Plant Archives Vol. 24, No. 2, 2024 pp. 753-760 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.105

RESIDUAL RICE HERBICIDE EFFECT ON WEED CONTROL, PRODUCTIVITY, NUTRIENT UPTAKE AND QUALITY SUCCEEDING OKRA

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(Date of Receiving-29-04-2024; Date of Acceptance-12-07-2024)

ABSTRACT

The over utilization of pesticides has resulted in detrimental consequences on the ecosystem, with their residues affecting vital natural resources such as soil and water. Herbicide usage is steadily rising worldwide, leading to the persistence of herbicides in soil and creating residual toxicity to future crops. Furthermore, the negative consequences of agricultural effects on both animals and humans in rotation are also impacted. Hence, an investigation was conducted to evaluate the effects of residual herbicide from rice cultivation on weed control, productivity, nutrient uptake, and quality of okra during the *Rabi* season of 2016 and 2017. The weed control treatments include the residual effect of oxadiargyl encapsulated or loaded with biochar, zeolite, starch, water-soluble polymer, a commercial formulation of oxadiargyl and butachlor. In a Randomised Block Design with three replications, it was compared to a weed-free check, manual weeding, and a weedy check. The study found that the lingering impact of herbicides had a significant effect on both the density and dry weight of weeds during the whole growth cycle of the crop. At 20 DAS, the application of butachlor at a rate of 1.25 kg/ha, *fb* hand weeding at 40 DAT in rice and twice in okra, resulted in a significant reduction of 80.7% and 76.5% in weed density and dry weight, respectively, compared to the control plot with no weed management. Nevertheless, the application of butachlor at a rate of 1.25 kg/ha *fb* hand weeding 40 DAT in rice, and mechanical weeding twice in okra, resulted in a fruit yield that was 2.53 times higher than the yield obtained from the weedy check. The residual action of oxadiargyl loaded zeolite ensued. The weed-free check exhibited significantly greater levels of crude protein (34.6%), crude fibre (23.1%), ascorbic acid (23.6%), and mucilage content (23.9%) compared to the weedy check. Nevertheless, this was statistically similar to the remaining impact of butachlor 1.25 kg/ha *fb* hand weeding 40 DAT in rice, and hand weeding twice in okra. Thus, it may be inferred that the persistent impact of oxadiargyl loaded zeolite successfully managed weeds and promoted increased crop growth, productivity and nutritional quality of okra in a circumstance where manual labour is limited.

Key words : NPK uptake, Residual effect, Quality, Yield, Zeolite.

Introduction

Okra is a highly versatile crop that can thrive in diverse climatic situations. India ranks among the leading countries worldwide in terms of agricultural production, with a total output of 5.7 million tonnes and productivity rate of 11.9 t/ha (Bharthy e*t al.*, 2017). Okra serves as both a fresh vegetable and a canned dish. Okra is rich in a high-quality mucilaginous component that is often utilized in the creation of soups and stews worldwide. Nevertheless, the reduction in okra crop production varies significantly, ranging from 60% to 91%, primarily due to a greater prevalence of weed intensity. This increased weed presence might serve as an extra habitat for the survival of diseases and insects, further exacerbating the yield loss (Olabode *et al.*, 2017). Oroka and Omovbude (2016) shown that unmanaged or delayed weed growth leads to a decrease in the crop production of okra. While conditions without weeds resulted in the largest amount of fruit produced, the growing population has made it necessary to expand vegetable production utilizing limited resources. The intensification of agriculture offers significant potential to increase vegetable production in fallow rice systems due to the more demanding and costly nature of preliminary cultivation, which requires favourable conditions and considerable time and effort (Damodaran *et al*., 2015). Intensive farming involves the application of a large amount of agrochemicals for crop protection. However, only 0.1% of these chemicals really reach the intended target organism. The rest remains in the soil and can pose a threat to non-target creatures, including animals, humans, plants and beneficial organisms (Varma and Dubey, 1999). The permanence of herbicides in soil is determined by several processes, including photolysis, volatility, leaching, surface runoff, chemical hydrolysis, and microbiological destruction (Aktar *et al*., 2008). Hernandez-Sevillano (2001) and Janaki *et al*., (2015) discovered that the existence of low concentrations of sulfonylurea herbicidal residues can have an impact on the rotation crops. The longevity of herbicides is a crucial determinant of the success of subsequent crops, as even little concentrations can lead to crop failure (Brar *et al*., 2006; Sireesha *et al*., 2011). 2, 4-Dichlorophenoxyacetic acid, 2,4 Na salt, butachlor and pretilachlor residue was found to be lower than the detectable level 45 days after the herbicide application in both the soil and crop across consecutive seasons (Chinnusamy *et al*., 2012; Sondhia, 2013). In recent times, there has been a rise in the use of slow-release herbicide formulations that involve encapsulating herbicides at the nano level. This approach has proven to be a flexible solution for addressing the issue of residual herbicide effects on crops and soil, specifically targeting the intended area of action. Farmers lack awareness and knowledge about the presence of pesticide residue on subsequent crops. Plant bioassay methods are the most straightforward and economical approach for determining the phytotoxic element of herbicide residue in the soil. Nevertheless, the number of published field bioassay investigations is extremely limited. The study aimed to assess the impact of encapsulated preceding rice herbicide on weed, crop growth, yield, nutrient absorption and the nutritional value of subsequent okra crops.

Materials and Methods

A study was conducted from 2016 to 2018 to examine the impact of encapsulated preceding rice herbicide on weed, crop growth, yield, nutrient absorption and the nutritional value of subsequent okra crops. The farm is situated within the geographical coordinates of 9°54´ to 11°38´ North latitude and 78°54´ to 92°39´ East longitude. It is located at an altitude ranging from 15 to 147 meters above mean sea level (MSL). Okra seeds were planted in the rice fallow circumstances without altering the field layout of the preceding rice crop treatments. The weed control treatments used in the study were as follows: T_1- biochar loaded with oxadiargyl, T_2- zeolite loaded with oxadiargyl, T_3- starch encapsulated with oxadiargyl, T_4- water-soluble polymer encapsulated with oxadiargyl, T_5- oxadiargyl applied at a rate of 100 g/ha, T_6- butachlor applied at a rate of 1.25 kg/ha fb hand weeding on 40 DAT, T_7- weed free check and T_8- weedy check. A minor alteration was made to the T_6- butachlor treatment by applying hand weeding twice on the 20th and 40th days after sowing (DAS) in the subsequent okra crop. The soil physico-chemical properties of the experimental sites are shown in Table 1.

Table 1 : The details of soil physico-chemical characteristics of the experimental site.

Particulars	2016-17	2017-18
pH	7.3	6.9
EC (dSm^{-1})	0.34	0.30
Organic carbon (%)	0.32	0.38
Available N (kg/ha)	237.0	252.1
Available P (kg/ha)	19.3	15.8
Available K (kg/ha)	174.8	207.1
Texture	Sandy clay loam	Clay loam

The field experiments were conducted in RBD design with three replication. Okra hybrid CO-4 seeds were used as test crops with duration of 110 days and used recommended seed rate. Okra seeds dibbled in rice stubbles with 5.4 × 3.6 m plot area per treatment with an adopted spacing of 45 cm × 30 cm. Once the planting was over, irrigation was done immediately after sowing and repeated on the third day to save the crop. The next irrigation's were given as and when it is required. Gap filling and thinning was done on 10 DAS and leaving a single healthy plant/hill. The crop nutrition was given in the recommended dose of 200:100:100 kg of N: P: K per ha. N was supplied in three splits; 1/3 of N, 100% P and 50% K was applied as basal and the remaining N dose on 30 and 60 DAS. The balance half dose of potash was used on 30 DAS. Need-based plant protection chemical was applied (Dimethoate 1.5 ml/l and Imidachloprid 1 ml/l and neem seed kernel extract (NSKE) 5 %) to control sucking pest and fruit borer. Throughout the cropping season, species-wise weeds were observed in the unweeded check plots. At 20, 60 and 100 DAS, weed count was done in four representative samplings ($0.25m^2$) areas of each field 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 number of plants germinated per plot was observed in 10 DAS and calculated germination percentage. The leaf area index was calculated by using the procedure advocated by Mc Kee (1964).

$$\mathrm{LAI} = \frac{\text{Leaf length} \times \text{Maximum leaf width} \times \text{No. of leaves plant}^{-1} \times \text{Constant}\,(0.73)}{\text{Land area occupied by individual plant}\,(\mathrm{cm}^2)}$$

The weed index was worked out as per procedure suggested by Gill and Vijaykumar (1966).

$$\text{Weed Index (WI)} = \frac{\text{Yield from weed free plot} - \text{Yield in the treatment plot}}{\text{Yield in weed free plot}}$$

Fruits of okra were harvested in the appropriate stage of maturity. The yield obtained from each picking was weighed, accounted and summation of fruit yield per plot from which the yield per hectare was calculated. The nutritional quality parameters of okra fruits, such as crude protein, ascorbic acid, crude fibre, and mucilage content, were estimated as per procedure suggested by Humphries (1956), Chopra and Kanwar (1976), Whistler and Conrad (1954), respectively. The observed data on weeds and crops were statistically pooled (2016 and 2017) and analyzed based on the procedure given by Gomez and Gomez (1984). Observed data of weed density and weed dry weight showed wider variation, which was reduced by converting observed value into square root transformation as per the method suggested by Snedecor and Cochran (1967).

Results and Discussion

Weed dynamics : The experimental field comprised with major weed flora *viz*., *Echinochloa colonum*, *Leptochloa chinensis, Panicum flavidum, Cynodon dactylon, Acrachne racemosa, Setaria glauca* among grasses; *Cyperus rotundus*, *Cyperus difformis, Cyperus haspan, Cyperus iria, Cyperus eragrostis, Fimbristylis miliacea* among sedges; *Eclipta alba, Wedelia chinensis*, *Trianthema portulacastrum, Ammannia baccifera*, *Convolvulus arvensis, Phyllanthus maderaspatensis*, *Phyllanthus niruri*, *Boerhavia diffusa*, *Clome viscosa*, among in broad leaved weeds. Among the weeds, grasses were found to be the predominant species in okra.

Effect on weeds : The residual effect of weed control treatments showed significant variations among weed density and dry weight at 20, 60 DAS and harvest stage in both the experiments (Table 2). The weed-free check showed substantial variation among other weed control measures during entire crop growth stages. At 20 DAS, the residual effect of butachlor at 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra registered 80.7% lesser weed density in comparison to the weedy check. A similar line of findings was reported by Khan *et al*. (2018). Pre-emergence herbicide application followed by manual weeding in preceding rice crop reduced buildup of soil weed seed bank, which led to least emergence of weeds (Kumar *et al*., 2008; Gangaiah *et al*., 2015; Bommayasamy *et al*., 2019). At 60 DAS, weed control treatments consisting of the residual effect of butachlor at 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra registered minimum weed density (98.0/m^2). The residual effect of oxadiargyl encapsulated with water-soluble polymer on 3 DAT and the residual impact of oxadiargyl loaded with zeolite on 3 DAT were registered total weed density of 62.8 and 56.6 %, respectively, in comparison with an weedy check. Encapsulated herbicide slowly released active ingredient, which controls late-emerging weed of previous rice at the same time; it declined accumulation of weed seed in the soil. A similar trend was observed at the harvest stage. Whereas, the weed density was maximum (35.2 to 68.1%) in weedy checks compared to other treatments.

The various residual effect of herbicide showed remarkable influence in dry weed biomass during entire crop growth stages. Minimum weed biomass was registered under a weed-free situation throughout the growing season. At 20 DAS, the residual effect of butachlor at 1.25kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra obtained lesser total weed biomass (18.0 g/m^2). It was at par with the residual effect of oxadiargyl loaded with zeolite. The results indicated that pre-emergence herbicide application *fb* hand weeding effectively checked the accumulation of weed biomass. A similar line of findings was reported by Gowripriya *et al*. (2009), Pradeeshkumar (2014). At 60 DAS, minimum weed biomass (54.2g/m^2) was recorded under residual butachlor at 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra. It was followed by the residual effect of oxadiargyl loaded with zeolite. The next best treatment was the residual effect of oxadiargyl loaded with biochar. The residual impact of oxadiargyl encapsulated with starch recorded 50.9 and 54.7% declined accumulation of weed biomass compared to the weedy check. It might be a reason for the lesser collection of dry weed weight and its density in preceding crops, leading to a better weed control effect. Weedy check registered the highest weed biomass accumulation during the entire crop period. A similar trend was observed at

Table 2 : Encapsulated preceding rice herbicide residual effect on total weed density and weed dry weight of succeeding okra (Two year pooled mean).

Treatments	Total weed density (No./m^2)			Total weed dry weight (g/m^2)		
	20 DAS	60DAS	Harvest	20 DAS	60DAS	Harvest
Oxadiargyl loaded with biochar on 3 DAT	6.76[e] (43.8)	13.4[de] (178.2)	14.8[d] (217.0)	5.12[d] (24.2)	9.93[cd] (96.6)	11.4[cd] (128.6)
Oxadiargyl loaded with zeolite on 3 DAT	5.51[c] (28.3)	11.9[c] (139.3)	13.4[c] (177.5)	4.57[bc] (18.9)	9.57[c] (89.7)	11.0[c] (118.3)
Oxadiargyl encapsulated with starch on 3 DAT	7.74[f] (58.0)	13.2[d] (171.7)	14.5[d] (207.8)	4.97[cd] (22.8)	10.09[cd] (99.9)	11.6[cd] (131.6)
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	6.11[d] (35.3)	11.4[c] (128.2)	13.1[c] (170.3)	4.75[bcd] (20.5)	9.70[c] (92.1)	10.7[c] (113.3)
Oxadiargyl at 100 g/ha on 3 DAT	8.69[g] (73.5)	14.2[e] (199.3)	16.3[e] (262.8)	5.76[e] (31.1)	10.62[d] (110.9)	12.0[d] (142.6)
Butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra	4.90[b] (22.0)	10.0[b] (98.0)	11.5[b] (129.3)	4.47[b] (18.0)	7.50[b] (54.2)	9.4[b] (87.2)
Weed free check	1.41[a] (0.0)	1.4[a] (0.0)	1.4[a] (0.0)	1.41[a] (0.0)	1.41[a] (0.0)	1.4[a] (0.0)
Weedy check	10.74[h] (113.8)	18.6[f] (344.7)	20.2[f] (405.3)	8.85[f] (76.5)	14.29[e] (203.4)	15.7[e] (245.0)
LSD (P ≤ 0.05)	0.54	0.9	1.0	0.48	0.89	1.0

Figures in parentheses indicate original values subjected to square root √x+2 transformation; DAS-Days after sowing, LSD-Least significant difference; significance levels from one way (ANOVA); Data followed by different lower case letters differs significantly (significance level ≤ 0.05).

the harvest stage.

Effect on crop growth parameters : Okra seed germination did not influence by the residual effect of herbicide. Among weed control treatments, the germination percentage differs numerically from 76.0 to 91.2%. At the same time, the study noticed the highest germination percentage of 91.2% in weed-free checks. It showed that oxadiargyl encapsulated slow-release herbicides did not affect okra's succeeding crop. The same results were observed by Rathod *et al.* (2014). The residual effect of herbicide treatments exerted substantial differences in plant height and accumulation of dry matter in okra during the harvest stage (Bommayasamy and Chinnamuthu, 2019b). In comparison, other weed control treatments showed higher plant growth than weedy check. While, weed-free check registered the tallest plants, maximum accumulation of plant dry matter. Among weed control treatments, the residual effect of butachlor 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra obtained a maximum plant height of 90.2 cm. The next best treatment was the residual effect of oxadiargyl loaded zeolite on 3 DAT, which recorded a 59.5% taller plant than weedy check. However, weed-free check and residual effect of butachlor @ 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra registered 58.2 and 42.3% more leaf area index as against weedy check. The leaf area index was maximum as the weeds were effectively controlled, resulting in leaf development. Similar line findings were reported by Ram Murti *et al*. (2004), Bommayasamy and Chinnamuthu (2019a), who observed that leaf area index was substantially reduced with increased weed density. The residual herbicide effect is highly influenced by the accumulation of okra dry matter production. Irrespective of the residual herbicide effect, plant dry matter production was increased from 435 kg to 9302 kg compared to the weedy check. Higher plant dry matter production of 113.9 and 64.3% registered the residual impact of butachlor 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in okra and residual effect of oxadiargyl loaded with zeolite on 3 DAT in comparison to weedy check. Reduced weed competition meant more nutrients were available, which led to faster crop growth under effective weed control, which led to more plant dry matter

Table 3 : Residual effect encapsulated pre-emergence herbicide on germination, plant height, leaf area index, biomass production, fruit yield of succeeding okra (Two year pooled mean).

Treatments	Germination (%)	Plant height at harvest (cm)	Leaf area index at 60 DAS	Plant dry matter accumulation (kg/ha)	Fruit yield (kg/ha)	Weed index
Oxadiargyl loaded with biochar on 3 DAT	85.4	66.3[c]	2.02[de]	4673[d]	7450[d]	69.2
Oxadiargyl loaded with zeolite on 3 DAT	82.4	73.7[c]	2.23[cd]	6658[c]	9360[c]	61.3
Oxadiargyl encapsulated with starch on 3 DAT	83.5	65.7[c]	2.30[c]	4738[d]	7360[de]	69.6
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	81.4	72.2[c]	2.05[cde]	4871[d]	8070[de]	66.6
Oxadiargyl at 100 g/ha on 3 DAT	79.8	56.7[d]	2.05[cde]	4053[de]	7000[e]	71.0
Butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra	86.8	90.2[b]	2.79[b]	8670[b]	16960[b]	29.8
Weed free check	91.2	107.8[a]	3.10[a]	12920[a]	24150[a]	0.0
Weedy check	76.0	46.2[e]	1.96[e]	3618[e]	4800[f]	80.1
LSD ($P \leq 0.05$)	NS	9.0	0.26	869	0.8	-

DAS-Days after sowing, LSD- Least significant difference; significance levels from one way (ANOVA); Data followed by different lower case letters differs significantly (significance level ≤ 0.05).

production of okra.

Effect on fruit yield and weed index : The various weed control treatments showed significant evidence with increased okra fruit yield over the weedy check. Fruit yield of okra varied among the weed management treatments from 4800 to 24150 kg/ha. Increased green fruit yield can also be attributed to the favourable effect of accelerating the crop growth and yield attributes of okra. Whereas maximum okra fruit yield of 24150 kg/ha recorded under weed-free check. The residual effect of butachlor @ 1.25 kg/ha *fb* HW on 40 DAT in rice + HW twice (20 and 40 DAS) in subsequent okra registered a higher fruit yield of 16960 kg/ha 2.53 times higher fruit yield in comparison to unweeded check. Whereas the residual effect of oxadiargyl loaded with zeolite on 3 DAT recorded 95% higher okra fruit yield compared to weedy check. It could be a reason for better availability of nutrients at distinct physiological growth stages would have supported better assimilation of photosynthates towards fruits. Severe competition exerted for natural resources in the weedy check treatment led to lower fruit yield of okra (Khattak *et al*., 2015; Hamma *et al*., 2016; Subramani *et al*., 2023).

Weed index showed a yield reduction due to competition among weeds in the weedy check. However, weed-free check has minimum weed competition and maximum fruit yield. All other weed treatments had a fruit yield reduction of 11.36 to 23.47% compared to the weedy check, which indicates a varying degree of weed completion. The residual effect of butachlor at 1.25 kg/ha, *fb* HW on 40 DAT in rice and HW twice on 20, and 40 DAS in okra, led to a lower weed index of 29.8%. The weedy check had 62.8% lesser weeds than the weed free check. The higher the weed index was in the weedy check, the more important it was to control the weeds to get the most fruit from okra.

Crop nutrient uptake : Okra is a heavy feeder which requires more nutrients for vegetative growth, flowering and fruit formation. The residual effect of preceding crop herbicides registered significant variation in nutrient uptakes. Uptake of nitrogen varied between 60.1 to 165.3 kg/ha, phosphorus (10.0 to 43.0 kg/ha) and potash (40.6 to 81.4 kg/ha) due to crop biomass accumulation during the experiments. Weed-free check registered maximum uptake of nitrogen, phosphorus and potash. Irrespective of weed control measures, the

Table 4 : Residual effect encapsulated preceding rice herbicide on fruit quality and crop nutrient uptake of succeeding okra (Two year pooled mean).

Treatments	Nutrient uptake (kg/ha)			Nutritional quality of okra			
	N	P	K	Crude protein (%)	Crude fibre (%)	Ascorbic acid (mg/100g)	Mucilage (%)
Oxadiargyl loaded with biochar on 3 DAT	76.6^{de}	13.2^{de}	52.0^{ef}	2.05^{cde}	14.8^{b}	12.3^{b}	1.26^{bc}
Oxadiargyl loaded with zeolite on 3 DAT	107.9^{c}	20.6^{c}	61.1^{c}	2.09^{cd}	15.2^{ab}	12.7^{ab}	1.30^{abc}
Oxadiargyl encapsulated with starch on 3 DAT	81.0^{d}	14.3^{d}	55.5^{de}	1.97^{def}	15.1^{b}	12.2^{b}	1.25^{bc}
Oxadiargyl encapsulated with water soluble polymer on 3 DAT	85.0^{d}	15.4^{d}	59.4^{cd}	2.11^{c}	15.4^{ab}	12.6^{b}	1.33^{ab}
Oxadiargyl at 100 g/ha on 3 DAT	69.4^{e}	11.6^{ef}	47.0^{f}	1.94^{ef}	14.3^{bc}	12.0^{b}	1.19^{cd}
Butachlor at 1.25 kg/ha on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra	135.2^{b}	28.4^{b}	70.4^{b}	2.30^{b}	15.6^{ab}	12.9^{ab}	1.33^{ab}
Weed free check	165.3^{a}	43.0^{a}	81.4^{a}	2.49^{a}	16.5^{a}	13.6^{a}	1.40^{a}
Weedy check	60.1^{f}	10.0^{f}	40.6^{g}	1.85^{f}	13.4^{c}	11.0^{c}	1.13^{d}
LSD ($P \leq 0.05$)	8.6	2.4	5.3	0.14	1.4	0.9	0.11

DAS-Days after sowing, LSD- Least significant difference; significance levels from one way (ANOVA); Data followed by different lower case letters differs significantly (significance level ≤ 0.05).

residual effect of butachlor @ 1.25 kg/ha followed by MHW on 40 DAT in rice + two MHW on 20 and 40 DAS in subsequent okra registered significantly more N, P and K uptake, which was on par with oxadiargyl encapsulated with a water-soluble polymer, residual effect of oxadiargyl loaded zeolite and the residual impact of oxadiargyl loaded biochar. It may be due to the nutrients directly involved in the plant metabolic process like photosynthesis, respiration, enzyme activation and carbohydrate and protein metabolism (Bommayasamy and Chinnamuthu, 2022). The application of pre-emergence herbicide *fb* hand weeding recorded lower removal of nutrients by weeds, leading to higher uptake of the crop (Singh *et al*., 2011).

Nutritional quality of okra : Okra fruit quality is an integrated effect of nutritional, physiological and biochemical factors. Fruit quality like crude protein, crude fibre, ascorbic acid and mucilage content are important parameters that showed marked differences by various weed control treatments. Weed-free check registered higher crude protein, crude fibre, ascorbic acid, and mucilage content of 34.6, 23.1, 23.6 and 23.9%, respectively, compared with weedy check. However, this was comparable with residual effect of butachlor @ 1.25 kg/ha *fb* HW on 40 DAT in rice + two HW on 20 and 40 DAS in subsequent okra. Next order best weed control treatments were the residual effect of oxadiargyl encapsulated with water-soluble polymer on 3 DAT, the residual effect of oxadiargyl loaded zeolite, and the residual effect of the residual effect oxadiargyl loaded biochar. It might be due to higher N and K uptake enhanced enzymatic activities of amino acid synthesis which led to higher crude protein and ascorbic acid synthesis in okra fruit. A similar line of findings was reported earlier by Jena *et al*. (2002), Singhal *et al*. (2007), Chandolia (2009).

Conclusion

The results clearly showed that the residual effect of oxadiargyl loaded zeolite effectively controlled weeds and realized higher crop growth, productivity and nutritional quality of okra in the absence of sufficient physical labour.

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