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Impact of agronomic approaches in optimizing weed control and productivity of black gram [*Vigna mungo* (L.) Hepper]: A review

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Abstract
Black gram [*Vigna mungo* (L.) Wilczek], also known as urd bean, is an essential part of the daily diet since it is a rich source of protein. Weeds are one of the major factors limiting the production of black gram as the reduction in yield of black gram due to weed infestation is 45-70%. In black gram, the first 30 days are crucial for crop weed competition. Different strategies incorporating non-chemical and chemical methods have been practiced for efficient weed control in black gram. Non-chemical methods, such as row spacing, timing of hand weeding, tillage practices, *etc*., which not only controls the weed population but also improves the soil properties. Herbicides with varying degrees of selectivity and efficacy that are available for use in black gram are among the chemical control options. Herbicides (pre- and post-emergence) should be used at the recommended rate and time for effective weed control to prevent suppression of growth, grain yield and symbiotic properties, *i.e.*, number of nodules, dry weight of nodules and leghaemoglobin content in nodules of black gram crop. This review covers the several weed management techniques, such as chemical and non-chemical weed control methods and evaluates how well they work to control weeds in black gram. Additionally, their impact on soil microbiology, black gram yield, symbiosis and growth, as well as any leftover effects on subsequent crops have all been evaluated in this review.

Keywords: Black gram, herbicides, weed management, growth, yield

Introduction
Pulses serve various purposes in farming systems, including soil enrichment and nitrogen fixation, providing a vital source of protein in predominantly vegetarian diets like those common in India. Their ability to fix nitrogen and enrich soil fertility through addition of organic matter is crucial for maintaining soil health and productivity, especially in rotations. Pulses are an affordable alternative to expensive animal protein for people who are mostly vegetarians or whose daily meals consist primarily of cereals and starchy foodstuffs. That's why, pulses are considered meat of the poor people (Kumar, 2014) [29]**.** Pulses are becoming more and more in demand in both developed and developing nations. India has a total pulse area of roughly 23.10 million hectares, with a production of almost 17.19 million tonnes and an average productivity of 744 kg/ha (Anonymous, 2017) [4].

Black gram, scientifically known as *Vigna mungo* L. and belonging to the family *Leguminoseae*, is indeed a crucial pulse crop within India. Its significance is to enhance soil fertility through nitrogen fixation. Its seeds are highly nutritious, containing approximately 24% protein, 60% carbohydrate and 1.3% fat and additionally, it is rich in phosphoric acid, thiamine (B_1), riboflavin (B_2), niacin (B_3) and various minerals (Islam *et al*., 2011) [22]. Primarily cultivated for its protein-rich seeds, which are commonly used as dal, black gram holds substantial agricultural importance. In India, during the 2021-22 period, its cultivation covered approximately 4.63 million hectares, yielding around 2.77 million tonnes with a productivity of 599 kg/ha, while black gram in Haryana is cultivated on 2500 ha of land area, producing 1300 tonnes with a productivity of 500 kg/ha during the same period (Indiastat, 2023) [21]. Black gram-producing states within India include Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar

Pradesh, West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka, Orissa and Gujarat. These states collectively cultivate around 3.10 million hectares, yielding approximately 1.40 million tons with an average productivity rate of 452 kg/ha (Anonymous, 2013) [3].

Black gram faces infestation from various weed species, such as *Echinochloa colona*, *Echinochloa crusgalli*, *Cynodon dactylon*, *Amaranthus viridis*, *Cyperus rotundus*, *Chenopodium album*, *Digera arvensis* and *Trianthema portulacastrum*, (Shweta *et al.*, 2017) [54] which compete with crop plants for essential resources like nutrients, moisture and light, significantly reducing the growth and yield potential of black gram and first 15-45 days are crucial for crop-weed competition (Khot *et al*., 2016) [27]. Studies have shown that weed space infestation can lead to 66% yield reduction in black gram (Singh *et al*., 2017) [64]. Therefore, timely weed control is crucial for optimizing black gram yield. While manual hand weeding is considered the most effective method, allowing for weed population control and improving soil aeration and moisture conservation, it is labor-intensive, time-consuming and expensive. One of the best choices for controlling weeds is the application of herbicides at appropriate level. Herbicides control the weeds effectively and are economically feasible one (Muoni *et al*., 2013) [40]. Herbicide combinations may be particularly effective, as broad-spectrum weed management with single herbicides may not suffice (Nandan *et al*., 2011) [41]. Application of a post-emergence herbicide is a suitable alternative to control the 2nd weed flush in pulses since it also minimizes the need for human labour (Singh *et al*., 2014) [59, 63]. Herbicides cannot completely eradicate weeds, due to their selectivity. However, hand 2 weeding or hoeing should be added to them to increase their efficacy (Komal *et al*., 2015) [28].

Weed flora of black gram

The composition of weed flora associated with crops is influenced by a variety of factors, such as agro-climatic conditions, soil type, season and crop management practices. Jakhar *et al.* (2015) [25] observed *Amaranthus viridis* (green amaranth), *Amaranthus spinosus* (spiny amaranth), *Trianthema portulacastrum* (horse purslane), *Euphorbia hirta* (asthma weed), *Verbesina encelioides* (golden crownbeard), *Digera arvensis* (false amaranth), *Corchorus acutangulus* (ajute), *Phyllanthus niruri* (chanca piedra) and *Physalis minima* (pygmy ground cherry) the dominant dicot weeds in black gram field and are *Cyperus rotundus* (purple nutsedge), *Dactyloctenium aegyptium* (crowfoot grass), *Cynodon dactylon* (bermuda grass), *Digitaria sanguinalis* (crabgrass), *Cenchrus biflorus* (**hedgehog** grass) the grassy weed species. However, Chandra and Kumar (2017) observed *Amaranthus viridis*, *Celosia argentea*, *Cleome viscosa*, *Parthenium hysterophorus*, *Phyllanthus niruri* and *Trianthema portulacastrum* among broad leaved weeds, *Digera arvensis*, *Elusine indica*, *Dectyloctenium aegyptium*, *Echinochloa* spp., *Setaria glauca*, *Cynodon dactylon* among grassy weeds and *Cyperus rotundus* and *Cyperus difformis* among sedges. Singh *et al*. (2016) identified *Echinochloa colona* (18.5%), *Eleusine indica* (17.1%), *Dactyloctenium aegyptium* (4.9%), *Digitaria sanguinalis* (1.8%), *Panicum maximum* (1.8%), *Digera arvensis* (1.4%) and *Cleome viscosa* (0.5%) the major weed species, categorized into grasses and broad-leaf weeds and *Cyperus rotundus* the dominated weed flora, accounting for 44.9% of the observed weeds in black gram. Raju *et al.* (2017) [49] identified *Cyperus iria* (sedge), *Dactyloctenium aegyptium* (grass) and *Commelina benghalensis*, *Phyllanthus niruri* and *Amaranthus viridis* (broad-leaved weeds) in Kharif black gram. Singh *et al.* (2018) [62] observed *Echinochloa colona* (30%) *Cyperus rotundus* (29%) and *Trianthema monogyna* (18.5%) the most dominating weeds in summer black gram crop. Susmitha *et al.* (2019) [68] identified *Dactyloctenium aegyptium*, *Cyperus iria*, *Amaranthus viridis*, *Digera arvensis* and *Parthenium hysterophorus* the weed species in black gram field. Rana *et al.* (2019) [52] identified *Cyperus rotundus*, *Echinochloa colona*, *Eleusine indica*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis* and *Commelina bengalensis* the major weed species in black gram fields. Black gram field was dominated by natural infestation of broad leaf weeds like *Grangea maderaspatana*, *Gnaphalium polycaulon*, *Nasturtium indicum*, *Chrozophora rottleri*, *Cardanthera uliginosa*, *Xanthium strumarium* and grasses like *Echinochloa colona*, *Dinebra retroflexa* and *Leptochloa chinensis* (Rao *et al.*, 2010) [53]. In sandy loam soil of Aduthurai, Tamil Nadu, *Echinochloa crus-galli* (L.) Beauv., *Cyperus rotundus* L. and *Phyllanthus maderaspatensis* L. were the most common weed flora linked to black gram (Jagadesh *et al*., 2019) [23]. The common weeds associated with black gram are *Echinochloa colonum*, *Sorghum halepense*, *Echinochloa crusgalli*, *Cyperus rotundus*, *Commelina benghalensis*, *Cyperus iria*, *Cynodon dactylon*, *Cleome viscose*, *Trianthema monogyna*, *Amaranthus* spp., *Eleusine indica* and *Physalis minima* (Shweta *et al*., 2017 [54]; Rana *et al*., 2019b [52]; Pankaj *et al*., 2020) [45]. Sharmitha *et al*. (2023) [57] identified *Cynodon dactylon*, *Brachiaria reptans* (grasses), *Cyperus rotundus* (sedges), *Cleome viscosa* and *Trichodesma indicum* (broad leaved) weeds in black gram crop.

Critical period for crop-weed competition

The determination of critical period for weed competition in black gram is crucial for optimizing weed management practices. This is the period during which weeds must be controlled to prevent significant yield loss. Singh *et al*. (2018) [62] suggested that the first 20-40 days of a black gram crop are the most important time for crop-weed competition. Sukumar *et al*. (2018) [66] observed that the critical period of weed competition in black gram was 10-30 DAS on clay loam soil of Coimbatore, Tamil Nadu. According to Sivakumar *et al*. (2019) [65], the critical period of crop-weed competition in black gram was 20-40 DAS. Similarly, Bhowmick *et al*. (2015) [7] reported that the period from 20 to 40 days after sowing is important for crop-weed competition in black gram, reducing production by up to 64% depending on the types and severity of weed flora over the entire growing season.

Effect of physical methods on weeds

The maximum weed control efficiency was recorded with two hand weeding at 20 and 40 days after sowing, which was at par with the application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg a.i/ha as pre-emergence as compared to application of quizalofop-ethyl 5 EC and fenoxaprop-p-ethyl 9 EC as post-emergence in black gram crop (Singh *et al*., 2014) [63]. Tamang *et al*. (2015) [39] reported that hand weeding at 20 and 40 DAS significantly reduced weed density and weed biomass, increased grain yield of green gram and gave less benefit to cost ratio owing to higher cost of farm labour as compared to different herbicides. Chaudhry *et al*. (2014) [10] demonstrated that hand hoeing at 30 and 60 days after sowing was highly effective in controlling both broad and narrowleaf weeds in black gram, achieving weed control of 95.77 and 98.12%, respectively and resulting in lowest weed dry matter (15.46 g/m^2). Suryavanshi *et al*. (2018) [67] found that hand weeding twice at 20 and 40 DAS resulted in higher weed control efficiency and higher pod yield

of black gram. Mansoori *et al*. (2015) [33] indicated that hand weeding twice at 25 and 50 days after sowing and resulting in significantly lower weed density at 20, 40 and 60 DAS, as well as at harvest (21.4, 3.0, 2.7 and 3.6 number m^{-2}, respectively) in kharif black gram. Susmitha *et al.* (2019) [68] reported that hand weeding twice at 20 and 40 DAS resulted in lower weed dry weight and high weed control efficiency in black gram crop in Andhra Pradesh.

Effect of chemical method on weeds

Chemical weed control indeed offers significant benefits in terms of effectiveness, efficiency and economy, particularly in terms of saving time, money and labour. Weeds pose a significant threat to pulse crops by competing for essential nutrients, both major and secondary, which are already in limited supply due to under-fertilization, especially in India. This situation is compounded by the fact that pulse crops are predominantly cultivated in marginal lands by resource-poor farmers. Chandra and Kumar (2017) reported that most weeds emerge before or along with crops and thereby necessitate the use of pre plant incorporation and pre-emergence herbicides. Chemical weed control in black gram has been found effective and economical.

Pendimethalin is quite versatile herbicide, especially with its dual pre- and post-emergence activity but its efficacy relies heavily on proper application timing and conditions. It controls annual grasses and broad-leaved weeds in various agronomic and horticultural crops (Chourasiya, 2013) [13]. Post-emergence application of pendimethalin controls broad-leaved weeds up to 2 to 3 leaf stages. Sahoo *et al.* (2017) [55] reported that pre-emergence application of pendimethalin 0.75 kg/ha recorded significantly lower weed density in black gram crop. Patel *et al.* (2017) noted that pre-emergence application of pendimethalin 0.9 kg/ha or quizalofop-p-ethyl 40 g/ha as post-emergence at 20 DAS supplemented with hand weeding at 40 DAS resulted in higher weed control efficiency. Likewise, the lowest weed density and weed biomass with higher weed control efficiency in black gram was obtained with pre-emergence application of pendimethalin 1.0 kg/ha during *Kharif* season in Uttarakhand (Singh *et al*., 2016) [64].

Imazethapyr appears to share a similar broad-spectrum efficacy against various annual broad-leaved weeds and several grass species, much like pendimethalin. Its effectiveness both pre- and post-emergence, particularly targeting weeds at two-leaf stage, indicates its versatility in weed control strategies. Sukumar *et al*. (2018) [66] found that post-emergence spraying of imazethapyr 50 g/ha considerably reduced the density and dry weight of all kinds of weeds. According to Mishra *et al*. (2017) [36], post-emergence application of imazethapyr 80 g/ha in green gram resulted in lowest density of monocot and dicot weeds. Likewise, Sasikala *et al*. (2014) [56] discovered that post-emergence application of imazethapyr 100 g/ha decreased density and dry matter production of all categories weeds in black gram. According to a study by Nirala *et al*. (2012) [43], the lowest weed density, dry matter production of weeds, weed growth rate and relative weed density were observed with the application of herbicide imazethapyr at the rate of 25 g/ha as pre-emergence (PE). Similarly, Jha *et al*. (2014) [26] observed that imazethapyr when applied at the rate of 100 g/ha significantly controlled the weed (up to 92.7%) in soyabean field.

According to Upasani *et al*. (2017) [70], pre-emergence application of pendimethalin + imazethapyr 1.0 kg/ha (pre-mix) resulted in significantly lower weed dry weight and higher weed control efficiency in black gram. In green gram, pre-emergence application of pendimethalin + imazethapyr at 1.0 kg/ha (pre-mix) during kharif season produced the maximum weed control efficiency and lowest weed index (Singh *et al*., 2017) [61]. Similarly, Pre-emergence application of pendimethalin + imazethapyr 960 g/ha (pre-mix) produced the maximum level of weed control efficiency in soyabean (Meena *et al*., 2018) [34]. According to Kumar *et al*. (2015) [33], pre-emergence treatment of pendimethalin + imazethapyr (pre-mix) at 1000 g/ha considerably decreased the density of *Trianthema portulacastrum* L. weed species in black gram crop.

Among various treatments, pre-emergence application of readymix compound imazethapyr + imazamox 80 g/ha was found best to control weeds in black gram, which was followed by the combined application of imazethapyr + imazamox 70 g/ha, however, both did not differ significantly to each other (Malhi *et al*., 2020) [32]. The application of imazamox + imazethapyr at the rate of 75 g/ha as the post-emergence treatment at 20 days after sowing (DAS) was highly effective in managing various weeds in soybean fields, and the treatment resulted in significant reductions in weed density, with a recorded value of 56.28 g m^{-2}, indicating a substantial decrease in weed population (Devi's, 2012) [14].

Clodinafop propargyl, which is effective against post-emergent grassy weeds, such as wild oats, rough meadow grass, green foxtail, barnyard grass, Persian darnel and canary grass, can be used in crops like wheat, groundnut, pulses and soybean, while Sodium acifluorfen is a versatile post-emergence herbicide effective against various annual broad-leaved weeds, such as morning glory, black nightshade, cocklebur, ragweed, jimson weed, lambs quarter, pigweed and wild mustard (Choudhary, 2020) [12]. Harithavardhini *et al.* (2016) [20] stated that application of acifluorfen sodium + clodinafop-propargyl herbicides at rate of 300 and 240 g/ha as post-emergence at 15 days after sowing resulted in maximum weed control efficiency with value 70.6 and 68.0%, respectively. Barla *et al.* (2018) [6] also reported that the application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% at the rate of 1.0 kg/ha as post-emergence at 20 days after sowing resulted in significantly lower density and dry weight of broad-leaved weeds, grassy weeds and sedges at 30 and 60 DAS. According to Elankavi *et al*. (2019) [16], post-emergence treatment of sodium acifluorfen + clodinafop propargyl @ 1250 g/ha led to the lowest weed density, weed dry matter and improved weed control efficacy in black gram. After applying sodium acifluorfen + clodinafop propargyl @ 187.5 g/ha post-emergence, Jagadesh *et al*. (2019) [236] observed considerably lower weed density and dry weight with higher weed control efficacy than propiquizafop + imazethapyr @ 125 g/ha in summer urd bean.

Integrated approach for weed management

Integrating multiple weed control methods, such as combining chemical herbicides with cultural practices like hand weeding, can be highly effective. This approach not only helps in managing weed population more efficiently but also reduces the reliance on any single method. By diversifying weed management strategies, farmers can potentially achieve better long-term outcomes in terms of both crop yield and economic returns. From different experiments conducted all over the country, it can be interpreted that combined use of chemical and one hand weeding yielded better than any single component (Chandra and Kumar, 2017). Chandrakar *et al*. (2014) [8] found hand weeding twice at 20 and 40 DAS and applying imazethapyr 40 g/ha post-emergence at 15-20 DAS the best

weed control techniques to maximize growth and quality yield. For managing weeds without causing toxicity or reducing black gram yield, Patel *et al*. (2014) concluded that pendimethalin at 1000 g/ha as pre-emergence, mixture of pendimethalin, imazethapyr at 800-1000 g/ha and imazethapyr at 50 g/ha as post-emergence were equally effective to nonchemical hand weeding carried out at 20 and 40 days after sowing. Likewise, Singh (2011) [60] reported that in summer, pendimethalin 0.75 kg/ha at 25 DAS, pendimethalin 0.45 kg/ha at 25 DAS and hand weeding at 40 DAS, as well as weedy check recorded weed dry matter of 4.87, 3.45, 3.40 and 23.6 q/ha and grain yield of 11.47, 11.75, 11.95 and 7.02 q/ha, respectively, however, in kharif season, the respective treatments had weed dry matter of 4.16, 4.26, 2.90 and 20.9 q/ha and grain yield of 10.43, 10.76, 11.76 and 6.86 q/ha, respectively. Ram *et al*. (2013) obtained maximum net return from imazethapyr applied @ 75 g/ha at 25 DAS, which was found to be statistically comparable to imazethapyr applied @ 75 g/ha at 15 DAS, imazethapyr applied @ 100 g/ha at 15 or 25 DAS and pendimethalin @ 45 g/ha + hand weeding at 40 DAS, however, it was significantly higher than imazethapyr applied @ 50 g/ha at 15 or 25 DAS, two hand weeding and weedy check at Ludhiana.

Effect of weed management practices on black gram

Growth

In black gram, hand weeding twice specifically at 20 and 40 days after sowing was found most effective among various treatments, resulting in higher seed and stover yield as compared to other treatments (Patel *et al*., 2014). The maximum value for growth was recorded with hand weeding twice at 15 and 30 DAS followed by sodium acifluorfen + clodinafop propargyl applied @ 306.2 g/ha as post-emergence (Sharmitha *et al*., 2023) [57]. Goud *et al*. (2013) [19] achieved the largest reduction in number of nodules per plant with imazethapyr and quizalofop-ethyl applied @ 100 g/ha at 25 DAS, respectively. Similarly, higher number of nodules and dry weight have also been reported by Aggarwal *et al*. (2014) [1]. Likewise, Verma *et al*. (2017) [71] found that the application of imazethapyr + pendimethalin at the rate of 900 g/ha resulted in significantly higher grain and straw yield of black gram as compared to other treatments.

Yield attributes

According to Choudhary *et al*. (2012) [12], the black gram crop with integrated treatment of pendimethalin @ 1.5 lit/ha + hand weeding at 25 DAS produced more-number of pods per plant (38.1) than fluchloralin @ 1.5 lit/ha (34.1), which was comparable with pendimethalin @ 1.5 lit/ha (36.0). Similarly, Raju *et al*. (2017) [49] achieved maximum values for number of pods plant^{-1} (43.0), seeds pod^{-1} (7.0) and seed (833 kg/ha) and haulm (1697 kg/ha) yield with the application of pendimethalin 30% EC at 0.75 kg a.i./ha in kharif black gram crop. In green gram crop, Punia *et al*. (2017) [48] found that among herbicidal treatments, the post-emergence application of a ready mix of imazethapyr and imazamox @ 60 to 80 g/ha resulted in maximum number of pods per plant (34.6), seeds pod^{-1} (11), seed yield (11.4 q/ha) and harvest index (29 %). Likewise, Barla *et al*. (2018) [6] concluded that among the treatments of red gram crop, the post-emergence application of sodium acifluorfen 16.5% SL + clodinafop-propargyl 8% EC @ 1.0 kg/ha resulted in maximum number of pods plant^{-1} (142 and 115), number of grains pod^{-1} (6.65 and 5.75), 100 seeds weight (8.35 and 6.75 grams) and seed yield (2185 and 1772 kg/ha) on sandy loam soil of Ranchi. In green gram crop, Singh *et al*. (2024) [58] obtained maximum growth and yield attributes, such as pods count per plant, seed count per pod and yield q/ha with hand weeding at 15 and 30 DAS. The application of imazethapyr 100 g a.i. ha^{-1} at 25 DAS got maximum pod length, number of seeds pod^{-1}, test weight, harvest index, seed and stover yield (Kumawat *et al*., 2024) [31].

Yield

According to Susmitha *et al*. (2019) [68], pre-emergence application of pendimethalin + imazethapyr @ 1.0 kg/ha resulted in considerably higher seed production, straw yield and harvest index of black gram. Aliveni *et al*. (2016) [2] observed that post-emergence application of sodium aciflourfen + clodinafop propargyl 400 g/ha resulted in higher seed and haulm yield of black gram. Similarly, Suryavanshi *et al*. (2018) [68] found that post-emergence application of imazethapyr 100 g/ha recorded significantly higher seed and haulm yield of black gram. In kharif soyabean, Jha *et al*. (2014) [26] noted that among the herbicidal treatments, the application of clodinafop-propargyl 8% EC + sodium acifluorfen 16.5% SL at 100 + 206.2 g a.i/ha resulted in a higher haulm yield (2508 kg/ha). Application of pendimethalin @ 1 kg/ha as pre-emergence was effective to control weeds and to increase the yield of moong bean (Goswami *et al*., 2015) [18].

Economics

The maximum net return (Rs. 34810/ha) and benefit to cost ratio (3.34) was obtained from black gram crop with pre-emergence application of pendimethalin + imazethapyr (pre-mix) @ 1000 g a.i./ha (Chicham *et al*., 2020) [9]. Divya *et al*. (2017) [15] obtained maximum gross income (Rs. 35175/ha), net return (Rs. 24477/ha) and benefit to cost ratio (2.29) with post-emergence application of clodinafop propargyl l8 EC + aciflourfen sodium 16.5 EC @ 187.5 g/ha. Meena *et al*. (2011) [35] concluded that application of imazethapyr XL 10% SL at 100 g/ha recorded significantly higher net return (Rs. 14,237g/ha) and benefit to cost ratio (1.68) followed by imazethapyr XL 10% at 150 g/ha over weedy check and imazethapyr XL 10% at 50 g/ha. Similarly, Aggarwal *et al*. (2014) [1] achieved maximum gross and net return from black gram crop with the application of imazethapyr @ 100 g/ha at 15 DAS and two hand-weeding at 20 and 40 DAS than all other treatments like imazethapyr @ 50 and 75 g/ha at 15 DAS, imazethapyr @ 50 and 75 g/ha at 20 DAS and weedy check under Punjab condition. Ramesh and Rathika (2015) [51] got higher net return from black gram crop with the application of imazethapyr 50 g/ha + quizalofop-ethyl 50 g/ha. Mukherjee (2021) [38] obtained maximum net return and benefit to cost ratio from pre-emergence application of pendimethalin 1.25 kg/ha + one hand weeding at 35 DAS. According to Gelot *et al*. (2018) [17], pre-emergence treatment of pendimethalin 1.0 kg/ha supplemented with inter-cultivation resulted in considerably greater net return and benefit to cost ratio in green gram. Mudulli *et al*. (2023) achieved maximum net return (Rs. 40324/ha) and benefit to cost ratio from black gram crop with the application of pendimethalin 30 EC + imazethapyr 2% SL (pre-mix) at 800 g/ha. The application of pendimethalin followed by acifluorfen-sodium + clodinafop propargyl on 20 DAS had maximum gross return (Rs. 64,234 and 72,383/ha), net return (Rs. 37,374 and 44,722/ha) and benefit to cost ratio (2.39 and 2.62) in black gram crop during *Kharif* and winter seasons, respectively (Jagadesh *et al*., 2021) [24].

Effect of weed management on succeeding crop

Pre-emergence application of pendimethalin 30 EC @ 750 g/ha

in black gram did not show phytotoxic effect on succeeding crops, *viz*. wheat, gram and mustard on sandy clay loam soil under Rajasthan conditions (Mundra and Maliwal, 2012) [39]. Similarly, at Hisar, Anonymous (2013) [3] observed that all herbicide treatments except imazethapyr @ 70 g/ha and its readymix combination with imazamox applied in black gram showed only 5% toxicity up to 15 DAS on mustard crop, which mitigated within one month after planting. In other studies, Naveen *et al.* (2019) [42] reported that pre-emergence application of pendimethalin 0.75 kg/ha on preceding groundnut did not show any phytotoxicity on succeeding fodder sorghum in Andhra Pradesh. Pre-emergence application of pendimethalin in soybean produced persistence in soil for 45 and 60 DAS (Arora and Dubey, 2014) [5].

Conclusion

Weed management in food legume crops is indeed challenging due to factors like varying weed emergence patterns, unpredictable weather, unsuitable soil conditions, labor availability and limited access to broad-spectrum herbicides. Given this complexity relying on a single method of weed control, whether manual, mechanical, or chemical, often proves inadequate. Combining pre-emergence herbicides with manual or mechanical weeding is essential for effective weed management in food legume crops. This integrated approach helps in controlling weeds more efficiently. Weeds would not become resistant to herbicides if herbicide rotation or herbicide combinations are used. Hence, hand weeding during the crucial crop-weed competition phase combined with pre-emergence herbicides like pendimethalin and others, post-emergence herbicides like imazethapyr, imazamox and sodium acifluorfen is very successful way to control weeds in black gram crop.

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