

Review Paper

Integrated weed management strategies for climate-resilient pulse production

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ABSTRACT

Pulses are vital for food and nutritional security, soil health, and sustainable cropping systems due to their nitrogen-fixing ability and high protein value. In India, pulses are grown on about 28.9 million ha with a production of 26.06 million tonnes (2022-23), yet productivity (902 kg/ha) remains below the global average. Weed infestation is one of the most severe constraints to pulse productivity, causing 30-80% yield losses, particularly under rainfed conditions. Weeds also remove large quantities of soil nutrients, impair nodulation and nitrogen fixation, and act as alternate hosts for pests and diseases. Pulses are poor weed competitors because of slow initial growth and weak canopy development. Weed management is further complicated by diverse weed flora, limited herbicide options, labour shortages, poor mechanization, and low adoption of integrated approaches. This paper critically reviews major weed management challenges in pulse crops across seasons and agro-ecologies in India and synthesizes crop- and season-specific integrated weed management (IWM) strategies for major and minor pulses. Emphasis is placed on integrating cultural, mechanical, and judicious chemical methods for sustainable and effective weed control. Adoption of IWM can enhance pulse productivity by 20-45% while improving resource-use efficiency and system resilience under changing climatic conditions.

Key words: Integrated weed management, Yield loss, Herbicide resistance, Crop-weed competition, Weed flora

INTRODUCTION

Pulses play a vital role in global food and nutritional security, ecological sustainability, and cropping system diversification owing to their ability to fix atmospheric nitrogen, enhance soil fertility, improve dietary protein supply, and diversify cropping systems. Chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), greengram (*Vigna radiata*), blackgram (*Vigna mungo*), lentil (*Lens culinaris*), fieldpea (*Pisum sativum*), clusterbean (*Cyamopsis tetragonoloba*), kidney bean (*Phaseolus vulgaris*), mothbean (*Vigna aconitifolia*), horsegram (*Macrotyloma uniflorum*), lathyrus (*Lathyrus sativus*) and cowpea (*Vigna unguiculata*) are the twelve major and minor pulses in India cultivated on about 28.9 million hectare area under diverse climatic and edaphic conditions, with total production of 26.06 million tones (2022-23). However, the average productivity (902 kg/ha) is quite low as compared to the global average (969 kg/ha). Weed infestation remains one of the most significant constraints limiting pulse productivity across seasons. Compared to cereals, pulses have low

competitiveness against weeds due to their slow initial growth and poor canopy development, and are more sensitive to herbicides. Consequently, weeds remain a major production constraint and contribute significantly to yield instability across regions. Most of the area under pulses is rainfed/dry land. Weeds compete with crops for soil moisture and nutrients, which are the most limiting factors for crop growth under such situations. Ali and Lal (1989) reported that among various production inputs, weed management was found to be the most important, contributing 30.9 % in pigeonpea, 109.7 % in blackgram, and 60 % in greengram towards total productivity. Therefore, when improved agricultural practices are adopted, efficient weed management becomes even more important; the weeds, rather than the crops, benefit from the costly inputs.

MAJOR ISSUES OF WEED MANAGEMENT IN PULSES

The following are the major issues of weed management in pulses.

Slow initial growth and poor crop competitiveness

Most pulses, such as chickpea, lentil, pigeonpea, mungbean, and urdbean, possess a slow early growth habit, narrow leaf area, and short plant stature during initial stages. This results in a prolonged period during which crops are unable to suppress emerging weeds. Their weak canopy and limited shading ability allow weeds to establish dominance quickly, often reducing crop root development and nutrient uptake. Moreover, most of the pulses tend to allocate substantial resources to reproductive development rather than vegetative biomass, which further reduces their ability to compete with weeds.

Complex and diverse weed flora

Pulse ecosystems harbor a highly complex weed flora, including a mixture of grasses, broadleaf weeds, and sedges. For instance, chickpea and lentil in the *rabi* season are infested by *Chenopodium*, *Melilotus*, *Vicia*, *Fumaria*, *Phalaris minor*, and *Avena ludoviciana*, while pigeonpea and mungbean in the *kharif* season are dominated by *Echinochloa*, *Amaranthus*, *Digera*, *Commelina*, and *Cyperus rotundus*. This diversity complicates management because no single herbicide or cultural practice is effective against all species. Additionally, weed flora vary across regions based on rainfall, cropping system, soil types, and residual herbicide use, necessitating site-specific integrated strategies.

Severe weed-crop competition leading to heavy yield loss

Weeds compete aggressively with pulse crops for water, nutrients, and light, leading to substantial yield losses. Reported losses range from 30 to 80%, depending on weed density, species composition, and duration of interference. Under rainfed conditions, weeds often capture early-season soil moisture more efficiently, leading to severe moisture stress in pulse crops and poor pod formation. Competitive weeds such as *Chenopodium album*, *Phalaris minor*, *Avena ludoviciana*, *Amaranthus viridis*, *Convolvulus arvensis*, *Medicago polymorpha*, *Vicia* spp., *Asphodelus tenuifolius*, and *Cyperus rotundus* during the winter season, and *Echinochloa colona*, *Commelina* spp., *Alternanthera sessilis*, *Trianthema portulacastrum*, *Digitaria sanguinalis*, *Dinebra retroflexa*, *C. rotundus*, during summer and rainy season, pulses significantly reduce crop vigour. Early-season weed competition is particularly more damaging because it coincides with crucial stages such as branching and root nodulation.

Herbicidal issues

Pulses are highly sensitive crops with limited physiological tolerance to herbicides, making weed management one of the most challenging aspects of production. Despite the rising need for effective weed control under labour scarcity and climate variability, herbicide use in pulses remains constrained by multiple agronomic, ecological, and regulatory issues. The major herbicidal issues in pulse production systems are summarized below.

Limited herbicide options

Herbicide options in pulses remain significantly restricted compared to cereals. Selective, broad-spectrum, and safe herbicides are scarce, particularly for broadleaf weeds, which dominate most pulse ecosystems. Pendimethalin is the most widely used pre-emergence herbicide in pulses. However, its efficacy is variable on broad-leaved weeds, and reduced under dry soil conditions. Only a few herbicides, such as imazethapyr, quizalofop-p-ethyl, propaquizafop, haloxyfop, and fenoxaprop, offer partial control but often lack the desired level of efficacy. Post-emergence options, especially against broadleaf weeds, are inadequate in many pulse crops. Bentazone is available only for specific pulses and shows phytotoxicity under moisture stress. Issues such as narrow margins of selectivity, crop injury under moisture stress, and variability in soil type further limit widespread herbicide adoption. Additionally, many pulse varieties display herbicide sensitivity, making them prone to phytotoxicity even at recommended doses.

Emerging issues of herbicide resistance in associated weeds

The emergence of herbicide-resistant weeds in pulse-based cropping systems further exacerbates management challenges. Weeds such as *Phalaris minor* and *Avena ludoviciana*, which have evolved resistance to ALS- and ACCase-inhibiting herbicides during the winter season, and *Echinochloa* spp. to imidazolinone-resistant populations during the rainy season in cereal systems, often escape control when pulses are grown in rotation. Since pulses have few alternative herbicide modes of action registered for use, managing resistant weed biotypes becomes extremely difficult. The limited chemical options make it challenging to implement herbicide rotation or mixture strategies, increasing reliance on cultural and mechanical practices, which may not be feasible for large-scale farms or labour-scarce regions.

Residual herbicide carryover from previous crops

Pulses are highly sensitive to residual herbicides applied to preceding crops such as wheat, maize, soybean, and sugarcane. Herbicides such as sulfosulfuron, metsulfuron, atrazine, metribuzin, and imidazolinones (imazethapyr, imazapyr, imazapic, and imazamox) can persist in soil depending on soil pH, organic matter, and moisture. Chickpea, lentil, and lathyrus are extremely sensitive to ALS-inhibitor residues. Even low concentrations of residues may injure pulse seedlings, causing chlorosis, stunting, or plant mortality. This issue is particularly severe in intensively cultivated regions and under conservation agriculture, where herbicide applications are frequent, and soil disturbance is minimal. Crop rotation planning is often overlooked by farmers, resulting in frequent carryover injury. In addition, repeated use of herbicides in pulse-based cropping systems affects rhizobial activity, N-fixation, soil microbial biomass, and earthworm activity.

Problem of parasitic weeds

Parasitic weeds pose a serious and often underestimated challenge in pulse production, particularly in regions where species like *Cuscuta* (dodder) and *Orobancha* (broomrape), aggressively infest fields, leading to 60–90% yield loss under heavy infestation. Their tiny, long-lived seeds persist in the soil seedbank for many years, making eradication extremely difficult. Early infection frequently goes unnoticed because parasitic weeds establish internal haustorial connections before visible symptoms appear. In pulses such as lentil, chickpea, field pea, pigeonpea, and mungbean, these parasites stunt growth, reduce nodulation, impair photosynthesis, and ultimately cause poor pod set and grain filling. Limited chemical control options, host specificity, climate-driven shifts in distribution, and the risk of spread through contaminated seed further compound the problem.

Labour shortage and raising weeding costs

Manual weeding and inter-cultivation—traditionally the primary weed control methods in pulses—have become increasingly expensive due to labour shortages and rising wages. Critical weeding operations often coincide with peak labour demand seasons, making labour either unavailable or unaffordable. Delayed weeding results in rapid weed growth, making subsequent removal more difficult and costlier. This challenge is particularly

acute for small and marginal farmers, who constitute the majority of pulse growers in India and other developing countries.

Rainfed cultivation with poor soil fertility

The majority of pulse cultivation occurs under rainfed conditions, characterized by irregular rainfall, limited irrigation, and poor soil fertility. Under such conditions, crop vigour is compromised, further lowering competitiveness against weeds. Moisture stress during early growth favours weed proliferation, as many weeds are more efficient than pulses in extracting water from the soil. Degraded soils with low organic matter diminish crop root growth and nodulation, compounding the competitive advantage enjoyed by weeds.

Intercropping complexity

Pulses are widely grown as intercrops with cereals, oilseeds, and commercial crops (e.g., pigeonpea with cotton or soybean; chickpea with mustard). Herbicide use in such systems is restricted due to the risk of phytotoxicity to the companion crop. For example, herbicides recommended for mustard may damage chickpea in mixed stands, while options for pigeonpea + soybean or pigeonpea + cotton systems are also limited due to differential tolerance. Mechanical weeding is also difficult in intercropped configurations with narrow row spacing, making weed management more complex.

Lack of improved weed-tolerant varieties

Unlike cereals, limited breeding effort has been directed towards developing weed-competitive or herbicide-tolerant pulse varieties. Traits such as early vigour, rapid canopy closure, allelopathic potential, or height advantage are underexplored. Although transgenic or herbicide-tolerant technologies exist for soybean, similar innovations in other pulses are absent due to regulatory, research, and acceptance barriers. The lack of genetic improvement in weed competitiveness leaves pulses heavily dependent on external weed control inputs.

Limited mechanization options

Small and fragmented landholdings in major pulse-growing regions limit the adoption of mechanical weeders or tractor-mounted intercultivation implements. Non-uniform sowing, improper row spacing, and uneven fields further restrict effective mechanization. In many regions, farmers still practice broadcasting of seeds, which

makes inter-row cultivation impossible. Although manual and animal-drawn weeders are available, their use remains low due to poor awareness, drudgery, and labour constraints.

Limited extension and farmers' adoption

Despite the availability of several components of integrated weed management, such as cultural, mechanical, and chemical approaches, field-level adoption remains low. Farmers often rely on a single method, such as hand weeding or pendimethalin application, which may not provide season-long control. Inadequate knowledge of herbicide dose, timing, spray volume, nozzle type, and soil conditions further reduces effectiveness. Training, demonstrations, and extension services on IWM in pulses are insufficient, especially in remote rainfed areas.

MAJOR WEEDS AND LOSSES

In India, diverse pulse crops are grown across multiple agro-ecological regions and seasons throughout the year. While pigeonpea is mainly grown during rainy-season, greengram and blackgram are grown during both the rainy and summer seasons. Chickpea, pea, and lentil are the major pulse crops during the winter season. Weed flora density and diversity in pulses vary according to season, agro-ecological conditions, and management practices. Rainy season pulses are mainly infested with *Commelina benghalensis*, *Alternanthera sessilis*, *Triathema portulacastrum*, *Celosia argentea* (broad-leaved weeds), *Echinochloa colona*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Panicum maximum* (grasses), and *Cyperus rotundus* (sedge). *Triathema portulacastrum* is the most serious problem in greengram and blackgram during the spring/summer season. During winter, *Chenopodium album*, *Anagallis arvensis*, and *Fumaria parviflora* are found in irrigated as well as in rainfed pulses. Infestation of *Convolvulus arvensis* and *Medicago denticulate* in chickpea, pea, and lentil in northern and central India makes harvesting difficult. *Phalaris minor* and *Avena ludoviciana* are the major grassy weeds in winter pulses under irrigated conditions. Because of the seed mimicry, weeds such as *Lathyrus aphaca*, *Vicia sativa*, and *V. hirsuta* are serious concerns in the seed production and processing of lentil. In some parts of the country under rainfed conditions, *Pluchea lanceolata* and *Carthamus oxycantha* are very serious weeds. *Asphodelus tenuifolius* is posing a serious threat to chickpea cultivation in the Bundelkhand

region, South Haryana, Northern and Central Madhya Pradesh. Parasitic weed *Cuscuta* is a serious problem causing a lot of damage in greengram and blackgram in coastal Andhra Pradesh and Tamil Nadu, and in chickpea and lentil in parts of Madhya Pradesh (Mishra 2009), Chhattisgarh, and Bihar (Prakash et al. 2019). *Orobanche* spp., commonly known as broomrape, are a total root parasite that infests chickpea, pea, faba bean, lentil, and many forage legumes in the Mediterranean countries, Europe, Asia, and America (Goldwasser et al. 2000, Rubiales et al. 2009, Abu Irmillah and Haddad 2011). Volcu et al. (2020) reported that broomrape infestation in lentil reduced the grain yield by 59% with an economic loss of \$555/ha.

In addition to direct yield loss, weeds also deplete a significant amount of N, P, and K from the soil. Several studies have documented that weeds remove a substantial proportion of soil-available and applied nutrients, often exceeding crop uptake during the early growth period of pulses (Rao et al. 2015, Zimdahl 2018). Nutrient depletion is particularly severe during the critical period of crop-weed competition, leading to poor nodulation, reduced biological nitrogen fixation, and low nutrient-use efficiency (Singh and Yadav, 2018). Nutrient depletion by weeds often exceeds crop uptake in unweeded pulses (Singh and Yadav 2018). Weeds may remove 40–80% of available nitrogen in pulse crops during early growth stages (Rao et al. 2015; Zimdahl 2018). In chickpea, lentil, and field pea, weeds such as *Chenopodium album*, *Phalaris minor*, and *Avena ludoviciana* have been reported to remove 35–70 kg N/ha, 8–20 kg P/ha, and 30–60 kg K/ha under unweeded conditions (Malik et al. 2013, Kumar et al. 2017). Similar trends have been observed in *kharif* pulses such as greengram, blackgram, cowpea, and pigeonpea, where fast-growing grasses (*Echinochloa*, *Cenchrus*) and broadleaf weeds (*Triathema*, *Amaranthus*) act as strong nutrient sinks (Chauhan et al. 2017, Rana et al. 2020). In long-duration pulses like pigeonpea, uncontrolled weeds depleted 60–100 kg N/ha (Rao and Nagamani, 2010). Effective weed management significantly reduces nutrient losses and improves fertilizer recovery and crop nutrient uptake (Yadav et al. 2019). Many weeds act as an alternate host for insect-pests, pathogen and nematodes. For example, *Chenopodium album* acts as an alternate host for the gram caterpillar in pigeonpea and peas, and for greasy cutworm (*Agrotis ipsilon*) in chickpea and peas (Das 2008).

INTEGRATED WEED MANAGEMENT STRATEGIES IN PULSES

Integrated weed management integrates cultural (tillage, stale-seedbed, plant spacing, crop diversification -rotation and intercropping, weed seed harvesting, mulching, weed competitive varieties, etc.), mechanical weeding, and chemical approaches to achieve effective and economical weed control during the critical crop-weed competition period, combining herbicides with timely hand weeding or inter-cultivation to address labour constraints and minimize environmental impacts.

Pigeonpea

Pigeonpea is the major pulse crop of India, grown during the rainy season. It is cultivated in an area of 4.63 million ha with a total production of 4.01 million tons. The average productivity (866 kg/ha) is below the global average of 891 kg/ha. Being a slow-growing, wide-spaced, long-duration crop, several flushes of weeds compete with the crop and cause severe yield losses (often 30–80%). Application of pre-emergence herbicides alone is not enough to manage repeated flushes of weeds during the rainy season, which necessitates a manual/mechanical weeding or post-emergence application of selective broad-spectrum herbicides. The initial 40-60 days are the most critical for crop-weed competition. Cultural options like intercropping, crop rotation, closer spacing, tillage, etc. have been reported to reduce the weed infestation in pigeonpea and pigeonpea-based cropping systems. In pigeonpea-based intercropping, cowpea, greengram, and blackgram suppress weeds by 30 to 40% compared to sole cropping (Ali 1991). Intercropping of pigeonpea with soybean (2:4) had a smothering effect on weeds and resulted in 32% more grain yield than in a sole crop (Kaur et al. 2015). Talnikar et al. (2008) reported only 38.2% yield losses due to weeds in the pigeonpea + soybean intercropping system as compared to 79.9% in sole pigeonpea. Pre-emergence application of pendimethalin 1.0 kg/ha *fb* post-emergence application of imazethapyr 0.075-0.10 kg/ha at 30-35 DAS, has been found effective (Kumar et al. 2020). Post-emergence herbicides should be used as per the spectrum of weed flora. Details of herbicides recommended for pigeonpea are listed in Table 1.

Herbicides alone often don't maintain season-long weed control in pigeonpea because of the long crop duration and prolonged weed emergence. Pre-emergence application of pendimethalin

Table 1. Recommended herbicides for pigeonpea

Herbicide	Dose (g ai/ha)	Time of application	Target weeds
Pendimethalin	1000	PRE (0-3 DAS)	Grasses + broadleaf
Pendimethalin + Imazethapyr (RM)	1000	PRE (0-3 DAS)	Broadleaf + grasses
Imazethapyr	75-100	POST (~20-25 DAS)	Broadleaf + some grasses
Quizalofop-ethyl	50	POST (~20-25 DAS)	Grassy weeds
Propaquizafop + Imazethapyr (RM)	125	POST (~20-25 DAS)	Broadleaf + grasses
Imazamox + Imazethapyr (RM)	70	POST (~20-25 DAS)	Broadleaf + grasses
Imazethapyr + Quizalofop ethyl	75+50	POST (~20-25 DAS)	Broadleaf + grasses

DAS: Days after sowing; RM: Ready-mix

(or pendimethalin + imazethapyr) at sowing suppresses early weed flushes. Post-emergence application of imazethapyr or herbicide mixes (e.g., propaquizafop + imazethapyr or imazethapyr + quizalofop ethyl) at 20–25 DAS controls weeds that escaped early control. Tank-mix strategies and sequential applications often give the best balance of weed control and economics in pigeonpea systems. Mechanical hoeing using wheel hoes or power weeders or hand weeding at ~25-30 DAS further improves weed suppression and yield responses when combined with herbicides. Due to wider row spacing, tractor-mounted cultivators can also be used during the initial stages to manage weeds. These strategies must be integrated with appropriate cultural operations such as sowing on ridges, stale-seedbed, intercropping, weed seed harvesting, mulching, etc.) to have a sustainable weed management.

Chickpea

In India, chickpea is cultivated on 10.11 million ha and produces 11.57 million tons, with an average productivity of 1145 kg/ha. Weeds are one of the most serious threats to chickpea production worldwide, reducing the crop yields by 24-85%, depending on the density and diversity of weed flora and management practices (Kumar et al. 2025, Mahajan and Chauhan 2022, Nath et al. 2021, Tanveer et al. 2015). Crop sensitivity to many post-emergence herbicides is the major challenge in chickpea weed management. Grassy weeds in chickpea can be effectively controlled with post-emergence application of quizalofop-p-ethyl, propaquizafop, haloxyfop, and clodinafop-propargyl without

harming the crop. However, infestation of broadleaf weeds is a major concern that remains uncontrolled after commonly used pre-emergence herbicides (Nath *et al.* 2018, Kumar *et al.* 2025). Pendimethalin that inhibits cell division and effectively suppresses many grasses and broadleaf weeds, is the most common herbicide applied as pre-emergence. In several field experiments, pendimethalin showed good weed control and increased yield compared with untreated fields. Pendimethalin + imazethapyr (RM) applied as a pre-emergence is a highly effective combination for controlling a broad spectrum of weeds in chickpea, significantly boosting seed yields by reducing crop-weed competition, though some studies indicated potential for slight phytotoxicity at higher doses or when applied post-emergence. Oxyfluorfen is another effective pre-emergence herbicide for broadleaf weed control in chickpea. In recent studies, application of topramezone as post-emergence has been found very effective against broad-leaved weeds in chickpea (Nath *et al.* 2018, Nath *et al.* 2021, Kumar *et al.* 2025). Details of herbicides recommended for chickpea are listed in Table 2.

Integration of cultural practices such as early sowing, zero tillage, higher seed rate, and soil moisture control (high soil moisture encourages weed seed germination and causes phytotoxicity of pre-emergence herbicides), and mechanical (hand weeding at 25-30 DAS) approaches with pre- and

Table 2. Recommended herbicides for chickpea

Herbicide	Dose (g ai/ha)	Time of application	Target weeds
Pendimethalin	1000	PRE (0-3 DAS)	Grasses + broadleaf
Pendimethalin + imazethapyr (RM)	1000	PRE (0-3 DAS)	Broadleaf + grasses
Oxyfluorefen	125-150	PRE (0-3 DAS)	Broadleaf + grasses
Quizalofop-ethyl	50	POST (~20-25 DAS)	Grassy weeds
Clodinafop-propargyl	60	POST (~20-25 DAS)	Grassy weeds
Oxyfluorefen <i>fb</i> topramezone	125-150 20.6	PRE (0-3 DAS) <i>fb</i> POST (~20-25 DAS)	Broadleaf + grasses
Pendimethalin <i>fb</i> topramezone	1000 20.6	PRE (0-3 DAS) <i>fb</i> POST (~20-25 DAS)	Broadleaf + grasses
Pendimethalin + imazethapyr (RM) <i>fb</i> topramezone	1000 <i>fb</i> 20.6	PRE (0-3 DAS) POST (~20-25 DAS)	Broadleaf + grasses

DAS: Days after sowing; RM: Ready-mix

post-emergence herbicides is the key for successful weed management in chickpea.

Field pea

India cultivates field pea on 0.69 million hectares with a total production of 0.91 million tons of dry pea. The average productivity (1326 kg/ha) is significantly lower than the global average (1899 kg/ha). Being an irrigated crop, it suffers badly due to severe infestation of weeds such as *Medicago polymorpha*, *Chenopodium album*, *Rumex dentatus*, *Malva parviflora*, *Cichorium intybus*, *Cenchrus ciliaris*, *Anagalis arvensis*, *Melilotus* spp., *Convolvulus arvensis* (broad-leaved weeds), *Phalaris minor*, and *Avena ludoviciana* (grasses). Broad-leaved weeds are more competitive and often difficult to control in field pea, resulting in yield loss up to 60%. Annual grasses can be easily managed using post-emergence herbicides such as clodinafop-propargyl and quizalofop-ethyl. Pre-emergence application of pendimethalin at 1.0 kg/ha or pendimethalin+imazethapyr (RM) at 1.0 kg/ha or metribuzin at 0.25 kg/ha provides broad-spectrum weed control. Sequential application of pendimethalin+imazethapyr (RM) at 1.0 kg/ha as pre-emergence followed by metribuzin at 0.25 kg/ha as post-emergence (25-30 DAS) has been found quite effective for weed control and safe to the field pea crop. Integrated weed management involving zero tillage sowing with anchored crop residue of the previous season, selection of weed competitive varieties such as JP 885, Shikhar, and Arpan, along with sequential application of pre- and post-emergence herbicides, further broadens the weed management spectrum in field pea.

Lentil

In India, lentil is grown on 1.42 million ha, with a total production of 1.34 million tons. The average productivity of lentil in the country (947 kg/ha) is below the global average of 1187 kg/ha. Weeds are one of the major bottlenecks in sustaining its productivity. Shorter plant stature, slow initial plant growth, allows the broad-leaved weeds such as *Chenopodium album*, *Convolvulus arvensis*, *Asphodelus tenuifolius*, *Vicia sativa*, etc. to grow vigorously and suppress the lentil growth. Uncontrolled weeds in lentil have been reported to reduce its productivity by 20-60%, depending on weed flora density and diversity, and management practices. Therefore, making timely and effective weed control is crucial for achieving good yields of lentil. Very few herbicides have been found safe and effective for weed management in lentil. Pre-

emergence application of pendimethalin at 0.75-1.0 kg/ha or oxyfluorfen at 125-150 g/ha, followed by quizalofop-ethyl at 50 g/ha or clodinafop-propargyl at 60 g/ha as post-emergence (20-25 DAS) significantly reduces the weed pressure in lentil without harming the crop. Pendimethalin and oxyfluorfen provide initial control of annual grasses and small-seeded broad-leaved weed control, and quizalofop-ethyl and clodinafop-propargyl are effective as post-emergence against annual grasses such as *Phalaris* and wild oats.

Greengram and blackgram

In India, both greengram and blackgram are grown during the rainy and summer seasons. These crops are of short-duration (60–80 days), and poor competitors with weeds during the first 30–40 DAS, and yield losses of 30–70% are common if weeds are not controlled. During the summer season, high temperature slows crop vigour, but weeds thrive. Pendimethalin is a widely recommended pre-emergence herbicide in both crops. It provides effective early weed suppression and forms the backbone of chemical weed control. Pendimethalin + imazethapyr (RM) at 1.0 kg/ha applied as a pre-emergence provides broader and longer-lasting weed control than pendimethalin alone. Propaquizafop has been found very effective against *Echinochloa*, *Dactyloctenium*, and *Cynodon* spp. Pre-emergence application of pendimethalin followed by post-emergence application of imazethapyr or one hand weeding at 30 DAS remains the most economical and agronomically sound weed management strategy in greengram and blackgram. Details of herbicides recommended for greengram and blackgram are listed in Table 3.

Minor Pulses

Clusterbean is the most drought-tolerant legume. Being a slow-growing crop during early stages, it is highly vulnerable to weed competition up to 30–40 DAS. Weeds such as *Cenchrus*, *Echinochloa*, *Dactyloctenium*, *Trianthema*, *Digera*, and *Amaranthus* can cause 30–60% yield losses if not managed timely. Pre-emergence application of pendimethalin at 0.75-1.0 kg/ha followed by one hand weeding at 25-30 days after sowing provides effective weed control and satisfactory crop yield in clusterbean. If hand weeding is not possible, imazethapyr at 80-100 g/ha or imazethapyr + imazamox at 40-70 g/ha can be applied as post-emergence at the 3-4 leaf stage of the crop. Grassy weeds can be managed with post-emergence application of quizalofop-ethyl at 50

Table 3. Recommended herbicides for greengram/blackgram

Herbicide	Dose (g ai/ha)	Time of application	Target weeds
Pendimethalin	1000	PRE (0-3 DAS)	Grasses + broadleaf
Pendimethalin + Imazethapyr (RM)	1000	PRE (0-3 DAS)	Broadleaf + grasses
Imazethapyr	75-100	POST (~20-25 DAS)	Broadleaf + grasses
Quizalofop-ethyl	50	POST (~20-25 DAS)	Grassy weeds
Propaquizafop	75-100	POST (~20-25 DAS)	Grassy weeds
Propaquizafop + Imazethapyr (RM)	125	POST (~20-25 DAS)	Broadleaf + grasses
Sodium acifluorfen + Clodinafop propargyl	245	POST (~20-25 DAS)	Broadleaf + grasses
Imazethapyr + Imazamox (RM)	70	POST (~20-25 DAS)	Broadleaf + grasses
Fomesafen + Clodinafop propargyl	300	POST (~20-25 DAS)	Broadleaf + grasses

DAS: Days after sowing; RM: Ready-mix

g/ha. Mothbean is another drought-tolerant rainy season legume crop, extensively grown in arid and semi-arid regions. Weed competition may cause a 30-50 reduction in seed yield. Pre-emergence application of pendimethalin at 0.75 kg/ha or post-emergence application of imazethapyr + imazamox at 50 g/ha + one hand weeding 35 DAS have been found promising (Pratap et al. 2018).

In Frenchbean initial 30-45 DAS is most crucial for crop-weed competition. Uncontrolled weeds may cause seed yield loss by 45-60%. Application of imazethapyr 100 g/ha at 20 DAS can be useful for effective and economical weed control (Goud and Dikey 2016).

Fababean is a slow-growing, erect winter-season pulse and is highly susceptible to weed competition during the first 40–50 DAS. Dominant weeds include *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Melilotus* spp., *Anagallis arvensis*, and *Vicia* spp. Unmanaged weeds may lead to a 30-70% yield reduction. Pre-emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of imazethapyr at 25-30 DAS or one hand weeding at 35–40 DAS is the most effective and economical weed management strategy. Quizalofop ethyl at 50 g/ha or clodinafop-propargyl at 60 g/ha are highly effective against annual grasses such as *Phalaris minor* and *Avena* spp.

SUMMARY AND RECOMMENDATIONS

Pulses are crucial for global food security and sustainable agriculture. Weeds remain a major

production constraint in pulses. *Kharif* pulses face the severity of grassy weeds, monsoon-induced flushes, and intercropping herbicide conflicts. *Rabi* pulses suffer from the dominance of broad-leaved weeds, herbicide residues, and herbicide-resistant grasses. Summer pulses are threatened by irrigation-induced weed flushes, short duration, and heat stress. Season-wise, integrated strategies combining cultural, mechanical, and chemical tactics are essential to realize the optimum yield potential. It is important to identify safe and effective post-emergence herbicides, particularly for winter-season pulses. Adoption of integrated weed management technologies can increase pulse productivity by 20–45%, ensuring sustainability and resilience against weed shifts under climate change.

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