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Integrated weed management: The key to successful pulse production

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Abstract

India is a leading global producer and consumer of pulses, and crops like mung bean, urd bean, lathyrus, rajma, chickpea, pigeon pea and lentil. These crops help in promoting sustainable agriculture and food security and are essential to Indian agriculture because of their nutritional value and ability to enhance soil fertility. However, the production of pulses faces many challenges, including pests, diseases, unpredictable erratic weather conditions, and suboptimal soil conditions. Among these challenges, weeds are a significant threat as they compete with crops for resources and can harbour pests. Therefore, it is necessary to adopt Integrated Weed Management (IWM), a comprehensive approach combining cultural, mechanical, chemical and biological methods to control weeds and boost pulse production. By implementing strategies such as optimal sowing times, intercropping and cover crops, weed infestation and crop yields can be reduced. Technological advancements like drones and robotics for targeted herbicide applications can also be used to reduce the environmental footprint and costs associated with chemical usage. However, socio-economic constraints, such as limited access to quality seeds and essential inputs coupled with insufficient policy support, make these challenges even more complex. Therefore, it is necessary to adopt holistic strategies that address both agronomic and socio-economic issues. By managing weeds effectively and improving crop management practices along with leveraging technological innovations, the productivity and sustainability of pulse cultivation can be substantially increased in India. This, in turn, will contribute to food security and the prosperity of farming communities.

Keywords: Cultural methods, drone application, parasitic weeds, robotics, mechanical

1. Introduction

The United Nations has declared the year 2016 as the "International Year of Pulses" (IYP). India is the world's largest producer of pulses, accounting for 25% of global output, consuming 27% of global consumption, and importing 14% of it. About 20 per cent of the area under cultivation of cereal crops is intercropped with pulses, which contribute 7-10 per cent to the nation's total food grain production (Mohanty and Satyasa, 2015) ^[1].

Among the prominent pulses cultivated in India are chickpea or Bengal gram, pigeon pea or red gram, lentil, urd bean or black gram, mung bean or green gram, moth bean, horse gram, peas, cowpea and broad bean. Chickpea, the most popular pulse account for approximately 40% of the total pulse production, followed by pigeon pea (18-20%), mung bean (11%), urd bean (10-12%), lentil (8-9%), and other legumes (IIPR Vision 2030) ^[2]. In 2025, India grew pulse crops over an area of 27.72 million hectares, which resulted in a production of 25.68 million tonnes (Statistica, 2026).

Globally, weeds, insects, diseases and other pests contribute to losses of 45%, 30%, 20%, and 5% respectively (Katiyar and Singh, 2015) ^[3, 4]. Pulses have slow growth at the initial stages of the crop and weeds play a major role in causing yield losses (Balas et al., 2023; Kumar et al., 2022) ^[73, 5]. Weeds widely inhibit crop growth and lower yield and quality by competing with crops for resources such as light, food, water, nutrients and space or by harbouring insects and diseases (Balas et al., 2023; Kandasamy, 2000) ^[73, 6].

2. Pulse production constraints

Biotic and abiotic stresses are the major constraints for the production of pulses. The main biotic constraints for higher producers of chickpea are pod borer, wilt, rots, and blight and for pigeon pea, the main constraints are pod borers, wilt, and mosaic and for lentil are powdery mildew, rust,

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wilt, aphids, and pod borer. Legume crops contain higher amounts of nitrogen and phosphorus because these pulses attract more insects and pests. (Sinclair and Vadez, 2012) ^[67]. In India, most of the pulses are grown in low-fertility soils, problematic soils, and unpredictable environmental conditions. Over 87% of the area is under pulses as rainfed. Drought and high temperatures may reduce the seed yield by half, particularly in dry and semi-dry regions. Inadequate drainage or waterlogging during the rainy season leads to significant losses in pigeon pea cultivation due to reduced plant density and heightened occurrence of pests and diseases. (Gowda *et al.*, 2013) ^[7]

Farmers prioritise allocating inputs primarily to staple crops and cash crops, with pulses being given secondary importance. Consequently, pulses are often cultivated in lowproductive soils with minimal inputs. Furthermore, there is a deficiency in policy support and advancements in post-harvest technologies for pulse production. The limited availability of high-quality seeds of improved varieties and other essential inputs stands out as a significant obstacle to enhancing grain legume production are some of the constraints for pulse production (David *et al.*, 2002) ^[8].

3. Why weed management?

Weeds are particularly problematic in pulse crops due to their slow initial legume growth, prolific seed production and highly efficient weed seed dispersal mechanism (Das 2008) ^[9]. Weeds can lead to reduced profitability due to the reduction in yield and increased labour costs for manual removal. Weeds affect agricultural production by reducing crop yields and will also act as a shelter for pests and diseases (Zimdahl., 2018) ^[10]. The extent of losses depends on the nature and intensity of weeds and weed species. Weeds can reduce the quality of legumes by contaminating them with seeds, residues, or toxins, affecting their market value. Weeds can serve as hosts for pests and diseases affecting the pulse crops, increasing the risk of infestations. Weeds are also responsible for depleting a significant quantity of nutrients from soil and the amount is directly correlated to the level of weed infestation. (Sinchana *et al.*, 2023) ^[11]

Table 1: Yield losses due to weed infestation in pulses

Crop	Grain yield loss (%)	References
Pigeon pea	41.9	Singh <i>et al.</i> , 2013 ^[12]
Green gram	56.7	Shriram Osari <i>et al.</i> , 2019 ^[13]
Black gram	Kharif- 43.2 to 64.1	Rathi <i>et al.</i> , 2004 ^[14]
Black gram	Summer- 46 to 53	Rathi <i>et al.</i> , 2004 ^[14]
Chickpea	54.7	Poonia and Pithia 2013 ^[15]
Pea	20 to 40	Blackshaw and O'Donovan 1993
Lentil	37.7	Yadav <i>et al.</i> , 2013 ^[16]
Cowpea	82	Tripathi and Singh, 2001 ^[17]

4. Weed flora in pulses

The weed flora in pulses is dependent on the agroecological conditions and management techniques followed. Weed flora in pulse crops is highly diverse and comprises broad-leaved weeds, grasses and sedges, with broad-leaved weeds generally dominating the weed population. The predominant broad-leaved weed species associated with pulse cultivation include *Celosia argentea*, *Cleome viscosa*, *Commelina benghalensis*, *Cucumis trigonus*, *Digera arvensis*, *Eclipta prostrata* (syn. *Eclipta alba*), *Euphorbia hirta*, *Phyllanthus niruri*, *Trianthema monogyna*, *Convolvulus arvensis*, *Ageratum conyzoides*, *Anagallis arvensis*, *Argemone mexicana*, *Asphodelus*

tenuifolius, *Carthamus oxyacantha*, *Chenopodium album*, *Coronopus didymus*, *Fumaria parviflora*, *Gnaphalium indicum*, *Lathyrus aphaca*, *Launaea nudicaulis*, *Medicago denticulata*, *Melilotus alba*, *Rumex dentatus*, *Solanum nigrum*, *Spergula arvensis*, *Vicia hirsuta*, *Vicia sativa*, *Amaranthus viridis*, and *Physalis minima*.

Grassy weeds also constitute an important component of the weed flora in pulse ecosystems. The major grass species infesting pulse fields include *Echinochloa colona*, *Cynodon dactylon*, *Eleusine indica*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Setaria glauca*, *Saccharum spontaneum*, *Sorghum halepense*, *Eragrostis tenella*, *Avena ludoviciana*, *Phalaris minor*, *Lolium temulentum*, *Poa annua*, and *Polypogon monspeliensis*. These weeds compete vigorously with pulse crops during the early stages of growth, resulting in significant losses in crop growth and yield.

Compared with broad-leaved weeds and grasses, sedges occur in relatively lower abundance in pulse fields. However, certain sedge species are persistent and difficult to manage due to their prolific reproductive ability and perennial nature. Among these, *Cyperus difformis*, *Cyperus iria*, and *Cyperus rotundus* are the most common and economically significant sedges encountered in pulse-growing regions (Sinchana and Sheeja, 2023) ^[11].

5. Critical period of weed competition in pulses

Nieto *et al.* (1968) ^[18] introduced the concept of critical periods within the crop growth cycle, which denotes the timeframe wherein weeds can compete with crops for vital resources like water, nutrients, sunlight, and space. The critical period of weed control (CPWC) is defined as the duration between the critical time for weed removal and the critical weed-free period. This period signifies when the presence of weeds shouldn't substantially diminish crop yield (Dawson, 1986) ^[19]. As undesired plants, weeds can detrimentally affect crop production by reducing yield and quality. The critical period spans several weeks post-crop emergence, during which the crop must remain free of weeds to avert yield losses surpassing 5%. CPWC denotes the specific period within the crop growth phase when maintaining the crop free of weeds is imperative to forestall yield reduction caused by weed interference (Hall *et al.*, 1992) ^[20].

Table 2: Critical crop-weed competition periods vary across different pulse crops.

Crop	Critical period of crop weed competition (DAS)	References
Pigeon pea	55	Tomar <i>et al.</i> , 2003 ^[21]
Green gram	45	Singh <i>et al.</i> , 1996 ^[22]
Black gram	20-40	Saraswat <i>et al.</i> , 1993 ^[23]
Chickpea	40-50	Chopra <i>et al.</i> , 2003 ^[24]
Pea	60	Kumar <i>et al.</i> , 2009 ^[25]
Lentil	40-45	Yadav <i>et al.</i> , 2007 ^[26]
Cowpea	15- 45	Tripathi and Singh, 2001 ^[17]

6. Strategies for weed management

To develop a successful weed management strategy, it is important to know the biology and ecology of weed flora and critical crop weed competition. It is crucial to consider the specific legume crop, prevalent weed species, local conditions, and available resources. Implementing integrated weed management practices that combine cultural, mechanical, chemical, and biological methods can effectively control weeds

while protecting the quality and quantity of pulse production. The key period of crop weed competition is up to 30 DAS for short-duration pulses and up to 60 DAS for long-duration pulses (Kumar *et al.*, 2016a) ^[27].

7. Integrated weed management

Integrated weed management (IWM) is a systematic approach that harmonizes the utilizing the information on the environment, ecology, and biology of weeds. It involves ecologically controlling weeds in agricultural fields through the application of various technologies. Research on integrated weed management (IWM) is centered on decisionmaking processes, weed ecology, and biology, and the various components of IWM typically employed in crop rotation, herbicide resistance levels, ecological issues associated with transgenic plants, and the welfare of weeds. (Rao and Nagamani, 2010) ^[28].

Integrated weed management (IWM), is a useful technique to change agricultural weed competition in favour of crops by implementing chemical, cultural, biological, and mechanical weed control techniques.

7.1 Preventive methods

The main objective of preventive weed control is to minimize the entry, growth, and spread of weeds in new areas, while also preventing the production and dispersal of weed seeds from existing plants. Several methods are utilized to reduce the introduction of weed seeds into the soil. These methods include using clean or certified seeds, avoiding foreign and invasive species and weeds, using well-rotted compost, using clean farm equipment, cleaning farm bunds, and so on. To prevent the germination of potentially thousands of weed seeds, it is necessary to manually remove and burn existing weeds. Given that annual weeds are primarily propagated through seeds, controlling their spread requires their elimination before flowering, to prevent the laying of seeds and subsequent infestation. (Narendra Kumar *et al.*, 2016) ^[27]

7.2 Cultural method

Cultural methods are essential in improving crop health and competitive ability. These methods allow crops to survive under weed pressure and utilize both above and belowground resources. Being inherently recommended agro-practices for a crop, the cultural practices usually do not incur extra costs for weed management (Donovan *et al.*, 2001) ^[29]. These practices include competitive crops/crop cultivars, tillage, geometry, time, method, rate, and depth of sowing.

Choosing the optimum time of sowing, weed density, and dry matter can be greatly decreased. Malik and Yadav (2014) ^[30] opined that the pigeon pea crop planted in May yielded more than the crop planted in June. To get a better yield, sowing should be done on 10-25th May, which gives higher yield in May due to less competition of weeds for their resources and better vigour of the crop. Similarly, chickpea that were sown on November 10 showed the greatest production and nutrient uptake, since the weed count might be less, resulting in nutrient depletion at a lower rate. (Singh *et al.*, 2014) ^[31]

The germination and development of weeds vary depending on the planting method used. Therefore, choosing an appropriate planting method is important for the partial removal of weeds. (Sinchana *et al.*, 2023) ^[11]. Chickpea grown under raised beds give higher yield and harvest index compared to flatbeds (Patidar *et al.*, 2023) ^[32]

The implementation of crop rotation can be an effective way to mitigate weed issues by altering the microclimate in each field. Liebman and Gallandt (1997) ^[33] reported that “crop rotation is an important tool for weed management in pulses. It affects the demography of weeds and subsequent population dynamics”. Kumar *et al.* (2016a) ^[27] suggested that crop rotation disrupts the cycle of weed seeds and inhibits the proliferation of various weed species. Crop rotation is effective in controlling parasitic weeds/crop-associated weeds. Parasitic weeds in pulses like *Striga hermonthica/asiatica*, *Orobancha ramosa*, and *Cuscuta* spp. can be effectively controlled by adopting crop rotation with cereals (Kaur *et al.*, 2015) ^[34].

The goal of soil solarisation (SS), a pre-plant soil disinfection technique, is to eliminate or greatly reduce crop pests, dormant weed seeds, current weed seedlings, and existing soil inoculum of different weed species using transparent polyethylene (PE) plastic mulch. (Katan 1981) ^[35]. Solarisation has two modes of action, thermal and hydrothermal, whereas the upper layer of soil is heated by capturing solar radiation (Horowitz 1980) ^[36]. Johnson grass, Bermuda grass, and field bindweed are difficult to control with soil solarisation because of their profuse rhizome-reducing ability. The emergence of annual weeds is prevented by solarisation at 37 °C for 2-4 weeks, especially at the upper layer. Soil solarisation effectively controls many weeds like broomrapes (*Orobancha* spp.) but does not control *Cuscuta* sp., bindweed, or purple nutsedge. Increased irrigation at least two or three weeks before solarisation allowed weed growth, and incorporated the weeds into the soil by the following tillage practice before application of the soil solarisation treatment. *Avena sterilis* subsp. *ludoviciana* and *phalaris minor* were completely controlled by soil solarisation; the solarised plots give better yields, resulting in a 25% increase in the yields of soybean (Yaduraju and Ahuja, 1996) ^[37].

Intercropping inhibits weed growth by creating dense crop cover. Ali (1988) ^[38] observed that by incorporating fast-growing, short-duration crops within the interrow spaces of long-duration, tall-growing crops, weeds are effectively suppressed and lead to a significant decrease in weeding costs. Due to wider spacing and slow initial growth of the main crop the weed infestation will be higher in pigeon pea. Also, short-duration legumes like urd bean, mung bean, soybean, and cowpea crops intercropped with pigeon pea suppressed weed flora considerably. In central and peninsular India, the sorghum + pigeon pea intercropping system has been designated as the most productive system of Vertisols (Kaur *et al.*, 2015) ^[34]. Intercropping cowpeas, urd bean, and mung beans reduces the amount of weed flora in pigeon peas by 30 to 40%. (IIPR 2009). The stale seedbed technique involves encouraging weed seeds to germinate through pre-sowing irrigation, then eliminating emerged weeds either with non-selective herbicides or pre-plant tillage methods. (Gnanavel and Kathiresan, 2014) ^[39]. The success of a stale seedbed is determined by the method of seedbed preparation, weed genera present in the soil, method of weed killing, and lastly, duration of the stale seedbed (Ferrero, 2003) ^[40]. Compared to the normal seedbed, the stale seedbed (SSB) recorded lower total weed density at 45 DAS and higher green pod yield in cowpea. (Sinchana *et al.*, 2023) ^[11].

Mulching is the practice of covering the soil around plants with a layer of organic or inorganic material. This protective layer acts as a barrier, preventing the growth and establishment of weeds in the area. Mulching suppresses weed germination by blocking sunlight, reducing soil moisture loss through evapotranspiration, and providing physical protection to plants.

Mulching is an effective strategy used in weed management to minimise weed competition and enhance the growth and health of desired plants. In chickpea, out of various types of straw mulches, using paddy straw mulch (5 tons ha⁻¹) achieved a higher weed control efficiency (WCE of 61.34%) followed by wheat straw mulch (WCE of 53.04%), soybean straw mulch (WCE of 32.62%) as compared with no mulch at all resulted in the lowest (WCE of 22.03%) (Sahu *et al.*, 2020) ^[41].

7.3 Mechanical methods

Mechanical method refers to the use of physical methods and tools to control and remove weeds from an area. These methods include hand weeding, hoeing, ploughing, and other mechanical tools that help to remove weeds from the soil. It is more labour-intensive and time-consuming than chemical methods. The commonly used weeders are handoperated/power-operated/animal-drawn harrows/cultivators and manual or power-operated weeders. Manual weeding using a hand hoe is uneconomical due to the higher costs involved but it is effective. Utilising a rotary hoe and cultivator could prove advantageous in managing weeds in soybean crops, achieving nearly 70% weed control effectiveness until the weed's growth reaches the 1-3 leaf stage.

Tillage is one of the major mechanical weed control methods which has been followed by many farmers for several years. Tillage controls weeds by changing the soil conditions, burying weed seeds deeply to inhibit their emergence, removing them from the soil, and influencing the germination and establishment of weed seeds through both vertical and horizontal seed movement. (Swanton *et al.*, 2000) ^[42]. Zero tillage with crop residues and integrated weed management practices has significantly recorded and gives higher seed yield and weed control in green gram (Narendra Kumar *et al.*, 2023) ^[64].

Young *et al.*, (2013) ^[71] revealed that "hoeing is the removal of weeds either by uprooting or plucking with hand-operated implements or animal-drawn implements." It includes utilising various tillage tools such as blade harrows, weeders and cultivators, which can be powered by animals or by power. Both annual and perennial weeds can be controlled effectively by hoeing. Hand weeding at 20, 30, and 40 DAS of green gram during summer, gives a higher yield (Chhodavadia *et al.*, 2014) ^[43].

7.4 Chemical methods

Chemical weed control in pulses is an effective approach for managing weeds due to its affordability and high effectiveness. It offers extensive coverage, making it suitable for large areas, and is easy to apply. It is particularly advantageous in areas where labour is limited or expensive, and where intercultural operations are not feasible. It reduces the preplanting tillage cost and kills the weeds without the dissemination of vegetative propagules. (Sinchana 2023) ^[11]. The yield in pulses increased by 10 to 50% due to the chemical method of weed management (Ashiq and Aslam., 2014) ^[44].

Shwetha *et al.*, 2024 reported that next to weedy check Imazethapyr + Imazamox @ 100 g a.i., Propanil + Imazethapyr @ 100 g a.i. suppressed the weed density effectively and increased the weed control efficiency (88.41 % and 84.14%) ^[45] in soybean. In pea sequential application of pendimethalin 1kg ha⁻¹ (PE) + Imazethapyr 50 g ha⁻¹ (PoE) was proved to be the most effective in reducing the weed density and dry weight (Rakesh Kumar *et al.*, 2023) ^[65].

7.5 Biological method

Biological weed control utilizing living organisms such as bacteria, fungi, nematodes, insects, fish, and birds represents an economically and ecologically responsible method for the eradication of challenging weeds. In Louisiana, Mississippi, and Arkansas, the leguminous weed, northern joint vetch (*Aeschynomene virginica*), is controlled by the application of Collego®, a soybean herbicide based on the fungus *Collectotrichum gloeosporioides f.sp. aeschynomene*. This herbicide has shown its efficacy and has consequently been implemented as a promising solution for the management of this weed. (Sonaka Ghosh *et al.*, 2023) ^[62]. Biological control presents a cost-effective option that is minimally harmful to humans, animals, and the environment. It is both efficient and versatile in managing perennial, parasitic, and invasive weeds. (Narendra Kumar *et al.*, 2022) ^[5]. It will not completely eradicate weeds but instead, reduce the weed population to below the economic threshold level. (Bajwa *et al.*, 2015) ^[46]. Most bio-agents only target a single type of weed, which means that using them to control weed infestations in a crop with many different types of weeds can be difficult. Additionally, the process of killing or suppressing weeds using bio-agents is slow, and early weed competition can cause significant damage to crops before the bio-agents have a chance to act. The effectiveness of bio-agents can also be affected by the environment and ecology, which can vary greatly across different regions of the world (Narendra Kumar *et al.*, 2023) ^[64].

9. Parasitic weeds in pulses

In some parts of India, *Cuscuta* and *Orobanch* are the major parasitic weeds in pulses. *Cuscuta campestris* Yunck. poses a serious threat to pulse, oilseed, and fodder crops grown in rainfed and irrigated regions of Andhra Pradesh, Chhattisgarh, Gujarat, Odisha, West Bengal, and portions of Madhya Pradesh (Mishra, 2009) ^[47]. *Orobanch crenata* Forsskal causes significant harm to several crops such as peas, lentils, faba beans, and chickpeas (Punia, 2014) ^[48].

Orobanch crenata targets a range of crops including faba bean, pea, lentil, and chickpea. *Orobanch ramosa* and *O. aegyptiaca* specifically affect lentil crops. *Orobanch foetida* primarily infests faba bean plants. *Striga gesnerioides* poses a threat to cowpea cultivation. Lastly, *Cuscuta campestris* is known to parasitise faba bean, chickpea, mungbean, urdbean, and pigeon pea crops. Understanding these weed species and their preferred hosts is crucial for effective weed management strategies in agricultural settings. (Kumar *et al.*, 2016) ^[27].

9.1 Parasitic weed management

Preventing seed dissemination is crucial to control *Orobanch*. Burning residue from infested crops reduces seed carryover. Summer deep ploughing, soil solarization, crop rotation with trap or non-host crops and growing non-host crops like wheat and barley are the most effective strategies for reducing parasitic weed-seed banks in infested areas. (Mishra, 2009) ^[47]. To prevent the reproduction of thousands of *Cuscuta* seeds, it's important to hand-pull and burn the plants. Deep ploughing of infested land reduces the chances of the parasite establishing from recently shed seed, but the older seed may be brought to the surface by this practice. The stale-seedbed technique is effective for controlling parasitic weeds like *Cuscuta*. *Cuscuta* can be completely controlled through crop rotation, as it doesn't parasitise cereal crops. Broad-leaved weeds must be controlled to deprive *Cuscuta* of all hosts, preventing the production of new *Cuscuta* seed (Mishra, 2009) ^[47]. According to research studies conducted by Mishra *et al.* (2005) ^[72], applying pendimethalin at a rate of 0.5-1.5 kg ha⁻¹ is an effective way to control *Cuscuta* in pulses.

10. Integrated weed management in pulses

Table 3: The table summarizes effective integrated weed management practices for pulse crops.

Crop	IWM	Reference
Pigeon pea	Pendimethalin@1.0kg ha ⁻¹ (PE) + Imazethapyr 35 EC + Imazamox 35 EC @ 0.075 kg ha ⁻¹ (20 DAS) fb HW (40DAS) recorded significantly higher seed and straw yield.	Singh et al., 2018 ^[49]
Black gram	Pendimethalin 30 % EC@1.0kg ha ⁻¹ (PE) fb power weeder at 20 DAS with spacing 40×7.5 cm gives a significant reduction in weed density, increased weed control efficiency, and higher grain yield	Boya Mamatha Kumari et al., 2023 ^[50]
Cowpea	Combination Stale seedbed +dried banana leaf mulch @10 t ha ⁻¹ fb Quizalofop -P-ethyl @ 50 g ha ⁻¹ (25 DAS) recorded lower dry weight of weed and recorded the highest total N and P uptake by cowpea and green pod yield	Sinchana et al.,2023 ^[11]
Chickpea	Oxyfluorfen(PE) 0.120 kg ha ⁻¹ @ 3DAS fb Imazethapyr (POE) 50 g/ha @ 35 DAS fb 1 hoeing @ 60 DAS significantly gives lowest weed count compared to other weed management practices.	Kokate et al.,2023 ^[51]
Pea	Pendimethalin@0.75kg a.i./ha(PE)+HW@40 DAS is the most profitable integrated weed management	Singh, et al., 2019 ^[68]
Soybean	Sodium acifluorfen 16.5% +Clodinofof-propargyl was similar to imazethapyr application in controlling weeds	Jha et al.,2014 ^[52]
Green gram	Pendimethalin (pre) 1000g a.i./ha +1 hand weeding minimizes total weed density throughout the crop growth period and produces maximum yield.	Singh et al., (2015)

11. Recent weed management techniques

Inventive methods are emerging to handle weed species within sustainable production systems. These strategies focus on increasing the ecological functions of the system or leveraging technological advancements. They align well with traditional methods while offering increased flexibility and reliability to integrated weed management (IWM) practices.

11.1 Spraying and weeding with robotics

Weed-killing robots are designed to target specific weeds with microbursts of herbicides, resulting in a significant reduction in the number of herbicides required. These robots are equipped with advanced computer vision systems that help them identify individual weeds as they roll through the fields (Chang and Lin, 2018) ^[53]. This technology is a cheaper alternative to widespread spraying, enabling farmers to reduce their costs. An assumption was made for the sprayer, where field speeds would increase by 20% for preplanting applications and 10% for post-planting applications. It was assumed that these increases in speeds were due to the ability to drive faster during headland turns and quickly determine which row to enter to continue operating (Stombaugh, 2011) ^[54].

11.2 Weed management with drones

Drones (UAVs) transformed farming by saving costs and increasing efficiency and profitability and have gained academic interest over the past few decades in agriculture (Friha et al. 2021) ^[55]. Drones have become one of the most widely adopted robotic applications in agriculture and save a lot of time and labour in various agricultural operations. Equipped with multi-spectral and photo cameras, drones can monitor crop and soil health, assist in planning irrigation schedules, estimate yield data, apply fertilizers, and provide valuable data for weather analysis. (Sylvester, 2018) ^[56]. Based on the study, the AD610D model of the drone was employed for herbicide spraying. it was determined that the optimal dose of pendimethalin for green gram cultivation is 0.75 kg per hectare when used in combination with a spray fluid of 60 litres per hectare for drone application. This combination was found to have the best WCE (weed control efficiency), soil microorganisms, nodulation, and higher grain yield (Madhusree et al., 2023) ^[57]. The Link Net model with ResNet-34 was utilized to detect weed plants in real-time utilizing video feed from low-altitude flying drones. The study revealed that real-time detection of parthenium weed is possible using low-altitude drones in pulse crop fields. (Revanasiddappa et al., 2020) ^[58].

11.3 Laser weeding

Laser weeding is an effective and eco-friendly method for controlling weeds. It involves using lasers to specifically target and destroy weed tissues while leaving the desired crops unharmed. This technique reduces the need for herbicides and manual labour, making it an excellent choice for organic farming and environmentally sensitive areas. By providing a non-chemical and precise approach to weed management, laser weeding can help farmers achieve more efficient and sustainable crop production.

Different laser types utilize varying active media and release diverse wavelengths of light. When it comes to diode lasers, a semiconductor is the active medium that gets stimulated via an electrical current. The emission wavelengths of diode lasers can range from ultraviolet to infrared radiation, with typical wavelengths falling between 940 and 980 nm. Depending on the power, diode lasers can range from mW to several kW. Fibre lasers are a type of solid-state laser that uses a doped glass fibre as the active medium, and they're stimulated via optical radiation (Hitz et al., 2012) ^[59].

11.4 Biotechnological Approaches to Weed Management

Biotechnological approaches have emerged as effective tools for sustainable weed management, with the development of herbicide-resistant crops being one of the most significant advancements. Herbicide-resistant crops possess the ability to withstand the application of specific herbicides at doses that would normally damage susceptible crop varieties or effectively control associated weed species. According to Knezevic and Cassman (2003) ^[60], herbicide-resistant crops are developed either through the introduction of a foreign gene (transgene) from another organism into the crop genome or by identifying and incorporating naturally occurring herbicide-tolerant traits from the existing crop germplasm through breeding or selection.

12. Conclusion

India plays a significant role in global pulse production and consumption, which contributes to food security both nationally and internationally. However, pulse cultivation faces several challenges, including biotic and abiotic stresses and socio-economic constraints. Weeds pose a serious threat to pulse cultivation, leading to considerable yield and quality loss. For this reason, it is crucial to adopt integrated weed management strategies that are sustainable and eco-friendly. The use of modern technologies, such as drones and robotics, can provide innovative solutions for precise weed control. Additionally,

addressing socioeconomic barriers requires a multifaceted approach that improves access to resources, promotes policies that support farmers, and advances post-harvest technologies. By effectively managing weeds and overcoming these challenges, India can continue to increase the productivity and sustainability of its pulse cultivation, which will contribute significantly to global food security and the prosperity of its farming communities.

13. References

- Mohanty S, Satyasai K. Feeling the pulse: Indian pulses sector. NABARD Rural Pulse. 2015;10:1-4.
- Indian Institute of Pulses Research. IIPR Vision 2030. Kanpur, Uttar Pradesh: ICAR-IIPR; 2030.
- Katiyar A, Singh S. Ecological approaches of weed management in pulses: The need for new commands for sustainable farming. Pop Kheti. 2015;3:27-32.
- Singh RK, Akhilendra V, Singh D. Effect of weed management practices on yield of green gram (*Vigna radiata* L.) and weed population under guava-based agrihorticultural system in Vindhyan region. Environ Ecol. 2015;33:1932-1935.
- Kumar N, Nath CP, Hazra KK. Weed management in pulse crops: Challenges and opportunities. 2022.
- Kandasamy O. Cost-effective weed management strategies in pulse production. In: Proceedings of CASA on Recent Advances in Pulse Production Technology. Coimbatore: TNAU; 2000:116-119.
- Gowda CL, Samineni S, Gaur P, Saxena K. Enhancing the productivity and production of pulses in India. 2013.
- David S, Mukandala L, Mafuru J. Seed availability, an ignored factor in crop varietal adoption studies: a case study of beans in Tanzania. J Sustain Agric. 2002;21:5-20.
- Das TK, Yaduraju NT. Effect of soil solarization and crop husbandry practices on weed species competition and dynamics in the soybean-wheat cropping system. Indian J Weed Sci. 2008;40(1-2):1-5.
- Zimdahl RL. Fundamentals of weed science. 5th ed. London: Academic Press; 2018.
- Sinchana J, Raj SK. Weed management in pulses: A review. Legume Res. 2023;46:533-540.
- Singh G, Sekhon H. Integrated weed management in pigeonpea (*Cajanus cajan* L. Millsp.). World J Agric Sci. 2013;9:86-91.
- Osari S, Marskole J, Jatav SK, Bhadauria S. Efficacy of herbicides controlling weed flora and productivity of greengram. Int J Chem Stud. 2019;6:396-400.
- Rathi J, Tewari A, Kumar M. Integrated weed management in blackgram (*Vigna mungo* L.). Indian J Weed Sci. 2004;36:218-220.
- Poonia T, Pithia M. Pre- and post-emergence herbicides for weed management in chickpea. Indian J Weed Sci. 2013;45(3):223-225.
- Yadav R, Singh R, Yadav K. Weed management in lentil. Indian J Weed Sci. 2013;45(2):113-115.
- Tripathi S, Singh G. Critical period of weed competition in summer cowpea (*Vigna unguiculata* L. Walp.). Indian J Weed Sci. 2001;33:67-68.
- Nieto HJ, Brondo M, Gonzalez. Journal of Critical periods of the crop growth cycle for competition from weeds. 1968.
- Dawson J. The concept of period thresholds. 1986:327-331.
- Hall MR, Swanton CJ, Anderson GW. The critical period of weed control in grain corn (*Zea mays*). Weed Sci. 1992;40:441-447.
- Tomar S, Singh G, Tripathi S. Crop weed competition in arhar (*Cajanus cajan* L.) under Northern West Plain Zone. Indian J Weed Sci. 2003;35:217-220.
- Singh A, Sahadeva Singh SS, Bhan V. Crop-weed competition in summer greengram (*Phaseolus radiatus*). Indian J Agron. 1996;41(4):616-619.
- Saraswat V, Mishra J. Weed management in pulse crops. 1993.
- Chopra N, Chopra N, Singh H. Loss in seed yield and quality due to weed stress in chickpea (*Cicer arietinum*). Indian J Agric Sci. 2003;73:350-351.
- Kumar A, Sharma B, Nandan B, Sharma PK. Crop-weed competition in field pea under rainfed subtropical conditions of Kandi belt of Jammu. Indian J Weed Sci. 2009;41:23-26.
- Yadav SS, Rizvi AH, Manohar M, Verma A, Shrestha R, Chen C, et al. Lentil growers and production systems around the world. In: Lentil: An Ancient Crop for Modern Times. 2007:415-442.
- Kumar N, Nath CP, Hazra KK, Sharma A. Efficient weed management in pulses for higher productivity and profitability. Indian J Agron. 2016;61:5199-5213.
- Rao N, Nagamani A. Integrated weed management in India revisited. Indian J Weed Sci. 2010;42(3&4):123-135.
- O'Donovan JT, Harker KN, Clayton GW, Newman JC, Robinson D, Hall LM. Barley seeding rate influences the effects of variable herbicide rates on wild oat. Weed Sci. 2001;49:746-754.
- Malik R, Yadav A. Effect of sowing time and weed management on performance of pigeonpea. 2014.
- Singh R, Verma S, Singh R, Idnani L. Influence of sowing dates and weed management on weed growth and nutrient depletion by weeds and uptake by chickpea (*Cicer arietinum*) under rainfed condition. Indian J Agric Sci. 2014;84:468-472.
- Patidar T, Tyagi DB, Dwivedi A, Singh MD, Nigam P. Effect of land configuration and nutrient management on the yield and economics of chickpea (*Cicer arietinum* L.) in Malwa region of Madhya Pradesh. Technofame J Multidiscip Adv Res. 2023;12(1):58-63.
- Liebman M, Gallandt ER. Many little hammers: Ecological management of crop weed interactions. In: Jackson LE, editor. Ecology in Agriculture. San Diego: Academic Press; 1997:291-343.
- Kaur R, Raj R, Das TK, Shekhawat K, Singh R, Choudhary AK. Weed management in pigeonpea-based cropping systems. 2015.
- Katan J. Solar heating (solarization) of soil for control of soilborne pests. Annu Rev Phytopathol. 1981;19(1):211-236.
- Horowitz M. Weed research in Israel. Weed Sci. 1980;28:457-460.
- Yaduraju N, Ahuja K. Effect of soil solarization with or without weed control on weeds and productivity in soybean-wheat system. In: Proceedings of the Second International Weed Control Congress. Copenhagen, Denmark; 1996:721-727.
- Ali M. Weed-suppressing ability and productivity of short-duration legumes intercropped with pigeon pea under rainfed conditions. Int J Pest Manag. 1988;34(4):384-387.
- Gnanavel I, Natarajan SK. Eco-friendly weed control options for sustainable agriculture: A review. Agric Rev. 2014;35(3):172-183.

40. Ferrero A. Weedy rice: Biological features and control. FAO Plant Production and Protection Paper: Weed Management for Developing Countries. Rome: FAO; 2003.
41. Sahu MP, Kewat ML, Jha AK, Sharma JK, Sondhia S. Weed dynamics as affected by practices and straw mulches in chickpea. *Int J Chem Stud.* 2020;8(4):1857-1859.
42. SWANTON CJ, SHRESTHA A, CHANDLER K, DEEN W. An Economic Assessment of Weed Control Strategies in No-Till Glyphosate-Resistant Soybean (*Glycine max*)¹. *Weed Technology.* 2000;14(4):755-763.[https://doi.org/10.1614/0890-037x\(2000\)014\[0755:aeaowc\]2.0.co;2](https://doi.org/10.1614/0890-037x(2000)014[0755:aeaowc]2.0.co;2)
43. Chhodavadia SK, Sagarka BK, Gohil BS. Integrated management for improved weed suppression in summer green gram (*Vigna radiata* L. Wilczek). *Bioscan.* 2014;9(4):1577-1580.
44. Ashiq M, Aslam Z. Weeds and weedicides. Ayub Agricultural Research Institute, Department of Agronomy, Pakistan; 2014.
45. Shwetha BN, Anupama C, Vishwanatha S, Koppalkar BG, Kumar MV. Weed management in soybean through post-emergent herbicides. *Int J Plant Soil Sci.* 2024;36(2):190-196.
46. Bajwa AA, Mahajan G, Chauhan BS. Nonconventional weed management strategies for modern agriculture. *Weed Sci.* 2015;63:723-747.
47. Mishra JS. Biology and management of *Cuscuta* species. *Indian J Weed Sci.* 2009;41(1-2):1-11.
48. Punia SS. Biology and control measures of *Orobanche*. *Indian J Weed Sci.* 2014;46(1):36-51.
49. Singh VP, Singh K, Singh R, Singh B. Influence of integrated weed management on growth and development of rainfed pigeonpea (*Cajanus cajan* L. Millsp.). *J Crop Weed.* 2018;14(3):153-160.
50. Kumari BM, Yassin MM, Fanish SA, Vanitha K, Padmanathan PK. An integrated effect of weed management in blackgram. *Int J Plant Soil Sci.* 2023;35(18):1601-1610.
51. Kokate HG, Ghatak R, Gawali K, Sarda A, Bondre C. Integrated weed management in chickpea (*Cicer arietinum* L.). 2023.
52. Jha BK, Chandra R, Singh R. Influence of post-emergence herbicides on weeds, nodulation and yields of soybean and soil properties. *Legume Res.* 2014;37(1):47-54.
53. Chang CL, Lin KM. Smart agricultural machine with a computer vision-based weeding and variable-rate irrigation scheme. *Robotics.* 2018;7(3):38.
54. Shockley JM, Dillon CR, Stombaugh TS. A whole farm analysis of the influence of auto-steer navigation on net returns, risk, and production practices. *J Agric Appl Econ.* 2011;43(1):57-75.
55. Friha O, Ferrag MA, Shu L, Maglaras L, Wang X. Internet of Things for the future of smart agriculture: A comprehensive survey of emerging technologies. *IEEE/CAA J Autom Sin.* 2021;8(4):718-752.
56. Sylvester G. E-agriculture in action: Drones for agriculture. Rome: Food and Agriculture Organization of the United Nations and International Telecommunication Union; 2018.
57. Madhusree S, Ramesh T, Rathika S, Meena S, Raja K. Effect of drone application of pendimethalin on microbial population, nodulation, weed control and yield of green gram (*Vigna radiata* L.). *Int J Plant Soil Sci.* 2023;35(22):157-164.
58. Revanasiddappa B, Arvind C, Swamy S. Real-time early detection of weed plants in pulse crop field using drone with IoT. *Technology.* 2020;16(5):1227-1242.
59. Hitz CB, Ewing JJ, Hecht J. Introduction to laser technology. Hoboken: John Wiley & Sons; 2012.
60. Knezevic SZ, Cassman KG. Use of Herbicide-Tolerant Crops as a Component of an Integrated Weed Management Program. *Crop Management.* 2003;2(1):1-7.<https://doi.org/10.1094/cm-2003-0317-01-mg>
61. Blackshaw R, O'Donovan J. Higher crop seed rates can aid weed management.
62. Ghosh S, Das T, Nath C, Bhatia A, Biswas D, Bandyopadhyay K, *et al.* Weed seedbank, above-ground weed community and crop yields under conventional and conservation agriculture practices in maize-wheat-mungbean rotation. *Weed Res.* 2023;63:270-281.
63. Statista. Available from:<https://www.statista.com/>. Accessed July 25, 2026.
64. Kumar N, Choudhary VK, Sasode DS, Gajbhiye M, Sahu MP, Singh V, *et al.* Tillage and weed management practice influence on weed dynamics and yield of green gram in maize-wheat-green gram cropping system. 2023.
65. Kumar R, Kumar V, Prasad SK, Verma SK, Pal S. Yield attributes and weed management practices on field pea (*Pisum sativum* L.) in Indo-Gangetic plain of Varanasi. 2023.
66. Mishra J. Critical period of weed competition and losses due to weeds in major field crops. *Farmers Parliament.* 1997;33:19-20.
67. Sinclair TR, Vadez V. Physiological traits for crop yield improvement in low N and P environments. *Plant Soil.* 2002;245:1-15.
68. Singh DP, Rajiv R, Kumari M, Prakash HG. Efficient integrated weed management practices for higher productivity and profitability in vegetable pea (*Pisum sativum* var. hortense). *Indian J Agric Sci.* 2019;89(11):1937-1941.
69. Singh V. Integrated weed management in urdbean during kharif season. *Indian J Weed Sci.* 2005;37:121-122.
70. Swanton CJ, Mahoney KJ, Chandler K, Gulden RH. Integrated weed management: Knowledge-based weed management systems. *Weed Sci.* 2008;56(1):168-172.
71. Young SL, Pierce FJ, Nowak P. Introduction: Scope of the problem, rising costs and demand for environmental safety for weed control. In: *Automation: The Future of Weed Control in Cropping Systems.* New York: Springer; 2013.
72. Mishra V, Smith KR, Retherford RD. Effects of Cooking Smoke and Environmental Tobacco Smoke on Acute Respiratory Infections in Young Indian Children: VINOD MISHRA ET AL. *Population and environment.* 2005 May;26(5):375-96.
73. Balas M, Mathew DJ. Minimally invasive glaucoma surgery: a review of the literature. *Vision.* 2023 Aug 21;7(3):54.