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Effect of Weed Management Practices on Weed Density, Dry Weight and Growth of Kodo Millet (*Paspalum scrobiculatum* L.)

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A B S T R A C T

An experiment in Kodo millet was conducted during *Kharif* 2018 in red sandy loamy soil of Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru with different weed management practices. Twelve treatments replicated thrice in a randomized complete block design (RCBD). The weed density (4.59, 4.67 and 4.69 m^{-2}) and weed dry weight (9.00, 7.00 and 3.71g m^{-2}) were found significantly lower at 30, 45 days after sowing and at harvest, respectively in T_5 *i.e.* the application of Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165g a. i. ha^{-1} as pre emergent herbicide *fb* Bispyribac sodium 10 % SC 10g a. i. ha^{-1} among herbicide treatments was found supreme in controlling weeds growth and thereby enhancing the performance of crop and this treatment was found on found par with the treatment i.e. Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165g a. i. ha^{-1} *fb* Ethoxysulfuron 15 % WG 12g a. i. ha^{-1} (4.38, 4.78 and 4.72 m^{-2} of weed density and 7.33, 7.50 and 8.27g m^{-2} of weed dry weight), two intercultivation followed by hand weeding at 20 and 40 DAS (3.40, 3.17 and 3.78m^{-2}, and 4.00, 2.63 and 2.32gm^{-2} at 30, 45 DAS and at harvest, respectively) indicating the excelled efficiency of Bensulfuron methyl + pretilachlor *fb* Bispyribacsodium in controlling sedges, grasses and broad leaf weeds throughout the growth stages of kodo millet without any phytotoxicity on kodo millet crop.

Introduction

Kodo millet (*Paspalum scrobiculatum* L.) popularly known as Haraka in Karnataka is one of the important nutri cereals. It is a coarsest millet crop which is having a high drought tolerance capacity due to its deep root system and nutritionally superior over rice and wheat in terms of higher protein, dietary fibre and lesser fat content, which play an important role in the energy requirement and nutrient intake of human. It is also having a good fodder value, has immense potentiality and hence found the importance in rainfed areas of Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Bihar and Karnataka.

It is grown as a minor crop in many Asian countries, with the exception of the Deccan plateau in India where it is grown as a food source. It grows wild as a perennial in the west of Africa, where it is eaten as a famine food. Kodo millet is mainly cultivated for human consumption in Philippines, Indonesia, Vietnam, Thailand, West Africa and India. Nutri cereals are grown worldwide and in India, it is cultivated over an area of 0.62 m. ha with the production of 0.44 m. t. and with a productivity of 714 kg ha^{-1}.Whereas, in Karnataka, nutria cereals occupy an area of 21,000 ha, with a production of 7000 t. production and with a productivity of 333 kg ha^{-1}.

Weeds are serious problem in Kodo millet, both in irrigated areas and assured rainfed situations during monsoon season where there is adequate moisture throughout the crop growth period. Due to slower initial growth, kodo millet is susceptible to weed competition. Weeds compete with crop plants for nutrients, moisture, space and light and reduce not only the crop yields but also quality of produce accounting a loss of about 37 per cent in agricultural produce depending upon factors like type of weed flora and its density in standing crop in India (Yaduraju, 2006). So, timely weed management is essential for achieving higher yield. In kodo millet weeds must be controlled during the initial 2-6 weeks period after which, the canopy develops thick enough to smother the weeds.

Conventionally, weeds are controlled by hoeing and animal drawn implements. But scarcity of human labour along with higher wages have made the weed management difficult to go for hand weeding an impossible task now a days.

The best alternate solution for weed management in such situations is use of herbicides along with other weed management practices. In recent years the usage of herbicides has revolutionized weed management practices in all crops particularly cereals in specific to nutri cereals in India and the use of herbicides in integrated weed management practices for effective weed management in kodo is quite effective to manage the composite weed flora.

Materials and Methods

The experiment to study the performance of different weedicides on yield and economics in kodo millet consisted of twelve treatments replicated thrice in a randomized complete block design (RCBD). This experiment was conducted during *Kharif* 2018 at Gandhi Krishi Vignan Kendra (GKVK).The soil is red sandy loam and the treatments tested were, T_1: Oxadiargyl 80 % WP @150 g a. i. ha^{-1},T_2: Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G @ 165 g a. i ha^{-1}, T_3: Pendimethalin 38.7 % CS @ 450 g a. i ha^{-1}, T_4: Oxadiargyl 80 % WP @ 150 g a. i ha^{-1}*fb* Bispyribacsodium 10 % SC @ 10 g a. i ha^{-1}, T_5: Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G @ 165 g a. i ha^{-1} *fb* Bispyribacsodium 10 % SC @ 10 g a. i ha^{-1}, T_6: Pendimethalin 38.7 % CS @ 450 g a. i ha^{-1} *fb* Bispyribac sodium 10 % SC @10 g a. i ha^{-1}, T_7: Oxadiargyl 80 % WP @ 150 g a. i ha^{-1} *fb* Ethoxysulfuron 15 % WG @ 12 g a. i ha^{-1}, T_8: Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G @ 165 g a. i ha^{-1} *fb* Ethoxysulfuron 15 % WG @ 12 g a. i ha^{-1}, T_9: Pendimethalin 38.7 % CS @ 450 g a. i ha^{-1} *fb* Ethoxysulfuron 15 % WG @12 g a. i ha^{-1}, T_{10}: Two intercultivation + hand weeding @ 20 and 40 DAS, T_{11}: un weeded check and T_{12}: weed free check.

Kodo millet variety used was 'RBK-115' which was sown with a spacing of 30cm x 10cm. Observations on weed density, weed dry matter and other parameters were recorded in an area of 1 m^2.

Results and Discussion

The results of the investigation revealed that at 30, 45 DAS and at harvest, significantly lower density and dry weight of sedge was observed in the treatment T_4 *i.e* Oxadiargyl 80 % WP 150 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1}. Significantly lower number of grassy weeds was recorded with T_5 *i.e*., Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-}*fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1}, however it was at par with T_8, T_6 and T_{10} and rest of the treatments showed significantly higher incidence of weeds along with its dry weight.

The broad leaf weeds density and dry weight was significantly lower in T_5 *i.e*., Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} at 20 DAS compared to rest of the other treatments except T_6 and T_{10} in other they were found at par. During 45 DAS and at harvest, Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} at 20 DAS (T_5) recorded significantly lower total weed density and weed dry weight compared to other treatments and these findings are in line with the findings of Pradhan *et al.,* (2010).

Among all the treatments, weed free check (T_{12}) recorded the lowest sedge, grass, broad leaf weeds and total weed density as well as dry weight due to the physical uprooting of both above and below ground parts of weeds by the manual hand weeding imposed on during 20 and 40 DAS. Whereas, un-weeded control (T_{11}) recorded the highest sedge, grass, broad leaf, total weed density and weed dry weight due to the non-interruption for growth of weeds.

Among herbicide treatments, Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} recorded the highest plant height and number of leaves due to effective weed control and minimum crop weed competition leading to more nutrient availability resulting in better plant growth attributes.

The Leaf area index differed significantly at all the stages due to the application ofdifferent weed management practices. At harvest, leaf area index of herbicide treatment T5 *i.e*., Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} (T5:3.45), T8 (3.28) and T4 (2.71) were statistically found on par with T12 *i.e* weed free check (3.77). Whereas, significantly the lowest leaf area index was reported in treatment of un-weeded control *i.e*., T11 (2.24). Persistence of the assimilatory surface area is pre requisite for a prolonged photosynthetic activity and productivity. Leaf area being the photosynthetic surface plays a vital role in production and availability of photosynthates. Due to less competition from weeds, plots treated with Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1}*fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} recorded higher leaf area as well as leaf area index.

Among the herbicide treatments, significantly higher total dry weight of kodo millet was recorded in treatment received the combination of herbicides Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1}. The next best herbicide treatment was Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Ethoxysulfuron 15 % WG 12 g a. i. ha^{-1}.This might be attributed to the reduced competition from weeds and increased availability of resources like nutrients, soil moisture and light which paved the way for improvement of crop stature as reflected by taller plants and higher leaf area, which consequently increased the biomass of the crop (Table 1–4).

Table.1 Category wise weed density (number m^{-2}) and weed dry weight (g m^{-2}) at 30 DAS in Kodo millet as influenced by weed management practices

Treatments	Weed density				Weed dry weight			
	Sedge	Grasses	BLWs	Total	Sedge	Grasses	BLWs	Total
T_1	2.37 (4.67)	4.79 (22.00)	5.00 (24.00)	7.18 (50.67)	1.47 (1.33)	4.42 (18.67)	4.57 (20.00)	6.40 (40.00)
T_2	2.69 (6.33)	4.14 (16.30)	4.15 (16.33)	6.31 (39.00)	1.95 (3.00)	3.70 (13.00)	3.57 (12.00)	5.36 (28.00)
T_3	2.77 (6.67)	4.61 (20.33)	4.71 (21.33)	7.02 (48.33)	2.08 (3.33)	4.15 (16.33)	4.22 (17.00)	6.13 (36.67)
T_4	1.99 (3.00)	4.47 (19.30)	3.71 (13.33)	6.04 (35.67)	1.14 (0.33)	4.05 (16.00)	3.02 (9.00)	5.09 (25.33)
T_5	2.70 (6.33)	2.81 (7.00)	2.80 (7.00)	4.59 (20.33)	1.95 (3.00)	2.06 (3.33)	1.87 (2.66)	3.08 (9.00)
T_6	2.76 (6.67)	3.96 (14.70)	3.21 (9.33)	5.62 (30.67)	2.06 (3.33)	3.51 (11.33)	2.44 (5.00)	4.54 (19.67)
T_7	2.31 (4.33)	4.38 (18.70)	4.04 (15.33)	6.25 (38.33)	1.38 (1.00)	3.96 (15.33)	3.46 (11.00)	5.28 (27.33)
T_8	2.64 (6.00)	2.56 (5.70)	2.74 (6.66)	4.38 (18.33)	1.90 (2.67)	1.76 (2.33)	1.76 (2.33)	2.85 (7.33)
T_9	2.54 (5.67)	4.19 (16.70)	3.65 (12.33)	5.97 (34.67)	1.73 (2.33)	3.76 (13.33)	3.00 (8.00)	4.95 (23.67)
T_{10}	1.63 (1.67)	1.90 (2.70)	2.67 (6.33)	3.40 (10.67)	1.24 (0.67)	1.28 (0.67)	1.75 (2.66)	2.02 (4.00)
T_{11}	3.46 (11.00)	5.65 (31.000	6.85 (46.00)	9.43 (88.00)	3.23 (9.67)	5.49 (29.33)	6.65 (43.33)	9.12 (82.33)
T_{12}	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00(0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
S.Em+	0.16	0.26	0.25	0.25	0.25	0.31	0.34	0.38
C. D. at 5%	0.47	0.769.00)	0.76	0.75	0.74	0.92	1.00	1.12

Data within parentheses are original values; data analyzed using square root (x+1) transformation
DAS-Days after sowing, BLWs= broad leaved weeds.

Table.2 Category wise weed density (number m^{-2}) and weed dry weight (g m^{-2}) at 45DAS in Kodo millet as influenced by Weed Management Practices

Treatments	Weed density				Weed dry weight			
	Sedge	Grasses	BLWs	Total	Sedge	Grasses	BLWs	Total
T_1	2.76 (6.67)	4.99(24.00)	5.13 (25.33)	7.55 (56.00)	1.38 (1.00)	4.39 (18.33)	4.54 (19.66)	6.32 (39.00)
T_2	2.87 (7.33)	4.37(18.30)	4.26 (17.33)	6.62 (43.00)	1.88 (2.67)	3.66 (12.67)	3.52 (11.66)	5.27 (27.00)
T_3	2.94 (7.67)	4.83(22.30)	4.86 (22.66)	7.32 (52.66)	1.99 (3.00)	4.12 (16.00)	4.18 (16.66)	6.05 (35.67)
T_4	2.29 (4.33)	4.69(21.30)	3.86 (14.66)	6.64 (43.33)	1.28 (0.67)	4.02 (15.67)	2.98 (8.66)	5.06 (25.00)
T_5	2.88 (7.33)	3.15 (9.00)	2.90 (7.66)	4.67 (21.00)	1.80 (2.33)	1.87 (2.67)	1.72 (2.00)	2.78 (7.00)
T_6	2.94 (7.67)	4.20(16.70)	3.21 (9.33)	5.88 (33.66)	1.99 (3.00)	2.78 (7.00)	2.38 (4.66)	3.95 (14.67)
T_7	2.58 (5.67)	4.60(20.70)	4.12 (16.00)	6.64 (43.33)	1.14 (0.33)	3.89 (14.67)	3.41 (10.66)	5.13 (25.67)
T_8	2.76 (6.67)	2.93 (7.70)	3.05 (8.66)	4.78 (22.00)	1.82 (2.33)	1.92 (2.83)	1.76 (2.33)	2.87 (7.50)
T_9	2.73 (6.67)	4.42(18.70)	3.78 (13.33)	6.29 (38.66)	1.62 (2.00)	3.72 (13.00)	2.94 (7.66)	4.85 (22.67)
T_{10}	1.82 (2.33)	2.14 (3.70)	2.85 (7.33)	3.78 (13.33)	1.14 (0.33)	1.21 (0.50)	1.69 (2.33)	1.86 (3.17)
T_{11}	3.20 (9.33)	5.47(29.00)	6.72 (44.33)	9.14 (82.66)	3.40 (10.67)	5.61 (30.67)	6.75 (44.66)	9.32 (86.00)
T_{12}	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
S.Em+	0.16	0.24	0.30	0.23	0.20	0.32	0.31	0.34
C. D. at 5%	0.47	0.71	0.88	0.70	0.61	0.95	0.91	1.01

Data within parentheses are original values; data analyzed using square root (x+1) transformation
DAS-Days after sowing, BLWs= broad leaved weeds

Table.3 Category wise weed density (number m^{-2}) and weed dry weight (g m^{-2}) at harvest in Kodo millet as influenced by Weed Management Practices

Treatments	Weed density				Weed dry weight			
	Sedge	Grasses	BLWs	Total	Sedge	Grasses	BLWs	Total
T_1	2.23 (4.66)	5.61 (30.66)	3.95 (14.66)	7.13 (50.00)	1.71 (1.93)	2.65 (6.03)	3.40 (10.66)	4.42 (18.63)
T_2	2.35 (4.00)	5.21(26.33)	3.82 (13.66)	6.69 (44.00)	1.78 (2.22)	2.61 (5.82)	3.31 (10.00)	4.36 (18.04)
T_3	2.18 (3.33)	5.35(27.66)	4.35 (18.00)	7.06 (49.00)	1.75 (2.06)	2.49 (5.21)	3.21 (9.33)	4.20 (16.60)
T_4	1.63 (5.33)	5.02(24.33)	3.74 (13.00)	6.60 (42.66)	1.39 (1.02)	2.23 (4.07)	3.16 (9.00)	3.88 (14.09)
T_5	2.48 (65.15)	3.81(13.66)	2.55 (5.66)	4.69 (21.00)	1.49(1.21)	1.33 (0.83)	1.63 (1.66)	2.17 (3.71)
T_6	2.14 (3.66)	5.08(25.00)	4.00 (15.00)	6.68 (43.66)	1.52 (1.32)	2.39 (4.78)	2.27 (4.33)	3.38 (10.43)
T_7	1.72 (3.00)	4.12(23.66)	3.87 (14.00)	6.45 (40.66)	1.56 (1.45)	2.33 (4.58)	2.50 (5.33)	3.49 (11.36)
T_8	1.99 (2.00)	3.40(10.66)	2.87 (8.66)	4.72 (21.33)	1.68 (1.87)	1.54 (1.4)	2.43 (5.00)	3.04 (8.27)
T_9	2.30 (4.33)	4.89(23.00)	3.81 (13.66)	6.47 (41.00)	1.66 (1.77)	2.17 (3.87)	2.81 (7.00)	3.67 (12.64)
T_{10}	1.28 (0.66)	3.31(10.00)	1.91 (2.66)	3.78 (13.33)	1.20 (0.46)	1.38 (1.00)	1.36 (0.85)	1.81 (2.32)
T_{11}	2.99 (8.00)	6.25(38.33)	6.95 (47.33)	9.72 (93.66)	3.64 (12.33)	5.64 (31.00)	6.24 (38.00)	8.00 (63.00)
T_{12}	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
S.Em+	0.18	0.27	0.13	0.21	0.11	0.20	0.19	0.20
C. D. at 5%	0.53	0.79	0.39	0.64	0.35	0.60	0.57	0.58

Data within parentheses are original values; data analyzed using square root (x+1) transformation
DAS-Days after sowing, BLWs= Broad leaved weeds

Table.4 Different growth parameters, weed control efficiency and phytotoxicity of kodo millet as influenced by weed management practices

Treatments	Plant height (cm)	LAIat harvest	Total dry weight (g plant^{-1})	WCE at 45 DAS	WCE at harvest	Phytotoxicity score
T_1	57.01	2.37	43.30	54.6	70.42	2
T_2	57.67	2.64	50.10	68.6	71.36	0
T_3	57.33	2.56	47.53	58.5	73.65	0
T_4	68.19	2.71	55.33	70.9	75.98	2
T_5	69.62	3.45	65.20	91.8	94.63	0
T_6	68.33	2.96	61.70	82.9	83.44	0
T_7	57.33	2.76	52.40	70.1	81.96	2
T_8	68.31	3.28	62.67	91.2	86.87	0
T_9	57.28	2.82	59.00	73.6	79.93	0
T_{10}	70.31	3.37	65.20	96.3	96.31	-
T_{11}	55.39	2.24	28.17	100	100	-
T_{12}	70.44	3.77	66.83	0.00	0.00	-
S.Em+	3.70	0.24	2.17	54.6	70.42	-
C. D. at 5%	10.85	0.71	6.36	68.6	71.36	-

T_1: Oxadiargyl 80 WP @150 g a. i. ha^{-1}, T_2:Bensulfuron methyl 0.6 G + Pretilachlor 6.0 G (165 g a. i/ha), T_3:Pendimethalin 38.7 CS (450 g a. i/ha), T_4: Oxadiargyl 80 WP (150 g a. i/ha) *fb*Bispyribacsodium 10 SC (10 g a. i/ha), T_5: Bensulfuron methyl 0.6 G + Pretilachlor 6.0 G(165 g a.i/ha) *fb*Bispyribacsodium 10 SC (10 g a. i/ha), T_6: Pendimethalin 38.7 CS (450 g a. i/ha) *fb*Bispyribac sodium 10 SC (10 g a.i/ha), T_7: Oxadiargyl 80 WP (150 g a.i/ha) *fb* Ethoxysulfuron 15 WG (12 g a.i/ha), T_8: Bensulfuron methyl 0.6 G + Pretilachlor 6.0 G (165 g a. i/ha)) *fb*Ethoxysulfuron 15 WG (12 g a. i/ha), T_9: Pendimethalin 38.7 CS (450 g a. i/ha) *fb*Ethoxysulfuron 15 WG (12 g a.i/ha), T_{10}: Two intercultivation + hand weeding @20 & 40 DAS, T_{11}: Un weeded check, T_{12}: Weed free check.
DAS-Days after sowing

Whereas, the lower total plant dry weight was recorded in un-weeded control (T_{11}), as a result of severe weed interference and constant competition throughout the crop growth period which suppressed the growth of kodo millet crop, as projected by the studies of Arunachalam *et al.*, (1995) and Travis and James (2016).

Highest weed control efficiency in weed free check (T_{12}) was due to highest efficiency of human labour in removing all the types of weeds. Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} recorded next higher weed control efficiency due to control of broad spectrum of weeds including sedge, grasses and broad leaf weeds.

Whereas the lowest weed control efficiency in T_4 *i.e.*, Oxadiargyl 80 % WP 150 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} was due to control of only some specific weed flora like broad leaf weeds more efficiently, sedge to some extent and no control of grassy weeds.These results are in accordance with Saha (2009) and Singh *et al.*, (2005).

In conclusion the application of Bensulfuron methyl 0.6 % G + Pretilachlor 6.0 % G 165 g a. i. ha^{-1} *fb* Bispyribac sodium 10 % SC 10 g a. i. ha^{-1} is more effective due to control of the broad spectrum of weeds more efficiently and thereby increasing all the growth parameters of kodo millet.

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