Original Research Article

Effect of herbicide (propaquizafop and imazethapyr) on weed flora associated with blackgram (*Vigna munga* L.) in central India

Comment [A1]: It is preferable to remove the scientific name from the title and include it only in keywords

ABSTRACT

Comment [A2]: Include general objective at the beginning, Experimental design used, treatments (quantity and its repetitions), parameters evaluated, analyzes used and the most important results.

An experiment was conducted at Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur to study the effect of application of propaquizafop and imazethapyr herbicide on weeds associated with blackgram. The experimental field was having mixed weed flora comprising of grassy as well as broad leaved weeds. Nine treatments comprised of four rates of application of propaquizafop+ imazethapyr at 47+70, 50+75, 53+80 and 56+85 g/ha and alone application of propaquizafop (100 g/ha), imazethapyr (100 g/ha), pendimethalin (1500 g/ha) and hand weeding twice at 20 and 40 DAS including weedy check, were laid out in Randomized Block Design with three replications. All herbicide treatments were applied in 500 liters of water per hectare, using flat fan nozzle as per the treatments. The dominant weed flora, species wise weed density, weed biomass, Weed control efficiency and weed index were recorded at different interval. The study revealed that the*Echinochloa colona* (29.39%) and *Dinebraretroflexa* (24.30%) were the found as dominant weeds in the field whereas, other monocot weeds like *Cyperus iria* (18.19%) and dicot weeds like *Mullugo* pentaphylla (12.23%), Eclipta *alba* (7.58%)and *Alternanthera philoxeroides* (8.31%) were also present in less numbers in blackgram under weedy check plots.Among the herbicidal treatments, activity of propaquizafop+imazethapyr mixture at the dose 53+80 and 56+85 g/ha emerged as effective control for the weeds associated with blackgram.

Keywords: Blackgram, weed flora, herbicide, propaquizafop, imazethapyr, weed biomass, weed control efficiency, weed index

Comment [A3]: Include scientific name

INTRODUCTION

Comment [A4]: Use citations not older than 10 years.

Include results of other previous studies, in addition the general objective is not observed at the end of the introduction

Blackgram is one of the important *kharif* pulse crops grown throughout the India, next to green gram. It is consumed in the form of 'dal' (whole or split, husked or unhusked). It is chief constituent of 'papad' and also of 'bari' (spiced balls) which make a delicious curry. In the south, the husked dal is ground into a fine paste and allowed to ferment and mixed with equal quantity of rice flour to make 'dosa' and 'idli'. It is also fried to serve as savoury dish. Urd dal is also used in the preparation of 'halwa' and 'imarti' (Singh *et al.*,2010).Besides, it is highly priced and nutritionally rich crop having good source of protein (20-24%), carbohydrates (60%) and fats (1.3%). It is also a good source of calcium, iron and niacin and has medicinal importance too. Being rich in lysine and poor in methionine, it makes a good complimentary protein diet when mixed with cereals.

Blackgram is mainly grown in tropical and sub-tropical climate. It is grown all over the country in *kharif* and summerseasons, while in south India, it is cultivated mainly inrabiseason. Urdbean contributes 13 per cent to the total area and 10 percent to the total production of pulses in India. It occupies 3.1million hectares and contributes nearly 1.9 millon tonnes production with an averge productivity of 642 kg/ha (Shukla and Mishra, 2020). In India, Uttar Pradesh, Maharashtra, Madhya Pradesh, Tamilnadu, Orissa, Chhattisgarh, Karnataka, Gujrat, Jharkhand, West Bengal, Assam,

Uttranchal and Bihar are the major urdbean producing states.In Madhya Pradesh, it occupies an area of 0.64 million hectares, with the production and productivity of 0.26million tonnes and 413 kg/ha, respectively(Shukla and Mishra, 2020).Inspite of the importance of this crop in our diet and in agricultural production system, the productivity of blackgram is very low in India as well as in Madhya Pradesh due to many reasons. Ofthe various reasons, the weed infestation is one of the major limiting factors in production, especially during rainy (*kharif*) season. Grassy as well as broad leaved weeds competes with the blackgram for moisture,nutrients,space, light etc. and reduces the yield to extent of 49 percent (Rao and Rao,2003).Uncontrolled weeds during critical period of crop-weed competition, caused reduction in the yield of blackgram to the tune of 80-90% depending upon the type and intensity of weed infestation (Kumar *et al.*,2001). Weed species infesting urdbean vary according to the agro-ecosystem of the growing region. Therampant weed species which infest blackgram fields are *Trianthema portulacastrum, Echinocloa colona, Cyperus iria, Panicum repens, Eclipta alba, Phyllanthus niruri, Digera arvensis, Celosia argentia* and *Commelina benghalensis*(Randhawa *et al.*,2002 and Raman *et al.,* 2005). Considering the importance of blackgram in central India, present investigation was conducted to study the weed flora associated with blackgram.

MATERIALS AND METHODS

Experimental site and climate

A field experiment was conducted during *kharif* season of the year 2014 at Product Testing Unit, Department of Agronomy, Jawaharlal Nehru Kirshi Vishwa Vidyalaya, Adhartal, Jabalpur (M.P.). The field selected for experimentation was having uniform topography and fairly infested with location specific weeds representing to this area. All physical facilities viz., labours, agrochemicals, equipments and irrigation water etc. were adequately available as and when needed on the research farm.The climate of Jabalpur region is typically Sub humid, featured by hot dry summer and cool dry winter. Jabalpur is situated at 23^0 09' North latitude and 79^0 58' East longitudes with an altitude of 411.78 meters above the mean sea level. It is classified under "Kymore Plateau and Satpura Hills" agro- climatic zone as per norms of National Agriculture Research Project (NARP), New Delhi. Recently, it has been identified as agro-ecological region number 10, named as Central Highlands (Malwa and Bundhelkhand), Sub region number 10.1, named as hot sub-humid eco-region (Malwa Plateau, Vindhyanscarpland and Narmada Valley). The mean annual rainfall of Jabalpur is 1350 mm, mostly received between mid-June to end of September with a little and occasional rains in remaining parts of the year. The mean monthly temperature scale down to the extent of 4^0C during winter, while the maximum temperature reaches as high as 45^0C during the summer. Generally, relative humidity remains very low during summer (15 to 30%), moderate during winter (60 to 75%) and attains higher values (80 to 95%) during rainy season.

Comment [A5]: More procedurally describe the experiment setup process so that readers can replicate the experiment

parameters evaluated?

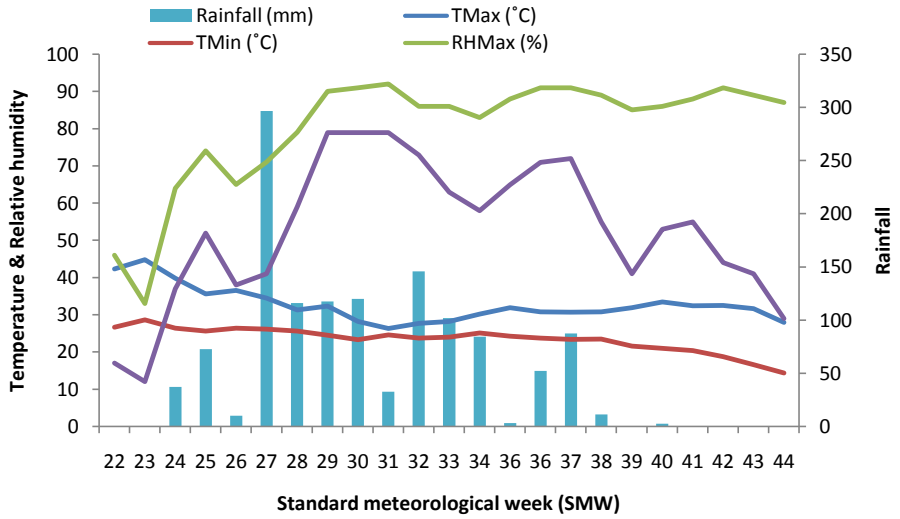

Fig. 1 Meteorological observations during crop growth season

Weather conditions during crop growing season

It is evident from the data that weather conditions were almost favorable for the growth and development of blackgram. The monsoon commenced in the third week of June and terminated in the second week of October. The total rainfall received during the crop season was 1289.9mm against the average annual rainfall of 1350 mm and distributed in 55 rainy days from June to last week of October. Minimum and maximum mean temperature ranged from 23.39 ^{0}C to 32.68 ^{0}C, respectively. The relative humidity ranged from 33 to 92% in morning and 17 to 79 % in evening. The mean sunshine hours ranged between 2.3 to 10.4 hours per day (Fig. 1).

Initial characteristics of experimental soil

The soil of the Jabalpur region is broadly classified as Vertisol as per norms of US classification of soil. It is medium to deep in depth and black in colour. It swells by wetting and shrinks when dries. Thus, it develops wide cracks on the surface during summer season. The soil of the experimental field offers infestation of several weeds depending on the season and crops grown and management practices followed during the course of investigation. The soil of the experimental field was clayey in texture. It was medium in organic carbon (0.65 %), available nitrogen (363 kg/ha) and phosphorus (17.20 kg/ha), but high in available potassium (335 kg/ha). The soil was nearly neutral in reaction (pH 7.1) and soluble salt concentration was also below harmful limit.

The field experiment

In order to get a good tilth for sowing of blackgram in the present experimental field, one summer ploughing followed by one pass of tractor driven cultivator and two pass of disc harrow were made at the onset of monsoon during *kharif*2014 and then the field was finally leveled before seeding of the blackgram crop in the experimental field.Total nine weed control treatments were laid out in Randomized Complete Block Design with three replications. These different treatments were randomized within each replication using random table. The details of the treatments are given in Table 1.Full dose of major plant nutrients (20 kg N + 60 kg P_2O_5 + 20 kg K_2O/ha) was applied as basal application through urea, single super phosphate and muriate of

potash. The whole quantities of all the fertilizers were applied manually at the time of sowing as basal dressing in the rows about 2-3 cm below the seed. Before sowing, the seeds were treated with carbendazim at 1.0 g/kg of seed followed by inoculation with *Rhizobium* culture at 5 g/kg of seed.Sowing of seed was done manually. The furrows were opened with the help of pick axe and later sowing was done for each plot using a seed rate of 20 kg/ha. Seeds were sown manually in each experimental plot keeping a row to row distance of 30 cm at the depth of 3 cm. Then seeds were covered with fine and loose soil to save from birds and sunstroke. There was light rainfall after sowing which helped in proper germination and emergence of crop seeds.

Table 1. Details of the treatments

Treatment	Treatment details
T1	Propaquizafop + imazethapyr (47+70 g/ha)
T2	Propaquizafop + imazethapyr (50+75 g/ha)
T3	Propaquizafop + imazethapyr (53+80 g/ha)
T4	Propaquizafop + imazethapyr (56+85 g/ha)
T5	Propaquizafop (100 g/ha)
T6	Imazethapyr (100 g/ha)
T7	Pendimethalin (1500 g/ha)
T8	Hand weeding (20 and 40 DAS)
T9	Weedy check (Control)

Application of herbicides

The herbicide spray solution was prepared by mixing required quantity of herbicide(s) (propaquizafop and imazethapyr alone or mixture) as per the herbicidal treatments in water @ 500 litre /ha. The spray solution for individual plot was prepared separately as per the treatment. After completing the spraying of one herbicide, in the respective plots in all the three replications, the sprayer was washed thoroughly including flat fan nozzle by detergent and rinsed several times with fresh water, before being used for another treatment. Knapsack sprayer with flat fan nozzle was used for the spraying of herbicidal treatments. Uniform pressure was maintained to pump out nearly equal quantity of the herbicide uniformly as fine droplets during the course of spray in each plot.Propaquizafop and imazethapyr were applied as post-emergence herbicides in blackgram. These were sprayed at 17 days after sowing with 2 ml/litre of MSO adjuvant to facilitate faster absorption of herbicides by the weeds and to avoid washing of herbicides by rains during *kharif* season 2014.Hand weeding was done as per treatment manually with the help of *Khurpi* at 20 and 40 days after sowing so as to keep crop free from weeds during critical period of crop-weed competition.

Florastic composition of weeds

The observations on density of major weeds *viz., Echinochloa colona,Dinebra retroflexa, Cyperus iria, Mullugo pentaphylla, Alternanthera philoxeroides* and *Eclipta alba* were recorded at 30, 45 DAA and harvest by quadrat count method. The quadrat of 0.25 square meter (0.5 m x 0.5 m) was randomly placed at four places in each plot and then the species wise weed count was recorded. The data thus obtained, were transformed and expressed in numbers per square meter. The percentage composition of weed flora was estimated from weedy check plots. Later, the relative density of individual weed was worked out as per formula proposed by Mishra (1968).

Weed dry weight

The weed biomass from different plots under all the treatments were recorded at 30, 45 DAA and at harvest. The associated weeds which were counted for recording weed

density, were removed species wise with in the 0.25 square meter quadrat from four places in each plot. The weeds thus obtained, were first sun dried and thereafter kept in paper bags and dried in oven at 60 ^{0}C for 48 hours and dry weight was recorded till constant weight was achieved. Later, the data were transformed and expressed in gram per square meter.

Weed control efficiency (WCE) and Weed index (WI)

Weed control efficiency measures the efficiency of any weed control treatment in comparison to weedy treatment (Mani *et al.*, 1968). Weed index may be defined as the per cent reduction in the seed yield under a particular treatment due to the presence of weeds in comparison to the seed yield obtained in weed free plot i.e. hand weeding as suggested by Gill and Kumar (1969).

Statistical Analysis

The data obtained on various observations were tabulated and subjected to statistical analysis by using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967) and the treatments were tested by F test. Critical difference (C.D.) at 5% level of significance was determined for each character to compare the differences among treatment means.

RESULTSAND DISCUSSION

Comment [A6]: Update references used. Improve reference format

Improve considering material and methods

Weed flora associated withblackgram

Data on species wise weed density were recorded in weedy check plots at 30, 45 DAA and harvest then mean relative density of weeds has been calculated and presented in Table 2 and Fig 2.It is evident from the data that there was predominance of monocot weeds (71.88 %) in weedy check plots in blackgram crop. Among the monocot weeds, *Echinochloa colona, Dinebra retroflexa andCyperus iria* were rampant as they contributed 29.39, 24.30 and 18.19 per cent of the relative density of weeds respectively. However,dicot weeds like *Mullugo pentaphylla*, *Eclipta alba* and *Alternanthera philoxeroides* also marked their presence in less numbers (12.23, 7.58 and 8.31 per cent respectively) in blackgram. Species wise weed data recorded in weedy check plots at 30 DAA of blackgram, indicated that there was pre-dominance of monocot weeds (71.88%) as compared to dicots weeds (28.12%) in the experimental field cropped with blackgram.Almost similar weed flora associated with blackgram was reported by Vyas and Jain (2003), Halvankar *et al.* (2005), Girothia *et al.* (2006), Singh and Raj Kumar (2008).

Table 2. Weed flora of blackgram during *kharif* season in weedy check plots at30, 45 DAA and harvest

Weed flora	Weed Density /m^2			Mean	Mean relative density (%)
	30 DAA	45 DAA	At harvest		
Monocot					
Echinochloa colona	74.33	63.00	63.00	66.78	29.39
Dinebra retroflexa	60.33	53.67	51.67	55.22	24.30
Cyperus iria	46.33	40.00	37.67	41.33	18.19
Sub total					71.88
Dicot					
Mullugo pentaphylla	32.00	28.33	23.00	27.78	12.23
Eclipta alba	19.67	18.33	13.67	17.22	07.58
Alternanthera philoxaroides	21.33	17.67	17.67	18.89	08.31
Sub total					28.12
Total	253.96	221.00	206.68	227.22	100.00

DAA- Days after application

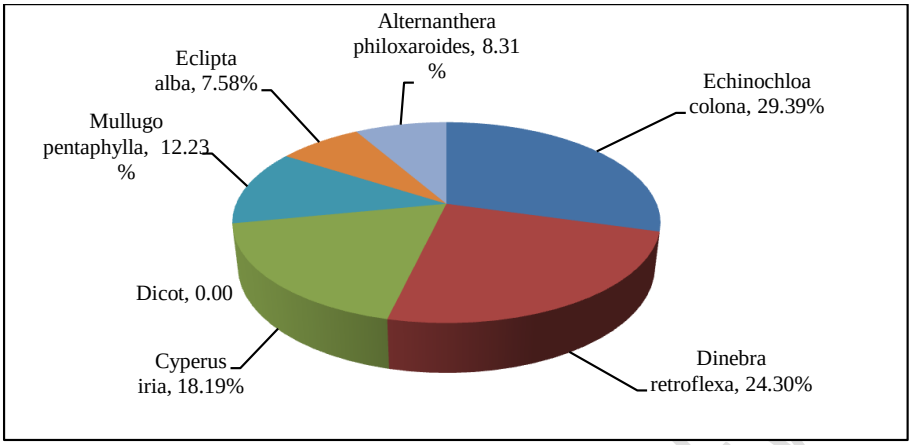

Fig.2. Relative density of different weed flora of the experimental field in weedy check plots

Effect on weed density

The data recorded on density of associated weeds in blackgram viz., *Echinochloa colona*, *Dinebra retroflexa*, *Cyperus iria*, *Mullugo pentaphylla*, *Ecliptaalba* and *Alternanthera philoxeroides* as influenced by various weed control treatments at 30days after application (DAA) are presented in Table 3.The comparison among different treatment means, however, have been made on transformed values in case of weed parameters only.

Echinochloa colona

Data on density of *Echinochloa colona* was significantly influenced by different weed control treatments at 30 DAA (Table 3). It is evident from the data that weed control treatments caused significant reduction in the density of *Echinochloa colona*. The density was maximum (8.64/m^2) under weedy check plots where no weed control measures were adopted. Post emergence application of propaquizafop + imazethapyr mixture at the lower doses (47+70 and 50+75 g/ha) caused appreciable but similar reduction in the density of *Echinochloa colona* to that of imazethapyr (100 g/ha), propaquizafop (100 g/ha) applied alone and proved better as compared to alone application of pendimethalin (1500 g/ha)and weedy check plots. But, efficacy of mixture was further increased with corresponding increase in rates of application from 53+80 g/ha to 56+85 g/ha and proved superior over other herbicidal treatments. However, hand weeding twice, excelled to all the herbicidal treatments as it curbed the density of *Echinochloa colona* to greater extent (2.20/m^2).

Dinebra retroflexa

The density of *Dinebra retroflexa* was significantly influenced by different weed control treatments at 30 DAA. The data presented in Table 3.showed that weed control treatments caused significant reduction in the density of *Dinebra retroflexa* at30 DAA. The density was maximum (7.80/m^2) under weedy check plots where control measures not adopted in blackgram. But, there was identical reduction in the density of *Dinebra retroflexa*was occurred when mechanical and herbicidal weed control measures were adopted. Application of propaquizafop + imazethapyr mixture at the lower doses (47+70and 50+75 g/ha) as post emergence caused reduction in density of *Dinebra retroflexa*over alone application of propaquizafop (100 g/ha),

pendimethalin (1500 g/ha) and weedy check. However, the activity of mixture was further improved with increase in application rates being higher when mixture was applied at 53+80 g/ha or higher rate (56+85 g/ha) and proved statistically superior over imazethapyr 100 g/ha and lower rates of propaquizafop + imazethapyr mixture (47+70 and 50+75 g/ha), pendimethalin 1500 g/haand propaquizafop 100 g/ha applied alone in blackgram. However, hand weeding excelled in curbing the density of *Dinebra retroflexa* to the maximum extent (93.37%) at 30 days of weeding.

Cyperus iria

It is evident from the data presented in Table 3 that weed control treatments caused significant reduction in the density of *Cyperus iria* at 30 days after application. The density of *Cyperus iria* was maximum (6.33/m^2) under weedy check plots where weed control was not done at all.Post emergence application of propaquizafop + imazethapyr mixture at the lower doses (47+70 and 50+75 g/ha) caused identical but similar reduction in the density of *Cyperus iria* to that of imazethapyr (100 g/ha), propaquizafop (100 g/ha) and pendimethalin (1500 g/ha) applied alone and proved better as compared to weedy check plots. But, efficacy of mixture was further improved with corresponding increase in rates of application from 53+80 g/ha to 56+85 g/ha and proved superior over other herbicidal treatments. However, hand weeding twice, excelled to all the herbicidal treatments as it curbed the density of *Cyperus iria* to maximum extent (2.12/m^2).

Table 3. Influence of weed control treatments on the density of weeds(g/m^2) at 30DAA in blackgram

Treatment	Weed flora					
	W1	W2	W3	W4	W5	W6
T1	6.82 (46.00)	6.28 (39.00)	4.30 (18.00)	4.64 (21.00)	3.94 (15.00)	3.89 (14.67)
T2	6.49 (41.67)	6.23 (38.33)	4.26 (17.67)	4.45 (19.33)	3.58 (12.33)	3.23 (10.00)
T3	6.33 (39.67)	5.61 (31.00)	4.10 (16.33)	3.94 (15.00)	3.29 (10.33)	3.13 (9.33)
T4	5.99 (35.33)	5.43 (29.00)	3.53 (12.00)	3.67 (13.00)	2.97 (8.33)	2.96 (8.33)
T5	6.59 (43.00)	6.60 (43.00)	4.38 (18.67)	4.71 (21.67)	3.94 (15.00)	3.94 (15.00)
T6	6.47 (41.33)	5.82 (33.33)	4.18 (17.00)	4.38 (18.67)	3.18 (9.67)	3.03 (8.67)
T7	7.22 (51.67)	6.57 (42.67)	4.38 (18.67)	4.49 (19.67)	4.02 (15.67)	3.98 (15.33)
T8	2.20 (4.33)	2.12 (4.00)	2.34 (5.00)	1.46 (1.67)	2.19 (4.33)	1.86 (3.00)
T9	8.64 (74.33)	7.80 (60.33)	6.33 (46.84)	5.70 (32.00)	4.49 (19.67)	4.67 (21.33)
SEm±	0.13	0.05	0.11	0.09	0.09	0.11
CD at 5%	0.39	0.16	0.32	0.28	0.28	0.33

T1-Propaquizafop+Imazethapyr(47+70 g/ha); T2- Propaquizafop+Imazethapyr (50+75 g/ha); T3- Propaquizafop+Imazethapyr (53+80 g/ha); T4- Propaquizafop+Imazethapyr (56+85 g/ha); T5 - Propaquizafop (100g/ha); T6- Imazethapyr (100 g/ha); T7 - Pendimethalin(1500 g/ha); T8 - Hand weeding (20 & 40 DAS); T9 - Weedy check;W1- Echinochloa colona; W2- Dinebra Retroflexa; W3- Cyperus iria; W4- MullugoPentaphylla; W5- Eclipta Alba; W6- Alternanthera

philoxeroides; Figure in parentheses are original values, DAA- Days after application

Mullugo pentaphylla

It is obvious from the data presented in Table 3 showed that weed control treatments caused significant reduction in the density of *Mullugo pentaphylla*. The density of *Mullugo pentaphylla* was maximum (5.70/m^2) under weedy check plots at 30 DAA. Post emergence application of propaquizafop + imazethapyr mixture at the lower doses (47+70 and 50+75 g/ha) caused appreciable but similar reduction in the density of *Mullugo pentaphylla* to that of imazethapyr (100 g/ha)and pendimethalin (1500 g/ha) and proved significantly superior to propaquizafop (100 g/ha) and weedy check plots. But, efficacy of mixture was further enhanced with corresponding increase in application rates being higher at 53+80 g/ha and proved statistically superior over all other herbicidal treatments but found at par to propaquizafop + imazethapyr mixture applied at 56+85 g/ha. However, none of the herbicidal treatments surpass the hand weeding twice (at 20 and 40 DAS) which reduced the density of *Mullugo pentaphylla* to the maximum extent (1.46/m^2).

Eclipta alba

Data on density of *Eclipta alba* at 30 DAA under different weed control treatments are presented in Table 3. It is evident from the data that weed control treatments caused appreciable reduction in the density of *Eclipta alba* at 30 DAA. The density of this weed was maximum (4.49/m^2) under weedy check plots at 30 DAA. The activity of propaquizafop and imazethapyr mixture at lower rate (47+70 g/ha) and alone application of propaquizafop (100 g/ha) and pendimethalin (1500 g/ha) was poor against *Eclipta alba*but it was improved when applied in combination with imazethapyr at 53+80 g/ha or higher rate 56+85 g/ha and found at par to imazethapyr (100 g/ha) in controlling this weed and surpassed to propaquizafop + imazethapyr mixture applied at 47+70 and 50+75 g/ha and alone application of propaquizafop (100 g/ha) and pendimethalin 1500 g/ha.However, none of the herbicidal treatment exceeded to hand weeding in which caused maximum reduction (2.19/m^2) in the density of *Eclipta alba*and proved superior to all the herbicidal treatments applied in mixtures and alone as a post emergence and pre emergence in blackgram.

Alternanthera philoxeroides

Data on density of this weed at 30 DAA under different weed control treatments are presented in Table 3. It is obvious from the data that weed control treatments caused marked reduction on the density of*Alternanthera philoxeroides*. The density of this weed was maximum (4.67/m^2) under weedy check plots at 30 DAA. The activity of propaquizafop and imazethapyr mixture at lower rate (47+70 g/ha) was appreciable but similar to alone application of propaquizafop (100 g/ha) and pendimethalin (1500 g/ha) which were found superior over weedy check.But it was enhanced, when it was applied in combination with imazethapyr at higher rates, being higher at 56+85 g/ha and proved statistically superior over propaquizafop + imazethapyr mixture 47+70 g/ha, propaquizafop (100 g/ha) and pendimethalin 1500 g/ha, but at par topropaquizafop and imazethapyr combination at the rate (50+75 and 53+80 g/ha) andimazethapyr (100 g/ha) applied alone. However, all the herbicidal treatments proved inferior to hand weeding in eliminating the density of *Alternanthra philoxeroides*.

The application of propaquizafop + imazethapyr mixture at lowest dose (47+70) g/ha as post emergence, caused appreciable reduction in density and dry weight of broad and grassy weeds as compared to weedy check plots, but reduction was more

pronounced when propaquizafop + imazethapyr mixture was applied from 53+80 g/ha or higher rate (56+85 g/ha). The presence of propaquizafop+ imazethapyr mixture in non lethal concentration at the site of action could be the reason for poor activity of propaquizafop + imazethapyr mixture when applied at the lowest dose (47+70 g/ha) but the reverse was true when mixture was applied at higher rates. On the other hand, check herbicides propaquizafop at 100 g/ha as post emergence caused more reduction in the density and dry weight of grassy weeds as it is a grass killer and similarly imazethapyr at 100 g/ha as post emergence caused more reduction in the density of both grassy and broad leaved weeds as compared to weedy check plots. Similar views were also endorsed by Das (2011).Hand weeding twice at 20 and 40 DAS reduced the density including dry weight of weeds to the maximum extent over herbicidal treatments due to elimination of all sort of weeds during the course of hand weeding. Singh and Jolly (2004) also made similar observation and reported minimal density and dry weight of weeds under hand weeding treatment due to elimination of all sorts of weeds during the course of weeding.

Weed dry weight

Dry matter accumulation by weeds per unit area is an indication of weed growth under particular weed control treatment.The observation on dry weight of weeds were recorded at 30, 45 DAS and harvest.Weeds were separated out specieswise and their dry weight was recorded treatment wise after sun drying and then in oven at 60 0c for 48 hours till constant weight was achieved. Data thus obtained species wise for 30 DAA are given in Table 4.

Echinochloa colona

The dry weight of *Echinochloa colona* differed significantly at 30 DAA due to weed control treatments and data are presented in Table 4. The dry weight of *Echinochloa colona* was maximum (15.00 g/m^2) under weedy check plots where weeds were not controlled at all. Whereas, its dry weight was reduced identically when weed control measures were adopted in different plots. Post emergence application of propaquizafop + imazethapyr mixture at the lowest dose (47+70 g/ha) caused (59.72%) reduction in the dry weight of this weed over weedy check and the activity of mixture was further increased with corresponding increase in application rates from 50+75 to 53+80 g/ha, being higher under 56+85 g/ha and latter mixture proved significantly superior to other mixtures and alone application of propaquizafop (100 g/ha), imazethapyr (100g/ha) and pendimethalin (1500 g/ha). But, found inferior to hand weeding which curbed the dry weight of *Echinochloa colona* to the extent of 92.66 per cent and excelled to all the herbicidal treatments.

Dinebra retroflexa

The data on dry weight of this weed as influenced by different weed control treatments at 30 DAA have been presented in Table 4. The data showed that the weed control treatments caused significant influence on the dry weight of *Dinebra retroflexa* at 30 DAA. The dry weight of this weed was maximum (12.41 g/m^2) under weedy check plots due to unintrupted growth of this weed during critical period of crop-weed competition. The activity of propaquizafop + imazethapyr mixture at lowest dose (47+70 g/ha) was proved better in curbing the dry matter production of this weed over propaquizafop (100 g/ha) and pendimethalin (1500 g/ha). But efficacy was increased remarkably with the increase in application rates being the higher when propaquizafop+ imazethapyr mixture was applied at 53+80 g/ha or higher rate (56+85 g/ha) and latter treatment proved superior over other mixtures and alone application of imazethapyr (100 g/ha), propaquizafop (100 g/haand pendimethalin (1500 g/ha).

However, hand weeding curbed the dry weight to the maximum extent and proved significantly superior to herbicidal treatments.

Cyperus iria

Data on dry weight of this weed at 30 DAA under different weed control treatments are presented in Table 4. It is obvious from the data averaged over replications that all the treatments had significantly lowered the density of *Cyperus iria* at 30 DAA over weedy check plots. Application of propaquizafop + imazethapyr mixture at the lowest rates (47+70 g/ha) caused 40.56% reduction in the dry weight of *Cyprus iria* over weedy check plot. But reduction was further inhanced with the increase in application rates being higher in plots receiving combined application of propaquizafop and imazethapyr from 50+75 to 56+85 g/ha. However, the hand weeding twice caused maximum reduction in the dry weight of *Cyperus iria* ascompared to herbicidal treatments including weedy check plots.

Mullugo pentaphylla

Data on dry weight of *Mullugo pentaphylla* at 30 DAA under different weed control treatments are presented in Table 4. It is evident from the data that weed control treatments caused marked reduction in the dry weight of *Mullugo pentaphylla* as compared to weedy check plots. The dry weight of *Mullugo pentaphylla* was maximum (6.86 g/m^2) under weedy check plots at 30 DAA. But, it was reduced with the post emergence application of propaquizafop + imazethapyr mixture at the lowest rate (47+70 g/ha) which caused 76.32 per cent reduction in the dry weight of *Mullugo pentaphylla* over weedy check plots. The reduction in dry weight was further increased with the increase in the application rates from 47+70 g/ha being higher (87.75 %) under plots receiving propaquizafop + imazethapyr mixture (53+80 g/ha) and proved significantly superior to plots receiving their mixture at lower rates (47+70 and 50+75 g/ha) and alone application of propaquizafop (100 g/ha), imazethapyr (100 g/ha) and pendimethalin (1500 g/ha) but found at par with propaquizafop + imazethapyr mixture at 56+85 g/ha . However, hand weeding twice curbed the dry weight production of *Mullugo pentaphylla* to the maximum extent (98.13%) and excelled to all the herbicidal treatments.

Eclipta alba

The data on dry weight of *Eclipta alba* at 30 DAA due to weed control treatments have been presented in Table 4. It is obvious from the data that weed control treatments had significantly lowered the dry weight of *Eclipta alba* as compared to weedy check plots at 30 DAA. The dry weight of *Eclipta alba* was maximum (7.32 g/m^2) under weedy check plots when weeds control measures were not adopted in blackgram. The activity of propaquizafop (100 g/ha) was poor against *Ecllpta alba*andsimilar to pendimethalin (1500 g/ha) when it was applied alone but increased when it was applied in combination with imazethapyr being higher under 53+80 g/ha and proved better than their mixtures applied at lower rates, imazethapyr 100 g/ha and pendimethalin 1500 g/ha but found at par with mixture applied at 56+85 g/ha. However, hand-weeding twice excelled to all the herbicidal treatments which reduced the dry weight of *Eclipta alba* to the maximum extent (1.21 g m^2).

Alternanthera philoxeroides

The data recorded on the dry weight of *Alternanthera philoxeroides* at 30 DAA under different weed control treatments are given in Table 4. It is evident from the data that weed control treatments caused marked reduction in the dry weight of *Alternanthera philoxeroides* as compared to weedy check plots. The dry weight of *Alternanthera philoxeroides* was maximum (7.15 g/m^2) under weedy check plots. The activity of propaquizafop (100 g/ha) was poor against *Alternanthera philoxeroides* when

propaquizafop was applied alone but it was increased appreciably when applied in combination with imazethapyr at different rates being higher under higher rate (56+85 g/ha) followed by 53+80 g/ha and both proved at par but significantly superior over rest of the herbicidal treatments. However, hand weeding stood first among all the weed control treatments in reducing the dry weight of *Alternanthera philoxeroides.*

Weed biomass

The weed biomass was influenced significantly due to weed control treatments at 30 DAA. Post emergence application of propaquizafop + imazethapyr mixture at thelowest rate (47+70 g/ha) curbed the weed biomass production only to the tune of 65.90 per cent. But, the reduction in weed biomass was well marked when applied at 53+80 g/ha or higher rate 56+85 g/ha (80.13 to 83.14%, respectively) and both the treatments proved at par but significantly superior over rest of the herbicidal treatments. However, none of the herbicidal treatments proved superior over hand weeding twice which caused nearly 99.04 per cent reduction in weed biomass (Table 4).

Table 4. Influence of weed control treatments on the dry weight of weeds, weed biomass and weed control efficiency at 30 DAA in blackgram

Treatment	Dry weight of weed (g/m^2)						Weed Biomass (g/m^2)	WCE (%)	Weed index
	W1	*W2*	*W3*	*W4*	*W5*	*W6*			
T1	9.54 (90.45)	6.87 (46.76)	6.55 (42.37)	3.39 (11.02)	3.81 (14.02)	4.16 (16.82)	14.90 (221.44)	65.90	24.54
T2	9.26 (85.25)	6.10 (36.71)	6.26 (38.70)	3.37 (10.84)	3.27 (10.22)	3.76 (13.69)	13.21 (175.41)	72.99	16.56
T3	7.05 (49.31)	4.94 (23.92)	5.89 (34.22)	2.49 (5.70)	2.64 (6.480)	3.15 (9.45)	11.38 (129.07)	80.13	6.75
T4	6.45 (41.15)	4.46 (19.42)	5.37 (28.38)	2.42 (5.35)	2.53 (5.90)	3.13 (9.30)	10.49 (109.51)	83.14	3.68
T5	9.62 (92.06)	7.20 (51.42)	6.86 (46.60)	3.78 (13.84)	4.24 (17.45)	4.31 (18.07)	15.49 (239.44)	63.13	31.29
T6	9.07 (81.84)	6.00 (35.48)	6.22 (38.16)	3.35 (10.75)	2.92 (8.07)	3.48 (11.63)	13.65 (185.71)	71.40	24.54
T7	10.09 (101.44)	7.25 (52.11)	6.93 (47.59)	3.85 (14.34)	4.29 (17.88)	4.32 (18.15)	15.87 (251.38)	61.29	34.36
T8	1.10 (1.47)	1.15 (0.82)	1.45 (1.62)	1.17 (0.87)	1.21 (0.97)	0.97 (0.45)	2.59 (6.20)	99.04	0.00
T9	15.00 (224.53)	12.41 (153.59)	11.02 (120.98)	6.86 (46.54)	7.32 (53.14)	7.15 (50.65)	25.49 (649.44)	0.00	60.74
SE.m±	**0.16**	**0.08**	**0.11**	**0.07**	**0.06**	**0.07**	**0.30**	-	-
CD at 5%	**0.50**	**0.26**	**0.33**	**0.23**	**0.20**	**0.22**	**0.90**	-	-

T1-Propaquizafop+Imazethapyr(47+70 g/ha); T2- Propaquizafop+Imazethapyr (50+75 g/ha); T3- Propaquizafop+Imazethapyr (53+80 g/ha); T4- Propaquizafop+Imazethapyr (56+85 g/ha); T5 - Propaquizafop (100g/ha); T6- Imazethapyr (100 g/ha); T7 - Pendimethalin(1500 g/ha); T8 - Hand weeding (20 & 40 DAS); T9 - Weedy check W1- Echinochloa colona; W2- Dinebra Retroflexa; W3- Cyperus iria; W4- MullugoPentaphylla; W5- Eclipta Alba; W6- Alternanthera philoxeroides; Figure in parentheses are original values, DAA- Days after application

Weed control efficiency

Weed control efficiency (WCE) was calculated on the basis of weed biomass obtained under weedy check plots and other treatments at 30 DAA and the data so obtained have been presented in Table 4. Among weed control treatments, the higher weed control efficiency (80.13 to 83.14%) was noted in plots receiving combined application of propaquizafop+ imazethapyr at 53+80 g/ha or higher rate(56+85 g/ha)at 30DAA as compared to alone application of imazethapyr 100 g/ha (71.40%), propaquizafop 100 g/ha (63.13%), and pendimethalin 1500 g/ha (61.29%). However, all the herbicidal treatments could not surpass the hand weeding which curtailed the weed biomass production to the extent of 99.04%and excelled to herbicidal treatments.The maximum weed control efficiency (99.04 %) was recorded under hand weeding due to complete check on weeds, confirming the view of Sumathi *et al.* (2000), Mane *et al.*(2003), Kamble *et al.* (2003) and Wesley *et al.* (2008). The poor weed control efficiency (61.29 % and 63.13%) was noticed in case of alone application of pendimethalin (1500 g/ha) and propaquizafop (100 g/ha), respectively, due to poor activity against broad leaved weeds. Das (2011) also reported poor efficacy of propaquizafop against dicot weeds. Further, the results of Mansoori *et al.* (2015) are in accordance with present findings with respect to the weed control efficiency.

Weed index

The data pertaining to weed index indicated that maximum reduction in yield (60.74 %) was noticed in weedy check plots due to presence of weeds throughout the crop season (Table 4). Combined application of propaquizafop and imazethapyr at53+80 g/ha or higher rate 56+85 g/ha checked reduction in yield to the tune of 6.75 to 3.68 % due to weeds and proved superior over propaquizafop + imazethapyr mixture at lower rates (47+70 and 50+75 g/ha) and alone application of imazethapyr (100 g/ha), propaquizafop (100 g/ha) and pendimethalin (1500 g/ha). This is because of minimal weed stress due to effective control of weed menace under former treatments during critical period of crop growth and consequently recorded less reduction in seed yield due to presence of weeds, whereas, reverse was true for latter herbicidal treatments (Table 4). Similar observations were reported by Veeraputhiran (2009), Adhikary and Ghosh (2014) and Shashidhar *et al.* (2020).

CONCLUSION

The study revealed that the *Echinochloa colona* (29.39%) and *Dinebra retroflexa* (24.30%) were predominant weeds in blackgram. However, other monocots like*Cyperus iria* (18.19%) and dicots like *Mullugo pentaphylla* (12.23%), *Eclipta alba* (7.58%)and *Alternanthera philoxeroides* (8.31%) were also associated with blackgram in less numbers. Further, the post emergence application of propaquizafop+imazethapyr mixture from 53+80 was foundsuitable for effective control ofcomposite weed flora associated withblackgram in central India.

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