***Review Article***

# Impact of weed management options in optimizing weed control and productivity of rapeseed-mustard: A review

**Abstract**

This study investigates the weed flora in rapeseed-mustard fields and evaluates the effectiveness of various weed management strategies to enhance crop yield and productivity. Mustard fields are infested by a diverse range of weed species, including annual, biennial and perennial, which compete with crops for essential resources, leading to significant yield loss. The key grassy weeds identified include *Avena ludoviciana*, *Cynodon dactylon* and *Phalaris minor*, while the notable broad-leaved weeds include *Chenopodium album*, *Anagallis arvensis* and *Melilotus alba*. The critical period for weed competition in mustard lies between 20 and 40 days after sowing. Literature about various weed management practices, including cultural, mechanical and chemical methods, was studied and it was found that chemical herbicides, such as pendimethalin, oxadiargyl, isoproturon, clodinafop and oxyfluorfen showed significant efficacy in controlling weed population and improving crop yield. Mechanical methods, though labor-intensive, were also effective, particularly when combined with chemical treatments. Integrated weed management (IWM) approaches, which combine multiple strategies, were found to be the most effective in maintaining weed population, crop health and productivity. The study highlights the importance of understanding local weed flora and utilizing a combination of pre- and post-emergence herbicides, along with mechanical weeding to achieve optimal weed control. This review article underscores the need for disseminating knowledge about effective herbicide use and integrated weed management among small and marginal farmers for sustainable agriculture.

***Keywords:*** *Rapeseed-mustard, weeds, weed flora, weed control, integrated weed management*



## Introduction

India ranked third in production of rapeseed-mustard after Canada and China and accounts for one-third of the total oil production in India (Shekhawat *et al*., 2012). It is a very significant oilseed crop as its seeds contain 40-46% oil (Hussain *et al*., 2020), moreover, its meal contains 38-40% protein, which has a comprehensive quantity of amino acids together with lysine, methionine and cysteine (Amjad, 2014). Among the oilseed crops grown in the country, it occupies about 24.70% of the total area with 48.28% of the total oilseed production in India (Dayanand, 2016) where rapeseed-mustard is primarily cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat, covering an area of 7.99 million hectares with a production of 11.96 million tonnes and productivity of 1497 kg $ha^{-1}$ during 2021-22 (Anonymous, 2023). Its oil is utilized for human consumption throughout the northern India for cooking purpose (Kuma, 2012; Singh and Kumar, 2020; Singh *et al*., 2022). Rapeseed-mustard has many industrial uses, and its oilcake serves as animal feed and manure (Bora *et al*., 2021).

Weeds are one of the major factors, which inflict yield losses in Indian mustard crop to the extent of more than 35% (Bharat *et al*., 2015). They cause loss of seed yield up to 35-60% or even more depending upon the weed density, type of weed flora and duration of infestation (Kumar *et al*., 2020). While experimenting, Kumar *et al*. (2015) noted 41.7% reduction in yield due to uncontrolled weeds in mustard and Gharde *et al*. (2018) reported 21.4% yield reduction in mustard crop in India. However, Mishra *et al*. (2016) estimated approximately 15-30% yield reduction due to weeds in mustard crop. In India, the more losses caused by weeds up to 33% come after by the insects 20%, pathogens 26%, storage pests 7%, rodents 6% and others 8% (Kalita *et al*., 2017). The presence of weeds like *Physalis minima, Medicago sativa, Sonchus arvensis, Chichorium intybus* in mustard field reduced the productivity (Suryavanshi *et al*., 2018). However, *Chenopodium album*, *Asphodelus tenuifolinus*, *Melilotus indica*, *Cornopus didymus*, *Spergula arvensis* and *Phalaris minor*, *etc*. caused serious yield loss in mustard (Brar and Gill, 2021). The crop is infested with both wide leaved and grassy weeds, and if not managed at appropriate time, they may seriously reduced

the productivity of mustard (Gill and Singh, 2020). Higher seed rates, altered row orientation, narrower row spacing and selection of competitive species have been estimated as encouraging integrated weed management methods to improve competitiveness of the crop (Khaliq *et al*., 2013).

For the management of weeds, the pre-emergence application of pendimethalin was found effective (Mukherjee, 2014; Rao and Chauhan, 2015), and hence, it is the most common herbicide to control weeds in Indian mustard. Mechanical control is the method to remove weeds from the field physically or with the help of small tools or implements, and in biological methods, the weeds are controlled with living organisms, however, in chemical methods, weeds are managed by the use of herbicides (Brar and Gill, 2021). Manual weeding at 3-4 weeks after sowing is the most common practice to control weeds in Indian mustard but increasing wages and scarcity of labour compel the farmers to search for other alternatives (Chishi *et al*., 2021).

**Weed flora in Mustard field**

Based on their summed dominance ratio, the most dominant weed species followed the following order, *i.e*., *Medicago sativa*, *Anagallis arvensis*, *Cyperus rotundus*, *Trachyspermum* spp. and *Cynodon dactylon*, however, *Medicago sativa* was the top ranking dominant weed followed by *Anagallis arvensis* (Kour *et al*., 2014). According to Kumar *et al*. (2015), the dominant broadleaf weeds were *Amaranthus spinosus* L., *Gallinsoga parviflora* Cav., *Coronopus didymus* L., while the monocot weeds were *Digitaria sangunalis* L., *Poa annua* L., *Avena fatua* L., other weeds were *Polygonum alatum* L., *Malva parviflora* L., *Chenopodium botrys* L., *Setaria galuca* L., *Panicum dicotomiflorum* L. and *Medicago denticulate* Wild. Bijarnia *et al*. (2017) observed the weed species like *Melilotus indica*, *Rumex denticulatus*, *Asphodelus tenuifolinus*, *Chenopodium album* and *Chenopodium murale* in mustard crop. Kalita *et al*. (2017) reported *Anagallis arvensis*, *Convolvulus arvensis*, *Chenopodium album*, *Fumaria parviflora*, *Cyperus rotundus*, *Chenopodium murale*, *Asphodelus tenuifolinus*, *Cynodon dactylon*, *Melilotus indica* and *Phalaris minor* weeds in mustard field. The dominant weed species found in mustard field were *Chenopodium album* (37%), *Chenopodium murale* (22%), *Portulaca oleracea* (14.5%), *Melilotus indica* (6.5%), *Asphodelus tenuifolius* (5.6%) and *Rumex dentatus* (5.6%), however, some other species like *Amaranthus blilum*, *Cyperus rotundus*, *Heliotropium subulatum*, *Glinus lotoides* and *Cynodon dactylon* were also observed in minor abundance, *i.e.*, 8.8% (Yadav *et al*., 2017). Gupta *et al*. (2018) found *Chenopodium album* (Bathua), *Thithoria diversifolia* L. (wild sunflower), *Anagallis arvensis* (Krishan neel), *Melilotus alba* (Senji), *Cyperus rotundus* (motha) and *Cynodon dactylon* (Doob) the predominant weeds in mustard field during crop season. Suryavanshi *et al*. (2018) found the dominant dicot weeds like *Medicago sativa*, *Sonchus arvensis*, *Cichorium intybus* and *Physalis minima* associated with gobhi mustard. Bhawana *et al*. (2019) observed eleven weeds in mustard field, *i.e.*, *Cyperus rotundus*, *Cynodon dactylon*, *Anagallis arvensis*, *Melilotus alba*, *Rumex* sp., *Parthenium hysterophorus*, *Convolvulus arvensis*, *Chenopodium album*, *Vicia hirsute*, *Phalaris minor* and *Polypogonmon speliensis*. In mustard crop, Choudhary and Bhagawati (2019) have shown the broadleaved weeds, such as *Ageratum conyzoides*, *Galinsoga parviflora*, *Commelina benghalensis*, *Chromolaena odorata*, and *Borreria hispida*, as well as the grassy weeds including *Digitaria sanguinalis*, *Eleusine indica*, *Dactyloctenium aegyptium*, *Echinochloa colona* and *Cynodon dactylon* in mustard field. Sidar (2019) found the mustard crop infested with grassy weeds, *i.e.*, *Phalaris minor* (21.35%) and *Cynodon dactylon* (7.78%), and broad-leaved weeds, *i.e.*, *Chenopodium album* accounted for 17.58% loss, *Anagallis arvensis* 27.43%, *Cyperus rotundus* 10.61% and *Melilotus alba*, *Vicia hirsuta*, *Lathyrus asphaca* and *Rumex* sp. 19.22%. The most common weeds in rapeseed mustard field are *Avena ludoviciana*, *Phalaris minor*, *Chenopodium album*, *Rumex dentatus*, *Anagallis arvensis*, *Convolvulus arvensis* and *Cirsium arvensis* (Singh and Kumar, 2020; Singh *et al*., 2020; Singh *et al*., 2021; Brar *et al*., 2021). Weeds found in mustard crop include *Chenopodium album*, *Lathyrus* spp. *Anagallis arvensis*, *Cynodon dactylon*, *Argemone mexicana* and others (Hadke *et al*., 2021).

**Crop-weed competition**

The loss in seed yield of rapeseed-mustard due to weed competition with crop was estimated 32.27% with net return minimum (Singh *et al*., 2016**)**. Weed competition in mustard is more serious during early stages since crop growth remains slow during the first 4-6 weeks after sowing (Adhikary and Ghosh, 2014; Sheoran, 2016; Gupta *et al*., 2018; Das *et al*., 2020; Sharma *et al*., 2021). Asif *et al*. (2020) also considered weed crop competition duration a major factor influencing quality of crop production. Hand weeding twice at 30 and 60 days after sowing recorded maximum weed control efficiency and minimum weed index (Chishi *et al*., 2021). Many weeds are crop and/or region-specific. *Orobanche aegyptiaca*, for example, has become a severe danger in rainfed areas of Rajasthan, Madhya Pradesh and Haryana, while *Chenopodium*, *Asphodelus*, *Melilotus* and *Trianthema* spp. cause considerable yield loss in other location (Kumar and Barkha, 2022).

**Weed management by agronomic practices**

Shrivas *et al*. (2013) demonstrated that one-hand weeding at 20 days after sowing followed by the application of oxyfluorfen at 100 ml $ha^{-1}$ as pre-emergence at 2 days after sowing resulted in lowest weed density. The application of herbicidal treatments in conjunction with one hand weeding at 35 days after sowing led to a significant increase in the seed yield of mustard compared to the weedy check. Specifically, this combined approach resulted in a boost of seed yield ranging from 32 to 68% over the weedy check condition (Mukherjee, 2014). The maximum plant height was noticed in two-hand weeding, while the lowest in weedy check throughout the growing season and the number of branches per plant was noted higher in two-hand weeding while lowest in weeded plots, moreover, a greater seed yield of 898.50 kg $ha^{-1}$ and test seed weight of 3.14 g was recorded in two hand weeding and lowest in weedy check (Akhter *et al*., 2016). Bamboriya *et al*. (2016) found the lowest weed density and dry weight as well as the maximum weed control effectiveness and also noted that the interaction of herbicides with one hoeing was equally effective in reducing the weed population at 60 days after sowing. One-hand weeding at 25 days after sowing significantly increased both seed and oil yield of Indian mustard, with oxadiargyl also showing promising results in this regard **(**Kalita *et al*., 2017). The superior weed management treatment with respect to oil yield of Indian mustard was one hand weeding 25 DAS (908 kg $ha^{-1}$ ) closely followed by oxadiargyl 0.09 kg $ha^{-1}$ (899 kg $ha^{-1}$), while the performance of pendimethalin 0.75 kg $ha^{-1}$ and quizalofop-ethyl 0.05 kg $ha^{-1}$ was statistically at par in respect of oil yield as 722 and 661 kg $ha^{-1}$, respectively (Sontara *et al*. 2017). Gupta *et al*. (2018) suggests that both two hand weeding and the pre-emergence application of pendimethalin can contribute to optimizing mustard yield, highlighting the efficacy of these practices in mustard cultivation. The number of siliquae per plant, number of seeds per siliqua and length of siliqua were recorded maximum in two hand weeding at 20 and 40 days after sowing being statistically at par with pendimethalin @ 1.0 kg $ha^{-1}$ + hand weeding 30 days after sowing and found superior over rest of the weed management practices (Singh *et al*., 2020). Hand weeding twice at 30 and 60 days after sowing was most effective in achieving significantly higher mustard seed and straw yield and it was at par with pendimethalin 750 g $ha^{-1}$ as pre-emergence followed by one-hand weeding (Chishi *et al*., 2021). The application of pendimethalin 1.0 kg *a.i*. $ha^{-1}$ followed by clodinafop-propargyl 0.06 kg *a.i*. $ha^{-1}$ at 30 days after sowing was found most efficient in lowering the dry matter of weeds, followed by the application of fluazifop-p-butyl 0.08 kg *a.i*. $ha^{-1}$ at 30 days after sowing, clodinafop-propargyl 0.06 kg *a.i*. $ha^{-1}$ at 30 days after sowing, propaquizafop + oxyfluorfen 0.08 kg *a.i*. $ha^{-1}$ at 30 days after sowing and propaquizafop 0.10 kg *a.i*. $ha^{-1}$ at 30 days after sowing over weedy check (Meena *et al*., 2023 ). Conducting hand weeding twice at 20 and 40 days after sowing resulted in reduced dry weight of weeds to 27.05 g $m^{-2}$ at 60 days after sowing and gave weed control efficiency of 80.87% (Kumar, 2020).

**Weed management by chemicals**

Soltani *et al*. (2013) reported that pendimethalin achieved 97% control of *Amaranthus retroflexus*, 90% control of *Ambrosia artemisii-folia*, 90% control of *Chenopodium album*, 12% control of *Sinapsis arvensis* and 96% control of *Setaria viridis* as compared to the weedy

check plot. The use of application of oxyfluorfen at 100 ml $ha^{-1}$ as pre-emergence at 2 days after sowing led to increased pod and biological yield due to reduced weed dry matter accumulation, more branches per plant, more pods per plant and higher 100 kernels weight (Shrivas *et al*., 2013).

The pre-emergence application of pendimethalin 0.75 kg $ha^{-1}$ increased the seed yield of Indian mustard by 48.1% as compared to control (Bharat *et al*., 2015). Gohelet *et al*. (2015) reported that pre-emergence application of oxadiargyl 0.09 kg $ha^{-1}$ to Indian mustard increased seed yield by 18.2% as compared to weedy check. Yadav *et al*. (2017) observed that oxadiargyl, pendimethalin, trifluralin and oxyfluorfen were more effective in reducing the population of *Chenopodium album* and *Anagaliis arvensis* however, oxadiargyl 90 g $ha^{-1}$ as pre-emergence herbicide gave maximum weed control efficiency (81.82%) as compared to control, and the integration of quizalofop and clodinafop proved to be beneficial in managing *Phalaris minor*. Use of pre-emergence herbicides assumes greater importance given their effectiveness from the initial stages of crop growth, and later emergence can be tackled by applying selective post-emergence herbicides (Choudhary *et al*., 2021; Choudhary and Dixit 2021).

**Effect of weed management on nutrients uptake**

All the weed management practices had significant effect on N, P and K removal by mustard over weedy check. Significantly higher uptake of N, P and K was recorded under two hand weeding at 20 and 40 days after sowing by mustard plant followed by fluazifop-pbutyl @ 0.055 kg $ha^{-1}$ 10 days after sowing + hoeing 40 days after sowing and fenoxa-prop-p-ethyl @ 0.075 kg $ha^{-1}$ 10 days after sowing + hoeing 40 days after sowing as compared to rest of the treatments, although the N, P and K removal under these treatments were statistically at par (Bamboriya *et al*., 2017). The maximum uptake of nitrogen, phosphorous and potassium by crop was recorded in plots treated with pendimethalin 1.25 kg $ha^{-1}$ followed by one hand weeding (Verma *et al*., 2017). The two hand weeding and pendimethalin 0.75 kg $ha^{-1}$ as pre-emergence were found significantly better in enhancing nitrogen, phosphorus and sulphur concentration in seed and straw as well as their uptake and protein content in seed (Kumar *et al*., 2019). Kumar *et al*. (2020) recorded highest nutrient uptake by mustard sown on november 17 and supplied with nitrogen 103.31 kg, phosphorus 33.73 kg, potassium 87.38 kg and sulphur 16.83 kg $ha^{-1}$. The application of nitrogen, phosphorus and potassium content (%) did not significantly influence due to various integrated weed management practices, however, the highest content of nitrogen, phosphorus and potassium was recorded with two hand weeding at 20 and 40 days after sowing as compared to rest of the integrated weed management practices (Raj *et al*., 2021).

**Effect of weed management on growth parameters**

Two hand weedings, applying trifluralin 0.60 kg $ha^{-1}$ before planting and pendimethalin 0.70 kg $ha^{-1}$ before planting and before the emergence of plants led to a significant reduction in dry weight of the associated weeds as compared to the unweeded control (Kaur *et al*., 2013). Patel *et al*. (2013) recorded higher plant growth and yield attributing characters under weed-free conditions and found that the use of pendimethalin 0.5 kg $ha^{-1}$ as pre-emergence with one hand weeding at 25 days after sowing, oxadiargyl 75 g $ha^{-1}$ as pre-emergence with pne hand weeding at 25 days after sowing and pendimethalin 0.5 kg $ha^{-1}$ as pre-emergence alone resulted in significantly higher values for dry matter production per plant (51.00 g) and number of siliquae per plant (280.37), number of seeds per siliqua (14.70) and test weight (4.25 g) as compared to other treatments. One-hand weeding at 30 days after sowing was found as effective as oxyfluorfen 0.125 kg $ha^{-1}$, fluchloralin 1.0 kg $ha^{-1}$ and metribuzin 0.125 kg $ha^{-1}$ in terms of improving the number of siliquae per plant, seeds per siliqua, test weight and seed yield of mustard as compared to the weedy check (Sah *et al*., 2013). Mukherjee (2014) observed the minimum weed density and weed dry matter production with the application of pendimethalin 0.75 kg $ha^{-1}$ and one hand weeding at 35 days after sowing, and this method was as effective as hand weeding twice during both the years. Kumar *et al*. (2015) recorded the lowest weed density under manual weeding (H7$m^2$) and quizalofop-ethyl

60 g ha$^{-1}$ (288 m$^2$) at initial crop growth stage (25 DAS) and also recorded the lowest weed biomass in the weed-free treatment and pendimethalin application. Jangir *et al*. (2017) found that the combination of pendimethalin 1.0 kg ha$^{-1}$, quizalofop-P-ethyl 0.04 kg ha$^{-1}$ applied at 20 days after sowing and hand-weeding and IC treatments applied at 40 days after sowing led to maximum plant height, number of branches per plant, dry matter accumulation, number of siliquae per plant and seed and stover yield. The total dry matter accumulation decreased significantly with the delay in sowing during both the years at all the growth stages, *i.e.*, 30, 90, 120 and at harvest, however, the difference in dry matter accumulation at 60 days after sowing between october 25 and november 5 was statistically at par with each other (Keerthi *et al*., 2017). Tomar (2015) observed that hand weeding and the application of pendimethalin showed the maximum seed yield as compared to the weedy control plot. Yadav *et al*. (2017) observed that oxadiargyl, pendimethalin and trifluralin resulted in lower nitrogen uptake and higher yield attributes, such as the number of siliquae per plant, siliqua length and seed yield per siliqua, as well as increased overall seed yield in mustard plants. Performing two hand weeding at 20 and 40 days after sowing led to maximum grain yield of 14.79 q ha$^{-1}$ and stover yield of 47.05 q ha$^{-1}$ (Kumar, 2020). Two hand weeding at 20 and 40 days after sowing being at par with pendimethalin applied @ 1.0 kg ha$^{-1}$ + straw mulch 5 t ha$^{-1}$ and straw mulch 10 t ha$^{-1}$ (3 DAS), however, the crop had significantly maximum plant height and dry matter accumulation over weedy check plot at all stages of crop growth (Raj *et al*., 2021).

**Effect on yield parameters**

The maximum seed yield of mustard was achieved with the application of pendimethalin @ 1.25 kg ha$^{-1}$, which resulted in seed yield levels comparable with all other treatments except for the weedy check, as well as the treatments involving fluchloralin at 0.75 kg ha$^{-1}$ and pendimethalin at 0.75 kg ha$^{-1}$ (Mukherjee, 2014). Akhter *et al*. (2015) reported that delayed planting of brown sarson resulted in a significant decline in yield contributing components, *i. e.*, number of siliquae per plant, number of seeds per siliqua and 1000 seeds weight. Among sowing dates, the crop sown on 20th October showed its supremacy in obtaining yield (1.35 t ha$^{-1}$ ) with the delay in sowing, resulting in considerable yield loss (4-11%) during both the years of experiment (Dinda *et al*., 2015). Singh *et al*. (2016) reported that the loss in seed yield due to weeds was 32.27% and the net return being minimum. Gupta *et al*. (2018) found that hand weeding performed at 25-30 and 40-45 days after sowing resulted in maximum mean plant height (165.4 cm), number of siliquae per plant (153.7), seeds per siliqua (13), test weight (4.33 g), as well as mustard seed and stover yield were statistically comparable to the outcomes obtained from one round of hand weeding (16.08 and 50.39 q ha$^{-1}$ for seed and stover yield, respectively) and the pre-emergence application of pendimethalin 38.7CS (15.86 and 48.49 q ha$^{-1}$ for seed and stover yield, respectively). Pandey *et al*. (2019) found that combining pendimethalin 1000 g per hectare with hand weeding performed at 40 days after sowing resulted in maximum grain (51.83 q ha$^{-1}$) and and stover (53.80 q ha$^{-1}$) yield of mustard crop, suggesting that integrating pendimethalin application with timely hand weeding could be an effective weed management strategy for optimizing both grain and stover yield in mustard cultivation. Raj *et al*. (2020) found that performing two hand weeding at 20 and 40 days after sowing resulted in lowest total weed population, dry weight of weeds and weed index throughout their study. Furthermore, the growth parameters, yield attributes, overall yield and quality of the mustard crop significantly increased when two hand-weeding were performed at 20 and 40 days after sowing. The maximum seed yield of mustard was recorded with two hand weeding at 20 and 40 days after sowing, which was statistically at par with pendimethalin @ 1.0 kg ha$^{-1}$ + hand weeding 30 days after sowing (Singh *et al*., 2020).

The mustard crop produced significantly higher seed yield (13.44 q ha$^{-1}$), plant height (156.7 cm), number of branches per plant (5.18), number of siliquae per plant(182.85), and number of seeds per siliqua (13.16) with the application of oxadiargyl @ 0.09 kg ha$^{-1}$ as pre-emergence followed by one-hand weeding at 40 days after sowing (Kumar, 2020). Higher seed (1483 kg ha$^{-1}$) and stover (3280 kg ha$^{-1}$) yield was recorded under the treatment where intercultivation and hand weeding was done at 15 and 30 days after sowing, which was at par

with oxadiargyl 6% EC 0.09 kg $ha^{-1}$ as pre-emergence followed by intercultivation at 30 days after sowing (Yernaidu *et al*., 2023).

**Effect of weed management on economics**

Indian mustard crop gave higher gross and net returns due to weed control over other treatments by the application of trifluralin 0.75 kg $ha^{-1}$ + hand-weeding, pendimethalin 1.50 kg $ha^{-1}$and isoproturon 1.50 kg $ha^{-1}$ (Kumar *et al*., 2012). Kour *et al*. (2014) recorded the maximum yield, weed control efficiency (85.16%), net returns (Rs. 20,373 $ha^{-1}$) and benefit to cost ratio (1.71) from Indian mustard intercropped with chickpea when pendimethalin was applied @ 1 kg $ha^{-1}$ as pre-emergence. Mukherjee (2014) obtained the maximum net returns (Rs. 19,950 ha) from mustard crop with hand-weeding twice (Rs. 19,950 ha) followed by the application of pendimethalin (0.75 kg $ha^{-1}$) + hand-weeding at 35 days after sowing (19,850 $ha^{-1}$), however, the maximum benefit to cost ratio (2.06) was recorded with the application of pendimethalin (1.25 kg $ha^{-1}$), closely followed by pendimethalin (0.75 kg $ha^{-1}$) + one hand-weeding at 35 days after sowing (1.91). Dinda *et al*. (2015) achieved a maximum net monetary return of ₹ 39405.58 $ha^{-1}$ with a benefit cost ratio of 3.00 when the crop was sown 20th October. Singh *et al*. (2017) reported the maximum net return (₹ 55287.26 $ha^{-1}$) and benefit to cost ratio (2.38) from mustard crop when sown on 25th October. Gupta *et al*. (2018) reported that the maximum net returns Rs. 47178 $ha^{-1}$ and benefit to cost ratio (3.75) from mustard crop under pre-emergence application of pendimethalin 38.7 CS. From Indian mustard crop, Jangir *et al*. (2018) obtained the maximum economical gain of 60,458 $ha^{-1}$ and benefit to cost ratio of 3.41 with lowest values for total weed population, dry weight of total weeds, weed index and better weed control efficiency with the application of pendimethalin 1.0 kg $ha^{-1}$ as post-emergence + quizalofop-P-ethyl 0.04 kg $ha^{-1}$ at 20 days after sowing + hand-weeding and IC at 40 days after sowing but it was at par with pendimethalin 1.0 kg $ha^{-1}$ as pre-emergence + hand weeding and IC at 49 days after sowing. Dwivedi and Puhup (2019**)** obtained the maximum gross return and benefit to cost ratio (3.91) with hand weeding twice at 21 and 45 days after sowing, while net return was maximum with the application of isoproturon + metsulfuron-methyl (1 kg + 4 g $ha^{-1}$) as post-emergence. Osari *et al*. (2019) recorded the maximum net returns of Rs. 42490 $ha^{-1}$ and benefit to cost ratio of 3.18 with the pre-emergence application of pre-mix imazethapyr + imezamox at 80 g $ha^{-1}$ + two hand weeding at 20 and 40 days after sowing followed by pre-emergence application of pendimethalin + imazethapyr 750 g $ha^{-1}$. Raj *et al*. (2020) reported that the application of pendimethalin 1.0 kg $ha^{-1}$ + straw mulch 5 t $ha^{-1}$ resulted in maximum net returns (Rs. 69277.00 $ha^{-1}$) and benefit to cost ratio (2.07) for the mustard crop. Singh *et al*. (2020) obtained the maximum gross return of Rs. 102326 $ha^{-1}$ and net return of Rs. 72862 $ha^{-1}$ with hand weeding at 20 and 40 days after sowing and pre-emergence application of pendimethalin 1.0 kg $ha^{-1}$.

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