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Influence of pre-emergence and post-emergence of herbicide on weed parameters, growth and yield attributes of blackgram: A review

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Abstract
Blackgram (*Vigna mungo* L.) is one of the important pulse crops grown in India under wide range of agro-climate zones which belong to the family "Leguminoseae". It can be cultivated in all the seasons, but most of the area is in *Kharif* cultivation with irrigated condition. The importance of weed control measure in blackgram is emphasized by the fact that weeds alone cause more damage to crop than all pests and diseases. Therefore it is essential to maintain weed free condition to attain higher economic yield. With the changing scenario of weed control practices, farmers are looking for broad spectrum post emergence herbicides to control sedges, narrow leaved and broad leaved weeds at later stage. Review of various literatures revealed that it is very important for enhancing the weed efficiency by application of suitable pre and post emergence herbicides and other methods for effective control of diversified weed flora in blackgram.

Keywords: Blackgram, weed management practices, weed control efficiency, yield

Introduction
India is the world's largest producer as well as consumer of black gram. It produces about 1.5 to 1.9 million tons of blackgram annually from about 3.5 million hectares of area, with an average productivity of 555 kg per hectare. Black gram output accounts for about 10% of India's total pulse production. Blackgram producing states are Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka, Odisha and Gujarat. In Tamil Nadu, blackgram is one of the valuable crops among the pulses group grown under both irrigated and rainfed situation. Recently, the area under winter blackgram is also increasing in Tamil Nadu due to higher demand in the market. It occupies an area of 3.54 lakh hectare with a production of 2.59 lakh tonnes and moderate yield of 731 kg/ha (Pulses in India: Retrospect and Prospects 2018). The productivity of blackgram is very low in both India and Tamil Nadu due to various factors.

Among various reasons of low productivity, severe competition by wide range of weed flora especially under high rainfall, high temperature and high humidity are most important. Continuous rains also pose a serious problem to remove weeds manually because of wet conditions of soil. In addition, blackgram being a wide spaced crop provides enough opportunity for weeds to invade and offer competition. The benefits of different production inputs are mitigated by weeds, if left uncontrolled. Weeds affect crop from emergence stage onwards by showing severe competition and result in considerable yield reduction. Keeping this view, the several research articles pertain to weed characters, growth and yield attributes on pulses were analyzed and furnished in this review article for the benefit of scientists and farming community.

Seasonal effect on weed flora of blackgram under different ecosystem
Shweta and Singh (2005) [47] noted the weeds of *Cyperus rotundus, Echinochloa colona, Cynodon dactylon. Eleusine indica, Trianthema monogyna*, and *Commelina benghalensis* in the silty clay loam soil of blackgram field during *Kharif* season. Weeds like *Cleome viscosa, Echinochloa crusgalli, Cyperus rotundus, Echinochloa colona, Cynodondactylonand Oryza*

sativa in the relay cropped blackgram field at Killikulam, Tamil Nadu was found by Veeraputhiran and Chinnusamy (2008) [58].

Weeds like *Cynodon dactylon, Echinochloa* spp., *Cyperus rotundus, Amaranthus viridis, Parthenium hysterophorus, Trianthema portulacastrum* in the sandy clay loam soil of irrigated blackgram field during the *Rabi* season was found by Mundra and Maliwal (2012) [28]. Rice fallow blackgram infested with *Grangea maderaspatana, Vicia sativa, Phyllanthus maderaspatensis, Cardiospermum helicacabum, Chrozophora rottleri* (Naidu *et al.*, 2012) [29].

Sangeetha *et al.* (2013) [43] observed grass weeds like *Dactyloctenium aegyptium, Arachne racemosa, Bracharia reptans* and broad leaved weeds like *Boerhavia diffusa, Digera arvensis, Parthenium hysterophorus, Trichoderma indicum* in *Kharif* blackgram cultivated in red sandy loam soil of Agricultural Research Station, Bhavanisagar, Tamil Nadu. Sasikala *et al.* (2014) [44] reported that in the sandy loam soil of blackgram infested with weeds of *Echinochloa colonum, Cleome viscosa, Panicum repens, Ecliptaalba, E. crusgalli, Sphaeranthus indicus*and *C difformis* during the *Rabi* season.

Monocot weeds like *Bracharia SP, Dactylectinum aegyptium, Echinochloa colona*. sedges like *Cyperus rotundus* and dicot weeds like *Amaranthus viridis, Phyllanthus niruri, Commelina diffusa, Parthenium hysterophorus, Digeria arvensis* was noted in *Kharif* blackgram in clay soil (Khairnar *et al.*, 2014) [17]. Yadav *et al.* (2015) [61] found that in sandy loamy soil of blackgram are infested with weeds of *Echinochloa crusgalli, Phyllanthus niruri, Commelina benghalensis, Digera arvensis and Cyperus rotundus* during *Kharif* season.

(Kumar *et al.*, 2017) [20] observed that infestation of *Cyperus rotundus, Cyprus iria, Phyllanthus niruri, Digera arvensis and Commelina benghalensis* weeds in a green gram field of sandy loam soil during the *Rabi* season. In the clay soil of *Kharif* blackgram weeds namely *Amaranthus spinosus, Trianthema portulacastrum, Eleusine verticillata, Portulaca oleracea, Euphorbia hirta, Cenchrus biflorus, Celosia viscosa, Tribulus terrestris, Cyperus rotundus* and *Digera arvensis* were registered by (Singh *et al.*, 2017) [48].

Crop weed competition period in pulses

Competition between crops and weeds was usually more rigorous when there were similar vegetative habits and demands on resources among competing plants. Generally, the critical period of weed competition in pulse crops exists during the initial 4- 5 weeks after sowing.

Singh *et al.* (1991) [49] revealed that economic yield of both blackgram and greengram maximized with an increase in weed free period upto 30 days after sowing during *Kharif* and summer seasons. But keeping weed free condition after 30 days after sowing had no beneficial effect on crop yield because after 30 days of sowing the crop itself suppresses the weed growth by smothering effect. Therefore the period of first 30 days after sowing and 15-30 days after sowing were found to be critical crop-weed competition in *Kharif* & summer planted blackgram and green gram.

Singh *et al.*, (2002) [52] observed that summer urd bean's economic yield curtailed to 4.1 percent, 22.2 percent, 44.6 percent, and 46.7 percent when weeds grown up to 20, 30, 40 and 60 DAS respectively. Kumar and Tewari (2004) [18, 41] found that early unweeded condition upto 10 DAS did not bring any yield reduction in crop. On the other hand, allowing weed free state after 40 DAS did not get maximum yield. Therefore in blackgram, the critical weed competition period ranges from 10 to 40 DAS.

In blackgram greater crop-weed competition took place between the periods of 20 to 40 days after sowing. Weed competition for entire crop season curtailed the crop yield to the tune of 87% was reported by (Bhandari *et al.*, 2004) [2]. (Sheoran *et al.*, 2008) [46] revealed that in greengram unchecked weed condition curtailed the yield by 53.7 percent over the weed free check. Maintaining weed free condition for the 1st 20 DAS and weedy condition for the first 40 days after sowing significantly curtailed the crop yield by 38% & 20% respectively. Therefore, the weed free condition should be between 20 to 40 DAS period to attain greater yield.

During the early stages weed infestation will be quite higher and first 4 to 5 weeks will be the critical crop-weed competition period in blackgram (Rao, 2008a) [39]. Superior yield of 0.83 t ha^{-1} was documented with weed free condition for initial 30 days after sowing over the weed free condition for initial 15 DAS and was on par with treatment weed free condition for entire crop period (0.92 t ha^{-1}) (Rao, 2008b) [40]. (Vivek *et al.*, 2008) [60] observed that weeds presence after 30 days after sowing curtailed the yield significantly and weeds absent after 45 days had no positive impact on grain yield. Therefore the crop-weed competition between the periods of 30 to 45 days after sowing will be critical.

Weed control methods in blackgram

Effect on crop growth and yield by hand weeding

The utmost economic yield of blackgram 2.25 t $ha^{-1}$was noted with hand weeding twice and it significantly augmented the yield to 68% over the unweeded check owing to reduced weed competition period (Chand *et al.*, 2004) [5]. Hand weeding twice treatment reduced weed competition period that ultimately improved the economic yield in blackgram. It augmented the seeds per pod (5.58), pods per plant (38.10), test weight (28.50 g) and economic yield (0.85 $kgha^{-1}$) by 8.9 %, 109.9%, 3.3% and 114.5% respectively over the unweeded checks reported by Raman *et al.* (2005) [37].

Sharma and Yadava (2006) [45] noticed that utmost economic yield (1.95 t ha^{-1}) in hand weeding twice treatment plot. It was about 61.2% higher than the unweeded treatment plot. Malliswari *et al.* (2008) [25] noted that hand weeding at branching & flowering stages of blackgram registered uppermost economic yield (831 kg ha^{-1}) among rest of the weed control measures and boosted the yield to 73.1% over unweeded plot owing to complete eradication of weeds. (Kaur *et al.*, 2009) [14] observed that uppermost values of primary branches $plant^{-1}$ (2.6), secondary branches $plant^{-1}$ (6.2), pods $plant^{-1}$ (21.9), $seedspod^{-1}$ (9.2), seed index (5.82 g) and economic yield (1510 kg ha^{-1}) in blackgram under two hand weeding and improved over the control by 160%, 8.7%, 46%, 4.5%, 15.4% and 44.2%, respectively.

In blackgram, hand weeding twice on 25 & 40 DAS attained superior economic yield of 1260 $kgha^{-1}$ during *Kharif* season and the yield was 70.2% & 71.4% higher than unweeded plot was found by Singh (2017). Chhodavadia *et al.*, (2013) [6] revealed that two HW at 20 and 40 DAS significantly improved the crop height (39.3 cm), branches $plant^{-1}$ (6.73), pods plant-1 (15.4), pod length (8.6 cm), $seeds\ pod^{-1}$ (7.1), seed weight $plant^{-1}$ (6.9 g), test weight (35.9 g), economic yield (970 $kgha^{-1}$) and biological yield (1370 kg ha^{-1}) which was augmented by 67.9%, 49.5%, 50.9%, 72.3%, 32%, 40.8%, 23.3%, 49.2%, 29.2% and 65.7%, respectively over unweeded check.

Kumar *et al.* (2015) revealed that yield and yield contributing factors of blackgram were favorably affected in two hand weedings plot. It remarked with seed yield (900 kg ha^{-1}) of 291% higher than the unweeded plot. Effective weed control at initial stages of blackgram crop would lead to superior yield characters and economic yield. The hand weeding twice resulted in better values of pods $plant^{-1}$ (23.45), seeds pod^{-1} (7.60), test weight (51.20 g) and yield (0.86 t ha^{-1}). Which was higher by 50.3%, 54.4%, 66% and 200%, respectively over the unweeded treatment (Mansoori *et al.*, 2015) [26].

Patel *et al.* (2015) [35] observed that HW on 20 and 40 DAS in blackgram produced superior plant height (52.3 cm) at 30 DAS, (88.5 cm) at harvest, nodule biomass $plant^{-1}$ (48.6 mg), branches $plant^{-1}$ (5.05), pods $plant^{-1}$ (43.4) test weight (42.2 g), protein content (23.6%), economic yield (1.73 t ha^{-1}) and biological yield (3.65 t ha^{-1}) which was higher by 34.7%, 12.5%, 36.4%, 70.1%, 11.3%, 10.2%, 100.1% and 201.6%, respectively over unweeded control.

In blackgram, hand weeding twice at 20 and 40 DAS produced higher leaf area index at 30 DAS (3.23), 45 DAS (4.15) and 60 DAS (4.02), crop biomass at 30 DAS (26.8 g m^{-2}), 45 DAS (128.5 g m^{-2}) and 60 DAS (333.6 g m^{-2}), pods per square meter (409.5), seeds per pod (10), test weight (41.20 g) and economic yield (0.97 t ha^{-1}). It maximized the leaf area index (47.4%)at 30 DAS, (55.4%) at 45 DAS, (15.7%) at 60 DAS, crop biomass (34.9% at 30 DAS, 74.8% at 45 DAS and 129.4% at 60 DAS), pods per square meter (96.9%), seeds pod^{-1} (5.2%), test weight (3.3%), economic yield (110.8%) compared to unweeded check (Tamang *et al.*, 2015) [55].

Nirala *et al.*, (2016) [31] revealed that growth & yield characters of blackgram namely plant height (47 cm), leaves $plant^{-1}$ (22), branches $plant^{-1}$ (6.77), plant biomass (10.66 g), nodules $plant^{-1}$ (40.3), nodules biomass $plant^{-1}$ (31 g) and seed yield (0.69 t ha^{-1}) were superior in hand weeding twice. It produced (20.5%), (37.5%), (35.4%), (56%), (21%), (42.8%) and (103.2%) over the unweeded check. Gupta *et al.* (2017) [9] observed that uppermost plant height (74.67 cm), pods per plant (38.30), seeds per pod (6.93), yield (0.92 t ha^{-1}) under hand weeding twice and it augmented the pods per plant (85.9%), seeds per pod (46.5%), yield (147.5%) over unweeded check.

Manual weeding on 20 & 40 DAS in blackgram produced utmost values of pods $plant^{-1}$ (36.3), seeds pod^{-1} (8.13), seed weight pod^{-1} (0.31 g), test weight (38.5 g), economic yield (1.4 t ha^{-1}) which was increased by70.4%, 64.9%, 63.1%, 15.6%, 114.9% over the unweeded check significantly. It was caused by greater weed control and dry matter production during the premature stages of the crop that led to more translocation of food materials to the sink and eventually brought higher yield (Jain *et al.*, 2018) [11]. Singh *et al.* (2018) [50] found that superior values of blackgram viz., plant height (70.5 cm), branches $plant^{-1}$ (6.9), pods $plant^{-1}$ (45.7), nodules $plant^{-1}$ (18.2), nodules biomass $plant^{-1}$ (27.1 g), seeds pod^{-1} (4.8) and test weight (3.01 g) with manual weeding twice and which were 10.5%, 7.8%, 9.2%, 3.4%, 38.9%, 9%, 4.51%higher of unweeded check.

Influence of hand weeding on weed parameters

Chand *et al.* (2004) [5] revealed that greater decrease in total weed count and weed biomass in blackgram under two HW on 20 and 40 DAS and which was significantly superior over remaining herbicidal treatments. Raman *et al.* (2005) [37] reported that in respect of weed count, weed biomass and weed control efficiency, HW twice produced minimal value and curtailed the weed count and biomass by 89.5% and 90.8%, respectively compared to unweeded control. Lower biomass of *C rotundus*, *T monogyna* and other weeds at 60 DAS & harvest was found under HW twice (20 & 40 DAS). It cut down the biomass of *C rotundus*, *T monogyna*, and other weeds by 93.2%, 96.6%, 92.1% at 60 DAS & 90.1%, 100%, 163% at harvest than control was observed by Sharma and Yadava (2006) [45].

Manual weeding at branching and flowering stages of blackgram registered the least count of grass weeds (21.5 no. m^{-2}), broad leaved weeds (408.1), sedge weeds (11.3) and reduction in weed population was by 36.5%, 13% and 33.9%, respectively than the unweeded treatment. The minimal weed biomass (14.9 g m^{-2}) also documented under manual weeding at branching and flowering, which decreased the biomass by 84.2% over the unweeded check (Malliswari *et al.*, 2008) [25].

In blackgram the population of *Cyperusspp*, *Trianthema portulacastrum*, *Eragrostistenella* and other weeds were curtailed by 60.7%, 11.1%, 66.6% and 42.5%, respectively at 25 DAS, 35.7%, 81.8%, 80% and 55%, respectively at 40 DAS, 56.6%, 74.4%, 94.5% and 69.5%, respectively at harvest in hand weeding twice plot over the unweeded plot. It also cut down the weed biomass by 21%, 58.6%, 81.6% at 25, 40 DAS & harvest (Kaur *et al.*, 2009) [14].

Singh (2017) revealed that two HW on 20 & 40 DAS showed lowest weed biomass (290 kg ha^{-1}) and highest weed control efficiency of 92.3% in greengram during *Kharif* season. Chhodavadia *et al.*, (2013) [6] observed that minimal NPK uptake of weeds (16.9 kg ha^{-1}), (0.9 kg ha^{-1}), (9.4 kg ha^{-1}) under manual weeding& inter-culturing at 20 and 40 DAS treatment. It documented least weed count & biomass at 30, 60 DAS and harvest in monocots, dicots, and sedges. A superior weed index (2.6%) and weed control efficiency were also noticed. This outstanding performance of manual weeding& inter-culturing treatment was owing to effective control of sedges which accounts for more than 70% of total weed population.

Minimal weed population at 20 DAS (21.4), 40 DAS (3.0), 60 DAS (2.70), harvest (3.65 no./m^2) was noted in hand weeding. It also documented with minimal weed biomass of broad leaved weeds (2.84 gm^{-2}), narrow leaved weeds (10.89 gm^{-2}) at 60 DAS. It curtailed the weed count by (77.8%) 20 DAS, (96.4%) 40 DAS, (93.7%) 60 DAS, (95.5%) harvest and biomass of broad leaved weeds, narrow leaved weeds by 97.5%, 90.9% over the unweeded check. It also produced the minimal weed index value (Mansoori *et al.*, 2015) [26]. HW twice significantly curtailed the population of monocot weeds by 98.2% (25 DAS) and 96.2% (50 DAS) & dicot weeds by 98.3% (25 DAS) and 97.5% (50 DAS) compared to the unweeded control. It recorded greater weed control efficiency of 97.4% (25 DAS), 96.1% (50 DAS) and 84.3% (harvest) than other weed control measures was revealed by Patel *et al.* (2015) [35].

Tamang *et al.* (2015) [55] found that HW treatment found with minimal broad leaved weed count at 30 DAS (15.8) & 40 DAS (20.9), narrow leaved weed count at 30 DAS (16.3) & 40 DAS (17.3), sedges count at 30 DAS (6.44) & 40 DAS (7.44) and curtailed the population of broad leaved weeds by 48.3%, 48.1% at 30 & 40 DAS, narrow leaved weeds by 75.1%, 74.2% at 30 & 40 DAS, sedges by 71.2%, 71.4% 30 & 40 DAS over the unweeded treatment. Nirala *et al.* (2016) [31] revealed that in blackgram the uppermost WCE (71.4%) was noticed with HW twice (20 & 40 DAS). This was because of minimal weed biomass and weed index as result of curtailed weed growth.

Gupta *et al.* (2017) [9] observed superior values of weed count (60), weed biomass (4.84 g m^{-2}), herbicide efficiency index (29.9) and weed persistence index (0.11) with HW twice which curtailed the weed count and biomass by 93.2% & 94.6%, respectively over the unweeded check. Compared to unweeded plot, it significantly cut down the narrow leaved, broad leaved and sedges weeds population by 93.5%, 96.8%, 86.9%, respectively. Kaur *et al.* (2016) [15] noted that in blackgram HW on 25 & 45 DAS treatment significantly cut down the population of broad leaved weeds, sedges and narrow leaved weeds by 92.4%, 87.8% and 99.3% at 25 DAS, 93.7%, 90.7%, and 93.3% at 45 DAS and 62.5%, 89.7% and 96.7%, respectively at harvest than unweeded control.

HW twice significantly curtailed the population of *C rotundus, E aegyptiacum, C benghalensis* and total weed biomass by 68%, 91.8%, 71.2%, 129% over the unweeded check and documented minimal weed biomass (129 kg ha^{-1}) & weed index (6.2) was found by Singh *et al.* (2018) [50]. Jain *et al.* (2018) [11] revealed that HW twice superseded all the herbicidal treatments and accomplished lowest weed count (13), weed biomass (3 gm^{-2}) and highest weed control efficiency (96.5%). It significantly curtailed the population of *Cyperus rotundus, Echinocloacolona, Cynodondactylon, Commelinabenghalensis, Corchorusolitorius, Phyllanthusniruri and Euphorbiahirta*by 91.8%, 97.2%, 88.8%, 90.9%, 94.7%, 97.3% and 100%, respectively compared to unweeded check.

Impact of hand weeding on economics of pulses

Manual weeding on 20 & 40 DAS in greengram was superior in gross monetary returns (₹16.720 ha^{-1}) and ranked second in net monetary returns (₹9330 ha^{-1}) after the pendimethalin + hand weeding treatment was found by Singh (2017). Chhodavadia *et al.* (2013) [6] noticed that two HW and inter culturing on 20 & 40 DAS performed better with uppermost net returns (₹18,350 ha^{-1}) and benefit: cost ratio (2.41) and was on par with oxyfluorfen + manual weeding at 30 DAS. Besides post emergence spraying of imazethapyr + pendimethalin (premix) 1kg ha^{-1} at 20 DAS treatment, manual weeding twice produced higher net monetary return (₹12,088 ha^{-1}) and B:C ratio (1.82) (Mansoori *et al.*, 2015) [26].

Gupta *et al*. (2017) [9] noticed that compared to PE and POE herbicides treatments in blackgram, manual weeding on 20 and 40 DAS found less profitable with B:C ratio of (1.57) owing to huge labour cost. Jain *et al.*, (2018) [11] reported that uppermost net returns of ₹42,650 ha^{-1} was gained in manual weeding but it received lower benefit: cost ratio (2.90) than herbicidal treatments.

Crop growth and yield of pulses influenced by mechanical weeding

In the middle of mechanical weed control methods, six row CRIJAF nail weeder performed excellently in controlling weeds at initial stages (5-15 DAS) in jute and recorded 4568 kg ha^{-1} economic yield was found by Ghorai *et al.* (2013) [8]. Veeraputhiran (2009) [57] found that compared to HW twice, star type manually operated weeder on 20 and 35 DAS recorded less grain yield in blackgram (408.7 Kg ha^{-1}) and greengram (462.5 kg ha^{-1}). It reduced the pods $plant^{-1}$ (14.1% & 25.5%) and grains pod^{-1} (31.4% & 32.3%), respectively over two HW in blackgram and greengram.

Sai and Tigga (2018) [42] reported that mechanical weeding on 15 and 30 DAS documented uppermost yield attributes and yield as compared to pre emergence herbicide + mechanical weeding on 30 DAS and pre emergence herbicide + sodium acifluorfen (16.5%) + clodinafop propergyl (8%) at 0.245 litre a.i. ha^{-1} at 20DAS in blackgram. it augmented the pods $plant^{-1}$, seeds pod^{-1}, pods weight, seed index, seed yield, haulm yield and biological yield by 48.4%, 12.5%, 64.8%, 5.73%, 64.5%, 17.8% and 31.1%, respectively over the unweeded check.

Weed parameters influenced by mechanical weeding in pulses

Veeraputhiran (2009) [57] noticed that star type manually operated weeder on 20 and 35 DAS documented lower weed control efficiency (41.9% & 44.4%) and utmost weed index (57.3% & 58.3%), respectively as compared to HW twice and mechanical weeding on 20 and 35 DAS in both blackgram and greengram. it is because of higher weed population and dry matter accumulation in manually operated weeder plots.

Integrated weed management practices influenced on growth and yield of pulses

Raman and Krishnamoorthy (2005) [37] observed that integrated application of pendimethalin 1.0 kg ha^{-1} and HW on 20 DAS in blackgram produced utmost values of economic yield (0.92 t ha^{-1}), nodules count (28 No. $plant^{-1}$) and nodule dry weight (3.8g $plant^{-1}$) and it was statistically at par with hand weeding twice because of more air circulation in rhizosphere of crop. It multiplied the nodule count (95.8%), nodule dry weight (97.8%) and economic yield (73.7%) over the weedy plot. In blackgram, spraying pendimethalin (750g ha^{-1}) as PE in integration with HW on 45 DAS produced economic yield of 1.7 t ha^{-1} in 1st year & 1.59 t ha^{-1} in 2nd year. It boosted the yield by 73.3% in 1st year, 117% in 2nd year over unweeded plot (Kumar *et al*., 2006) [24].

In both *Kharif* and summer seasons, hand weeding on 25 & 40 DAS obtained the utmost economic yield of (1176 & 1195 kg ha^{-1}) which was statistically at par with PE spraying of pendimethalin @ 450 gha^{-1} + HW on 25 DAS (1076 & 1175 kg ha^{-1}) in blackgram. Application of PE herbicide in combination with hand weeding heightened the economic yield by 67.3% (summer) and 56.8% (*Kharif*) compared to the weedy plot was observed by Singh (2011) [51]. Nandan *et al.* (2011) [30] revealed that out of treatments tested in blackgram, utmost economic yield (631 kg ha^{-1}) was obtained with treatment pendimethalin (1000 gha^{-1}) on 3 DAS + HW on 30 DAS and which was on par with HW on 20 and 40 DAS which was significantly higher by 117% over unweeded plot.

Maximum economic yield was witnessed with HW at 15 & 25 DAS followed by pendimethalin @ 1.5 litre ha^{-1} on 3 DAS + HW on 25 DAS in blackgram. Integrating PE herbicide and HW enhanced the factors namely pods $plant^{-1}$ (40%), seeds pod^{-1} (14.1%), economic yield (52.9%) & biological yield (3.2%) over the weedy plot (Choudhary *et al.*, 2012) [7]. Bhowmick *et al.* (2015) [4] found superior values of crop growth and yield characters namely branches per plant (13.5), pods per plant (33) and economic yield (1197 kg ha^{-1}) with treatment pendimethalin at a lower dosage (750 g ha^{-1}) on 3 DAS together with HW on 40 DAS. Which was maximized by 9.6%, 18.6%, and 11.8%, respectively over the hand weeding at 20 DAS.

Kumar (2015a) [19] noticed superior values of yield factors namely pods $plant^{-1}$ (34.70), seeds pod^{-1} (6.95), seed index (43.90 g), economic yield (954 kg ha^{-1}) and biological yield (3424 kg ha^{-1}) with integrated weed control measure of pendimethalin 1000 g ha^{-1} on 3DAS and HW on 40 DAS. It augmented the plant height by 13.2% (20 DAS), 23.4 % (40 DAS), 19.7% (60 DAS) and 19.4% (harvest) and branches $plant^{-1}$ by 45.2% (20 DAS), 74.7% (40 DAS), and 69.4%

(harvest) respectively. It also improved the pods plant^{-1}, seeds pod^{-1}, test weight, economic yield and biological yield by 88.5%, 43.2%, 13.5%, 76.3%, 68.7%, and 28.6%., respectively. In greengram the uppermost values of yield contributing factors are noted with pendimethalin 1 kg ha^{-1} as PE + 1 HW at 30 DAS. It bought higher economic yield (11 quintalha^{-1}) and biological yield (18.5 quintal ha^{-1}) which was on par with treatment pendimethalin 1 kg ha^{-1} as PE + imazethapyr 0.75 kg ha^{-1} on 30 DAS. It boosted the grain yield & haulm yield by 139% & 85%, respectively over the unweeded check as observed by (Jinger *et al.*, 2016) [13].

Patel *et al.* (2016) found that out of tested weed control treatments, pendimethalin 0.5 kg ha^{-1}*fb* inter culturing + HW on 30 DAS revealed their progressive impact on growth and yield characters in greengram. It produced utmost values of economic yield (1.51 tonnes ha^{-1}) and biological yield (1.76 tonnes ha^{-1}) which were higher by 49.2% and 89.5%, respectively over unweeded plot. It also produced higher plant height at 30 DAS & harvest by 9.45% & 33.9% than unweeded control plot. Among the distinct IWM treatments, uppermost economic yield was witnessed with pendimethalin (500 g ha^{-1}) on 3 DAS + HW on 30 DAS which was on par with HW on 20 and 30 DAS. It documented a maximal yield of 698 kg ha^{-1}which were higher by 117% over unweeded control plot (Rathi *et al.*, 2004) [41].

Kavad *et al.* (2016) [16] observed that in the middle of distinct IWM treatments, pendimethalin application at 1.0 kg ha^{-1} on 3 DAS + hand weeding on 30 DAS produced superior yield followed by oxyfluorfen application at 180g ha^{-1} + HW on 30 DAS. Application of pendimethalin + HW treatment enhanced the plant height (57.6%), pods plant^{-1} (42.3%), test weight (23.2%), economic yield (121%) and biological yield (113%), respectively over the control. It was because of effective management of weeds during critical stages. In blackgram superior values of factors namely plant height (83.6 cm), branches (12.8 No. plant^{-1}), pods count (15.2 No. plant^{-1}), test weight (42.7 g), yield (1375 kg ha^{-1}) were witnessed with PE pendimethalin 0.9 kg ha^{-1} + HW treatment which were higher by 43.6%, 70.6%, 30.3%, 13.8% and 105.2%, respectively over unweeded check (Tomar and Singh, 2016) [56].

Patel *et al.* (2017) [34] reported that out of tested IWM treatments, pre emergence herbicide application supplemented with HW on 40 DAS produced uppermost economic yield (1130 kg ha^{-1}) and biological yield (1330 kg ha^{-1}) and which was on par with HW twice. It significantly augmented the plant height, branches plant^{-1}, pods plant^{-1}, seed yield and haulm yield by 10.7%, 45.3%, 43.9%, 79.3% and 70.5%, respectively over the weedy plot. Usage of chemical weed control method accompanied with cultural method suppressed the weeds timely, which caused favorable weed free condition during critical crop-weed competition period. In blackgram, Pongen and Nongmaithem (2017) [36] witnessed greater values of plant height (42.45 cm), leaf area index (0.99), crop growth rate (1.88 g/m^2/day), nodules count (79.81 No. plant^{-1}), seeds per pod (5.99), economic yield (1390 kg ha^{-1}) and haulm yield (2640 kg ha^{-1}), respectively with pendimethalin (750g ha^{-1}) on 3 DAS + HW on 25 DAS and was on par with HW twice. It augmented the plant height (43.8%), nodules plant^{-1} (56.5%), pods plant^{-1} (77.8%), seed yield (162%) & haulm yield (30%), respectively over unweeded check. It might be owing to lesser crop-weed competition in these treatments as they control weeds more effectively than other treatments.

Weed attributes influenced by integrated weed management practices on pulses

Rathi *et al.* (2004) [41] noticed that pendimethalin (500 g ha^{-1}) followed by HW on 30 DAS resulted in significant reduction in biomass of *C rotundus* (40.1%), *P hysterophorus* (86.2%), *T monogyna* (93.3%) and *P niruri* (79.3%) as compared to unweeded plot owing to extended weed control in blackgram. The consecutive application of chemical and cultural method has been witnessed as more effective than their sole application in reducing weed biomass. This might be because of earlier weed flush inhibition by pre-emergence herbicide and manual weeding at later stage which controlled subsequent weed flushes.

Raman and Krishnamoorthy (2005) [37] found that all integrated weed control treatments were performed greatly in checking weed growth. PE spraying of pendimethalin @ 1.0 kg ha^{-1} + hand weeding on 20 DAS documented lower weed count (14.2 no. m^{-2}) & biomass (42.1 g m^{-2}) which were significantly curtailed by 70% & 70.5% over the unweeded check. This was because of successful weed control by combined application of herbicide and manual weeding. Kumar *et al.* (2006) [24] noticed that in the middle of various weed control treatments in blackgram, a combination of pendimethalin (750 g ha^{-1}) on 3 DAS and HW on 45 DAS significantly decreased the total weed count & biomass by 62.3% & 92.3% over unweeded treatment. It curtailed the populations of *P dichotomiflorum, E clona, C benghalensis, C iria, P alatum* and *A conyzoides* by 62.4%, 56%, 35.7%, 57.2%, 50.3%, and 65.2%, respectively over the unweeded check.

Pendimethalin 1.0 kg ha^{-1} on 3 DAS followed by HW on 30 DAS in urd bean exhibited desirable performance in managing the weed composites. It curtailed the weed count &biomass by 76.8% and 68.25%, respectively and was on par with imazethapyr 0.25 litre ha^{-1} on 20 DAS as witnessed by Nandan *et al.* (2011) [30]. In both the *Kharif* and summer seasons of blackgram, pendimethalin 450 gha^{-1} followed by HW on 25 DAS showed lowest weed biomass of 345 kg ha^{-1} (summer), 426 kg ha^{-1} (*Kharif*) and highest weed control efficiency of 84.8% (summer), 78.2% (*Kharif*) which were on par with two HW on 20 & 40 DAS was noticed by Singh (2011) [51].

Choudhary *et al.* (2012) [7] suggested that PE herbicide along with hand weeding would be the best weed control measure in blackgram. Spraying pendimethalin (1.5 litreha^{-1}) + HW on 25 DAS reduced the weed population by 59.1% (25 DAS) and 82.7% (50DAS), respectively& biomass by 52.1% (25 DAS), 71.2% (50 DAS), respectively over unweeded plot. It resulted higher weed control efficiency (78%) which was on par with hand weeding twice. Bhowmick *et al.* (2015) [4] concluded that integrated pre emergence herbicide (Pendimethalin 750 gha^{-1}) and HW at 40 DAS was desirable treatment for weed management in blackgram as it reduced the weed population by 27% (30 DAS) and 58.9% (60 DAS), respectively and weed biomass by 41.1% (30 DAS) and 51% (60 DAS), respectively as compared to unweeded control plot.

Pendimethalin 500 g ha^{-1} on 3 DAS *fb* IC + HW at 30 DAS in greengram significantly curtailed weed count by 61.4% (monocot) & 69.4% (dicot) over unweeded plot. It also reduced the weed biomass by 59.7% (monocot) & 54.6% (dicot) over unweeded control plot (Patel *et al.*, 2016). Jinger *et al.* (2016) [13] noticed that spraying pendimethalin (1 kg ha^{-1}) along with hand HW on 30 DAS registered weed control efficiency (75.2%), herbicide efficiency index (4.57%), weed index (8.3%) and weed biomass (35.8 g m^{-2}).

Higher weed control efficiency (81%) and lower weed index (2.1%) and weed biomass (27.3 kg ha^{-1}) were observed with application of pendimethalin 1.0 kg ha^{-1} on 3 DAS *fb* HW at 30 DAS in blackgram was reported by Kavad *et al.* (2016) [16]. Tomar and Singh (2016) [56] found that in blackgram all types of weed flora were effectively managed by pendimethalin 0.9 kg ha^{-1} on 3 DAS followed by HW. It perceived utmost weed control efficiency of 72.7% at 60 DAS and cut down the density of *Echinochloa crusgalli, Cyprus rotundus, Digera arvensis, Commelina benghalensis and Phyllanthus niruri* by 76.6%, 80.3%, 70%, 76.4%, and 79.6%, respectively over the unweeded check.

Patel *et al.* (2017) [34] concluded that PE usage of pendimethalin 900 g ha^{-1} + HW at 40 DAS displayed excellent performance in weed control in *Kharif* blackgram. It curtailed the weed count and biomass by 27.3% (20 DAS) & 4.76% (harvest) over the two hand weeding and showed minimum weed index (9.7%) and highest herbicide efficiency index (81%) among the integrated treatments. The treatment pendimethalin 750g ha^{-1} on 3 DAS *fb* HW on 25 DAS in blackgram effectively cut down the population of grasses, broad-leaved weeds and sedges by 60.3%, 88.8% and 94.6%, respectively over weedy plot was noticed by Pongen and Nongmaithem (2017) [36].

Economics of integrated weed management practices on pulses

Rathi *et al.* (2004) [41] notice that pendimethalin (0.5 kg ha^{-1}) *fb* one manual weeding was a substitute for two HW in terms of monetary value and it fetched maximum net return (₹3611 ha^{-1}) with minimal expenditure (₹2064 ha^{-1}). In blackgram besides two hand weeding PE pendimethalin along with hand weeding on 25 DAS fetched highest gross monetary return of ₹16450 ha^{-1} in summer, (₹10035 ha^{-1}) in *Kharif* and the net monetary return of ₹15064 ha^{-1} in summer, ₹8649 ha^{-1} in *Kharif* as found by Singh, (2011) [51].

Choudhary *et al.* (2012) [7] reported that pendimethalin @ 1.5 litre ha^{-1} on 3 DAS *fb* HW at 25 DAS provided higher net monetary return (₹26,000 ha^{-1}) and net return per rupee investment (2.2) with minimum expenditure (₹11,900 ha^{-1}). It augmented the net return by 66.6% over hand weeding twice. In the middle of various PE and POE herbicides treatments, the economic analysis results revealed that PE application of pendimethalin 0.5 kg ha^{-1} along with inter culturing and HW on 30 DAS documented maximum gross monetary return (₹ 56,470 ha^{-1}), net monetary return (₹34,600) & B:C ratio (1.38) (Patel *et al.*, 2016).

Integrated weed management practices with mechanical & chemical measures would be productive and cost-effective in blackgram. The maximal net monetary return and the BCR were noticed with pendimethalin 0.9 kg ha^{-1} on 3 DAS *fb* HW at 40 DAS (₹21,160 ha^{-1}) & (1.80), quizalofop-ethyl *fb* HW at 40 DAS (₹21,230 ha^{-1}) & (1.80) was found by Patel *et al.* (2017) [34]. Jinger *et al.* (2016) [13] observed that among various herbicide application treatments, pendimethalin 1 kg ha^{-1} on 3 DAS *fb* HW on 30 DAS produced higher gross returns (₹52,200 ha^{-1}), net returns (₹ 41,100 ha^{-1}) & benefit: cost ratio (2.91).

Kavad *et al.* (2016) [16] concluded that in the middle of various integrated weed control measures in blackgram, higher gross monetary return, net monetary return, BCR of ₹ 67,846 ha^{-1}; ₹52,533 ha^{-1}, 4.18 were observed in pendimethalin 1.0 kg ha^{-1} on 3 DAS *fb* hand weeding on 30 DAS.

Herbicide combination of Propaquizafop + imazethapyr influenced on crop growth, yield, weed characters and economics

Application of propaquizafop + imazethapyr @ 56 + 85g ha^{-1} registered superior values of yield attributes, viz. number of pods plant^{-1} (40.67), economic yield (2210 kgha^{-1}), biological yield (4350 kgha^{-1}) in soybean was found by Panda *et al.* (2015) [32]. Bhimwal *et al.* (2018) [3] found that propaquizafop + imazethapyr @ 75+75g ha^{-1} on 21 DAS recorded maximum pods plant^{-1} (43.7), seeds plant^{-1} (3.0g), pod weight plant^{-1}(10.5 g), economic yield (2271 kg ha^{-1}), haulm yield (3127 kg ha^{-1}) and biological yield 5398 kg ha^{-1} than all other herbicidal and mechanical treatments.

Kumar *et al.* (2018) [21] reported that field mix propaquizafop + imazethapyr @ 50+100g ha^{-1} on 20 DAS produced higher plant height (82.2 cm), crop biomass (84.8g m^{-2}), leaf area index at 90 DAS (6.8), crop growth rate at 30-60 DAS (1.01 g ha^{-1} day^{-1}), relative growth rate at 60-90 DAS (0.12g ha^{-1} day^{-1}), branches plant^{-1} (13.3), pods plant^{-1} (42.7), seeds pod^{-1} (5.8), seed yield (2222 kg ha-^{1}) and haulm yield (5820 kg ha^{-1}) than overall POE herbicide treatments in soybean. Among the different doses of propaquizafop + imazethapyr mixtures in blackgram, propaquizafop + imazethapyr @ 56+78 gha^{-1} performed better with higher pods per plant (9.50), economic yield (17.19 quintalha^{-1}), biological yield (43.52 quintalha^{-1}) was found by Suryavanshi *et al*. (2014) [54].

Kumar, (2015b) [23] observed that propaquizafop efficacy improved more when it was applied in mixture with imazethapyr @ 62.5 + 75.0, 50.0 + 50.0 and 75 + 100 gha^{-1} doses. Propaquizafop + imazethapyr @ 75 + 100 gha^{-1}was effective in a wide spectrum of weed control with a maximum weed control efficiency of 96.5% in soybean. POE application of propaquizafop + imazethapyr @ 56 + 85 g ha^{-1} in soybean reduced the population of weeds significantly viz. *Echinochloa colona* (83.5%), *Dinebra retroflexa* (78.1%), *Cyperus rotundus* (67.4%), *Cynodon dactylon* (65.5%), *Alternanthera philoxeroides* (70.7%), *Eclipta alba* (73.3%) and *Mollugo pentaphylla* (70.6 %) and weed dry matter (81.5%) at harvest over weedy check. It registered higher weed control efficiency (81.59%) and lower weed index (6.89) among the herbicidal treatments (Panda *et al.*, 2015) [32].

According to (Bhimwal *et al.*, 2018) [3] propaquizafop + imazethapyr @ 75 + 75 g ha^{-1} at 21 DAS in soybean successfully reduced the monocot and dicot weeds population and biomass significantly compared to alone application of PE and POE herbicides and also registered greater weed control efficiency in narrow leaved (90.35 %), broad leaved (97.75 %) and total weeds (94.40 %). Kumar *et al.* (2018) [21] reported that post-emergence application of field mix propaquizafop + imazethapyr @ 50 + 100 g/ha on 20 DAS in soybean curtailed total weed population and total weed biomass and was statistically at par with two HW on 20 and 40 DAS. Among the herbicide treatments, it ranked first in weed control efficiency with 83.54%. It gave better control of *C. benghalensis, P. alatum, A. conyzoides* and *C. iria* than remaining treatments.

In blackgram, propaquizafop + imazethapyr mixture @ 56+78 g ha^{-1} produced considerable decline in weed population (70.33 m^{-2}) and biomass (131.67g m^{-2}) of weeds and also recorded superior weed control efficiency (53.5%), weed index (1.03), weed control index (69.5), crop resistance index (4.7), herbicide efficiency index (1.41), weed management index (1.08), and weed persistency index (0.65), respectively (Suryavanshi *et al.*, 2014) [54].

In soybean, Kumar, (2015b) [23] observed maximum gross monetary return, net monetary return (₹35,300 ha^{-1}) and BCR (2.41) in treatment with application of propaquizafop + imazethapyr @ 75 + 100g ha^{-1}. (Panda *et al.*, 2015) [32] found that treatment with propaquizafop + imazethapyr @ 56 + 85 g/ha performed more profitable for soybean, as it earned superior economic values namely gross monetary return (₹ 61,140 ha^{-1}), net monetary return (₹40,230 ha^{-1}) and BCR (2.92) over other post emergence herbicides.

Propaquizafop + imazethapyr @ 75+75g ha^{-1} on 21 DAS fetched highest net monetary return (₹51,550 ha^{-1}) and BCR (2.20) in soybean (Bhimwal *et al.*, 2018) [3]. (Kumar *et al.*, 2018) [21] reported that POE application of field mix propaquizafop + imazethapyr @ 50 + 100 g ha^{-1} on 20 DAS in soybean fetched superior values with expenditure (₹29,649 ha^{-1}), gross monetary return (₹87,030 ha^{-1}), gain threshold (26.5), gross return over weedy check (₹46,340 ha^{-1}), cost of weed control (₹3370 ha^{-1}), net return (₹42,971 ha^{-1}) and benefit : cost ratio (12.75) over weedy check.

Acifluorfen sodium + clodinafop propargyl combination influenced on crop growth, yield, weed parameters and economics of pulses

Venkateswarlu (2011) [59] observed that applying clodinofopproparxyl @ 52.50 g ha^{-1} on 20 DAS in blackgram produced significantly higher grain yield (922 kg ha^{-1}) due to increased pods plant^{-1} (33) and seeds pod^{-1} (6.2).Among various doses of clodinafop propargyl + acifluorfen sodium, using clodinafop propargyl + acifluorfen sodium @100.0 + 206.5 g a.iha^{-1} as POE herbicide resulted increased yield in crop. It recorded higher plant height (47.09 cm), branches plant^{-1} (3.60 plant^{-1}), pods plant^{-1} (31.48), seed yield (1.22 t ha^{-1}), biological yield (1.60 t ha^{-1}) and HI (43.3 %). It increased the economic yield by 61.1 % compared to unweeded plot (Meena *et al.*, 2012) [27].

According to Jha *et al.* (2014) [12] clodinafop propargyl+ Na-acifluorfen @ (100 + 206.2)g a.i. ha^{-1} at 20 – 25 DAS in soybean showed better yield due to superior crop growth & yield components like crop biomass (11.64 g plant^{-1}), pods plant^{-1} (58.4), economic yield (1.92 t ha^{-1}), and biological yield (2.5 t ha^{-1}), respectively. Which was at par with imazethapyr 10% @ 100 g a.i. ha^{-1}.In relay crop of blackgram applying post emergence herbicide of acifluorfen + clodinafoppropargyl 400 g ha^{-1} registered with better growth & yield components values namely branches plant^{-1} (9.3), pods plant^{-1} (10.9), seeds pod^{-1} (6.3), economic yield (762 kg ha^{-1}) and biological yield (1520 kg ha^{-1}), respectively. It was comparable with two HW (Aliveni *et al.*, 2016) [1].

From the study of post emergence herbicides in blackgram, Harithavardhini (2016) [10] reported that spraying acifluorfen sodium + clodinafop propargyl @0.3 kg a.i ha^{-1} on 15 DAS showed excellent performance with regard to crop growth and yield characters viz. leaf dry weight (7.12 g plant^{-1}), stem dry weight (7.05 g plant^{-1}), reproductive parts dry weight (5.04 g plant^{-1}), pods per plant (28.9), seeds per pod (4.9), pod weight (4.92 g plant^{-1}), economic yield (10 quintal ha^{-1}) and it was on par with HW twice.

Application of clodinofop propargyl @ 52.5 gha^{-1} in blackgram at 20 DAS found superior in weed control with minimum weed biomass (8 g m^{-2}). It declined the weed biomass by 90% over unweeded plot was observed by Venkateswarlu (2011) [59]. Meena *et al.* (2012) [27] found that in the middle of various herbicide control treatments in soybean, POE application of clodinafop- propargyl + acifluorfen sodium @ (80.0 + 165.0)& (100.0 + 206.25) g a.i ha^{-1} was found effective in weed control. Against monocots weeds, clodinafop propargyl + acifluorfen sodium @ (100 + 206.25) g a.i ha^{-1} performed well with minimal weed count and superior WCE (84.43 %). While in dicot, clodinafop-propargyl + acifluorfen sodium @ (80.0 + 165.0) g a.i ha^{-1} proved to be better herbicide treatment.

Jha *et al.* (2014) [12] noticed that mixed application of clodinafop-propargyl + Na-acifluorfen @ 160 + 330g a.i. ha^{-1} at 20 – 25 DAS in soybean registered lower weed population (43 m^{-2}), weed biomass (23.2 g m^{-2}), weed index (11.4) and higher weed control efficiency (91.7 %). It curtailed the weed population by 85.17% over unweeded control plot and it was at par with two HW Aliveni *et al.* (2016) [1] found that in blackgram, acifluorfen sodium + clodinafop propargyl 400 gha^{-1} at 25 DAS documented lower weed count (20 m^{2}) and biomass (3.3 kg ha^{-1}). The weed count and biomass were 84.2% and 80% lower than weedy check, respectively

Spraying acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha^{-1}as EPOE was successful in weed control method in blackgram with lower weed count (76.3 m^{-2}), weed biomass (25.56 g m^{-2}) at 60 DAS which were 66% & 69.7% lower than unweeded plot, respectively was found by (Harithavardhini, 2016) [10].

Clodinafop-propargyl + Na-acifluorfen @ 100 + 206.2 g.ai ha^{-1}incurred lower cost of cultivation (Rs. 9665 ha^{-1}), higher gross monetary return (₹46,080 ha^{-1}), net monetary return (₹ 36415 ha^{-1}) and B:C ratio (3.7). It increased the net monetary return by 85.75% compared to weedy check plot (Jha *et al.*, 2014) [12]. Aliveni *et al.* (2016) [1] concluded that spraying the POE herbicide acifluorfen + clodinafop propargyl at a higher dose (400 g ha^{-1}) was suitable for profitable weed management in relay crop of blackgram. It showed higher net monetary return (₹53,240 ha^{-1}) and BCR (2.25). Harithavardhini (2016) [10] noticed that using acifluorfen sodium + clodinafop propargyl @ 240g a.i ha^{-1} in blackgram fetched higher B: C ratio (1.59) owing to increased weed control efficiency and decreased cost of treatment.

Conclusion

The pulses are grown in three different situation namely rainfed, irrigated and rice fallow condition particularly blackgram and green gram. The blackgram is more sensitive to weed in almost all growth stages. The yield losses were also observed considerably due to heavy incidence of weed menace especially in the early stage of the crop. In this review papers provided sufficient knowledge on weed diversity in different seasons, influence of different management practices such as hand weeding, mechanical weeding, pre-emergence herbicide and post –emergence herbicide on growth and yield attributes of pulses.

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