + maize	Alachlor 2 kg/ha *fb* hand-weeding	Talnikar *et al.* (2008)
Sorghum + pigeonpea	Pendimethalin 1.5 kg/ha	Tomar *et al*. (2004)
Urdbean + sesame	Pendimethalin 1.0–1.25 kg/ha, metolachlor 1.0–1.5 kg/ha and oxyflurofen 0.1–0.2 kg/ha	Tewari *et al*. (1993)
Pigeonpea + cowpea	Pendimethalin at 1.0 kg/ha/fluchloralin at 1.0 kg/ha *fb* hand-weeding	Tomar *et al*. (2004)

chanical weeding after about a month of sowing is the widely adopted practice for managing weeds in most pulse crops. It is recommended to grow a crop like wheat for 1-2 years in fields infested with broad-leaf weeds and apply specific herbicides in wheat crop, exhaust the weed seed bank and then revert to chickpea or lentil. Integrated weed management practices recommended in different pulse crops are given in Table 11.

PARASITIC WEEDS IN PULSES AND THEIR MANAGEMENT

Cuscuta and *Orobanche* are problematic in pulses in some regions of India (Table 12). *Cuscuta campestris* Yunck. is a major problem in pulses, oilseeds and fodder crops in Andhra Pradesh, Chhattisgarh, Gujarat, Odisha, West Bengal and parts of Madhya Pradesh under rainfed as well as in irrigated conditions (Mishra, 2009). *Orobanche crenata* Forsskal inflicts considerable damage in faba bean, lentil, chickpea, pea and other crops (Punia, 2014). Field control of these weeds is challenging because the host and pathogen are both plants, their life-cycles are highly coordinated and the pathogenesis occurs underground.

Prevention of seed dissemination by different agents is a key measure to control *Orobanche*. Burning of residue from infested crops was observed to reduce carry-over of *Orobanche* seeds back to the soil. Summer deep ploughing can also reduce the infestation of *Orobanche* if the top soil layer is properly turned to the bottom. Soil solarization has been proven to be the most effective methods in controlling *Orobanche* in open crops fields. Crop rotation with trap crops or non-host crops is of great advantage. Growing of non-host crops like wheat and barley (*Hordeum vulgare* L.) is the most effective and commonly used management strategy for reducing the weed-seed bank in heavily infested areas (Mishra, 2009). *Orobanche* infestation tends to be more in less-fertile soil conditions. High levels of manure and fertilizer, especially N, have a sup-

Table 11. Weed management recommendations in pulse crops

Crop	Recommended practice	References
Rainy-season pulses		
Pigeonpea	Pendimethalin 0.75 kg/ha *fb* hand-weeding at 30 DAS	Ali (1991)
	Pendimethalin 0.75 kg/ha *fb* paraquat 0.48 kg/ha at 40 DAS (directed spray)	Padmaja *et al*. (2013)
	Pendimethalin 1.0 kg/ha (PE) *fb* imazethapyr 100 g/ha (PoE) at 20–25 DAS	Kumar *et al*. (2013a)
Urdbean	Pendimethalin 0.75 kg/ha PE *fb* hand-weeding at 25 DAS	Singh (2011)
	Pendimethalin 1.0 kg/ha (PE) *fb* imazethapyr 100 g/ha (PoE) at 20–25 DAS	Kumar *et al*. (2013a)
Mungbean	Pendimethalin 0.75 kg/ha PE *fb* hand-weeding at 30 DAS	Parasuraman (2000)
	Trifluralin 0.75 kg/ha (PPI), linuron 0.75 kg/ha and acetachlor 1.0 kg/ha (PE) *fb* hand-weeding at 30 DAS	Malik *et al*. (2000)
	Pendimethalin 1.0 kg/ha (PE) *fb* imazethapyr 100 g/ha (PoE) at 20–25 DAS	Kumar *et al*. (2013a)
Cowpea	Pendimethalin 0.75 kg/ha PE *fb* hand-weeding at 30 DAS	Parasuraman (2000)
Horsegram	Hand-weeding at 20 DAS	Anitha *et al.* (2003)
Winter-season pulses		
Chickpea	Pendimethalin 1.0 kg/ha PE *fb q*uizalofop-ethyl 100 g/ha at 20–25 DAS	Kumar *et al*. (2015a)
Lentil	Pendimethalin 0.75 kg/ha *fb* hand-weeding, metribuzin 250 g/ha as post-emergence (some varieties)	Yadav *et al*. (2013)
	Pendimethalin 1.0 kg/ha PE *fb* quizalofop-ethyl 100 g/ha at 20–25 DAS	Kumar *et al*. (2015a)
Peas	Pendimethalin 1 kg/ha *fb* hand-weeding	Dixit and Varshney (2009)
	Pendimethalin 1.0 kg/ha PE *fb* quizalofop-ethyl 100 g/ha at 20–25 DAS	Kumar *et al*. (2015a)
Rajmash	Pendimathalin 1.0 kg/ha *fb* hand-weeding	Ali (1988a)
Lathyrus	Trifluralin 0.75 kg/ha *fb* hand-weeding, trifluralin 0.75 kg/ha *fb* sethoxydim 0.3 kg/ha or metribuzin 250 g/ha	Wall and Friesen (1991)

fb, followed by; DAS, days after swing; PE, pre-emergence; PoE, post-emergence; PPI, pre-plant incorporation

Table 12. Important parasitic weeds and their main host plants

Weed species	Hosts of economic importance	References
Orobance crenata	Faba bean, pea, lentil, chickpea	Punia (2014); Dhanapal *et al*. (1996)
Orobanche ramosa/ O. aegyptiaca	Lentil	
Orobanche foetida	Faba bean	
Striga gesnerioides	Cowpea	Punia (2014)
Cuscuta campestris	Faba bean, chickpea, mungbean, urdbean, pigeonpea	Mishra (2009); Tosh *et al.* (1977)

pressive effect. Some herbicides like pendimethalin and imazethapyr as pre-emergence, and fluchloralin and trifluralin as pre-plant incorporation have been found effective for controlling *Orobanche*.

Hand-pulling and burning of *Cuscuta* plants is important to prevent the reproduction of thousands of seeds. *Cuscuta* seeds do not germinate if placed deeply. Deep ploughing of *Cuscuta* infested land greatly reduces the chances of the parasite and establishing from the most recently shed seed but older seed in the soil may be brought to the surface by this practice. Stale-seedbed technique is an effective method of controlling parasitic weeds particularly *Cuscuta*, as it germinates without host. This technique of stale seedbed is effective if followed with hand-pulling of germinated seedlings or by application of glyphosate/ paraquat. *Cuscuta* does not parasitize cereal crops. Hence it can be controlled completely by crop rotation. Without a host plant nearby, *Cuscuta* seedlings emerge and die. Broad-leaf weeds must be controlled in such crops to deprive *Cuscuta* of all hosts, so that no new *Cuscuta* seed is produced (Mishra, 2009). *Cuscuta* is very sensitive to shade. Therefore, the crop-management practices that favour vigorous crop growth would suppress the growth of *Cuscuta*. The pulse crops can be partially protected from *Cuscuta* parasitism by growing the *Cuscuta*-resistant clusterbean [*Cyamopsis tetragonoloba* (L.) Taubert] along with mungbean or urdbean in a mixed cropping system (Rao and Reddy, 1987). Application of pendimethalin 0.5–1.5 kg/ha is very effective in pulses for controlling of *Cuscuta* (Mishra *et al*., 2005). Fluchloralin 1.5 kg/ha as pre-emergence (Kumar, 2000) and 1.0–1.25 kg/ha as pre-plant soil incorporation (Mishra *et al*., 2004) also controlled *Cuscuta* effectively in urdbean. Non-selective herbicides application like paraquat and glyphosate are useful for treating scattered patches of *Cuscuta,* and thereby preventing seed production and expansion of infestation.

PULSES IN CONSERVATION AGRICULTURE SYSTEM

Conservation agriculture (CA) involves minimal soil disturbance (no-till, NT) and permanent soil cover (mulch) combined with sensible crop rotations. It is a recent agricultural management system that is gaining popularity in many parts of the world. Weed management has been recognized as an essential component for success of CA. Certain weeds decrease after consistent practices of CA but some others may increase (Chauhan *et al*., 2006a). The CA systems with low soil disturbance tend to leave more weed seeds on the surface, whereas high disturbance systems bury weeds. Usually, small-seeded weed species are favoured more in CA. There are many annual weeds that germinate well under no-till system, as they can germinate with less or no soil cover. Biennials also thrive well under CA. Perennial species can easily produce large populations under CA if a few plants get a good vegetative stand.

Tillage affects weeds by uprooting, dismembering and burying them deep in soil to prevent emergence. Summer ploughing significantly reduced the density and biomass of purple nutsedge (*Cyperus rotundus* L.). In zero tillage, the population of purple nutsedge increased significantly over normal tillage in rice–lentil system (IIPR, 2009).In another study at Kanpur, annual grasses like *Anagallis arvensis*, *Melilotus* spp., *Avena fatua*, *Phalaris minor* and *Chenopodium album* were dominant under conventional tillage, while perennial weeds like *Convolvulus arvensis* and *Sorghum halepense* were dominant under zero-tillage (Kumar *et al*., 2015b). In case of conservation tillage, the weed control cannot be done by tillage. Thus, tillage option is eliminated from weed-management strategies. With the adoption of conservation practices, weeds are more during initial years. Weed seeds are also confined to surface layer in the soil (Fig. 3). Therefore, a well-planned strategy should be adopted to control weeds during initial adoption period of conservation tillage. Weed seeds which remain on soil surface can be damaged by heat during summer season and subsequently by use of effective herbicides, which may result in decline in weed population in subsequent years.

A definite strategy need to be followed in CA for effective weed management and higher crop productivity. Good agronomic practices like proper sowing time, paired-rows planting, crop rotation, intercropping, cover crop, maintaining residue cover over soil and use of herbicides need to be incorporated to manage weeds effectively in CA. Intercropping safflower (*Carthamus tinctorius* L.), wheat and linseed (*Linum usitatissimum* L.) with chickpea suppressed weed flora to the extent of 43–60%. Similarly, weed-smothering effect was recorded in pigeonpea when

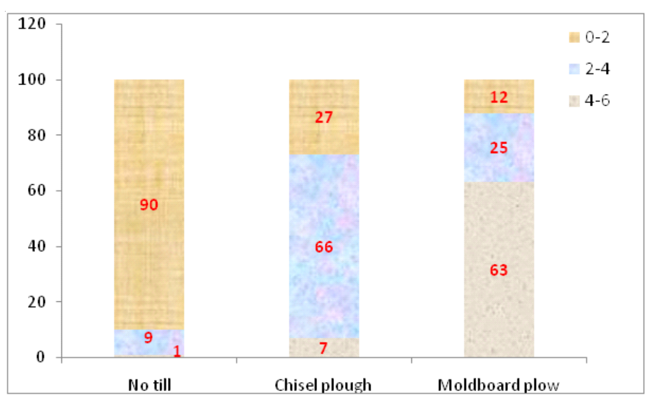

Fig. 3. Weed seed population in different soil depth (inches; 1 inch = 2.54 cm)
Source: Clements *et al.* (1996)

intercropped with cowpea (45.8%), urdbean (41.5%) and mungbean (38.2%) (IIPR, 2009). In a long-term study at Kanpur, less weed population including *Phalaris minor* was observed in wheat under rice–wheat–mungbean cropping system in comparison to rice–wheat (Hazra *et al*., 2012). In another study, *Avena fatua* and *Phalaris minor* were dominant in rice–wheat, *Chenopodium album* and *Melilotus* spp. in rice–chickpea, and *Sorghum halepense* in rice–chickpea–mungbean cropping system (Kumar *et al*., 2015b). Seed predation is important in systems where newly produced weed seeds remain on the soil surface under zero-till systems.

In CA, crop residues present on the soil surface improve soil and moisture conservation, and soil tilth. In addition, the residues can influence weed-seed germination and seedling emergence. However, the germination response of weeds to residue depends on the quantity, position (vertical or flat and below or above weed seeds), and allelopathic potential of the residue and the weed biology (Chauhan *et al*., 2006). Studies conducted at the IIPR, Kanpur, also revealed a great impact of root exuded allelochemicals of sesame (*Sesamum indicum* L.) against *Cyperus rotundus* and other weeds (Kumar *et al*., 2013a). Weed management through herbicides is more commonly recommended under CA in pulses. In rice fallows condition, rice ratooning is major problem which can be effectively controlled by quizalofop-ethyl (Kumar *et al*., 2013). Similarly, follow-up application of pre- and post-emergence herbicides such as pendimethalin and imazethapyr for rainy-season pulses, and pendimethalin and quizalofop-ethyl for winter season pulses can be used under CA for weed management (Kumar, 2010; Kumar *et al*., 2015, 2015a). Further, the development of herbicide-tolerant cultivars of pulse crops will add a new dimension to weed management in conservation agriculture.

The CA has shown the way for cultivation of pulses in diversified cropping systems. Based on the research work done at the Directorate of Weed Research (DWR), Jabalpur, over the last 4 years, it has been demonstrated that pulses can be included as cover crops which also help in weed control besides other benefits. The pulse crops can be grown under zero-till conditions with or without residue of the previous crop under limited irrigation and equally good or even higher yields can be obtained as with conventional tillage. The pulse-based cropping systems were found feasible under irrigated conditions:

Rice-based cropping systems:

- Rice–chickpea–mungbean
- Rice–wheat–mungbean
- Rice–mustard–mungbean
- Rice–field pea–mungbean

Non-rice-based cropping systems:

- Soybean–wheat–mungbean
- Soybean–chickpea–mungbean
- Maize–wheat–mungbean
- Maize–chickpea–mungbean
- Pigeonpea–wheat–mungbean

In a long-term direct-seeded rice–chickpea cropping system, hand-weeding resulted in the lowest weed population than all other herbicidal treatments in chickpea crop. The highest seed yield and attributes were also recorded with hand-weeding. Application of pendimethalin and oxyflourfen resulted in higher pods/plant and seed yield over weedy check (Table 13).

Table 13. Performance of chickpea following direct-seeded rice as influenced by different herbicides

Treatment	Weed density (no./m^2)	Pods/ plant	Seed yield (t/ha)
Pendimethalin	18.9 (376.7)	39.5	1.08
Oxyflurfen	20.0 (399.5)	42.2	1.05
Quizalofop-ethyl	36.2 (1,309.9)	27.7	0.67
Hand-weeding	14.9 (221.5)	44.4	1.38
Weedy check	35.9 (1,288.8)	21.9	0.21
CD (*P*=0.05)	2.9	6.6	0.20

In a trial on summer mungbean, pre-emergence application of pendimethalin controlled the grassy weeds. Further, the growth of purple nutsedge was checked by the post-emergence application of imazethapyr and quizalofop-ethyl. Significantly highest yield of mungbean was recorded with pendimethalin followed by either quizalofop-ethyl or imazethapyr.

On-farm research trials revealed that imazethapyr provided broad-spectrum weed control in zero-till summer mungbean. Seed yield of 1.3 t/ha as compared to 0.74 t/ha under farmers' practice provided additional net returns of ₹14,000/ha with higher benefit : cost ratio. Use of 'Happy Seeder' saved time and favoured early sowing, which also helped to utilize residual soil moisture, and saved field preparation cost. Unlike the conventional zero-till seed drill, happy seeder utilized the wheat crop residue to mulch the field, and thereby helped in managing weed menace and improved soil condition.

Based on these findings, the following recommendations are made:

- Follow zero-till sowing of winter season pulses like chickpea, fields peas and lentil by November first week after the harvesting of previous rainy-season crops of rice, maize or soybean. Further, after the harvesting of winter season crops, also adopt zero-till sowing of mungbean or urdbean by March-end or latest by 10 April, otherwise the crop may experience pre-monsoon showers by mid-June.

- Preferably retain the residues of previous crop and never burn any such biomass. Happy seeder machine can be used for sowing in the standing residue of the previous crop.
- Follow raised-bed method of sowing for better resource-use efficiency and higher productivity. Bed planters (narrow-bed, 70 cm; and broad-bed, 140 cm) are available and row spacing can be adjusted depending on the specific crop requirement.
- Must kill all the existing weeds before sowing through the use of non-selective herbicides like paraquat for annual weeds, and glyphosate if perennial and hardy types of weeds are present.
- Apply a basal dose of 100 kg diammonium phosphate (DAP)/ha below the seed through the seed drill. Never broadcast the fertilizer.
- Apply a pre-emergence herbicide like pendimethalin (0.75–1.00 kg/ha) within 2–3 days of sowing (following irrigation if required). Post-emergence herbicides like imazethapyr (100 g/ha) and quizalofop-ethyl (60 g/ha) can also be used in crops like mungbean, urdbean, soybean and pigeonpea for controlling grassy seeds. Oxyflourfen (0.20 kg/ha) in chickpea and metrubuzin (0.25 kg/ha) in peas can also be used. *Cuscuta* infestation in mungbean and urdbean can be checked with the pre-emergence application of pendimethalin (1 kg/ha). Do not grow chickpea or lentil in fields infested with *Medicago* and other broad-leaf weeds, for which no selective post-emergence herbicides are available at present.
- Apply 2–3 irrigations at monthly interval for the winter crops, and at 15–20 days interval for summer pulses, preferably through sprinkler. Do not over-irrigate as the excess foliage growth does not necessarily lead to more seed production.
- Keep a watch on the insect-pests and adopt timely spraying of insecticides.
- It is possible to harvest pulse crops through combine harvesters with proper adjustment of machine. Seed yields of 1.5–2.0 t/ha of chickpea, field peas and pigeonpea, and 1.0–1.5 t/ha of mungbean, urdbean and lentil can be harvested under normal conditions. Recycling of the residues of pulses in the same field improves productivity of the following cereal crop substantially.

CONCLUSION

- Weeds are a serious problem in pulses because of the short-statured plants of crops like lentil, chickpea and also slow initial growth of crops like pigeonpea. Weeds can cause complete crop failure if not checked in early stages.
- Broad-spectrum weeds species including grasses, broad-leaf, sedges and some parasitic weeds infest pulse crops.
- Non-chemical methods like preventive measures, mechanical and cultural methods including stale-seedbed practice are effective for weed management.
- Pre-emergence herbicides including pre-plant chemicals provide effective control of weeds up to about a month of crop growth. In some pulses when the canopy is not adequately developed, 1 hand-weeding or application of post-emergence herbicides is required at 20–25 days of growth.
- Options for post-emergence herbicidal control of weeds in pulses are limited. Herbicides like imazethapyr and quizalofop-ethyl can be used in specific crops for controlling specific weed flora.
- Pluses are an important component of conservation agriculture systems and can be profitably grown with good weed management.

FUTURE THRUSTS

There is a hue and cry about the rising prices of pulses in the country. Hence sustained efforts must be made to improve productivity of pulses in different production systems through the available approaches including good agronomy and weed management. Following issues may be important for improving weed management in pulse crops:

- Develop cultivars with early growth vigour to suppress weed growth.
- Must include a pulse in cereal-based cropping systems not only for soil-fertility replenishment but also for breaking the pest dynamics including weeds.
- Mechanical devices which are preferably machine driven are required for interculturing and weed control in pulse crops.
- Controlling broad-leaf weeds in pulses is a major issue but no effective herbicides are available in crops like chickpea and lentil. Identification of suitable herbicides and standardization of their doses and time of application is important.
- Technology for growing pulses in conservation agriculture systems is required to be developed under different soil and climatic conditions.
- Development of herbicide-tolerant cultivars of pulses will change of scenario of weed management in the coming years.

REFERENCES

Ali, M. 1988. Weed suppressing ability and productivity of short-duration legumes intercropped with pigeonpea under rainfed conditions. *Tropical Pest Management* **34**(4): 384–387.

Ali, M. 1988a. Efficacy of herbicides for weed control in winter French bean (*Phaseolus vulgaris*). *Indian Journal of Agricultural Sciences* **58**(2): 440–443.

Ali, M. 1991. Weed management in pigeonpea under rainfed conditions in India. *Tropical Pest Management* **37**(4): 345–348.

Ali, M. and Lal, S. 1989. Priority inputs in pulse production. *Fertiliser News* **34**(11): 17–21.

Ali, M. and Singh, K.K. 1997. Management of pulse crops under intercropping systems, pp. 489–508. (In) *Recent Advances in Pulses Research*. Asthana, A.N. and Ali, M. (Eds). Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur, Uttar Pradesh.

Anitha, S., Sreenivasan, E. and Purushothaman, S.M. 2003. Integrated weed management in horsegram (*Macrotyloma uniflorum*) in the Oxisols of Kerala. *Indian Journal of Weed Science* **35**(1, 2): 143–144.

Balyan, R.S. and Malik, R.K. 1996. Weed management studies in chickpea *(Cicer arietinum). Journal of Research, Haryana Agricultural University, Hisar* **26**: 191–194.

Banik, P., Midya, A., Sarkar, B.K. and Ghose, S.S. 2006. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *European Journal of Agronomy* **24**(4): 325–332.

Bathar, V.M., Patel, M.M., Patel, I.C. and Tikka, S.B.S. 2005. Weed management in mothbean [*Vigna aconitifolia* (Jacq.) Marechal], pp. 177–178. (In) *Arid Legumes for Sustainable Agriculture and Trade,* Vol. 1. Henry, A. and Kumar, D. (Eds). Scientific Publishers, Jodhpur, Rajasthan.

Chandra, S. 1982. Increasing pulse production in India. (In) *Constraints and Opportunities*. Report, All India Coordinated Pulse Improvement Project, Kanpur, Uttar Pradesh.

Chaturvedi, S.K., Muraleedhar, A., Gaur, P.M., Mishra, N., Singh, K. and Nadarajan, N. 2014. Genetic variations for herbicide tolerance (imazethapyr) in chickpea (*Cicer arietinum*). *Indian Journal of Agricultural Sciences* **84**(8): 968–970.

Chaudhary, S.U., Iqbal, J. and Hussain, M. 2011. Weed management in chickpea grown under rice-based cropping system of Punjab. *Crop and Environment* **2**(1): 28–31.

Chauhan, B.S., Gill, G. and Preston, C. 2006. Tillage system effects on weed ecology, herbicide activity and persistence: A review. *Australian Journal of Experimental Agriculture* **46**: 1,557–1,570.

Chauhan, B.S., Gill, G. and Preston, C. 2006a. Influence of tillage systems on vertical distribution, seedling recruitment and persistence of rigid ryegrass (*Lolium rigidum*) seed bank. *Weed Science* **54**: 669–676.

Choudhary, V.K., Kumar, P.S. and Bhagawati, R. 2012. Integrated weed management in blackgram (*Vigna mungo*) under mid hills of Arunachal Pradesh. *Indian Journal of Agronomy* **57**(4): 382–385.

Clements, D.R., Benoit, D.L., Murphy, S.D. and Swanton, C.J. 1996. Tillage effect on weed seed return and seed bank composition. *Weed Science* **44**: 314–322.

DAC. 2014. *Agricultural Statistics at a Glance,* p. 452. Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India.

Dhanapal, G.N., Struik, P.C., Udayakumar, M. and Timmermans, P.C.J.M. 1996. Management of broomrape (*Orobanche* spp.): A review. *Journal of Crop Science* **165**: 335–359.

Dixit, A. and Varshney, J.G. 2009. *Handbook on Herbicide Recommendations,* pp. 23–25. Directorate of Weed Science Research, Jabalpur, Madhya Pradesh.

FAOSTAT. 2009. *Online Interactive Database on Agriculture*. FAOSTAT. www.fao.org

Gaur, P.M., Jukanti, A.K., Samineni, S., Chaturvedi, S.K., Singh, S., Tripathi, S., Singh, I., Singh, G., Das, T.K., Aski, M., Mishra, N., Nadarajan, N. and Gowda, C.L.L. 2013. Large genetic variability in chickpea for tolerance to herbicides imazethapyr and metribuzin. *Agronomy* **3**(3): 524–536.

Gopinath, K.A., Kumar, N., Mina, B.L., Srivastva, A.K. and Gupta, H.S. 2009. Evaluation of mulching, stale seedbed, hand-weeding and hoeing for weed control in organic garden pea (*Pisum sativum* ssp. *hortense*). *Archives of Agronomy and Soil Science* **55**(1): 115–123.

Hazra, K.K., Kumar, N., Venkatesh, M.S. and Ghosh, P.K. 2012. Inclusion of pulses in rice–wheat system can reduce *Phalaris minor* population. *Pulses Newsletter* (July–September 2012) **23**(3): 6.

IIPR. 2009. *25 Years of Pulses Research at IIPR.* ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India

IIPR. 2013. *Vision 2050*, 28 pp. Indian Institute of Pulses Research, Kanpur, Uttar Pradesh.

Kaur, R., Kumar, A., Sharma, B.C., Brijnandan, Kour, P. and Sharma, N. 2014. Weed indices in chickpea + mustard intercropping system. *Indian Journal of Weed Science* **46**(4): 333–335.

Kumar, A., Saxena A. and Singh, P.K. 2014. Chemical and mechanical weed management for increased yield of French bean. *Indian Journal of Weed Science* **46**(4): 350–352.

Kumar, N. 2010. Imazethapyr: A potential post-emergence herbicide for kharif pulses. *Pulses Newsletter* (July–September 2010) **21**(3): 5.

Kumar, N. 2013. *Asphodelus tenuifolius:* An emerging weed of *rabi* pulses in Bundelkhand. *Pulses Newsletter* (January–March 2013) **24**(1): 6.

Kumar, N. and Yadav, S.L. 2013. Infestation of *Convolvulus arvensis* in rice under RCT trial. *Pulses Newsletter* (July–September 2013) **24**(3): 5.

Kumar, N., Ghosh, P.K., Hazra, K.K., Venkatesh, M.S., Basu, P.S. and Yadav, S.K. 2013. Management of rice ratoon in rice-fallow pulses system. *Pulses Newsletter* (October–December 2013) **24**(4): 3.

Kumar, N., Hazra, K.K., Singh, M.K., Venkatesh, M.S., Kumar, L., Singh, J. and Nadarajan, N. 2013a. *Weed Management Techniques in Pulse Crop,* 47 pp. Technical Bulletin 10/2013. Indian Institute of Pulses Research, Kanpur, Uttar Pradesh.

Kumar, N., Hazra, K.K., Yadav, S.L. and Singh, S.S. 2015. Efficacy of post-emergence herbicides in chickpea + mustard intercropping. *Indian Journal of Agricultural Sciences* **85**(8): 1,074–1,079.

Kumar, N., Hazra, K.K., Yadav, S.L. and Singh, S.S. 2015a. Weed dynamics and productivity of chickpea (*Cicer arietinum*) under pre- and post-emergence application of herbicides. *Indian Journal of Agronomy* **60**(4): 570–575.

Kumar, N., Paulraj, S., Singh, S.S., Yadav, A. and Yadav, S. 2015b. Weed shift under tillage and pulse-based cropping system.

Pulses Newsletter (January–March 2015) **26**(1): 8.

Kumar, R.M. 2000. Effect of herbicides on the control of parasitic weed *Cuscuta* in blackgram (*Vigna mungo*). *Journal of Research,* ANGRAU **3**: 1–5.

Kumar, N., Hazra, K.K. and Nadarajan, N. 2016.Efficacy of post-emergence herbicide imazethapyr in summer mungbean. *Legume Research* **39**(1): 96–100.

Malik, R.S., Yadav, A. and Malik, R.K. 2000. Efficacy of trifluralin, linuron and acetachlor against weeds in mungbean (*Vigna radiata*). *Indian Journal of Weed Science* **32**(3/4): 181–185.

Mishra, J. S. 2009. Biology and management of *Cuscuta* species. *Indian Journal of Weed Science* **41**(1, 2): 1–11.

Mishra, J.S., Bhan, Manish, Moorthy, B.T.S. and Yaduraju. N.T. 2004. Bio-efficacy of herbicides against *Cuscuta* in blackgram [*Vigna mungo* (L.) Hepper]. *Indian Journal of Weed Science* **36**: 278–279.

Mishra, J.S., Moorthy, B.T.S. and Bhan, M. 2005. Relative tolerance of *kharif* crops to dodder and its management in niger, pp. 213–214. (In) *Extended Summaries. National Biennial Conference.* ISWS, PAU, Ludhiana, Punjab.

Padmaja, B., Reddy, M.M. and Reddy, D. 2013. Weed control efficiency of pre-and post-emergence herbicides in pigeonpea (*Cajanus cajan* L.). *Journal of Food Legumes* **26** (1 and 2): 44–45.

Parasuraman, P. 2000. Weed management in rainfed cowpea (*Vigna unguiculata*) and mungbean (*Phaseolus radiatus*) under north-western agroclimatic zone of Tamil Nadu. *Indian Journal of Agronomy* **45**(4): 732–736.

Parihar, A.K., Dixit, G.P., Kumar, N., Mishra, V.D. and Chaturvedi, S.K. 2016. Genetic variability for herbicide tolerance in fieldpea. *Pulses Newsletter* (January–March 2016) **27**(1): 6.

Patel, B.D., Patel, V.J., Patel, J.B. and Patel, R.B. 2006. Effect of fertilizers and weed management practices on weed control in chickpea (*Cicer arietinum* L.) under middle Gujarat conditions. *Indian Journal of Crop Science* **1**(1–2): 180–183.

Patel, R.H., Shroff, J., Dutta, S. and Meisheri, T.G. 2005. Weed dynamics as influenced by soil solarization – A review. *Agricultural Reviews* **26**(4): 295–300.

Pramanick, B., Bera, P.S., Kundu, C.K., Bandopadhyay, P. and Brahmachari, K. 2014. Effect of different herbicides used in transplanted rice on weed management in rice–lathyrus cropping system. *Journal of Crop and Weed* **10**(2): 433–436.

Punia, S.S. 2014. Biology and control measures of *Orobanche*. *Indian Journal of Weed Science* **46**(1): 36–51.

Rana, K.S., Pal, M. and Rana, D.S. 1999. Nutrient depletion by pigeonpea (*Cajanus cajan*) and weeds as influenced by intercropping systems and weed management under rainfed conditions. *Indian Journal of Agronomy* **44**(2): 267–270.

Rao, P.N. and Reddy, A. 1987. Effect of China dodder on two pulses: greengram and clusterbean – the later a possible trap crop to manage China dodder, pp. 665–674. (In) *Proceedings of 4th International Symposium on Parasitic Flowering Plants,* held at Marburg.

Reddy, T.Y. and Reddi, G.H.S. 2003. *Principles of Agronomy*, edn 3, Kalyani Publishers, New Delhi.

Singh, G. 2011. Weed management in summer and *kharif* season blackgram [*Vigna mungo* (L.) Hepper]. *Indian Journal of Weed Science* **43**(1 and 2): 77–80.

Singh, G. and Sekhon, H.S. 2013.Integrated weed management in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *World Journal of Agricultural Sciences* **9**(1): 86–91.

Singh, M., Kumar, R., Kumar, S. and Kumar, V. 2016. Critical period for weed control in field pea. *Legume Research* **39**(1): 86–90.

Talnikar, A.S., Kadam, G.L., Karande, D.R. and Jogdand, P.B. 2008. Integrated weed management in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *International Journal of Agricultural Sciences* **4**(1): 363–370.

Tewari, A.N., Singh, V., Singh, B. and Jain, R.K. 1993. Weed control through herbicides in blackgram intercropped with sesamum under rainfed conditions, pp. 173–175. (In) *Proceedings of International Symposium on Integrated Weed Management for Sustainable Agriculture.* Indian Society of Weed Science, Hisar, Haryana, India, 18–20 Nov., III.

Tewari. A.N., Mishra, J.S., Singh, O.N. and Verma, V.K. 2009. Weed dynamics and management options in pulse based production systems, pp. 280–291. (In) *Legumes for Ecological Sustainability*. Ali, M., Gupta, S., Basu, P.S. and Naimuddin (Eds). Indian Society of Pulses Research and Development, Indian Institute of Pulses Research, Kanpur, Uttar Pradesh.

Tomar, J., Singh, H.B., Vivek and Tripathi, S.S. 2004. Integrated weed management in intercropping of mungbean (*Vigna radiata*) and cowpea fodder (*Vigna unguiculata*) with pigeonpea (*Cajanus cajan*) under western U.P. conditions. *Indian Journal of Weed Science* **36**(1, 2): 133–134.

Tosh, G.C., Patro, G.K. and Misra, A. 1977. Effect of pronamide and chlorpropham on *Cuscuta* stem parasite in niger, pp. 275–276. *Abstract Papers of Weed Science Conference.* Indian Society of Weed Science, Hyderabad, India.

Venkateswarlu, U. and Ahlawat, I.P.S. 1986. Studies on weed management in pigeonpea-based intercropping systems. *Indian Journal of Agronomy* **31**: 184–187.

Wall, D.A. and Friesen, G.H. 1991. Effectiveness of selective herbicides for the control of annual weed species in lathyrus (*Lathyrus sativus* L.). *Crop Protection* **10**(6): 496–500.

Yadav, R.B., Vivek, Singh, R.V. and Yadav, K.G. 2013. Weed management in lentil. *Indian Journal of Weed Science* **45**(2): 113–115.

Yaduraju, N.T. 2002. Importance of weeds in agriculture, pp. 4–5. (In) *Teaching Manual on Advances in Weed Management*. National Research Centre for Weed Science, Jabalpur, Madhya Pradesh.

Yaduraju, N.T. and Ahuja, K.N. 1990. Weed control through soil solarization. *Indian Journal of Agronomy* **35**(4): 440–442.