International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(8): 236-239
www.biochemjournal.com
Received: 09-05-2024
Accepted: 13-06-2024

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Effect of herbicides on yield and yield attributes of kodo millet (*Paspalum scrobiculatum* L.)

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DOI: https://doi.org/10.33545/26174693.2024.v8.i8d.1743

Abstract
The present experiment entitled "Effect of herbicides on yield and yield attributes of kodo millet (*Paspalum scrobiculatum* L.)" was conducted during *Kharif*, 2023 at section of Agronomy, Dau Kalyan Singh College of Agriculture and Research Station, Alesur Bhatapara (C.G.). The experiment was laid out in Randomized Block Design with 9 treatments and 3 replications. The treatment consists of weedy check (T_1), Isoproturon 500 g ha^{-1} at 3 DAS (T_2), Pretilachlor 500 g ha^{-1} at 3 DAS (T_3), Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS (T_4), Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_5), Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_6), Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_7), Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8) and weed free (T_9). The results showed that the weed free (T_9) performed the best in terms of number of earheads $plant^{-1}$, weight of earhead (g), number of grains earhead-1, test weight (g), grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}). This was closely followed by the treatment involving sequential application of Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8). Weedy check (T_1) consistently gave the lowest values for all the parameters measured. Overall, the study demonstrated that keeping the crop weed free using recommended herbicides resulted in superior yields and yields attributes of kodo millet compared to the weedy check. Among the herbicide treatments, sequential application of Bensulfuron methyl + Pretilachlor premix followed by Bispyribac-Na was found to be most effective in managing weeds and improving crop productivity.

Keywords: Kodo millet, herbicides, weed control, yield, yield attributes, Isoproturon, Pretilachlor, Bensulfuron methyl, Bispyribac-Na

Introduction
Kodo millet is an annual grain (*Paspalum scrobiculatum* L.) belonging to the family Poaceae. It is known as haraka (in kannada), cow grass, rice grass, ditch millet, native paspalum, Indian crown grass, known to be originated from tropical Africa, and it is estimated to be domesticated in India 3000 years ago. Kodo millet is a monocot and an annual grass. It has an inflorescence that produces 4-6 racemes that are 4-9 cm long. Its slender, light green leaves grow up to 20-40 cm in length and it produces seeds which are small and ellipsoidal, being approximately 1.5 mm in width and 2 mm in length. They vary in colour from being light brown to a dark grey (Chauhan *et al*., 2018) [1].

Kodo millet is grown majorly in the states of Rajasthan, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka. In Chhattisgarh, kodo millets are cultivated in 24087 ha with the Production 25627 Mt. Maximum area of kodo millet is occupies by Kabirdham district (7470 ha) followed by Bemetara (5330 ha) and Korea (2406 ha). Baster accounts for maximum production of kodo millet (6535 Mt.) followed by Kabirdham (4286 Mt.) and Dantewada (4137 Mt.).

Weed infestation is a major constraint in kodo millet cultivation, causing significant yield losses (Kathiresan and Manoharan, 2005) [6]. Isoproturon is a selective systemic herbicide that is used as a pre-emergence as well as early post-emergence herbicide in controlling weeds in kodo millet. It inhibits photosynthesis at photosystem II site and causes membrane disruption in susceptible weed species (Tomar *et al.*, 2003) [19]. Isoproturon provides effective control of major grassy weeds viz. *Echinochloa colona, Eleusine indica*, and *Cyperus rotundus* as well as broad-leaved weeds such as *Trianthema portulacastrum*,

Commelina benghalensis, and *Phyllanthus niruri* in kodo millet (Gupta *et al.*, 2001) [3]. Several studies have shown that pre-emergence application of isoproturon at 1.0-1.5 kg ha^{-1} provides excellent weed control in kodo millet without any significant phytotoxicity, resulting in higher grain yield (Mishra *et al.*, 2001) [10]. Isoproturon has thus emerged as an important weed management tool in kodo millet production systems.

Materials and Methods

The field experiment was conducted during *Kharif*, 2023 at section of Agronomy, Dau Kalyan Singh College of Agriculture and Research Station, Bhatapara (C.G.). The soil type was sandy loam. The experiment was laid out in a Randomized Block Design of nine treatments and three replications with recommended dose of fertilizer (RDF) of 40:20:20 NPK kg ha^{-1} as the standard. Kodo millet variety 'Indira Kodo -1' was used as test crop. Gross and net plot sizes were 5 m x 4 m (20 m^2) and 4.2 m x 3.6 m (15.12 m^2) respectively. There was a spacing of 1 m between blocks and 0.5 m between plots.

Results

Yield and yield attributes was significantly influenced by herbicides as presented in Table 1.

Number of earheads plant^{-1}

Significantly highest number of earheads plant^{-1} was recorded under weed free (T_9) (13.49). This was at par with the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8) (12.61). Weedy check (T_1) exhibited the significantly lowest number of earheads plant^{-1} of (5.59) across measured growth stages.

The weed free recorded the maximum number of earheads plant^{-1} due to absence of weed competition, allowing better plant growth. Timely herbicide application in other treatment-controlled weeds and facilitated higher earhead formation compared to weedy check with severe weed pressure. The finding of present study is in accordance with those of Meghana, (2019) [9].

Weight of earhead (g)

Significantly highest weight of earhead plant^{-1} was recorded under weed free (T_9) (8.00). This was followed by the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8) and Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_6) (7.27 and 7.02 respectively). Weedy check (T_1) exhibited the lowest weight of earhead plant^{-1} of (3.51) across measured growth stages.

The herbicides enhanced plant growth leading to higher photosynthesis and accumulation of more food materials in earhead, thus increasing their individual weight. Timely weed control enabled optimal resource utilization for crop growth and development resulting in highest earhead weight under weed free condition. The results obtained in the present study are supported by the works of Meghana, (2019) [9]

Number of grains earhead^{-1}

Significantly highest number of grains earhead^{-1} was recorded under weed free (T_9) (166.40). This was at par with the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8), Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_6), Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_7) and Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS (T_4) (161.72, 157.28, 151.69 and 148.73 respectively). Weedy check (T_1) exhibited the significantly lowest number of grains earhead^{-1} (133.84) across measured growth stages.

Timely and effective weed control using herbicides led to better growth of the crop, resulting in higher number of productive tillers and ultimately increased the number of grains earhead^{-1}. Maximum resources utilization under weed free condition helped the crop to produce highest number of grains earhead^{-1}. The results obtained in the present study is in accordance with the results of Jawahar *et al.*, 2018.

Test weight (g)

Significantly highest test weight was recorded under weed free (T_9) (5.91 g). This was at par with the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8), Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_6), Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_7) and Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS (T_4) (5.73, 5.69, 5.57 and 5.29 g respectively). Weedy check (T_1) exhibited the significantly lowest test weight (4.07 g) across measured growth stages.

Better weed free under herbicidal treatments resulted in higher availability of nutrients, space and light for crop which led to superior grain filling and thereby increased the individual grain weight and test weight under weed free and optimal weed control s compared to weedy check. The finding of present study is in accordance with those of Meghana, (2019) [9].

Grain yield (kg ha^{-1})

Significantly highest grain yield was recorded under weed free (T_9) (1894 kg ha^{-1}). This was at par with the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8), Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_6) and Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_7) (1856 kg ha^{-1}, 1750 kg ha^{-1} and 1694 kg ha^{-1} respectively). Weedy check (T_1) exhibited the significantly lowest grain yield (1115 kg ha^{-1}) across measured growth stages.

Timely herbicide application prevented early season weed competition and allowed optimum crop growth. This led to increased yield attributes resulting in maximum grain production under weed free compared to weedy check where weed interference reduced resources for crop. These outcomes are consistent with findings of Yadav *et al.*, (2017) [21].

Straw yield (kg ha^{-1})

Significantly highest straw yield was recorded under weed free (T_9) (2459 kg ha^{-1}) This was at par with the Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8) and Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac- Na 20 g ha^{-1} at 20 DAS (T_6) (2314 and 2293 kg ha^{-1} respectively). Weedy check (T_1) exhibited the significantly lowest straw yield (1624 kg ha^{-1}) across measured growth stages.

Straw yield was highest in the weed free as herbicides effectively controlled weeds, allowing the crop to utilize resources fully for vegetative growth. Less weed competition

led to higher dry matter partitioning into straw, resulting in maximum straw production comparable to sequential herbicide applications that provided good weed control. The results obtained in the present study are supported by the works of Sukanya *et al.*, (2022) [17].

Harvest index (%)

Significantly the highest harvest index was recorded under Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_8) (44.56%). This was followed by Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS (T_7) and weed free (T_9) (44.24 and 43.55%). Weedy check (T_1) exhibited the lowest harvest index (40.65%) across measured growth stages.

Highest harvest index in T_8 was due to effective weed control maximizing dry matter accumulation in grains relative to total biomass. Less competition for resources from weeds led to optimal translocation of photo-assimilates into grains, thereby elevating harvest efficiency compared to the untreated weedy control. The results obtained in the present study is in accordance with the results of Singh and Tiwari (2013) [16].

Table 4.1: Effect of herbicides on yield attributes of kodo millet

Tr. No.	Treatment	Number of earhead plant^{-1}	Weight of earhead plant^{-1}	Number of grains earheads^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	Weedy check	5.59	3.51	133.84	4.07	1115	1624	40.65
T_2	Isoproturon 500 g ha^{-1} at 3 DAS	8.50	5.16	144.21	4.97	1470	1979	42.09
T_3	Pretilachlor 500 g ha^{-1} at 3 DAS	7.45	4.61	140.48	4.74	1327	1828	42.26
T_4	Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS	9.24	5.60	148.73	5.29	1548	1999	43.51
T_5	Bispyribac-Na 20 g ha^{-1} at 20 DAS	6.20	4.20	137.40	4.46	1275	1770	41.86
T_6	Isoproturon 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS	11.52	7.02	157.28	5.69	1750	2293	43.37
T_7	Pretilachlor @ 500 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS	10.43	6.43	151.69	5.57	1694	2140	44.24
T_8	Bensulfuron methyl + Pretilachlor (Pre-mix) 165 g ha^{-1} at 3 DAS *fb* Bispyribac-Na 20 g ha^{-1} at 20 DAS	12.61	7.27	161.72	5.73	1856	2314	44.56
T_9	Weed free	13.49	8.00	166.40	5.91	1894	2459	43.55
	SEM (±)	0.46	0.24	6.14	0.28	96.58	100.54	1.71
	CD (5%)	1.38	0.71	18.41	0.84	289.54	301.43	5.13

Conclusion

The field experiment revealed that maintaining a weed free plot (T_9), produced superior kodo millet yield attributes and yield over other treatments. The highest grain yield 1894 kg ha^{-1} was recorded with the weed free (T_9) which was at par with the Bensulfuron methyl + Pretilachlor pre-mix at 3 DAS *fb* Bispyribac-Na at 20 DAS (T_8) (1856) and Isoproturon at 3 DAS *fb* Bispyribac-Na at 20 DAS (T_6) (1750). Weed free condition ensured optimum use of growth resources without any competition from weeds. Among herbicide treatments, sequential application of pre-emergence and post-emergence herbicides effectively controlled weeds and achieved higher yield of kodo millet comparable to weed free.

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