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Non-chemical weed management in chick pea: A review

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Abstract
One of the most significant pulse crops is the chickpea (*Cicer arietinum*), however productivity levels are fairly low in India. Among various reasons poor ability to compete with weeds is the main cause for low productivity. Weed control is the basic requirement and the major component of crop management. Weeds on an average reduce the crop yield by 40-87 percent. Deciding time to control weeds requires detailed knowledge of the weed populations in the field. Different management practices like altering spacing, competitive cultivars, etc. can help in enhancing the productivity. With the world entering the precision-farming era, more emphasis is being put on the use of post-emergence herbicides. Application of two or more herbicide at the same time or as a double knockdown and integrating with hand-weeding provides desirable control of different weed species besides reducing the hazard of chemical weed control.

Keywords: Chickpea, productivity, weeds, non-chemical weed control, bio-herbicides, integrated approach

Introduction

With their high nutritional content, extended shelf life, and ability to support a wider variety of diets, pulses are an excellent source of essential vitamins and minerals. They enhance soil fertility, biodiversity, and fertilizer usage efficiency by fixing atmospheric nitrogen in the soil. According to Anonymous (2022) [4], they improve ecosystem services, agrobiodiversity, and resistance to climate change in diverse cropping systems. The United Nations General Assembly (UNGA) recognized the importance of pulses and declared February 10 to be World Pulses Day to build on the success of the FAO-implemented International Year of Pulses (IYP) in 2016 and to acknowledge the potential of pulses to help further realize the 2030 Agenda for Sustainable Development (WPD) (Anonymous, 2022) [4]. The UNGA recognized the value of pulses and highlighted their role in healthy diets, subsistence, soil health, and the environment (Calles *et al*., 2022) [9]. Pulses are rich in dietary fiber, protein, minerals, vitamins, and carbohydrates. They also include phytochemicals. Pulses are a staple food and cereal for people all over the world, and they also help them meet their protein needs. Due to their high lysine and folate content, pulses are perfect for combining with cereals to create composite flours (Singh, 2017). Legume, also known as "poor man's meat", is frequently a good source of protein and slowly-releasing carbohydrates (Tharanathan and Mahadevamma, 2013) [45].

The most ancient and extensively grown important pulse crop in India is the chickpea (*Cicer arietinum* L.). Ancient writings and the Ayurvedic medical system have indicated the benefits of this rich supply of vitamins, protein, carbohydrates, and dietary fiber for several health conditions (Kaur and Prasad, 2021) [16]. In addition to being an excellent source of protein, minerals, vitamins, and fiber, chickpeas also contain phytochemicals that may be helpful to health (Wood and Grusak, 2007) [53]. Chickpea is considered unique because of its high level of protein content, which accounts for almost 40% of its weight. According to Merga and Haji (2019) [25], there are further possible health advantages of the grain-chickpea legume crop, such as lower risks of cancer, diabetes, and cardiovascular disease.

One of the major obstacles to growing chickpea successfully is their poor ability to compete with weeds (Whish *et al*., 1996) [52]. In weedy conditions, crop losses might reach 90% (Knights 1991) [20]. Various weed management techniques, such as integrated weed management, mechanical and manual weed management, cultural and ecological weed management, biological weed management, chemical weed management, and biological treatments, are used to rid crops of weed infestation. The weed control techniques are conveniently divided into chemical and non-chemical. Much literature is available on chemical weed management methods and little information on non-chemical weed management; hence, an effort is made to review the literature available on non-chemical weed management in chickpea.

Major weed flora

Chickpea-related weeds have a similar ecology and biology to most other weeds that harm that particular crop. According to Bhan and Kukula (1987) [7], cool-season broadleaf plants in chickpea mostly belong to the following families: Fabaceae, Polygonaceae, Chenopodiaceae, Brassicaceae, and others. While herbicides are an efficient and selective means of controlling many annual grass species, other species, including Phalaris and Avena, are resistant to the herbicides and are frequently seen in chickpea fields. In chickpea, the majority of grass weeds are often categorized as cool-season species. These grass species are often categorized as C3 plants based on their photosynthetic systems; additionally, perennial weeds can be a problem in chickpea production systems (Yenish, 2007) [50]. *Medicago polymorphism* L., *Anagallis arvensis* L., *Cyperus rotundus*, *Fumaria indica*, *Cynodon dactylon*, *Lathyrus aphaca* L., *Convolvulus arvensis* L., and *Carthamus oxycantha* are significant chickpea weeds in rain-fed areas (Rashid *et al*., 2009) [37]. According to Tripathi and Mishra (1971) [46], *Rabi* weeds infesting chickpea fields at Varanasi included *Anagallis arvensis*, *Asphodelus tenuifolus*, *Chenopodium album*, *Euphorbia dracunculoides*, *Vicia hirsuta*, and *Vicia sativa*. Of these weed species, *Anagallis arvensis* and *Chenopodium album* were the most prevalent. The most common weeds at Pantnagar, Uttaranchal, were *Chenopodium album*, *Polygonum plebogenum*, *Anagallis arvensis*, *Chenopodium album*, *Cyperus rotundus*, *Fumaria parviflora*, *Melilotus indica*, *Melilotus alba*, *Vicia sativa*, *Anagallis arvensis*, and *Phalaris minor* (Lal and Singh, 1984; Singh and Shah, 1996) [24, 42]. According to Panwar and Pandey (1977) [31] and Ali (1993) [2], the main *Rabi* weeds affecting the chickpea crop in Kanpur were *Chenopodium album*, *Asphodelus tenufolius*, *Anagallis arvensis*, *Melilotus indica*, *Trifolium alexamdrium*, and *Cyperus rotundus*. At Faizabad, *Anagallis arvensis* had the highest density of infestations among the chickpea crop, followed by *Vicia hirsute* and *Chenopodium album* (Vaishya *et al*., 1999) [47]. According to Carita (1993) [10], the most dangerous broadleaf weeds are *Asphodelus tenufolius*, *Phalaris minor*, and *Avena ludoviciana*. The annual grassy weeds in the winter season pulses grown on fertile, irrigated soils are *Phalaris minor* and *Avena ludoviciana*. In late-sown chickpea at Jabalpur Cuscutta, the most significant weed issues are common lambsquarters and chinensis (Mishra and Singh, 2003; Moorthy *et al*., 2004) [26, 28]. *Fumaria indica*, *Cynodon dactylon* (L.) Pers, *Cyperus rotundus* L., *Convolvulus arvensis* L., *Medicago ploymorpha* L., *Anagallis arvensis* L., *Lathyrus aphaca* L., and *Carthamus oxycantha* L. are among the significant weeds found in chickpea crop in rainfed areas (Saxena, 1987, Khan *et al*; 2012) [41, 17].

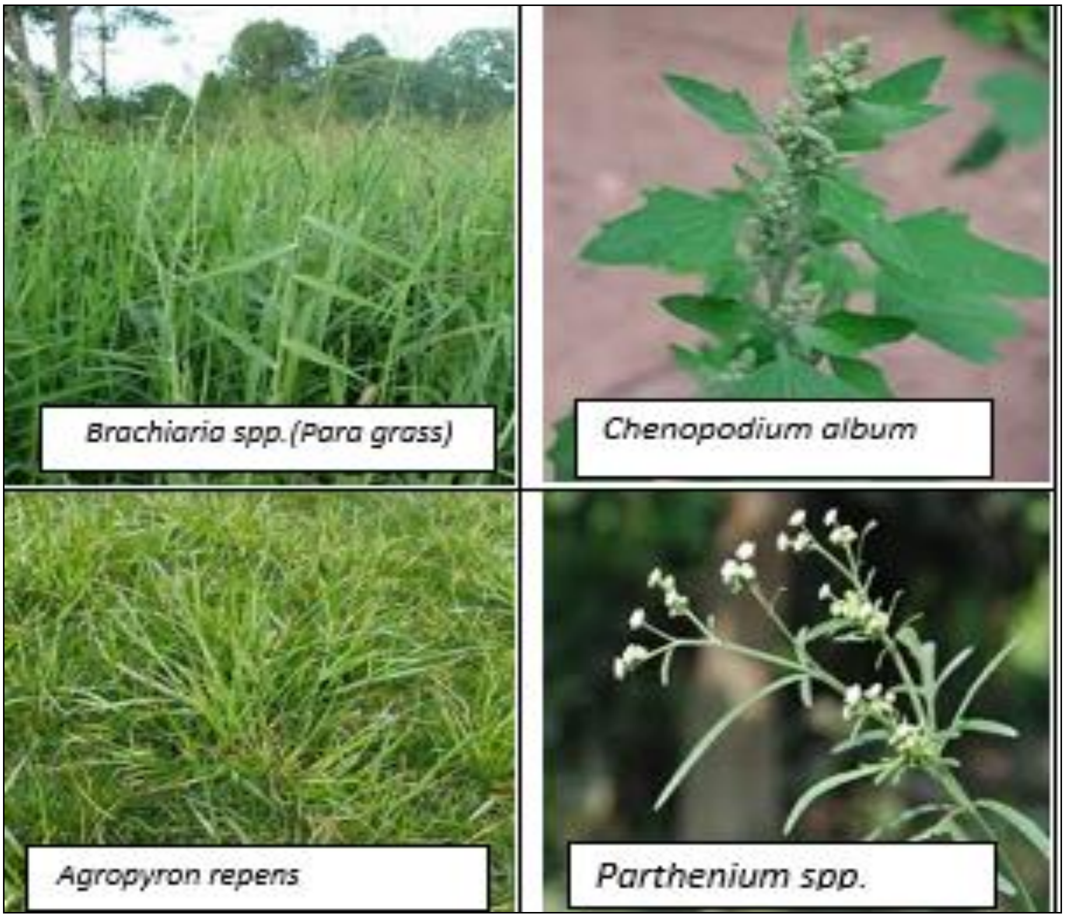

Fig 1: Notable weed species found in chickpea fields

Impact of weeds in chickpea

Weeds may successfully compete with cool-season legumes, such as chickpea, due to their slow emergence, modest plant height, and late canopy cover (Yenish, 2007) [50]. It has been demonstrated that weed competition can cause chickpea crop to have yield decreases of 23–87% (Bhan and Kukula, 1987; Yenish, 2007) [7, 50]. According to Mohammadi *et al*. (2005) [27], for every 26 g/m2 of dry weed weight added, the yield of chickpea seed will decrease by 10%. Weeds can sprout and establish themselves without being suppressed by the crop when crop emergence is delayed. A delayed canopy closure prolongs the period of time the soil surface is exposed to sunlight, which promotes more weed germination later in the growing season. As the crop produces seed, emerging weeds will compete with it, potentially lowering the quality and size of the seed. Weeds sabotaging agricultural harvests can also indirectly lower seed production and quality. Weeds with latex, like prickly lettuce (*Lactuca serriola*), can be difficult to harvest by hand or mechanically when they are dense, moist, and young. This can lead to further issues since the latex can interfere with machinery operation (Yenish, 2007) [50].

Non-chemical weed management

1. Preventive measures

Using certified seeds and clean crop seeds

In addition to seed certification, it is usually advised to use clean, pure crop seeds as much as possible. No new or existing weed species seeds are added to the soil seed bank by clean crop seeds. Over time, it serves as a safeguard against an escalating weed issue (including both exotic and native weeds). It lessens weed seed rain and furthers weed spread (Das, 2021) [11].

Well-decomposed Farm yard manure /compost, sewage and sludge

Fig 2: Illustration of vermicompost free from weed seeds

The majority of weed seeds became non-viable after a month of being stored in cow dung, according to Harmon and Keim (1934), because of warmth and decomposition. However, even after being stored in cow manure for a month, some chickpea weeds, such as Convolvulus arvensis (Saxena, 1987, Khan *et al*., 2012) [41, 17] and *Melilotus* sp. Lal and Singh, 1984 [24]; Singh and Sahu, 1996 [42]; Carita (1993) [10], showed some viability of 4% and 22%, respectively. Fermentation is the only method to create compost, FYM free of viable weed seeds (Das, 2021) [11]. Other preventive measures for weed control in chickpea include keeping farm machinery and livestock clean, cleaning irrigation channels, water, and alternate irrigation systems, maintaining clean farm bunds, roadsides, fences, and other non-crop areas, and implementing plant/weed quarantine laws to stop the spread of noxious and pernicious weeds.

2. Physical methods (manual and mechanical)

The main strategy for controlling weeds in chickpeas is mechanical. These techniques range from manually removing or hoeing weeds to tillage using a tractor. In less developed countries, it is typical to remove human-powered machinery like a wheel hoe or to pull weeds by hand (Knott and Halila, 1986; Bhan and Kukula, 1987) [21, 7]. That being said, labour costs are expensive even in these countries (Solh and Pala, 1990). Narrow row spacing, commonly used in advanced production, limits the mechanical management of weeds. The crop cannot be harmed by between-row cultivation since the row spacing is too small. Using ploughs, cultivators, or disks before planting and a harrow, culti-packer, or rotary hoe after planting to remove weeds early after emergence are the only methods of mechanical weed management (Yenish, 2007) [50].

Fig 3: Key strategies for weed management: Physical, cultural, and mechanical controls

Mechanical weed management needs to be carried out repeatedly throughout the crucial weed-free time in order to be successful. This usually implies that the first weeding can take place prior to the chickpea sprouting. To some extent, tiny weed seedlings can be removed with light tillage using a cultipacker, harrow, or rotary hoe without causing undue harm to chickpea seedlings. In comparison to fields that are left unweeded, crops damaged by more intensive tillage often have lower yields. This means that manual weeding is essentially the sole method of mechanically controlling weeds in chickpea following crop emergence. The frequency of mechanical weed removal varies according to the environment and production systems (Yenish, 2007) [50]. In experiments, it has been found that to guarantee weed-free conditions in chickpea or other legumes, up to five mechanical weed removals are required (Knott and Halila, 1986) [21]. But if weeds are permitted to grow to a point where they can be properly identified and grasped for removal, competition from weeds can occur. During this period, weeds compete with the crop, and removing them by hand or by machine frequently causes damage to the crop. According to Akbari *et al*. (2010) [1], double-hand weeding is advised for a grain yield that is satisfactory. Grain production can rise by up to 92% when hand weeding is done (Mousavi *et al*. 2007) [29]. Hand weeding once, i.e., three weeks after sowing in rain-fed chickpea and five weeks after sowing in irrigated chickpea, resulted in the highest yield and the lowest dry weight of weeds (Vesal *et al*. 2004) [48].

Soil solarization is one of the most important methods of weed management. The basic principle behind it is that the light received from the sun is in the form of electromagnetic short waves, which easily pass through the transparent colorless polythene films and reach the soil. As a result, the earth or soil is heated up and emits long-wave terrestrial radiation, which cannot pass through transparent polythene films and results in the buildup or trapping of heat (Katan *et al*., 1976; Das, 2021) [15, 11]. It may control weeds in crops in the wet season (*Kharif*) and winter (*Rabi*).

Mulching

The use of straw mulch has shown efficacy in weed management. In Cambodia, the application of rice mulch at a rate of 1 ton per hectare in Takeo Province significantly decreased weed biomass in greengram compared to areas without mulch treatment (Bunna *et al*., 2011) [8]. Similarly, applying straw mulch at a rate of 5 tons per hectare resulted in notably lower weed biomass compared to unchecked weed growth, although it may be slightly higher than hand weeding performed twice (Kundu *et al*., 2011) [23]. Mulching at 25 days after sowing (DAS) significantly reduced the accumulation of weed dry matter compared to areas without mulch treatment (Ram *et al*., 2016) [35]. Straw mulch has the potential to reduce the intensity of red-light solar radiation reaching the ground surface. Since many weeds rely on red wavelengths for germination, straw mulch could delay or diminish weed emergence. Additionally, straw mulch may physically impede weed emergence. However, the collection, storage, and application of straw as mulch require significant labor and incur costs for farmers. This is why the widespread adoption of straw mulch as a weed control method in greengram cultivation has been limited. Nonetheless, sowing greengram in fields with wheat straw leftover from combined wheat harvesting, using machinery like the Happy Seeder (PAU, 2019) [32], may offer a practical way to utilize wheat straw as mulch instead of burning it.

Cultural or ecological methods/approaches

In cultural control, the goal is to manage a crop or cropping system to maximize competition with weeds. In other words, make the crop as healthy and competitive as possible to lessen or better tolerate weed competition. Tools for cultural weed control include competitive varieties, timeliness of planting, cover crops, competitive rotational crops or rotational crops of different life cycles. Planting crops of differing life cycles prevents population increases for any single species of Weed (Radosevich *et al*., 1997) [34].

Cultivar selection

Fig 4: Selection of cultivar for effective non-chemical weed management

When aggressive cultivars grow alongside weeds, the weeds become smoother. Crop varieties vary greatly in their ability to compete with weeds. When compared to Avarodhi and Fant G 114, the chickpea genotype known as Radhey, decreased dry matter formation in the weeds.

In comparison to Pant Gl14, Radhey recorded a substantially higher grain yield. The competition index was lower in Avarodhi and Pant G114 compared to 10 Radhey and Pant G114 (Singh *et al*., 2003b) [26].

Light interception

Light is another environmental resource that influences chickpea growth. Gram is a dwarf-stature crop, and many times, weeds smother its growth, reducing yield severely (Donald, 1963). Numerous facets of plant growth and development are regulated by light. It varies in length, ferocity, and calibre. Weeds, in particular, can restrict the amount of light reaching a crop. Because plants develop quickly, light competition is most intense under high fertility conditions and sufficient moisture. Plants with large leaf area indices (LAIs) have a competitive advantage and normally compete with smaller leaf areas. In one of the field studies, chickpea cultivars with taller height and lateral canopy development (Avarodhi) proved to have better competition for weeds than dwarf varieties such as BG 244, GNG 146, CG588, Radhy and Pant Gl14 (Moorthy and Dubey, 2004a) [28].

Crop geometry

Studies on chickpea reported that increasing crop densities through manipulating seed rate and row spacing effectively reduces weeds' available niches and decreases weed growth.

Fig 5: Visualizing plant distribution in chickpea cultivation

The weed population and dry matter production have decreased due to an increase in seed rate, which affects grain output. Increasing the seed rate from 75 to 100 kg ha^{-1} has significantly reduced the dry matter production of weeds. High-yielding cultivars for sustainable systems should also be weed-competitive. Row spacing adjustments made to boost crops' ability to suppress weeds only slightly increased crop production.

Fig 6: Optimal input application for effective usage

Additionally, practices such as optimal fertilizer placement and timing, optimal irrigation timing and other input timing or placement benefit the crop at the expense of the weeds (Di Tomaso, 1995) [12]. Cultural practices are generally applied between and throughout the crop rotation, the primary benefit to chickpea weed control due to rotation is managing parasitic plants (Yenish, 2007) [50]. Fall planting of chickpea in the Mediterranean and other regions tends to result in greater losses due to weeds because of slower crop growth and development than with spring planting (Yau, 2005) [49]. Moreover, weed competition may be equal to or greater for winter- and cold-weather-tolerant weeds than for spring-annual weeds in a spring-seeded crop. While winter chickpea production may provide a yield advantage and an opportunity to relay crops within a year, weed competition has prevented the fall sowing of chickpea (Yenish, 2007) [50].

Seed size is an important quality component of chickpea. Decreasing chickpea plant density is a cultural practice that helps ensure the largest seed possible under growing conditions (Gan *et al*., 2002; Yau, 2005) [49]. Decreasing the density of chickpea plants may also reduce crop disease due to a more open canopy, which reduces the humidity in and around chickpea foliage (Krupinsky *et al*., 2002) [22]. However, decreasing the plant density of an already poor competitor like chickpea makes losses due to weeds even worse and requires greater intensity of weed control efforts. Rotational crops in chickpea production systems vary greatly within and between production areas. In some areas of the Indian subcontinent, chickpea may be rotated with millet, sorghum, maize, cotton, guar, sesame or rice (Saxena and Singh 1987) [41]. In other areas, chickpea may be grown in rotation with wheat, barley, forage, or as a crop in the understory of an orchard or vineyard. While the most common practice of growing chickpea is as a sole crop, there are instances in which they are grown as part of a mixed crop. Chickpea are an attractive crop regardless of crop rotation due to the disease-free, fertility and monetary benefits they bring to the rotation. They are not grown to provide a weed control benefit. Moreover, they could become a liability regarding weed control due to increased weed seed production due to poor competition or the limitations of using persistent herbicides in rotational crops.

Managing weeds by cultural methods/means reduces expenditures on pesticides, fuel and labor. While cultural management of weeds is an important part of crop rotations that include chickpea, the crop is more often the beneficiary of positive aspects of cultural weed control than a benefactor. Delayed emergence and crop canopy can be overcome to a certain extent by increasing the crop seeding rate. However, crop seed size is important in chickpea, and increasing the seeding rate to increase crop competitiveness with weeds may be detrimental to harvested crop quality (Gan *et al.*, 2002; Yau, 2005) [49].

Intercropping

Intercropping chickpea, safflower, linseed, and wheat led to a significant reduction in weed growth. Sarkar *et al*. (2000) [40] observed that a 1:1 row ratio of chickpea to safflower resulted in the highest yield equivalent for chickpea, along with the highest gross and net monetary returns, and benefit-to-cost ratio. This intercropping system also demonstrated superior Land Equivalent Ratio (LER), monetary advantage, and maximum product of crowding coefficient due to effective weed control. Similarly, a study by Arya (2004) [5] investigated integrated weed management techniques in chickpea-mustard intercropping under rainfed conditions and found that applying pendimethalin at 0.075 kg a.i ha^{-1} followed by one hand weeding at 45 days after sowing resulted in the highest chickpea equivalent yield (27.83 q ha^{-1}), net returns (Rs. 20,434 ha^{-1}), and benefit-cost ratio (2.30) on a pooled basis.

3. Biological methods

Another important non-chemical weed management method is the biological method, in which control of weeds is done by employing other living organisms or biological entities to a population density lower than what naturally occurs in the absence of the employed organism. The weeds of chickpea like *Cyperus rotundus* are controlled by *Bactra verutana* and *Cuscutta* by *Melanagromyza cuscutae* and *Smicronyx cuscuttae* (Das, 2021) [11].

Fig. 7 Biocontrol of *Cyperus rotundus* in chickpea by *Bactra verutana*

Allelopathy

Allelopathy entails the production and release of biologically active chemical compounds that influence the growth and development of nearby plants. Putnam (1988) [33] outlined six categories of allelochemicals originating from various plants, which can disrupt the normal growth of weeds by interfering with their metabolic processes (Weston and Duke, 2003) [51]. Allelopathy represents a chemical or biochemical interaction among plants (Rice, 1984) [39]. Simultaneously, mulching has emerged as a contemporary and efficient non-chemical approach to weed control (Ramakrishna *et al*., 1992) [36]. Regar *et al*. (2010) [38] observed that straw mulching led to improved grain yield and notably enhanced water usage efficiency across various chickpea cultivars. Khan *et al*. (2018) [18] demonstrated superior weed suppression through the use of mulches such as Eucalyptus leaf, crop or weed straw, *Asphodelus tenuifolius*, *Cyperus rotundus* extracts, and *Sorghum halepense* extracts.

Conclusion

Weeds are the most serious problem and, if unchecked, can cause 20–90 percent yield losses in different pulse crops. Weeds outcompete crops for resources such as light, water, space, nutrients, etc., lowering crop production. Weed-crop competition is critical in obtaining optimum chickpea yields because of the greater competing ability of the former (weeds) than the later (crops). Removing weeds increases activity by reducing crop competition for nutrients, moisture and light. Various weed management methods are followed like preventive measures, mechanical and manual methods, cultural and ecological methods, biological methods, chemical methods, biochemical methods and integrated weed management. Double-hand weeding is recommended for an acceptable grain yield (Akbari *et al*. 2010) [1]. Hand weeding can increase grain yield by up to 92% (Mousavi *et al*. 2007) [29].

Common chickpea weeds like *Cyperus rotundus* are controlled by *Bactraverutana* and *Cuscutta* by *Melanagromyza cuscutae* and *Smicronyx cuscuttae* (Das, 2021) [11]. According to Khope *et al.* (2011) [19], the economics of net profit indicate that chemical weed control in chickpea is not an alternative to the physical and mechanical methods of weed control.

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