Impact of weed management options on weed dynamics and yield of chickpea (*Cicer arietinum* L.): A review

bstract

Chickpea (*Cicer arietinum*) is a vital legume crop in India, serving as a primary source of protein in the Indian diet.It is essential to the nutrition of thousands of people in the developing world but at present its productivity is extremely low in India. There are various reasons for low productivity.Among the various factors that contribute to the low production losses resulting from weeds, one of the most significant one's accounts for 30–54% of the total loss. Understanding the weed populations in the field in full detail is necessary to determine when to manage weeds.Due to their slow development and growth rate, chickpea is a poor crop competition with weeds. Up to 60 days after sowing, it competes with chickpea weeds due to its few branches and little leaf area. Various management techniques, such as cultivar competition, spacing adjustments,*etc*., are helpful in increasing output.Pre-emergence herbicides like pendimethalin, quizalofop,*etc.*, are more effective in order to control the weeds right from the germination. Post-emergence herbicides like imazethapyr,imazamox and topramezone *etc.*,applications is becoming more important as the world enters the era of precision farming. Chickpea is highly susceptible to weed competition and the weeds causes 75% of yield losses. Considering the losses caused due to weeds, it is essential to manage the weeds within their critical crop-weed competition period. Combining two or more herbicides, either simultaneously or in a sequential 'double knockdown' approach, and integration of hand-weeding with pre-emergence herbicides, offers effective management of various weed species while minimizing the risks associated with post-emergence chemical weed controlmethods.

Comment [D1]: Botanical classifier

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Introduction

Pulses constitute one of the most important components of human diet and major source of protein particularly for the vegetarian population (Patil and Namdeo, 2021). India is the largest producer (25% of the global production), consumer (27% of the world consumption) and importer of pulses (14%) in the world (Shukla and Mishra, 2018). The net availability of food grains per capita increased day by day from 144.1 kg year^{-1} in 1951 to 179.6 kg year^{-1} in 2019 in spite of growth in population, however, the net availability of pulses has reduced from 25 kg year^{-1} in 1961 to 17.5 kg year^{-1} in 2019 (Anonymous, 2020). Chickpea (*Cicer arietinum*L.) is the world's third most crucial pulse crop after French bean and field pea (Shiv *et al.*,2023). Chickpea commonly known as gram or Bengal gram is a legume of Asian origin (Niranjan *et at.*,2020). It contains major source of dietary protein (18-22%), carbohydrates (52-70%), fat (4-10%), minerals (calcium, phosphorus and iron) and vitamins for predominantly vegetarian population of India (Hosmath *et al.*,2023). Worldwide, the average grain yield of chickpea is 965.1 kgha^{-1}, while in Asia, it is 919.7 kgha^{-1} and in Iran, it is 443.2 kgha^{-1}(Anonymous, 2018). The total area, production and productivity of chickpea in India during 2021-22 was 10.74 million hectares, 13.54 million tonnes and 1261 kg^{-1}ha, respectively (Indiastat, 2023).

Chickpea is short stature crop with slow initial growth and therefore, heavily infested with wide spectrum of weeds (Yadav *et al.*,2018). Poor weed management is one of the most important yield limiting factors in chickpea (Sethi *et al.*,2021). Crop yield losses due to weeds have been estimated to be 54.7% (Poonia and Pithia, 2013). The degree of yield loss varies from 18 to 90%, depending on the growing conditions, crop species and management practices (Prasad, 2021). The critical period for crop-weed competition is defined as the number of weeks after crop emergence, during, which, a crop must be weed-free to prevent yield losses greater than 5% (Rathod *et al.*, 2017). Thus, weeds are one of the major constraints to obtain high grain yield of improved crop cultivars if they are not controlled timely and properly (Jangade *et al.*,2019). The weed management in chickpea is an important component of plant protection and improving production potential of the crop (Khose *et* *al.*,2021).

Crop-weedcompetition

Lossescausedbyweeds

About 68% of lower seed yield in chickpea was due to the presence of weeds throughout the crop season in Haryana (Kumar *et al.*, 2014).The yield reduction in chickpea was to the tune of 20 to 49.5% due to competition stress by weeds on clay loam soil in Maharashtra (Bhutada and Bhale, 2015).The maximum yield to the extent of 81 to 97 per cent has also been reported by Barker (2017).Chickpea is not a competitive crop, especially whenweed competition occurs at early stages of crop growth (Barker, 2017).The magnitude of yield reduction depends upon many factors, such as composition of the weed species and their intensity, crop cultivars grown and agronomic practices of cultivation method (Chandrakar and Raj, 2018). Merga (2019) reported that the crop yield loss caused by the weeds is assumed greater than 20% in Ethiopia. Singh *et al.* (2020) reported that weeds on an average reduced the chickpea crop yield by 40-87% if uncontrolled on loamy soil in Himachal Pradesh. In chickpea,Jaswal and Menon (2020) noticed the weeds one of the major factors as their infestation caused an average yield reduction of 37.7%.

Table 1 :Losses caused by different weed flora infesting the chickpea crop

Sr. Number	Weed Flora	Place	Author	Estimated Yield Loss
1.	*Parthenium hysterophorus,Amaranthus viridis* L.,*Physalis minima,Digera arvensis,Euphorbia hirta,Alternanthera philoxeroides,Echinochloacrusgalli* L.,*Brachiriamutica,Cyperus rotundus* and *Cynodon dactylon* L.	Parbhani (Maharashtra)	Gore *et al.* (2018)	40-90%
2.	*Chenopodium album,Chenopodium murale*and *Rumex dentatus*	Jodhpur (Rajasthan)	Yadav *et al.* (2018)	40-45%
3.	*Chenopodium album,Melilotus alba,Medicago hispida,Cynodondactylon* and *Phalaris minor.*	Varanasi (Uttar Pardesh)	Singh *et al.* (2016)	75%
4.	*Medicago polymorpha, Solanum nigrum,Galinsoga parviflora, Parthenium hysterophorus,Commelinabenghalensis*and *Cyperus rotundus.*	Haramaya (Ethiopia)	Merga and Alemu (2019)	20-50%
5.	*Celosia argentea, Euphorbia geniculata, Tridexprocumbance, Anagallis arvensis Argemone mexicana, Parthenium hysterophorus, Chenopodium album, Ipomea carnea,cyperusrotundus,cynodondactylon,dinebra arabica, panicum spp. Cynodondactylon,digitariasanguinalis, amaranthisviridis, Cyperus rotundus* and *Erogrostis.*	Akola (Maharastra)	Kakade (2020)	60-67%

6.	*Medicago denticulata, Convolvulus arvensis, Chenopodium album, Melilotus indica*and *Brachiariamutica*	Raipur (Chhattisgarh)	Dewangan *et al.* (2016)	53-62%
7.	*Melilotus alba, Chenopodium album,Cynodondactylon, Phalaris minor,Phylanthusniruri, Portulaca oleracea,Digera arvensis* and *Anagallis arvensis*	Fatehgargh (Punjab)	Kumar *et al.*(2020)	20-40%
8.	*Cynodondactylon,Dactylocteniumaegyptium, Euphorbia hirta, Chenopodium album, Solanum nigrum, Amaranthus viridis, Vicia hirsuta, Vicia sativa, Polygonum plebeium, Anagallis arvensis, Argemone mexicana, Melilotus indicus, Fumaria parviflora* and*Coronopusdidymus*	BAU, Bhagalpur (Bihar)	Kumar, *et al.* (2020)	18-52 %
9.	*Cyperus rotundus, Panicum dichotomiflorum,Commelinabenghalensis, Convolvulus arvensis, Euphorbia geniculata*and *Parthenium hysterophorus*	Dharwad (Karnataka)	Singh *et al.* (2017)	15-63%
10.	*Cynodondactylon, Launaea pinnatifida,Chenopodium album* and *Anagallis arvensis*	Madhya Pradesh	Singh and Jain (2017)	68%

Criticalperiodofweedinterference

A period from 30 to 60 DAS is considered critical for crop-weed competition in chickpea (Reddy (2012), hence, weeding operation during this period helps in reducing weeds and increases yield(Das, 2013). One hand weeding was found inadequate for getting higher chickpea seed yield as weedy situation prevailing throughout the crop period caused 57% reduction in seed yield of chickpea (Poonia and Pithia, 2013).In chickpea, a critical period for crop weed competition at 5% yield loss ranged from 50 to 69 days after sowing (DAS) on clay soil in Italy (Frenda *et al.*, 2013). Similarly, Kumar *et al.* (2014) reported that presence of weeds throughout the crop season reduced the seed yield of chickpea up to 68%.Khaliliaqdam *et al.* (2014) revealed that critical period for weed control to prevent 10% yield and total dry matter loss was from 43 to 53 and 36-48 days after emergence (DAE) and 5% yield and total dry matter loss 36-60 and 26-71 DAE but the critical period for weed control to prevent 2.5% yield and total dry matter loss was wide spread than other levelsand was 31-66 and 19-81 DAE in chickpea on silt loam soil in Iran. Though, Amaral *et al.* (2018) found the critical period of weed interference from 5 to 76 days after emergence, assuming an acceptable production loss of 5%.

Effect of different weed management approaches on
Tillage practices

The bulk density and porosity measures under four different tillage practices, namely zero tillage (ZT), minimum tillage (MT), conventional tillage (CT) and deep tillage (DT) result showed that tillage practices decrease the weed density (Khairul *et al.*, 2014). Among tillageoperations, zero-tillage registered significantly lower weeddensity and weed dry matter (Dixit *et al.*,2014). Chauhan *et al.*(2017)alsoconcludedthatbedplantingofchickpea was significantly better than the conventional tillagedue to better weed management, better root developmentand favorable soil environment.

Comment [D4]: The type of crop must be mentioned

Intercropping system

The grain biomass of chickpea (weed infested) in intercropping system (despite the less cultivated area) was not significantly different than pure cropping, thus indicating the superior performance of intercropping as compared to pure cropping (Solymanpour *et al.,* 2016). According to a study performed by Tabarraei *et al.* (2018), the cropping system cumin 50%-chickpea 50% had the minimum weed density, showing superiority over monoculture and other intercropping system. Intercropping reduced the density and dry weight of weeds by increasing the competitive pressure caused by the presence of cumin and chickpea plants (Tabarraei *et al.,* 2018).

Allelopathy

Mulching with strawresulted insignificantlyhigher grain yieldand enhanced the water use efficiency in different chickpea cultivars (Regar *et al.*,2010).Rye, sorghum, rice, sunflower, rape seed and wheat have been documented as important allelopathic crops, releasing allelochemicals, which not only suppress weeds but also promote underground microbial activities (Jabran *et al.*, 2014). Khan *et al.*(2018)noticed betterweedcontrol by using*Eucalyptus*leafmulch,croporweedstrawmulch,*Asphodelustenuifolius*mulch andextract of *Cyperusrotundus*and *Sorghumhalepense*.

Comment [D5]: What crop it is applied to should be given details

Chemical weed control

Effect of pre-emergence herbicides

Pedde (2016) found pre-emergence application of pendimethalin 750-1500 g ha^{-1} and quizalofop-p-ethyl 40-100 g ha^{-1} as post-emergence very effective for controlling weeds in chickpea crop.Metachlor83% and pendimethalin 13% 2.23litre ha^{-1} showed promisingresultsincontrollingweeds(Abbas *et al.*, 2016).Yadav *et al.*(2019)obtained significantly higher yield withpre-emergenceapplicationofpendimethalin 600g ha^{-1}+post-emergenceimazethapyr 60 g ha^{-1}at20DAS, whichwas found at par with pre-emergence application of pendimethalin 600 g ha^{-1} + post-emergence imazethapyr 40 g ha^{-1}. According to Kumar *et al.* (2015), the application of pendimethalin 1250 g ha^{-1} followed by quizalofop-ethyl 150 g ha^{-1} resulted in poor crop-weed competition and lower weed index. Gore *et al.* (2018) obtained maximum grain yield when pendimethalin herbicide was used 750 g ha^{-1} as pre-emergence. Kumar *et al.*(2020)concludedthat the crop chickpea gave maximum yield due tomaximumnutrientuptake and minimum nutrient depletion by weeds with pre-emergenceapplicationofpendimethalin 1000 g ha^{-1}. Among herbicidal treatments, the minimum weed density was recorded with pendimethalin 1000 g ha^{-1} being at par with oxyfluorfen 150 g ha^{-1}(Kumar *et al.,* 2020).

Effect of post emergence herbicides

The post-emergence application of imazethapyr 30 g ha^{-1} at 10 days after germination (DAG) resulted in the maximum plant height and a greaternumber of branches per plant as compared to its other doses and time of application (Rathod *et al.,* 2017).Rupareliya *et al.*(2018) recorded minimum dry weight of weeds and weedindex with pre-emergence application ofoxyfluorfen180 g ha^{-1}followed bypre-mixofimazamox+imazethapyr 30 g ha^{-1} as post-emergence at 40 DAS.Dubey *et al.*(2018) observed the toxic effect of post-emergence application of oxyfluorfen 200 g ha^{-1} followed byclodinafop 60 g ha^{-1} at 35 DAS on the formation of root nodules. Kakde *et al.* (2020) obtained maximum benefit to cost ratio with application of oxyflourfen 150 gha^{-1}, which was closely followed by imazethapyr 10% at 50 g ha^{-1}.Among herbicidal treatments,earlypost-emergenceapplicationof sodium acifluorfen 16.5% 165 g ha^{-1} + clodinafop propargyl 8% 80 gha^{-1} significantly reduceddensity anddryweightof weeds and showed maximumweedcontrol efficiency and closely followed by imazethapyr 3.75% 50 g ha^{-1} + propaquizafop 2.5% 75g ha^{-1}at20DAS (Meena *et al.*, 2020).Among different herbicidal treatments, application of imazathapyr 450 g ha^{-1} followed by atrazin 500 g ha^{-1} showedmaximum weed controleffeciency and minimum in case ofmetribuzin 150 g ha^{-1} followed by oxyflorfen 50 g ha^{-1} (Kumar *et al.*, 2021).

Mechanical weed control

Hand weeding

The minimum weed population and weed dry weight in chickpea was observed under the treatment hand weeding at 20, 40 and 60 DAS (Chandrakar *et al.*,2015). Hand weeding twice at 20 and 40 DAS in chickpea resulted in minimum density and dry weight of weeds and maximum weed control efficiency on clay loam soil (Singh and Jain, 2017). Among different weed management treatments, hand weeding twice at 30-35 DAS and 60-65 DAS showed maximum weed control efficiency in Bengal gram on clay loam soil (Hargilas, 2018).

Hand weeding twice at 20 and 30 DAS recorded maximum plant height, which was at par with two hand hoeing at 20 and 30 DAS in green gram on clayey soil (Chaudhari *et al.*, 2016). Among different weed control methods, hand weeding at 20, 40 and 60 DAS recorded higher values for plant height, number of branches per plant and dry matter accumulation per plant in chickpea on clay soil (Balwan *et al.*, 2016).

Among different weed control methods, hand weeding at 20, 40 and 60 DAS recorded higher values for number of pods per plant, number of grains per pod and test weight in chickpea on clay soil (Balwan *et al.*, 2016). Hand weeding twice at 20 and 30 DAS resulted in maximum number of pods per plant, which was at par with two hand hoeing at 20 and 30 DAS in green gram (Chaudhari *et al.*, 2016) and at 25 and 45 DAS in maximum seed yield in chickpea (Dewangan *et al.*, 2016) on clayey soil. Singh and Jain (2017) registered the maximum number of pods per plant, number of seeds per pod and test weight with two hand weeding at 20 and 40 DAS on clay loam soil.

Intercultural operations

The maximum weed control efficiency in soybean was noted with inter-cultivation followed by hand weeding at 20 and 40 DAS (Patel *et al.*, 2019).More plant height, number of branches per plant and dry matter per plant were recorded with inter-cultivation and hand weeding at 15 and 30 DAS over rest of the treatments in soybean on clayey soil (~~Rupareliya *et al.*, 2020~~). More number of pods per plant was observed with inter-cultivation and hand weeding at 15 and 30 DAS over rest of the treatments in soybean on clayey soil (~~Rupareliya *et al.*, 2020~~). More protein content, oil content and oil yield were registered with inter-cultivation and hand weeding at 15 and 30 DAS over rest of the treatments in soybean on clayey soil (Rupareliya *et al.*, 2020). Higher seed yield in chickpea was recorded with hand weeding + inter-cultivation at 30 and 45 DAS during *Rabi* season on loamy sand soil (Chavada *et al.*, 2017).

Comment [D6]: Rewriting the paragraph and documenting the end of the paragraph as it is for one researcher

Comment [D7]: spring

The mulching technique is very useful for protecting the plant roots from heat and cold, and it is used to cover soil surface around the plants to create congenial conditions for growth, which include temperature moderation, cutting back salinity and controlling weeds(Bhardwaj, 2013). Pre-emergence application of pendimethalin 750 g ha^{-1} + mulching with water hyacinth or pendimethalin 750 g ha^{-1} followed by bispyribac sodium 25 g ha^{-1} appeared to be promising weed management practices for higher weed control efficiency, yield and net return (Jagadish *et al.*, 2015). Chickpea crop gave significantly the maximum seed yield with two hoeing + two hand weeding, which was statistically at par with non-chemical treatments,*i.e.*, one hoeing + one hand weeding at 30 DAS with mulching of weed biomass and one hoeing + one hand weeding at 20 DAS in paired row planting + green gram with straw retained as surface mulch after harvest (Raut *et al.*, 2015).

Integratedweedmanagement

The minimum number of weeds m^{-2} was observed when imazethapyr was applied @ 75 g ha^{-1} aspost-emergencefollowed by hand weeding at 50 DAS (Kaushik *et al.*, 2014).

Pendimethalin 750 g ha^{-1} followed byonehand weeding at 45 days after sowing was found effective in controlling weeds(Chandrakar *et al.*,2015).The pre-emergence applicationof pendimethalin 750 g ha^{-1} + hand weeding at 25-30 DAS was the best option for controllingweeds(Rathod *et al.*,2017). S-metolachlor1000g ha^{-1}supplemented with hand weeding five weeks after emergence(WAE) resulted inminimum weedsfollowed by the weed free (MergaandAlemu,2019). The integrated treatments performed significantly superiorto alone pre-emergence application of pendimethalin 1000 g ha^{-1} followed bypost-emergenceapplication of imazethapyr 50 g ha^{-1} at 20DAS closely followed bymanual weeding at40DASrecordedmaximumweedcontrolefficiencyandminimumweed index (Tiwari *et al.*, 2019).

Figure 1: Weed management strategies(Scavo and Mauromicale, 2020)

Studies on phytotoxicity

Pre-emergence application of pendimethalin 1300 g ha^{-1}, S-metolachlor 960 g ha^{-1} and flumioxazin 110 g ha^{-1} caused least phytotoxicity to common v*etc*h, lentil, chickpea or red pea (Vasilakoglou *et al.*, 2013).The post-emergence application of quizalofop-p-ethyl 60 g ha^{-1}showed higher dry matter accumulation as compared to application of single treatment, except some in, which crop phytotoxicity was noticed (Dubey *et al.*, 2018). Topramezone 40 and 60 g ha^{-1}showed phytotoxicity on crop, however, the crop growth was more vigorous after its recovery at 25 days after the application of herbicides with satisfactory toxicity on weeds (Nath *et al.*, 2018).

Effect of herbicides on
Weed Population/ Weed Density

The chickpea field treated with pendimethalin 1250 g ha^{-1} as pre-emergence followed by one manual weeding at 40-45 DAShad minimum weed density (Kumar *et al.*,2015). Merga (2019) recorded minimum weed density with the application of S-metolachlor 1000 g ha^{-1} + hand

Comment [D8]: at the rate

Comment [D9]: Herbs Or crop

weeding at five weeks after emergence.The pre-emergence application of pendimethalin 750 g ha^{-1} + one hand weeding reduced the weed density and dry weight to a minimum level (Jaswal and Menon, 2020). Kakde *at el*, (2020) recorded minimum weed density at harvestwithhand weeding at 30 and 50 DAS as compared to chemical treatments. Kumar *et al.* (2020) recorded that among weed control treatments, hand weeding twice at 30 and 50 DAS recorded significantly minimum weed density, whereas among herbicidal treatments,the minimum weed density was recorded with pendimethalin 1000 g ha^{-1} being at par with oxyfluorfen 150 g ha^{-1}.Among the herbicide treatments, pre-emergence application of pendimethalin 38.7% 800 g ha^{-1}followed by propaquizafop 2.5% + imazethapyr 3.75% (RM) 125 g ha^{-1}as post-emergence at 25 DAS was found to be the most effective weed management practice for controlling complex weeds in term of weed density, weed dry weight, weed control efficiency and weed index (Girish *et al.*, 2024)

Comment [D10]: The paragraph should be rewritten to clarify the type of crop

Weed index

The combined pre- and post-emergence application of pendimethalin 600 g ha^{-1}and imazethapyr 60 g ha^{-1}at 20 DAS recorded significantly higher seed yield with higher weed control efficiency and weed index as compared to other weed management practices, which was at par with pre- and post-emergence application of pendimethalin 600 g ha^{-1}+ imazethapyr 40 g ha^{-1}at 20 DAS (Yadav *et al.*, 2019).The minimum weed index was observed in plots whereoxyflourfen was applied @ 150 g ha^{-1}as post-emergence 40 DAS (Kakade *at el.*, 2020).

Comment [D11]: Name crop

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Weed control efficiency

According to Kour *et al.* (2014),pendimethalin 1000 g ha^{-1}as pre-emergence in the chickpea + mustard intercropping system generated the maximum weed-control efficacy. The pre-emergence application of pendimethalin 38% 750 g ha^{-1}+ hand weeding at 30 to 35 DAS recorded the maximum weed control efficiency (Rathod *et al.*, 2016). Yadav *et al.*(2017) ~~it was evident from the data~~ that the weed control efficiency was recorded maximum next to the weed free (100%) treatment in treatment like pendimethalin 1000 g ha^{-1} + one hand weeding at 45 DAS during the year experimentation. Hand weeding at 25 DAS resulted inmaximum weed control efficiency (100%) followed by oxyfluorfen 180 g ha^{-1} as pre-emergence and pre-mix (imazamox + imazethaypr) 30 g ha^{-1}(Ruparelia *et al.*, 2017). Hand weeding twice between 30-35 and 60-65 DAS produced the maximum weed control effectiveness (WCE) in Bengal gram (Hargilas, 2018). Among the weed management practices, weed free andthe treatment pendimethalin as pre-emergence 1000 g ha^{-1} + one hoeing 35 DAS were recorded minimum weed dry weight, weed index and maximum weed control efficiency (Singh *et al.*, 2020).

Comment [D13]: proved

Yield Attributes and Yield

Thepre-emergenceapplicationofoxyfluorfen125 g ha^{-1}+metribuzin 350 g ha^{-1} increaseinthe yieldof chickpea notably over the control (Dewangan *et al.*,2016).Pre-emergence application of herbicides, such as oxyflourfen, pendimethalin,*etc.* had positive impact on yield and yield attributes of chickpea due to the control of weeds at early stage of crop growth and they further observed minimum values of yield attributes,*viz.* number of pods per plant, number of seeds per pod and test weight under weedy check plot (Rupareliya *et al.*, 2017). Among the treatments, hand weeding + inter-culture at 30 and 45 DAS established its superiority by recording significantly the maximum seed yield and the second-best treatment emerged out from the study was pendimethalin 1000 g ha^{-1}as pre-emergence + two inter-culture at 30 and 45 DAS, which recorded seed yield, closely followed by pendimethalin 750 g ha^{-1}as pre-emergence + two inter-culture at 30 and 45 DAS (Chavada *et al.*, 2018). The weed free plot was recording higher grain yield but it was economically similar to the treatment pendimethalin 1000 g ha^{-1}+ one hoeing 35 DAS (Singh *et al.*, 2020). The maximum seed, Stover and biological yield was obtained from the field treated withpre-

Comment [D14]: name crop

emergence application of pendimethalin 1000 g ha^{-1}+ quizalofop 60 g ha^{-1} as post-emergence, which was at par with pendimethalin 1000 g ha^{-1} + imazethapyr 40 g ha^{-1}(Kumar *et al.*, 2020). Veisi *et al.* (2022) obtained maximumyieldwithpost-emergence application of pyridate andpre-emergenceapplication ofoxyfluorfen125g ha^{-1}, whichwassimilartotheweedfreecondition.

Economics

The pre-emergence application of pendimethalin 1000 g ha^{-1} gave maximum weed-control efficiency, net returns and benefit to cost ratio in chickpea + mustard intercropping system (Kour *et al*., 2014). The pre-emergence application of oxyfluorfen 80 g ha^{-1} followed by hand weeding at 30 DAS recorded higher net returns with higher benefit to cost ratio (Patel *et al.*, 2016).The maximum net monetary returns and benefit to cost ratio was recorded under pre-emergence application of pendimethalin 30EC + imazethapyr 2EC (Gupta *et al*., 2017). Singh and Jain (2017) obtained the maximum net monetary returns and benefit to cost ratio with two hand weeding followed by pendimethalin + hand weeding and pendimethalin + hand hoeing.Manasa *et al.* (2022) recorded the maximum net return and benefit to cost ratio with pre-emergence application of pendimethalin 900 g ha^{-1}followed by sodium-acifluorfen + clodinafop-propargyl 80 + 165 g ha^{-1}(RM) as post-emergence at 40 DAS and hand weeding twice at 20 and 40 DAS. Kashyap *et al.* (2022) recorded thehigher net returns and benefit to cost ratio with post-emergence application of imazethapyr 55 g ha^{-1}, followed by pre-emergence application of pendimethalin 750 g ha^{-1}. The maximum net profit, gross return and benefit to cost ratio was obtained under weed free treatment and the higher benefit to cost ratio may be attributed due to higher seed yield underthecombination of lower cost chemical treatment (Bhosle *et al*., 2023).Among the herbicide treatments, pre-emergence application of pendimethalin 38.7% 800 g ha^{-1}followed by propaquizafop 2.5% + imazethapyr 3.75% (RM) 125 g ha^{-1}as post-emergence at 25 DAS was found to be the most effective weed management practice for controlling complex weeds in term of grain yield, net return and benefit to cost ratio (Girish *et al.*, 2024)

Conclusion

One serious issue that can lower output in many pulse crops by 20–90% is weeds. Weeds reduce crop yields by competing with crops for resources like light, water, space, nutrition, etc. Pulses are a highly diversified agricultural resource that is heavily compressed by weed stress. Therefore, switching to the usage of more recent herbicides is essential for better weed control. It is impossible for a single pesticide to eradicate every kind of weed. Various pre- and post-emergence herbicides have been incorporated into the current setup, and the cultural technique is helpful for effective weed management. Pre-emergence herbicides like pendimethalin, quizalofop *etc*., and post-emergence herbicides like imazethapyr, imazamox and topramezone *etc*., incorporated with hand weeding at critical crop-weed competitionperiod is very effective to manage the weeds in chickpea crop.

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