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Research Paper

The impact of leftover herbicide residue applied to okra on weeds and crops of subsequent blackgram

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ABSTRACT

In the present study, the impact of residual herbicide was studied from previous applications on okra plants, explicitly concerning the growth of weeds and subsequent black gram crops. The relative density of different weed species was determined, revealing that *Echinochloa colonum* had the highest density at 16.56% and 12.88%, followed by *Leptochloa chinensis* at 13.01% and *Acrachne racemosa* at 10.82%. However, within the group of sedges, *Cyperus rotundus* and *Cyperus haspan* had a greater relative density of 13.01% and 9.79%, respectively. The weed-free control treatment achieved the highest seed output of black gram, followed by two manual weeding on the 20th and 40th DAS. The herbicide residue resulted from application of metribuzin 500 g ha^{-1} on 3rd DAS, followed by post-emergence (POE) application of quizalofop-ethyl 50g ha^{-1} on 20 DAS recorded higher plant height 5.7%, dry matter production 32.7%, clusters plants^{-1} 33.3%, pods plant^{-1} 79.6%, grain yield 41.0%, halum yield 44.7%, nitrogen uptake 54.3%, phosphorus uptake 117.5%, and potash uptake 81.8% as compared to the weedy check.

Key words: Nutrient uptake, Pendimethalin, Productivity, Quizalofop-ethyl, Weed density

INTRODUCTION

Blackgram (*Vigna mungo* L. Hepper) is one of the most significant pulse commodities in India. It contains 25-26% protein, 60% carbs, 1.5% fat, vital amino acids, minerals, and other components considered helpful for human health. Incorporating pulses into the cropping system enhances soil fertility by adding nutrients and improving the soil's physical, chemical, and biological characteristics (Namrata 2017). The escalating population pressure has necessitated the improvement of pulse productivity within the constraints of limited resources. There are numerous factors contributing to the decrease in black gram productivity. The weed problem is significant due to inadequate soil preparation, weeds from previous crops, and delayed initial crop growth. These factors contribute to a yield loss ranging from 31 to 90%, depending on the severity and the type of weeds present (Rao 2011). In contemporary times, the escalating labor scarcity for agricultural pursuits has compelled farmers to resort to chemical methods for weed management. It is highly efficient in reducing weed infestations for an extended period, leading to a decrease in the soil weed seed bank. Certain herbicides sprayed into the soil can stay there for an extended duration, potentially leading to phytotoxic effects on subsequent crops. The AICRPWC (1998) observed the lasting impact of pendimethalin, alachlor, metolachlor, and imazethapyr, administered to groundnuts, on subsequent green gram and finger millet. According to Kulshrestha *et al*. (2000), there was a progressive decrease in herbicide residues over the year. By the end of the fifth year, the percentage of applied pendimethalin recovered from the soil was less than three, compared to 18% in the initial year of application. Therefore, farmers exercise greater caution when choosing herbicides because certain herbicides have prolonged soil persistence, impacting succeeding crops within the cropping system. The study investigated the impact of residual herbicides applied on okra on weeds and subsequent black gram crops.

MATERIALS AND METHODS

The field experiment was conducted during the summer season of 2017 and 2018 at Agricultural College and Research Institute, Madurai, and Central Island Agricultural Research Institute, Port Blair, respectively, to study the effect of leftover herbicide residue applied to okra on weeds and crops of succeeding black gram. The experimental sites are situated at 9°54′ and 11°38′ N latitude and 78°54′ and 92°39′ East longitude and altitude 15 and 147 m above MSL, respectively. At Madurai and Port Blair, the experimental field soil was sandy clay loam and clay loam in texture with 6.9 and 7.3 pH and EC 0.30 and 0.34 dS/m, respectively. Both the locations had medium soil organic carbon content and low, medium, and high content of available nitrogen, phosphorus, and potassium, respectively. The experiments were carried out in a Randomized Complete Block Design with three replications. The experiment consists of eight treatments *viz.,* T_1-metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 days after sowing (DAS), T_2-metribuzin at 500 g ha^{-1} on 3 DAS *fb* Hand Weeding (HW) on 40 DAS, T_3-metribuzin at 500 g/ha on 3 DAS *fb* twin wheel hoe weeder at 40 DAS, T_4- alachlor at 1.0 kg ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, T_5-pendimethalin at 1.0 kg ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, T_6- hand weeding twice on 20 and 40 DAS, T_7-weed free check, T_8-weedy check. The succeeding crop of black gram was sown without disturbing the layout of the preceding okra experimental field, and no treatment was imposed in treatments T_1 to T_5. However, T_6 to T_8 weed management treatments for black gram have been imposed. After removal of crop residues of okra, non-selective post-emergence herbicide glyphosate @ 1.0 kg ha^{-1} was applied. After seven days, in this same experimental field, black gram variety VBN (Bg)-8 was sown at the recommended spacing of 30 cm x 10 cm and a recommended dose of 25-50-25 kg NPK ha^{-1} was as basal. As there was no pest or disease infestation, no spraying was done. All other recommended packages were adopted as per schedule. Growth analysis *viz.,* Crop Growth Rate (CGR) and Relative Growth Rate (RGR) during the period from 25 to 50 days after sowing (DAS) were computed by using the standard procedure suggested by Watson (1958) and Williams (1946) and expressed in g m^{-2} day^{-1} and g g^{-1} day^{-1} respectively. Throughout the cropping season, species-wise weeds were observed in the weedy check plots. At 20 and 60 DAS, weed count was done in four representative sampling (0.25 m^2) areas of each plot and expressed weed density in Nos. m^{-2}. The same weeds were removed and dried in the oven until no change in moisture content was observed and expressed in g m^{-2}. The relative density (RD) of individual predominant weed species and group-wise weeds was calculated by the method suggested by (Kim and Moody 1983).

$$\mathrm{RD}\,(\%) = \frac{\text{No. of weeds of individual species}}{\text{Total no. of weeds}} \times 100$$

Monocot and dicot weed intensity and dry weight were recorded during 20 and 60 DAS. Observed data on weeds and crops were statistically analyzed based on the procedure given by Gomez and Gomez (2010). The method suggested by Snedecor and Cochran (1967) was used to transform the square root of the data obtained for weed density and dry weight. The least significant difference was constructed at a probability level of 5% whenever a significant difference existed.

RESULTS AND DISCUSSION

Absolute density and relative density of weeds in blackgram

The dominant weeds in the experimental field were C4 species. Species-wise weed data was recorded in weedy plots at 20, 40, and 60 DAS. Twenty-one weed species were documented during both years. The absolute and relative density of grasses, sedges, and broad-leaved weeds (BLW) in the experimental field have been presented in Table 1. Grassy weeds dominated the weed flora (44.37%), which was followed by sedges (29.59%) and broad-leaved weeds (26.04%) in 2017 at 20 DAS. In 2018, the dominance of grasses was higher (44.33%) than that of broad-leaved weeds (28.34%) and sedges (27.32%). The absolute density of grasses comprising *Echinochloa colonum* (9.33 and 8.33 weeds m^{-2} in 2017 and 2018, respectively) was predominant, followed by *Leptochloa chinensis* (7.33 weeds m^{-2}) in 2017, which was replaced by *Acrachne racemosa* (10.82 weeds m^{-2}) in 2018. In sedges, *Cyperus rotundus* and *Cyperus haspan* recorded absolute densities of 7.33 and 6.33 weeds m^{-2} in 2017 and 2018, respectively, which was followed by *Fimbristylis miliacea* in both years. In the case of BLW, *Ammannia baccifera* and *Wedelia chinensis* showed 4.33 and 6.33 weeds m^{-2} absolute density followed by *T. portulacastrum* and *Ammannia baccifera* (3.67 and 5.67 weeds m^{-2}) in 2017 and 2018, respectively. It might be due to wider ecological adoption and dominance of weeds in sandy loam to clay loam soil. Similar results were reported by Sangeetha (2010), Bommayasamy and Chinnamuthu (2019) and Kumawat *et al*. (2024). The relative density of individual weed species showed that among grassy weeds, *Echinochloa colonum* (16.56 and 12.88%) showed higher relative density followed by *Leptochloa chinensis* (13.01%) and *Acrachne racemosa* (10.82%) during 2017 and 2018,

Table 1. Effect of leftover herbicide residue applied to okra on absolute density and relative density of weeds of succeeding blackgram

Weed species	2017						2018					
	20 DAS		40 DAS		60 DAS		20 DAS		40 DAS		60 DAS	
	AD (no./m²)	RD (%)	AD (no./m²)	RD (%)	AD (no./m²)	RD (%)	AD (no./m²)	RD (%)	AD (no./m²)	RD (%)	AD (no./m²)	RD (%)
Grasses												
Echinochloa colonum	9.33	16.56	11.67	11.40	18.33	12.47	8.33	12.88	13.00	10.13	17.67	10.56
Leptochloa chinensis	7.33	13.01	6.33	6.19	11.00	7.48	6.67	10.31	8.67	6.76	10.33	6.17
Panicum flavidum	5.67	10.06	8.67	8.47	10.67	7.26	0.00	0.00	0.00	0.00	0.00	0.00
Cynodon dactylon	2.67	4.74	9.33	9.12	13.33	9.07	0.00	0.00	0.00	0.00	0.00	0.00
Acrachne racemosa	0.00	0.00	0.00	0.00	0.00	0.00	7.00	10.82	10.33	8.05	12.33	7.37
Setaria glauca	0.00	0.00	0.00	0.00	0.00	0.00	6.67	10.31	7.33	5.71	11.00	6.57
Total grasses	**25.00**	**44.37**	**36.00**	**35.18**	**53.33**	**36.28**	**28.67**	**44.33**	**39.33**	**30.65**	**51.33**	**30.68**
Sedges												
Cyperus rotundus	7.33	13.01	19.67	19.22	24.33	16.55	0.00	0.00	0.00	0.00	0.00	0.00
Cyperus difformis	3.67	6.51	4.33	4.23	12.00	8.16	0.00	0.00	0.00	0.00	0.00	0.00
Fimbristylis miliacea	5.67	10.06	10.33	10.09	15.67	10.66	3.67	5.67	24.67	19.22	29.67	17.73
Cyperus haspan	0.00	0.00	0.00	0.00	0.00	0.00	6.33	9.79	15.67	12.21	19.67	11.76
Cyperus iria	0.00	0.00	0.00	0.00	0.00	0.00	3.67	5.67	10.33	8.05	13.33	7.97
Cyperus eragrostis	0.00	0.00	0.00	0.00	0.00	0.00	4.00	6.19	13.33	10.39	12.33	7.37
Total sedges	**16.67**	**29.59**	**34.33**	**33.55**	**52.00**	**35.37**	**17.67**	**27.32**	**64.00**	**49.87**	**75.00**	**44.82**
Broad leaf weeds												
Eclipta alba	2.33	4.14	8.67	8.47	11.67	7.94	0.00	0.00	0.00	0.00	0.00	0.00
T. portulacastrum	3.67	6.51	5.33	5.21	7.00	4.76	0.00	0.00	0.00	0.00	0.00	0.00
Ammannia baccifera	4.33	7.69	6.67	6.52	7.67	5.22	5.67	8.77	6.33	4.93	8.67	5.18
Convolvulus arvensis	1.67	2.96	3.67	3.59	4.33	2.95	0.00	0.00	0.00	0.00	0.00	0.00
P.maderaspatensis	2.67	4.74	3.00	2.93	4.00	2.72	4.33	6.70	4.67	3.64	7.33	4.38
Phyllanthus niruri	0.00	0.00	2.33	2.28	2.67	1.82	2.00	3.09	3.33	2.59	5.67	3.39
Boerhavia diffusa	0.00	0.00	1.33	1.30	2.00	1.36	0.00	0.00	1.00	0.78	4.33	2.59
Cleome viscosa	0.00	0.00	1.00	0.98	2.33	1.59	0.00	0.00	1.00	0.78	2.67	1.60
Wedelia chinensis	0.00	0.00	0.00	0.00	0.00	0.00	6.33	9.79	8.67	6.76	12.33	7.37
Total BLW	**14.67**	26.04	**32.00**	31.27	**41.67**	28.35	**18.33**	**28.34**	**25.00**	**19.48**	**41.00**	**24.50**
Total weed density	**56.34**	**100.00**	**102.33**	**100.00**	**147.00**	**100.00**	**64.67**	**100.00**	**128.33**	**100.00**	**167.33**	**100.00**

AD- Absolute density RD- Relative density Data statistically not analysed

Table 2. Effect of leftover herbicide residue applied to okra on monocots and dicots weed density (No./m²) of succeeding blackgram

Treatment	2017				2018			
	20 DAS		60 DAS		20 DAS		60 DAS	
	Monocots	Dicots	Monocots	Dicots	Monocots	Dicots	Monocots	Dicots
T_1	3.69[b]	2.15[bc]	6.42[c]	4.20[b]	3.92[bc]	2.31[bc]	6.56[bc]	4.20[bc]
	(11.67)	(2.67)	(39.33)	(15.67)	(13.33)	(3.33)	(41.00)	(15.67)
T_2	4.28[c]	2.45[cd]	6.85[d]	4.69[c]	4.24[bc]	2.58[c]	7.16[de]	4.62[cd]
	(16.33)	(4.00)	(45.00)	(20.00)	(16.00)	(4.67)	(49.33)	(19.33)
T_3	3.79[b]	2.37[cd]	6.63[cd]	4.40[b]	4.04[bc]	2.51[c]	7.00[cd]	4.43[c]
	(12.33)	(3.67)	(42.00)	(17.33)	(14.33)	(4.33)	(47.00)	(17.67)
T_4	4.79[d]	2.51[d]	7.42[e]	5.13[d]	4.47[d]	3.11[d]	7.63[e]	4.96[d]
	(21.00)	(4.33)	(53.00)	(24.33)	(18.00)	(7.67)	(56.33)	(22.67)
T_5	5.19[e]	3.69[e]	8.40[f]	5.83[e]	5.48[e]	3.41[d]	8.43[f]	6.02[e]
	(25.00)	(11.67)	(68.67)	(32.00)	(28.00)	(9.67)	(69.33)	(34.33)
T_6	3.55[b]	2.00[b]	5.54[b]	4.20[b]	3.77[b]	2.08[b]	6.27[b]	3.89[b]
	(10.67)	(2.00)	(28.67)	(15.67)	(12.33)	(2.33)	(37.33)	(13.33)
T_7	1.41[a]	1.41[a]	1.41[a]	1.41[a]	1.41[a]	1.41[a]	1.41[a]	1.41[a]
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
T_8	6.53[f]	4.07[f]	10.36[g]	6.60[f]	6.93[f]	4.49[e]	11.32[g]	6.56[f]
	(40.67)	(14.67)	(105.33)	(41.67)	(46.33)	(18.33)	(126.33)	(41.00)
LSD (P=0.05)	0.35	0.34	0.43	0.22	0.58	0.33	0.51	0.46

Figures in parentheses are mean of original values; Data subjected to $\sqrt{x+2}$ transformation respectively. However, among the sedges, *Cyperus rotundus* and *Cyperus haspan* recorded higher relative densities of 13.01 and 9.79%. In broad-leaved weeds, *Ammannia baccifera* and *Wedelia chinensis* registered comparatively more relative density during 2017 and 2018 than the other weed species at 20 DAS. In 2017, the relative density of individual weed species showed that the grassy weed of *Echinochloa colonum* recorded higher values of 11.40 and 12.47% at 40 and 60 DAS, respectively. In sedges, the *Cyperus rotundus* recorded an absolute density of 19.67, 24.33 weeds m^{-2}, with a relative density of 19.22, 16.55%. The BLW, *Eclipta alba* registered higher absolute and relative densities of 8.67 weeds m^{-2}, 8.47% and 11.67 weeds m^{-2}, 7.94% at 40 and 60 DAS, respectively. However, in 2018, sedges were dominant, followed by grassy weeds and BLW. The highest absolute density and relative density were recorded by *Fimbristylis miliacea* (24.67, 29.67 weeds m^{-2} and 19.22, 17.73%) in sedges followed by *Echinochloa colonum* (13.00, 17.67m^{-2} and 10.13, 10.56%) in grasses and *Wedelia chinensis* (8.67, 12.33 m^{-2} and 6.76, 7.73%) in BLW at 40 and 60 DAS respectively. It was confirmed with the observation of Punia *et al.* (2013), Upasani *et al*. (2017), and Ahlawat *et al*. (2024).

Monocot and dicot weed density

Residual herbicides applied to the preceding okra crop significantly influenced monocot and dicot weed density during the entire crop growth stages of the current black gram (Table 2). A weed-free check recorded superiority in reducing monocot and dicot weeds during crop growth stages. At 20 DAS, among all weed control treatments, manual weeding on 20 and 40 DAS registered lesser monocot weed density of 10.67 and 12.33 weeds m^{-2} during 2017 and 2018, respectively, which was comparable with residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and residual impact of metribuzin at 500 g ha^{-1} on 3 DAS *fb* twin-wheel hoe weeder at 40 DAS. Whereas, the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* twin wheel hoe weeder at 40 DAS recorded 5.35 and 13.5% higher dicots weed density as compared to the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and hand weeding on 20 and 40 DAS respectively. At 60 DAS, Manual weeding twice on 20 and 40 DAS recorded 72.8 and 70.5 % reductions in monocots density during 2017 and 2018, respectively, compared to weedy check. The subsequent best treatment was the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, which was comparable with the residual impact of metribuzin at 500 g ha^{-1} on 3 DAS *fb* twin wheel hoe weeder at 40 DAS during both the year of experiments. A similar trend was recorded in dicots to that of monocot density.

Monocots and dicots weed dry weight

Various weed control methods significantly influenced the weed dry weight of monocots and dicots in both years. A weed-free check recorded distinctly the most minor weed dry weight of both monocots and dicots during the black gram's entire crop growth stage. At 20 DAS, manual weeding twice on 20 and 40 DAS registered significantly lower dry weight of weeds (2.84g m^{-2}), which was comparable with the residual effect of metribuzin at 500g ha^{-1} on 3 DAS *fb* POE quizalofop ethyl at 50g ha^{-1} on 20 DAS in 2017. In 2018, however, these two treatments were different. However, the tiniest weed dry weight was recorded with manual weeding on 20 and 40 DAS in dicots weed. In comparison, all other residual weed control treatments were at par with one another except for the residual effect of pendimethalin at 1.0 kg ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and weedy check during both the years. At 60 DAS, the minimum weed dry weight of monocot and dicot registered under weed-free check followed by manual weeding twice on 20 and 40 DAS in both years. The next order of best treatment was the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, which was comparable with treatment imposed in herbicide residue of metribuzin 500 g ha^{-1} on 3 DAS followed by twin-wheel hoe weeder on 40 DAS during both the year of experiments. Weedy check treatment recorded considerably more monocot dry weight of 21.72, 20.21, and 50.38, 68.62g m^{-2} and dicot weed dry weight of 7.41, 6.19, and 21.01, 26.35g m^{-2} at 20 and 60 DAS during 2017 and 2018, respectively.

Effect on crop growth parameters

Weed control treatment of preceding okra herbicide residue did not significantly affect the germination of succeeding black gram (Table 4). The germination of black gram ranged from 85.4 to 97.8%, indicating that the preceding crop's residual effect did not affect the emergence of succeeding black gram. Similar findings were noticed by Ryan *et al.* (2010), who reported that the application of sulfentrazone didn't show any ill effects on cabbage, cucumber, onion, sweet potato, tomato, or watermelon applied

Table 3. Effect of leftover herbicide residue applied to okra on monocots and dicots weed dry weight (g/m^2) of succeeding blackgram.

Treatment	2017				2018			
	20 DAS		60 DAS		20 DAS		60 DAS	
	Monocots	Dicots	Monocots	Dicots	Monocots	Dicots	Monocots	Dicots
T_1	2.30^{bc} (3.29)	1.67^{b} (0.78)	4.27^{c} (16.23)	2.98^{c} (6.90)	2.22^{b} (2.94)	1.72^{b} (0.96)	4.56^{c} (18.77)	3.02^{bc} (7.13)
T_2	2.73^{d} (5.45)	1.70^{b} (0.90)	4.69^{de} (19.97)	3.00^{c} (6.99)	2.39^{bc} (3.74)	1.83^{bc} (1.36)	5.14^{d} (24.43)	3.33^{de} (9.11)
T_3	2.41^{c} (3.84)	1.68^{b} (0.81)	4.48^{cd} (18.07)	3.06^{c} (7.37)	2.38^{bc} (3.64)	1.80^{b} (1.26)	4.99^{d} (22.91)	3.20^{cd} (8.26)
T_4	2.78^{d} (5.73)	1.81^{b} (1.27)	4.90^{ef} (21.99)	3.39^{d} (9.53)	2.53^{c} (4.40)	2.06^{cd} (2.25)	5.21^{d} (25.21)	3.62^{e} (11.09)
T_5	3.17^{e} (8.09)	2.09^{c} (2.41)	5.25^{f} (25.63)	3.59^{e} (10.90)	3.01^{d} (7.06)	2.19^{d} (2.85)	5.93^{e} (33.17)	4.23^{f} (15.91)
T_6	2.20^{b} (2.84)	1.58^{ab} (0.49)	3.61^{b} (11.02)	2.79^{b} (5.77)	2.21^{b} (2.89)	1.63^{ab} (0.67)	4.17^{b} (15.39)	2.83^{b} (6.06)
T_7	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)	1.41^{a} (0.00)
T_8	4.87^{f} (21.72)	3.06^{d} (7.41)	7.23^{g} (50.38)	4.79^{f} (21.01)	4.71^{e} (20.21)	2.85^{e} (6.19)	8.40^{f} (68.62)	5.32^{g} (26.35)
LSD (P=0.05)	0.20	0.23	0.39	0.17	0.27	0.23	0.24	0.31

Figures in parentheses are mean of original values; Data subjected to √x+2 transformation

Table 4. Effect of leftover herbicide residue applied to okra on crop growth, yield parameters, grain yield, halum yield and crop nutrient uptake of blackgram (pooled mean).

Treatments	Growth parameters					Yield parameters					Crop nutrient uptake (kg/ha)		
	Germination (%)	Plant height (cm)	25 to 50 DAS		DMP (kg/ha)	No of clusters/ plant	No of pods/ pod	Seed test weight (g)	Grain yield (kg/ha)	Haulm yield (kg/ ha)	N	P	K
			CGR (g/m^2/d)	RGR (g/g/d)									
T_1	90.3	37.5^{bc}	2.56^{cd}	0.01417^{c}	808^{cd}	7.60^{c}	27.3^{c}	6.22	585^{c}	854^{b}	12.5^{c}	3.61^{c}	14.0^{c}
T_2	90.6	34.8^{de}	2.65^{cd}	0.01630^{ab}	814^{c}	7.15^{cd}	20.0^{e}	6.03	532^{c}	739^{c}	11.2^{de}	2.69^{d}	11.6^{de}
T_3	85.9	35.7^{cd}	2.86^{c}	0.01693^{a}	884^{c}	7.38^{c}	24.2^{d}	6.12	576^{c}	781^{bc}	11.8^{cd}	2.90^{de}	12.8^{cd}
T_4	93.3	33.8^{de}	2.49^{d}	0.01630^{ab}	729^{d}	6.50^{de}	19.4^{e}	6.03	507^{cd}	716^{c}	10.8^{e}	2.36^{e}	10.1^{ef}
T_5	88.5	32.9^{ef}	2.42^{d}	0.01676^{ab}	731^{d}	6.00^{ef}	16.7^{f}	5.80	446de	699^{c}	8.9^{f}	1.87^{f}	8.5^{fg}
T_6	92.6	40.0^{ab}	3.54^{b}	0.01529^{bc}	1209^{b}	9.32^{b}	30.2^{b}	6.18	720^{b}	1011^{a}	16.2^{b}	4.89^{b}	18.6^{b}
T_7	97.8	42.2^{a}	4.28^{a}	0.01564^{abc}	1353^{a}	10.50^{a}	36.4^{a}	6.63	839^{a}	1105^{a}	20.4^{a}	5.37^{a}	20.6^{a}
T_8	85.4	31.0^{f}	2.05^{e}	0.01622^{ab}	609^{e}	5.70^{f}	15.2^{f}	5.63	415^{e}	590^{d}	8.1^{f}	1.66^{f}	7.7^{g}
LSD (P=0.05)	NS	2.66	0.34	0.00152	81	0.73	1.81	NS	79	97	0.9	0.48	1.6

at the recommended rate during the preceding year. Whenever weed competition is reduced in a crop management system, it is reflected in growth parameters such as plant height and dry matter production due to effective resource utilization by crops. The plant height was significantly exerted by weed control treatments of preceding okra crop herbicide residue. A weed-free check recorded the highest plant height, crop growth rate, and dry matter accumulation compared to all weed control treatments' residual effects. The subsequent best treatment was HW twice at 20 and 40 DAS. This treatment recorded a plant height of 40.0 cm, which was comparable with metribuzin at 500g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS. It might be due to pre-emergence herbicide followed by post-emergence or HW imposed in the preceding crop, which reduced the soil weed seed bank and led to effective control of weeds in succeeding crops. Weed control treatments of preceding herbicide residue significantly influenced the physiological parameters like crop growth rate and relative growth rate of black gram. Crop growth rate (CGR) represents the photosynthetic efficiency of a plant, which depends upon the leaf area index of the crop. The higher crop growth rate of 3.54 g m^{-2} d^{-1} was recorded under HW twice at 20 and 40 DAS. The next order was for the best treatments to be T3 >T2>T1. These treatments recorded 39.5, 29.3, and 24.9% higher crop growth rates than weedy checks. Pankaj *et al.* (2020) reported that a free environment favored better utilization of resources like moisture and nutrients, resulting in a higher crop growth rate. Whereas, in relative growth rate except the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, hand weeding (20 and 40 DAS) and weed-free check, all other weed control treatments were comparable with one another. The higher dry production was observed under manual weeding on 20 and 40 DAS. Similar results were reported by Ramesh and Rathika (2016). Weedy check recorded poor dry matter production compared to all residual effects of previous crop weed control plots. This might be owing to competition shown by weeds on available resources, which led to nutrient deficiency and reduced dry matter accumulation of crops (Bommayasamy and Chinnamuthu 2021).

Effect on crop yield parameters and yield

The number of pods plant^{-1} and number of clusters plant^{-1} were the most critical yield attributes that decided the grain yield of blackgram. Weed management practices significantly influenced the numbers of clusters plants^{-1}, pods plants^{-1}, seed yield and haulm yield (Table 4). A maximum number of clusters plants^{-1} was observed with hand weeding twice at 20 and 40 DAS. The next order's best treatments were the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS, followed by T_3 and T_1. These treatments were recorded 26.7, 23.0, 19.2% and 33.3, 29.5, and 25.4% more numbers of cluster/plant in comparison to the residual effect of pendimethalin at 1.0 kg ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and weedy check respectively. However, HW twice at 20 and 40 DAS recorded a 10.2% higher number of pods plant^{-1} compared to the subsequent best treatment of the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS. The lower number of clusters plants^{-1} and pods plants^{-1} were recorded under weedy check. It might be due to higher weed competition during crop growth, leading to poor yield attributing characteristics (Rana *et al.* 2015, Nirmala *et al*. 2016). The test weight of the seed is by and large heritable; hence, the residual effect of weed control measures failed to exert marked variation in the 100 seed weight of black gram.

Maximum grain yield of black gram was recorded with weed-free check followed by manual weeding on 20 and 40 DAS. This was mainly owing to better control of monocot and dicot weeds over a more extended period, thus providing a conducive microclimate condition for better improvement of the black gram crop, leading to enhanced grain yield. Among the residual effects of herbicides applied to the previous crop of okra, metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS recorded higher grain yield and comparable yields were observed with T_3, T_2 and T_4. This is mainly due to lesser weed competition during critical periods of crop growth, which led to improved yield-attributing characteristics like cluster plant^{-1} and pods plant^{-1} numbers. Kumar and Singh *et al.* (2018) also reported a similar line of findings. At the same time, a maximum haulm yield of 1105 kg ha^{-1} was registered in weed-free check and comparable with HW twice at 20 and 40 DAS. The next order best treatments were the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and the residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* twin wheel hoe weeder at 40 DAS. These two treatments were comparable with each other. The lowest grain yield and haulm yield were registered under weedy check.

Effect on crop nutrient uptake

Nutrient uptake by the crop is a function of dry matter production and its concentration of the plants. Weed control treatments significantly influenced nutrient uptake by black gram (Table 4). A weed-free check recorded significantly higher N, P, and K uptake of 20.4, 5.37, and 20.6 kg ha^{-1}, respectively, followed by hand weeding twice. It might be due to the reduced density of weed flora, biomass accumulation, and maximum weed control efficiency, resulting in more nutrient availability for the crop and better crop nutrient uptake. Kathepuri *et al.* (2007) reported a similar line of findings. The residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl at 50g ha^{-1} on 20 DAS and residual effect of metribuzin at 500 g ha^{-1} on 3 DAS *fb* twin wheel hoe weeder at 40 DAS recorded significantly higher nutrient uptake of 12.5, 3.61, 14.0 and 11.8.2.90, 12.8 kg of N, P, K respectively. It might be due to the effective control of weed density and dry matter accumulation in the preceding okra crop, which facilitated the lesser establishment of weeds in succeeding black gram and led to higher nutrient uptake. The lowest nutrient uptake of black gram was recorded under weedy check.

CONCLUSION

It can be inferred that under labour constraint situation, application of metribuzin 500 g ha^{-1} on 3 DAS *fb* POE quizalofop-ethyl 50g ha^{-1} on 20 DAS to the preceding okra crop and raising black gram as a second crop in the sequence considered as one of the best weed control methods without any additional cost and realising higher grain yield with effective weed control.

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