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Research Paper

Integrated weed management in chilli (*Capsicum annuum*) grown after rice (*Oryza sativa*) under rice–fallow system

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ABSTRACT

A field experiment was conducted at the Instructional-cum-Research Farm of Assam Agricultural University, Jorhat during 2012 and 2013 to study the effect of weed management practices on growth and yield of chilli (*Capsicum annuum* L.) grown after winter rice (*Oryza sativa* L.). The study revealed that the weed density as well as dry weight were the lowest in all the treatment with metribuzin @ 500g/ha combined with and hand weeding at 30 and 60 or 30, 50 and 60 or 30, 60 and 80 days after planting (DAP) over rest of the treatments. Among the weed management treatments, a higher weed density was observed in the 3 treatments of quizalofop-p-ethyl @ 50 g/ha followed by hand weeding at 45 and 75 or 60 and 80 or 50 and 80 DAP. Plant height, days to 50% flowering, number of primary and secondary branches were recorded the highest in metribuzin treated plots. The fruit yield (fresh and dry) was also found to be higher in the metribuzin treated plots. The available nutrients were found to be lower in the metribuzin treated plots and the treatments with only and hand weeding at different day's interval. The yield loss was 0.29 t/ha under weedy check treatment as compared to the highest yield (3.41 t/ha) obtained from metribuzin 500 g/ha and hand weeding at 30, 50 and 80 DAP. The benefit: cost ratio was found to be the highest (2.60) in metribuzin @ 500 g/ha along with and hand weeding at 30, 50 and 80 DAP. The biochemical attributes like ascorbic acid (62.1 mg/100g) and capsaicin content (60.8 mg/100g) were found to be higher in metribuzin @ 500 g/ha with and hand weeding at 30 and 60 or 30, 50 and 80 days after planting. From this study, it could be inferred that application of metribuzin @ 500g/ha with and hand weeding at 30, 50 and 60 DAP controlled the weeds in chilli effectively and resulted higher fruit yield, quality of chilli and benefit: cost ratio.

Key words: Ascorbic acid, Capsaicin, Chilli, Integrated weed-management, Metribuzin, Quizalofop-p-ethyl,

Chilli is one of the most important vegetable-cum-spice crops valued for its aroma, taste, flavour and pungency. The world production of chilli is about 7 million tonnes, which is cultivated on approximately 1.5 million ha of land. India, the largest producer and exporter of chillies in the world, accounts for 1.1 million tonnes of annual production followed by China (around 0.4 million tonnes), Mexico and Pakistan (around 0.3 million tonnes each). Among the Indian states, Andhra Pradesh stands first in terms of production and area coverage under chilli cultivation. It alone commands for 49% of the chilli production in India, with a production of around 0.27 million tonnes of chillies. Karnataka follows Andhra Pradesh, contributing 14% of the country's production. But chilli growers faces a market problems like low price, heavy commission charges, non-availability of resources and lack of technical knowledge (Dangore *et al.,* 2015). Weed problems and pest and disease infestation also ranked high in chilli cultivation in comparison to other crops. Among all these weed problem is very severe. Weeds emerge fast and grow rapidly competing with the chilli crop severely for growth resources, viz. nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of the crop. In addition, they also transpire lot of valuable conserved moisture and absorb large quantities of nutrients from the soil depriving the crop. Further, wide space planting provided to the chilli allows fast growth of weed species causing considerable reduction in yield by affecting the plant growth and yield components. Presence of weed reduces the photosynthetic efficiency and their dry matter production and its mobilization to economical parts, which finally reduces the sink capacity of crop resulting in poor fruit yield. The extent of reduction in fruit yield due to weeds has been reported to be in the range of

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60 to 70% depending on the intensity and persistence of weed density in standing crop (Patel *et al.*, 2004). Clean and weed free cultivation is pre-requisite for successful crop production. However, effective weed management practices require large human labour and therefore it is costly as well as time consuming. Hence, integrated weed management by combining chemical control with mechanical weeding is one of the effective and timely operations to reduce crop-weed competition. Herbicides not only control weeds but also offer a great scope of minimizing the cost of weed control irrespective of situation mainly in the states like Assam, where there is a huge floristic diversity and faster weed growth rate due to high rainfall and lesser bright sunshine hours. However, there is no documented evidence of any work or research on chilli as a succeeding crop after winter (*sali*) rice in medium land situation, as well as management of weeds in chilli under such situations but there is a huge scope of utilizing these lands for cultivation of chilli. The cultivation of chilli in the lean period can provide income to the farmers and also it can reduce the infestation by the monophagous pests due to changing cropping system.

MATERIALS AND METHODS

The study was undertaken during winter (*rabi*)-summer season of 2012 and 2013 at Assam Agricultural University, Jorhat, Assam to develop integrated weed management for chilli. The farm is situated at 26°47' N, 94°12' E and altitude of 86.6 m from the mean sea level. The soil of experimental field was sandy clay loam with *p*H 5.4, organic carbon content 8.2 g/kg, 282.4 kg/ha of available nitrogen, 22.8 kg/ha available phosphorus and 178.2 kg/ha available potassium. A local Chilli variety '*kharika jolokia'* of *Capsicum annuum* group was used in the experiment. It is very popular variety among the people of Assam and frequently used for everyday consumption. The 10 treatments, viz., metribuzin @ 500 g/ha + hand weeding (HW) at 30 and 60 days after planting (DAP); metribuzin @ 500 g/ha + HW at 30, 60 and 80 DAP; metribuzin @ 500 g/ha + hand weeding at 30, 50 and 80 DAP, quizalofop-p-ethyl @ 50 g/ha + HW at 45 and 75 DAP, quizalofop-p-ethyl @ 50 g/ha + HW at 60 and 80 DAP; quizalofop-p-ethyl @ 50 g/ha + HW at 50 and 80 DAP; HW at 20, 40, 60 and 80 DAP, and HW at 25, 50 and 75 DAP; HW 30, 60 and 80 DAP and weedy check were tested in randomized block design with 3 replications. Sowing was done in second fortnight of January in both the seasons. Irrigation was provided at an interval of 7–10 days depending upon the rainfall pattern. During land preparation, cowdung was applied @ 2 t/ha and nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, at the rate of 120: 60: 60 kg/ha. The fertilizers were applied in two split doses first at 20 days after planting and second at 40 days after planting. The fertilizers were well mixed with vermicompost at the rate of 3t/ha and applied in ring method 5 cm away from the plant. Observations on weed flora, weed density, dry weight, plant height, number of primary and secondary branches, capsaicin and ascorbic acid content, fresh and dry yield of chilli were recorded. The analysis of soil sample for available N was done by using Kjeldahl method, P by Bray's I method, K by photometric method and organic carbon by Walkley and Black's titration. The capsaicin content of chilli was determined from each treatment by the method described by Quagliotti (1971) and Theymoli *et al.* (1982). Red dried chilli powder of 0.5 g was taken and 10 ml of dry acetone was added to it. Content was centrifuged at 10,000 rpm for 10 min. from clear supernatant 1 ml was taken and evaporated to dryness in hot water bath. Then the residue was dissolved in 5 ml of 0.4% sodium hydroxide solution and 3 ml of 3% phosphomolybdic acid, shaken and allowed to stand for an hour. The solution was filtered into centrifuge tubes and centrifuged at about 5000 rpm for 10 to 15 minutes. The clear blue coloured solution was directly transformed into the cuvette and the absorbance was read at 650 nm. A blank sample was run along with the test samples. A standard graph was prepared using 0–200 ìg capsaicin simultaneously.

The capsaicin content is calculated by using the following formula

$$\text{Capsaicin (\%)} = \frac{\mu\text{g Capsaicin}}{200}$$

The % capsaicin was converted to mg/100g.

The ascorbic acid content was analyzed by using the volumetric method as given by Sadasivam and Theymoli (1987). Green dried powdered chilli of 0.5 g was taken and extracted using 4% oxalic acid and volume was made up to 100 ml and centrifuged. The supernatant was filtered immediately, 5 ml of the supernatant was taken, and 10 ml of 4% oxalic acid was added to it. The solution was titrated using the dye 2,6-dichlorophenol indophenol. Standard was run along with the sample using 1 mg of ascorbic acid.

The amount of ascorbic acid was calculated using the following formula:

$$\text{Amount of ascorbic acid (mg/100g sample)} = \frac{0.5\text{ mg}}{\text{Volume used for standard titration}} \times \frac{\text{Volume used for sample titration}}{15\text{ ml}} \times \frac{100\text{ ml}}{\text{Weight of the sample}} \times 100$$

RESULTS AND DISCUSSION

Weed flora

During the whole crop season, predominant weed species comprised of 2 grass species, 5 broad leaved species and 1 species belonging to sedge (Fig. 1 and Fig. 2). *Oryza sativa*, the cultivated rice species was encountered as one of the major weed species. It was followed by *Cyperus rotundus, Oldenlandia diffusa* and *Polygonum glabrum.* Gare *et al.* (2015) also reported the domination of broad leaved weeds and grasses in transplanted chilli, which includes *Euphorbia hirta, Cynodon dactylon, Cyperus rotundus, Phyllanthus niruri, Amararnthus spinosus, Digera arvensis, Parthenium hysterophorus, Alternanthera triandra.*

Weed density and weed dry weight

The effect of different weed management practices showed that the treatments of metribuzin @ 500 g/ha and hand weeding (HW) at 30, 60 DAP, metribuzin @ 500 g/ha + HW 30, 50, 80 DAP and metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP recorded the lowest weed density throughout the crop season (Table 1). The higher fruit yield of chilli due to lower weed density during its critical growth stages has been reported earlier (Gare *et al.,* 2015). The treatments involving metribuzin @ 500 g/ha as pre-emergence resulted significantly lowest weed dry weight at 20 DAP. However, at 40 and 60 DAP, metribuzin application combined with HW resulted the lowest weed dry weight but these were at par with HW alone at 25, 50, 75 or 30, 60, 80 DAP. This indicated an effective early control of weeds by metribuzin and this effect could be sustained by the subsequent HW. Weed biomass reflects the growth potential of the weeds and is better indicator of its competitive ability with the crop plants (Arvadiya *et al.,* 2012). Weed control-efficiency increased the adoption of weed control measures over the unweeded plot (Gare *et al.,* 2015). This is due to the lower weed population as shown in Table 2.

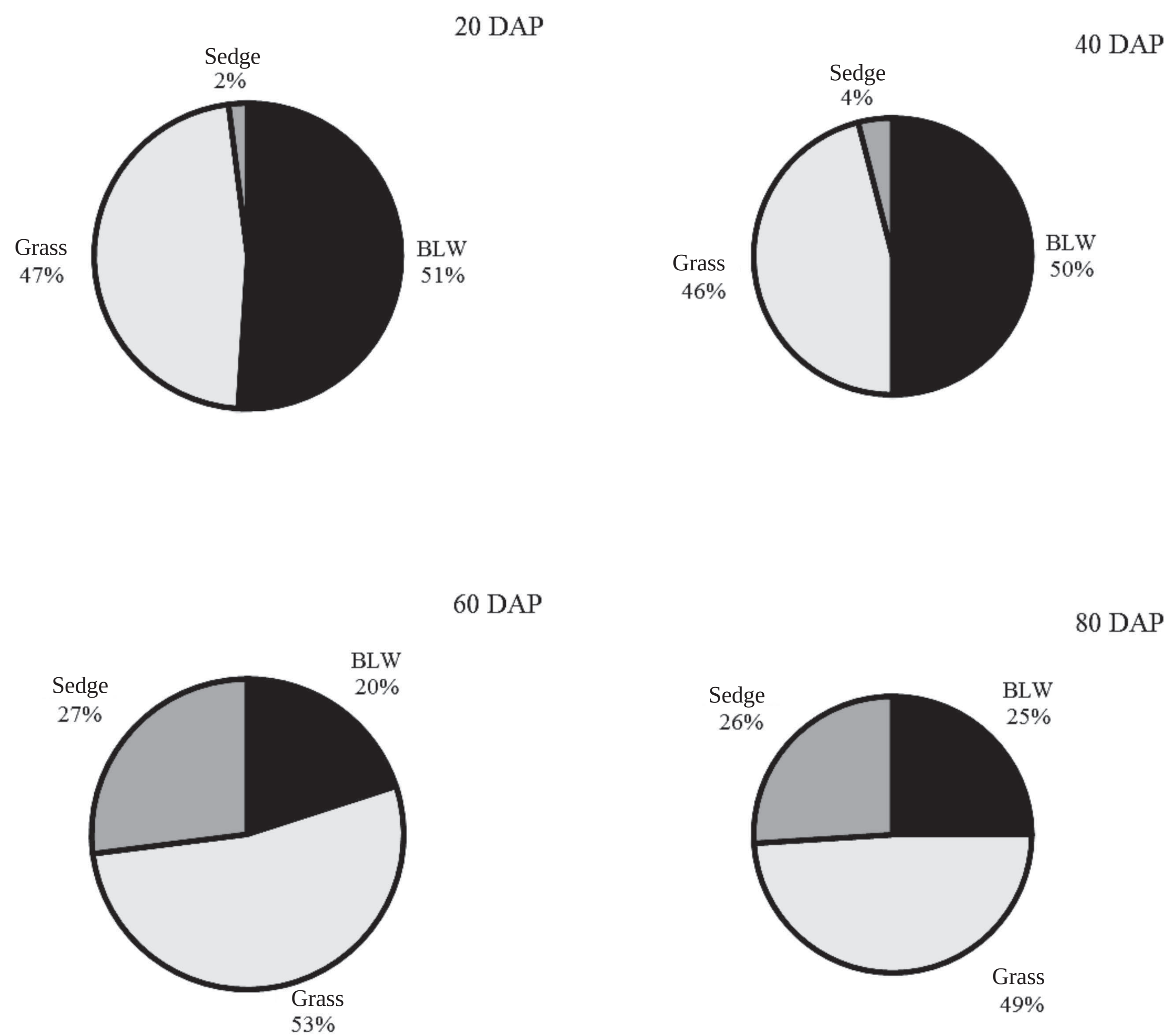

Fig. 1. Percentage of broad-leaved weeds (BLW), grasses, and sedge at 20, 40, 60, 80 DAP recorded in unweeded plot

Table 1. Effect of integrated weed management on weed density and weed dry weight (mean data of 2 years)

Treatment	Weed density (numbers/m^2)*				Weed dry weight (g/m^2)*			
	20 DAP	40 DAP	60 DAP	80 DAP	20 DAP	40 DAP	60 DAP	80 DAP
Metribuzin @ 500 g/ha + HW at 30, 60 DAP	3.9 (14.7)	5.4 (28.7)	5.8 (33.3)	5.1 (25.7)	1.5 (1.7)	3.9 (14.5)	4.6 (20.5)	5.2 (27.0)
Metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP	4.1 (15.79)	5.5 (29.3)	4.6 (21.0)	5.9 (34.0)	1.4 (1.5)	4.0 (15.3)	4.2 (16.9)	5.4 (28.3)
Metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP	4.0 (15.7)	5.4 (28.3)	5.6 (31.3)	5.2 (26.3)	1.4 (1.5)	4.0 (15.5)	4.5 (20.2)	5.1 (26.0)
Quizalofop-p-ethyl @ 50 g/ha + HW at 45, 75 DAP	7.8 (61.0)	9.5 (90.3)	6.9 (47.7)	7.2 (51.0)	3.8 (14.0)	7.8 (61.0)	4.9 (24.0)	5.9 (34.0)
Quizalofop-p-ethyl @ 50 g/ha + HW at 60, 80 DAP	7.6 (57.0)	9.8 (94.7)	7.9 (61.7)	6.1 (36.7)	3.8 (14.0)	7.7 (59.3)	5.8 (33.5)	5.6 (31.3)
Quizalofop-p-ethyl @ 50 g/ha + HW at 50, 80 DAP	7.8 (61.0)	9.6 (92.0)	6.5 (42.0)	7.4 (54.0)	3.7 (13.0)	7.9 (62.3)	4.6 (20.7)	5.8 (32.7)
HW at 20, 40, 60, 80 DAP	7.7 (59.3)	7.0 (48.7)	6.7 (44.0)	5.6 (31.0)	3.9 (14.9)	4.7 (21.3)	4.2 (16.8)	5.2 (26.7)
HW at 25, 50, 75 DAP	7.9 (62.3)	5.9 (34.0)	6.1 (36.7)	5.4 (28.3)	3.8 (14.0)	4.0 (15.7)	4.1 (16.4)	5.9 (34.7)
HW at 30, 60, 80 DAP	7.7 (59.3)	6.2 (38.0)	6.5 (42.0)	5.3 (27.3)	3.7 (13.3)	3.8 (13.7)	4.8 (22.7)	5.3 (27.5)
Unweeded control	7.8 (61.0)	11.6 (133.3)	14.1 (185.7)	14.1(198.7)	3.8 (14.2)	9.4 (88.0)	10.1(102.0)	11.3(126.3)
SEm±	0.36	0.43	0.60	0.36	0.30	0.43	0.28	0.46
CD (P=0.05)	1.08	1.28	1.78	1.07	0.89	1.27	0.83	1.36

*, Square root transformed data, Original data in parentheses; HW, hand weeding; DAP, days after planting

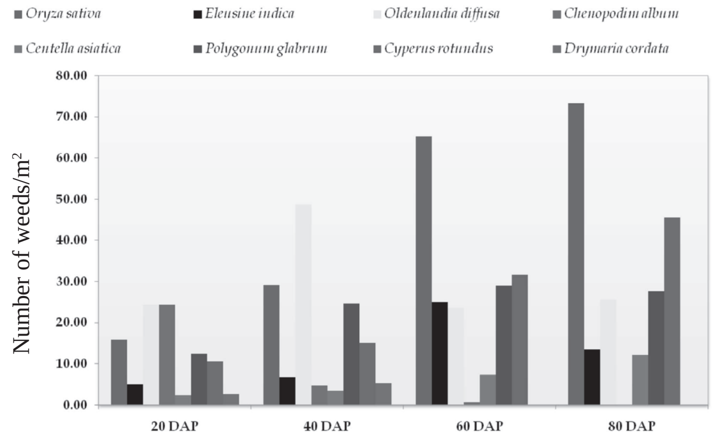

Fig. 2. Dynamics of weed flora in unweeded control in rice-chilli crop situation

Plant height and number of branches

The highest plant height at 30 DAP was recorded in treatment with metribuzin @ 500 g/ha + HW at 30, 60 DAP followed by metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP (Table 2). At 60 DAP, plant height was highest with metribuzin @ 500 g/ha + HW 30, 50, 80 DAP and it was at par with metribuzin @ 500 g/ha + HW 30, 60 DAP, metribuzin @ 500 g/ha + hand weeding at 30, 60, 80 DAP, quizalofop-p-ethyl @ 50 g/ha + hand weeding at 50, 80 DAP, hand weeding at 20, 40, 60, 80 DAP, hand weeding at 25, 50, 75 DAP and hand weeding at 30, 60, 80 DAP. The highest plant height was recorded at harvest in metribuzin @ 500 g/ha + HW 30, 60 DAP which was at par with HW at 20, 40, 60 and 80 DAP. The crop-weed interference is reported up to 39% reduction in plant height and other plant growth variables like stem diameter and internode length (Amador *et al.,* 2007). Integrated weed management practices helps in achieving good plant height and yield (Pal *et. al.,* 2016).

Primary branches per plant was recorded the highest with metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP, which was followed by the treatment with metribuzin @ 500 g/ha + HW at 30, 60 DAP, metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP, HW at 20, 40, 60, 80 DAP and HW at 25, 50, 75 DAP and HW at 30, 60, 80 DAP; while the number of secondary branches/plant was recorded the highest in metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP and it was at par with metribuzin @ 500 g/ha and hand weeding 30, 60 DAP, metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP and all other treatments involving and hand weeding alone. The difference in the number of branches is found to be one of the factors affected by weed since the growth rate of weed is faster as compared to chilli and weed covers the area and dominates over the main crop.

Fresh and dry weight of fruits

The fresh yield of chilli was the highest in metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP, which was at par with treatment metribuzin @ 500 g/ha + hand weeding at 30, 60, 80 DAP and metribuzin @ 500 g/ha + HW at 30, 60 DAP (Table 3). All these treatments resulted significantly higher yield of fresh fruit as compared to rest of the treatments. Similar trend of result was also observed in respect of dry fruit yield of chilli. Higher content of capsaicin and ascorbic acid in treatments with metribuzin followed by hand weeding confirmed better quality of chilli. Nearly weed free conditions maintained during the early crop growth stages in these above mentioned treatments, might have mainly contributed to better plant growth and yield attributing characters thereby resulting higher yields as compared to weedy check and rest of the treatments. A reduction of 91.6% in fresh fruit and dry fruit yield due to unchecked weed growth in weedy check as compared to the highest yield obtained in metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP was found. The yield reduction in chilli due to uncontrolled weed infestation throughout the crop life cycle was recorded up to 70 to 90 % (Prakash *et al.*, 2003). Moreover, losses due to weed also depends upon the nature of weed species as well as total intensity of weeds (Patel *et al*. 2004). Mandeep and Walia (2012) reported that application of pre-emergence herbicides followed by and hand weeding at 45 days after planting yielded better returns.

Biochemical parameters

Higher content of capsaicin and ascorbic acid with metribuzin followed by mechanical weeding confirmed better quality of chilli. The amount of capsaicin is known to increase under dry and stressful conditions. In the plots where the herbicide metribuzin was applied and weeding was done at regular intervals the capsaicin content was increased (Table 2). It was reported that water deficit affected the phenylpropanoid metabolism and the pungency of pepper fruits (Estrada *et al.*, 1999). The probable reasons would be due to the removal of weeds at regular intervals, which removes the moisture from the soil. Nevertheless, the plants in weedy check are covered or the presence of weeds that helps to retain soil moisture in the soil, which did not let the plant to suffer from water stress condition. Therefore, this has led to lower capsaicin content in the fruits obtained from weedy check.

Available soil N, P, K and organic carbon

Organic carbon content and available content of N, P and K were not significantly affected by the treatments. However, the highest available N and P-content were recorded in unweeded plot. Among the treatments, application of quizalofop @ 50 g/ha + HW at 60, 80 DAP recorded the highest N- content, while treatments involving metribuzin 500g/ha + HW at different stages as well as HW at 25, 50, 75 DAP and HW at 20, 40, 60, 80 DAP. The available P-content was higher in the treatment with quizalofop-p-ethyl @ 50 g/ha + HW at 60, 80 DAP and the lowest in treatment of metribuzin @ 500 g/ha + HW at 30, 60 DAP and hand-weeding at 25, 50, 75 DAP. The available K was found to be the highest due to quizalofop-p-ethyl @ 50 g/ha + HW at 45, 75 DAP and quizalofop-p-ethyl @ 50 g/ha + HW at 60, 80 DAP (Table 3). Treatments involving metribuzin caused decrease in the status

Table 2. Effect of integrated weed management on weed control efficiency, plant height, branches/plant and biochemical parameters of chilli (mean data of 2 years)

Treatment	WCE at 40 DAP	WCE at 80 DAP	Plant height (cm) (at harvest)	Primary branches/ plant	Secondary branches/ plant	Ascorbic acid content (mg/100g)	Capsaicin content (mg/100g)
Metribuzin @ 500 g/ha + HW at 30, 60 DAP	90.6	82.8	122.3	13.3	15.7	62.1	60.4
Metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP	91.2	79.7	112.7	14.4	15.9	62.1	60.8
Metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP	90.9	84.5	110.7	14.1	15.8	60.4	60.0
Quizalofop-p-ethyl @ 50 g/ha + HW at 45, 75 DAP	52.7	85.9	100.9	10.5	12.3	44.0	52.7
Quizalofop-p-ethyl @ 50 g/ha + HW at 60, 80 DAP	58.0	82.4	111.5	9.7	11.4	44.1	52.7
Quizalofop-p-ethyl @ 50 g/ha + HW at 50, 80 DAP	53.6	80.3	109.0	10.2	11.9	44.4	55.2
HW at 20, 40, 60, 80 DAP	76.1	80.1	121.4	12.3	14.4	53.3	59.0
HW at 25, 50, 75 DAP	79.1	86.0	118.9	12.1	14.8	52.9	54.8
HW at 30, 60, 80 DAP	82.1	78.0	109.1	11.9	14.9	59.3	48.5
Unweeded control	0.0	0.0	84.8	8.2	10.4	43.1	40.0
SEm±	-	-	1.35	0.350	0.361	0.40	0.99
CD (P=0.05)	-	-	4.02	1.039	1.072	1.62	1.62

HW, handing weeding; DAP, days after planting; WCE, weed control efficiency

Table 3. Effect of integrated weed management on yield of chilli, net returns, benefit: cost ratio and available nutrient contents (mean data of 2 years)

Treatment	Fresh weight (t/ha)	Dry weight (t/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Metribuzin @ 500 g/ha + HW at 30, 60 DAP	10.34	6.76	68.1	2.41	0.5	298.3	11.6	144.3
Metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP	10.62	6.92	73.9	2.58	0.5	298.7	11.7	147.7
Metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP	6.08	3.98	72.7	2.55	0.5	301.3	11.7	145.7
Quizalofop-p-ethyl @ 50 g/ha + HW at 45, 75 DAP	2.78	1.81	18.7	0.68	0.5	313.7	12.8	154.0
Quizalofop-p-ethyl @ 50 g/ha + HW at 60, 80 DAP	2.41	1.57	14.2	0.52	0.6	315.3	12.5	154.0
Quizalofop-p-ethyl @ 50 g/ha + HW at 50, 80 DAP	2.20	1.43	11.2	0.41	0.6	312.0	12.7	153.3
HW at 20, 40, 60, 80 DAP	8.84	5.74	57.2	2.05	0.5	297.7	11.7	144.7
HW at 25, 50, 75 DAP	8.07	5.24	50.4	1.82	0.6	293.3	11.6	147.7
HW at 30, 60, 80 DAP	7.65	5.05	49.0	1.77	0.6	313.7	12.6	152.0
Unweeded control	0.66	0.43	-18.3	-0.68	0.6	316.7	13.0	151.3
SEm±	6.87	5.38	0.37	0.04	0.03	1.23	0.20	0.45
CD (P=0.05)	17.56	14.71	1.11	0.13	NS	NS	NS	NS

HW, Hand weeding

of available K. It could be inferred that a better plant growth might have caused removal of more amount of nutrients from leaving lesser amount of available N, P and K in soil in the treatments with metribuzin as well as and HW. Rajkumara (2009) reported that unweeded check resulted in significantly higher nitrogen uptake.

Economic evaluation

Cost of cultivation was recoreded the lowest with HW at 25, 50, 75 DAP followed by weeding at 30, 60, 80 DAP excluding weedy check (Table 3). Gross and net returns were recorded the highest in metribuzin @ 500 g/ha + HW at 30, 50, 80 DAP, which was closely followed by metribuzin @ 500 g/ha + HW at 30, 60, 80 DAP. The highest benefit: cost ratio was obtained in these two treatments followed by metribuzin @ 500 g/ha + HW at 30, 60 DAP. Similar results were reported by Biradar (1999) by using herbicide at varied rate or in combination with and HW which gave more profit compared to weedy check.

Based on the study it is concluded that, application of metribuzin along with two to three mechanical weeding was able to give sustained weed control during the whole crop-growing season.

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