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Studies on Effect of different Pre-emergence Herbicides on Weed Dynamics in Kodo millet (*Paspalum scrobiculatum* L.)

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A B S T R A C T

A field experiment was conducted during *Kharif* 2019 at MRS, Hebbal under AICRP on weed management, Bengaluru to evaluate different pre-emergence herbicides in kodo millet. The experiment consists of twelve treatments laid out in randomised complete block design. The experiment consisted of five pre-emergence herbicides (oxadiargyl, bensulfuron methyl + pretilachlor, butachlor, pendimethalin and atrazine) each at two different doses which were compared with weed free control and unweeded check. Among different pre-emergence herbicides, application of bensulfuron methyl 0.6 G + pretilachlor6.0 Gat 0.330 kg a.i. ha^{-1} at 3 days after sowing recorded lower total weed density and weed dry dry weight at 30, 60 and 90 DAS (5.72m^{-2}, 1.41g m^{-2}; 6.96 m^{-2}, 2.06g m^{-2}; 6.56m^{-2}, 1.94 g m^{-2}respectively). The same treatment also recorded higher weed control efficiency (59.21 %) without any phytotoxic effect on kodo millet. Good control of weeds at critical stage in this treatment produced higher grain (2225kg ha^{-1}) and straw yield (4258 kg ha^{-1}) which gave higher net returns (49363 Rs. ha^{-1}) and B:C ratio (2.74), which was on par with bensulfuron methyl 0.6 G + pretilachlor6 Gat 0.165 kg a.i.ha^{-1}. These pre-emergence herbicides have reduced the cost of cultivation producing higher profit under the present situation of labour scarce and high labour cost for weeding.

Introduction

Millets are recognized as an integral part of Indian diet. Millets are referred as coarse cereals and also poor man’s cereals. India produces millets in a huge amount. Millets are of two groups namely minor or small millets and major millets. Finger millet, Kodo millet, Proso millet, Little millet, Barnyard millet and Foxtail millet are the dominant minor millets cultivated in India, they belong to family Poaceae. In the minor millets, kodo millet is more important in India and in the Deccan plateau. It is known as haraka (in kannada), cow grass, native paspalum, Indian crown grass and known to be originated from tropical Africa. It is rich in its nutrient content and it is supercilious to rice and wheat in terms of higher protein, fibre content and lesser fat content, which are main for the nutrient and energy requirement of human. It is drought tolerant, hardy crop which can be grown on poor unproductive soils where other crops may not survive. Frequently it comes up as a weed in the rice crop and consumed as kodo rice.

Small millets occupy an area of 24.21 m ha with 46.99 mt total production in India and kodo millet occupies an area of 1.96 lakh ha, production of 0.84 lakh tonnes and 429 kg ha^{-1} productivity. Kodo millet is grown majorly in the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka. In Karnataka, about 3.42 m ha area is occupied by small millets with production of 6.27 mt and have a productivity of 333 kg ha^{-1}(Directorate of economics & statistics, 2017-18).

The crop has higher yielding potential, but its lower productivity in India and Karnataka when compared to the world is because of biotic stress which is the major reasons for lower productivity and poor performance of kodo millet. The major biotic stress is weed and so the weeds are scrutinized as the main obstacle in crop cultivation during the rainy season. Weeds interfere with the crop and compete for nutrients, moisture, space and light and reduces not only the yield but also the quality of produce causing an agricultural loss of about 37 per cent (Yaduraju, 2006). As this kodo millet is widely grown in semi-arid areas and in marginal land under inadequate weed management practices weeds become major cause for lower productivity. Due to slow initial growth, it faces higher competition by weeds in the primary growth stages of the crop itself. Weed-free environment right from emergence up to 30-35 days after sowing as it is the critical time for the competition between crop and weeds. Kasasian and Seeyave (1969) suggested that the first quarter (1/4th) to one-third (1/3rd) period of total crop duration as "the critical period" for crop-weed competition. It is more important to control the weeds in the early growth stage of the crop to provide favourable weed free condition for good establishment of the crop. The control of weed growth by the application of weedicides will be most effective when applied in the early stage of weeds.

Common weeds in millets are *Echinochloa colonum, Echinocloa crusgulli, Dactyloctenium aegypticum, Digitaria marginata, Elusine indica, Setaria glauca, Cyperus rotundus, Cyanodon dactylon, Ageratum conyzoides, Alternanthera sessilis, Commelina benghalensis* (Mishra *et al.*, 2018). The decrease in the kodo millet yield because of weeds may be about 55-61 per cent if weeds are not controlled depending upon soil moisture level, cultivars, soil form and other environmental conditions. Therefore, weed management is a principal factor for improving the productivity of kodo millet. The current study is proposed to study the evaluation of pre-emergence herbicides in Kodo millet, with this background a field study was conducted on "Evaluation of pre-emergent herbicides in kodo millet (*Paspalum scrobicutalum* L.) at main research station, Hebbal, Bengaluru during the year 2019-20.

Materials and Methods

The field experiment was conducted at the Main Research Station (MRS), University of Agricultural Sciences, Hebbal, Bengaluru which is located in the agro-climatic zone V (Eastern Dry Zone) of Karnataka at a latitude of 12^{o} 50' North, a longitude 77^{o} 35' East and at an altitude of 899 meters above mean sea level. During the cropping period from July to October 2019, total rainfall of 768.6 mm was received with the maximum temperature ranged between 27.5°C and 34.7°C while the minimum temperature ranged between 13.10°C and 20.7°C. The soil of the experimental site was red sandyloam soil with acidic p^H (6.25) and low electrical conductivity is ($0.25 dSm^{-1}$). The soil was medium in available nitrogen($285.7 kgha^{-1}$), available phosphorus (29.62 kg P_2O_5 ha^{-1}) and available potassium (192.4 kg K_2O ha^{-1}). The experiment was laid out in randomized complete block design with three replications involving twelve treatments namely Oxadiargyl 80 WP at 150 g a. i. ha^{-1}, Oxadiargyl 80 WP at 200 g a. i. ha^{-1}, Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}, Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}, Butachlor 50 EC at 500 g a. i. ha^{-1}, Butachlor50 EC at 750 g a. i. ha^{-1}, Pendimethalin 38.7 EC at 500 g a. i. ha^{-1}, Pendimethalin 38.7 EC at 1000 g a. i. ha^{-1}, Atrazine 50 WP at 500 g a. i. ha^{-1}, Atrazine 50 WP at 750 g a. i. ha^{-1} which are compared with weed free and un weeded check. The main field was ploughed at optimum moisture condition with tractor and brought to a fine tilth. Line sowing of seeds was taken up by mixing the seeds with sand at 1:3 ratio for easy handling. The crop was sown on July 15^{th} during the *Kharif* season using kodo millet variety RK 390-25 at the seed rate of 8kg per ha. The crop was fertilized with 40:20:0 kg of N, P_2O_5 and K_2O ha^{-1} in the form of urea and DAP. These pre-emergence herbicides are sprayed on third day after sowing using knapsack sprayer fitted with flood jet nozzle. Total weed counts were recorded at 30, 60 and 90 DAS from two quadrats each of area 1m X1m and expressed in number m^{-2}. The weed in the sample quadrats were collected in each plot separately at 30, 60 and 90 DAS and was oven dried at 60°C ± 5°C for 48 hours, a constant weight obtained and expressed in gram m^{-2}. The phytotoxic effect of herbicides on the crop and effect of herbicides in weed control was recorded using phytotoxicity score rating (0-10), zero (no toxicity) to ten (100% toxicity) scale (Anon., 1981)at 1, 3, 5, 7, 10, 15, 20, 25 and 30 days after application of herbicide. The observations on weed control efficiency was calculated using the formulas given by Patel *et al.*, (1987).

$$WCE(\%) = \frac{(Wo - Wt)}{Wo} \times 100$$

Where,

WCE: Weed control efficiency expressed in percentage

Wo: Total dry weight of weeds from unweeded plot.

Wt: Total dry weight of weeds from treated plot.

Data obtained from the experiment was analysed by using the technique of analysis of variance (ANOVA) and the difference between treatment means was tested for their statistical significance with appropriate critical difference (CD) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Weed observations

Predominant weed species

The weed species noticed in the experimental field during the crop growth period in *Kharif*,2019 were of three categories, they were sedges, grasses and broad- leaf weeds (Appendix I).

The major sedge weed observed in association with crop was *Cyperus rotundus* and the grasses were *Cynodond actylon, Brachiraria ramose, Chloris barbata, Dactyloctenium aegyptium, Digitaria marginata, Eleusine indica* and *Echino cloacolona*. The broad leaf weeds observed were *Ageratum conyzoides, Alternanthera sessilis, Commelina* *benghalensis, Cinebra didema, Euphorbia hirta* and *Syndrella nodiflora.*

The other weeds observed in less numbers were *Sateriagluca (grass), Amaranthus viridis, Acanthospermum hispida, Cleome viscose, Borreria hispida, Mimosa pudica, Phyllanthus niruri, Sida acuta* and *Tridax procumbens* (Broad leaf weeds). The broad-leaved weeds were dominant and the lowest were sedges, based on the weed density under weedy check situation. As observed in this study, similar weed flora was reported by Patil *et al.*, (2013); Kujur *et al.*, 2015; Mishra *et al.*, 2018.

Total weed counts (m^{-2}) on 30, 60 and 90 DAS

Application of bensulfuron methyl 0.6 % G + pretilachlor 6.0 % G 0.330 kg a. i. ha^{-1}recorded significantly lower total weed density per square at all stages of 30, 60 and 90 DAS (5.72, 6.96 and 6.56 no. m^{-2} respectively) which was on par with bensulfuron methyl 0.6 % G + pretilachlor 6.0 % G 0.165 kg a. i. ha^{-1}(6.27, 7.01 and 6.72no. m^{-2} respectively) *fb* T_{11}: weed free (7.23, 7.29 and 6.92no. m^{-2} respectively) compared to other treatments.

However unweeded check(11.56, 10.7 and 10.19no. m^{-2} respectively) followed by atrazine 50 WP at 750 g a. i. ha^{-1}recorded higher number of all category weeds at all the stages (Table 1). Similar results were obtained in the works of Prashanth Kumar *et al.*, (2015) and Satish Kumar Pandey *et al.*, (2018).

Total weed dry weight (g m^{-2}) at 30, 60 and 90 DAS

Bensulfuron methyl 0.6 % G + pretilachlor 6.0 % G 0.165 kg a. i. ha^{-1} (1.41, 2.06 and 1.94 g m^{-2}respectively) and bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}(1.41, 2.24 and 2.04 g m^{-2} respectively) *fb* weed free condition (1.83, 2.42 and 2.44 g m^{-2} respectively) recorded significantly lower total weed dry weight compared to other treatments at 30, 60 and 90 DAS.

The next best herbicide treatment was found to be butachlor 50 EC at 500 g a. i. ha^{-1}(2.05g m^{-2}) for control of weeds at 30 DAS.

Unweeded check recorded highest total weed dry weight (3.94, 4.50 and 4.40 g m^{-2}, respectively) at all the crop growth stages (Table 2).

Lower dry weight of weeds in Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1} and Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}at all the stages was mainly attributed to effective control of sedges and broad leaf weedsand good establishment of crop plants in these treatments without any phytotoxicity of herbicides on crop plants (Shanmugapriya *et al*., 2019).

Weed control efficiency

Among different pre-emergent herbicidal treatments, significantly highest weed control efficiency (59.21 %) (Table 3) was recorded with the application of bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1} which was on par with bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1} (57.34 %) *fb* weed free treatment (49.44 %) which was because of good suppression and control of all types of weeds which led to lower dry matter production by the weeds.

Butachlor 50 EC at 750 g a. i. ha^{-1} and atrazine 50 WP at 750 g a. i. ha^{-1} recorded lower WCE of 21.95 and 22.13 % respectively which was due to poor and no proper control of weeds Shanmugapriya *et al.*, (2019) and Kabita Mishra (2019).

Table.1 Total weed count (no. m^{-2}) at 30, 60 and 90 DAS as influenced by application of different pre-emergent herbicides in kodomillet

Treatments	30 DAS	60 DAS	90 DAS
T_1: Oxadiargyl 80 WP at 150 g a. i. ha^{-1}	9.74(94.67)	9.78(95.33)	8.90(78.67)
T_2: Oxadiargyl 80 WP at 200 g a. i. ha^{-1}	9.02(81.00)	9.48(89.33)	8.86(78.00)
T_3: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}	6.27(39.00)	7.01(48.67)	6.72(44.67)
T_4: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}	5.72(32.67)	6.96(48.00)	6.56(42.67)
T_5: Butachlor 50 EC at 500 g a. i. ha^{-1}	9.07(82.00)	8.67(74.67)	8.47(71.33)
T_6: Butachlor 50 EC at 750 g a. i. ha^{-1}	10.15(102.67)	10.06(100.7)	9.19(84.00)
T_7: Pendimethalin 38.7 EC at 500 g a. i. ha^{-1}	10.12(102.00)	8.47(71.33)	7.86(61.33)
T_8: Pendimethalin 38.7 EC at 1000 g a. i. ha^{-1}	9.72(94.67)	8.15(66.00)	7.73(59.33)
T_9: Atrazine 50 WP at 500 g a. i. ha^{-1}	7.56(56.67)	10.12(102.0)	9.16(83.33)
T_{10}: Atrazine 50 WP at 750 g a. i. ha^{-1}	8.30(68.67)	9.58(91.33)	9.30(86.00)
T_{11}: Weed Free	7.23(52.00)	7.29(52.67)	6.92(47.33)
T_{12}: Un weeded check	11.56(133.3)	10.70(114.0)	10.19(103.33)
F test	*	*	*
S.E m±	0.299441	0.147	0.122
CD(p=0.05)	0.878285	0.431	0.358

Data analysed using Square root of (x+1) transformation, ( )= Data given in parenthesis are original values, DAS= Days after sowing

Table.2 Total weed dry weight of weedsat 30, 60 and 90 DAS (g m^{-2}) as influenced by application of different preemergent herbicides in kodo millet

Treatments	30 DAS	60 DAS	90 DAS
T_1: Oxadiargyl 80 WP at 150 g a. i. ha^{-1}	2.27(4.66)	2.68(6.70)	3.27(10.20)
T_2: Oxadiargyl 80 WP at 200 g a. i. ha^{-1}	2.39(5.23)	2.89(7.86)	3.14(9.37)
T_3: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}	1.41(1.49)	2.24(4.54)	2.04(3.67)
T_4: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}	1.41(1.48)	2.06(3.72)	1.94(3.27)
T_5: Butachlor 50 EC at 500 g a. i. ha^{-1}	2.05(3.70)	3.27(10.18)	3.36(10.80)
T_6: Butachlor 50 EC at 750 g a. i. ha^{-1}	2.62(6.37)	3.49(11.67)	3.90(14.77)
T_7: Pendimethalin 38.7 EC at 500 g a. i. ha^{-1}	3.11(9.15)	3.18(9.59)	3.17(9.57)
T_8: Pendimethalin 38.7 EC at 1000 g a. i. ha^{-1}	2.74(7.04)	3.10(9.10)	3.33(10.57)
T_9: Atrazine 50 WP at 500 g a. i. ha^{-1}	2.33(4.92)	3.52(11.87)	3.95(15.17)
T_{10}: Atrazine 50 WP at 750 g a. i. ha^{-1}	2.00(3.53)	3.64(12.74)	4.25(17.60)
T_{11}: Weed Free	1.83(2.86)	2.42(5.37)	2.44(5.47)
T_{12}: Unweeded check	3.94(14.99)	4.50(19.73)	4.40(18.87)
F test	*	*	*
S.Em±	0.055	0.059	0.084
CD(p=0.05)	0.161	0.175	0.245

Data analysed using Square root of (x+1) transformation, ( )= Data given in parenthesis are original values, DAS= Days after sowing

Table.3 Weed control efficiency in kodo millet as influenced by different pre-emergent herbicidal treatments

Treatments	WCE (%)
T_1: Oxadiargyl 80 WP at 150 g a. i. ha^{-1}	35.34
T_2: Oxadiargyl 80 WP at 200 g a. i. ha^{-1}	34.85
T_3: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}	57.34
T_4: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}	59.21
T_5: Butachlor EC at 50 500 g a. i. ha^{-1}	33.14
T_6: Butachlor 50 EC at 750 g a. i. ha^{-1}	21.95
T_7: Pendimethalin 38.7 EC at 500 g a. i. ha^{-1}	28.85
T_8: Pendimethalin 38.7 EC at 1000 g a. i. ha^{-1}	29.95
T_9: Atrazine 50 WP at 500 g a. i. ha^{-1}	23.74
T_{10}: Atrazine 50 WP at 750 g a. i. ha^{-1}	22.13
T_{11}: Weed Free	49.44
T_{12}: Un weeded check	-
F test	*
S.Em±	1.130
CD(p=0.05)	3.334

Table.4 Visual phytotoxicity symptoms score of pre-emergent herbicides on kodo millet crop and scale of weed control ratings as influenced by different pre-emergent herbicide treatments

Treatments	Phytotoxicity rating on crop (0-10 scale)			Rating on weeds (0-10 scale)		
	Days after herbicide application			Days after herbicide application		
	5	15	30	30	60	90
T_1: Oxadiargyl 80 WP at 150 g a. i. ha^{-1}	0	1	2	4	3	3
T_2: Oxadiargyl 80 WP at 200 g a. i. ha^{-1}	0	1	2	4	4	3
T_3: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}	0	0	0	8	7	6
T_4: Bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1}	0	0	0	8	7	7
T_5: Butachlor EC at 50 500 g a. i. ha^{-1}	0	1	1	4	4	3
T_6: Butachlor 50 EC at 750 g a. i. ha^{-1}	0	1	3	3	2	2
T_7: Pendimethalin 38.7 EC at 500 g a. i. ha^{-1}	0	0	1	5	4	4
T_8: Pendimethalin 38.7 EC at 1000 g a. i. ha^{-1}	0	0	1	5	5	4
T_9: Atrazine 50 WP at 500 g a. i. ha^{-1}	4	5	5	3	3	2
T_{10}: Atrazine 50 WP at 750 g a. i. ha^{-1}	5	9	10	3	2	1

Appendix.I List of weeds observed in the experimental site along with their botanical name, common name and family

Botanical name	Common name	Family
Sedges		
Cyperus rotundus L.	Purple nut sedge	Cyperaceae
Grasses		
Chloris barbata	Swollen finger grass	Poaceae
Cyanadondactylon L.	Bermuda grass	Poaceae
Dactylocteniumaegyptium L.	Egyptian crow foot grass	Poaceae
Digitariamarginata L.	Tropical finger grass	Poaceae
Echinochloacolona L.	Jungle rice	Poaceae
Eleusine indica L.	Indian goose grass	Poaceae
SetariaglaucaL.	Yellow fox tail millet	Poaceae
Brachiaria ramose L.	Browntop millet	Poaceae
Broad leaved weeds		
Acanthospermumhispidum	Goat's head	Asteraceae
Ageratum conyzoides L.	Goat weed	Asteraceae
Alternanthera sessilis (L.)	Dwarf copper	Amaranthaceae
Amaranthus viridis L.	Green amaranth	Amaranthaceae
Borreria stricta L.	Shaggy button plant	Rubiaceae
Commelinabenghalensis L.	Sow thistle	Asteraceae
Cleome viscosa L.	Tick weed	Cleomaceae
Euphorbia geniculate L.	Milk weed	Euphorbiaceae
Euphorbia hirta L.	Asthama weed	Euphorbiaceae
Mimosa pudica L.	Touch me not	Fabaceae
Phyllanthus niruri L.	Stone breaker	Phyllanthaceae
Synedrellanodiflora	Cinderella weed	Asteraceae

Fig.1 Gross income, Net income and cost of cultivation (Rs. ha^{-1}) of kodo millet as influenced by different pre-emergent herbicides application

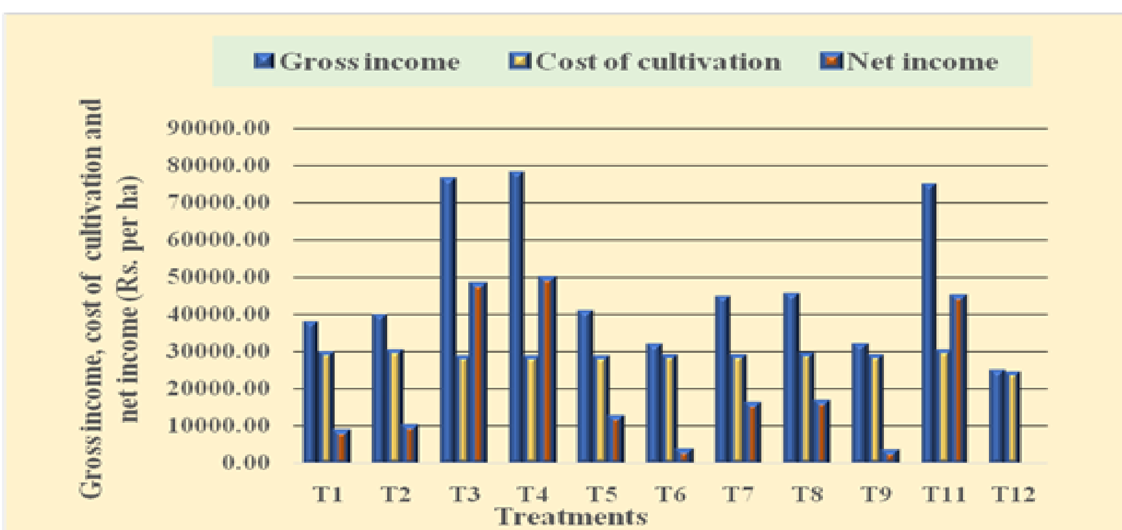

Plate.1 Phytotoxicity of application of atrazine 50 WP at 750g a. i. ha^{-1} on kodo millet

Visual phytotoxic symptoms on crop and scale of weed control ratings

Application of different pre-emergent herbicides spray was assessed for phytotoxicity on kodo millet crop and it was found that application of bensulfuron methyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1} and at 0.330 kg a. i. ha^{-1} had no injury or phytotoxic effect on the kodo millet crop, while application of atrazine 50 WP at 750 kg a. i. ha^{-1} showed discoloration and necrosis of the plants initially then complete destruction of the crop was noticed.

Weed control rating scale was also given and found that application of bensulfuron methyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1} (T$_3$) and at 0.330 kg a. i. ha^{-1} (T$_4$) gave good control of weeds but at later stages of70 DAS there was deficient control.

Economics

Higher net returns (49363 Rs. ha^{-1}) was obtained with bensufuron methyl 0.6 G + pretilachlor 6.0 G and at 0.330 kg a. i. ha^{-1} *fb*bensufuron methyl 0.6 G + pretilachlor 6.0 G and at 0.165 kg a. i. ha^{-1} (47650 Rs. ha^{-1}) and weed free treatment (44507 Rs. ha^{-1}) which was because of higher yields of grain (2225, 2175 and 2131 kg ha^{-1} respectively)and straw (4258, 4121 and 3938 kg ha^{-1} respectively) which fetched higher gross returns and cost of cultivation in these treatments was less due to lower price of herbicide (Fig. 1). B:C ratio of the herbicidal treatments bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.330 kg a. i. ha^{-1} (2.74) and bensulfuronmethyl 0.6 G + pretilachlor 6.0 G at 0.165 kg a. i. ha^{-1}(2.68) were higher because of higher gross returns and lower cost of cultivation (Yogananda *et al.*, 2017).

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