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Weed management practices in irrigated organic finger millet (*Eleusine coracana* (L.) Gaertn.)

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Abstract: Field experiment was conducted to know the effect of weed management practices on weed flora and weed growth in irrigated organic finger millet. All weed management treatments had significantly lower total weed density and weed dry weight as compared to unweeded control. Stale seed bed technique + inter cultivation twice at 20 and 35 DAP (23.9/m^2 and 10.3 g/m^2) significantly lowered the total weed density as well as weed dry weight and was on par with hand weeding twice at 20 and 30 DAP (22.6/m^2 and 9.4 g/m^2). Higher total weed density and weed dry weight was found in unweeded check (245.9/m^2 and 105.1 g/m^2). Highest weed control efficiency was found in manual weeding (93.2 %) followed by stale seedbed combined with inter cultivation twice (91.6 %) and passing wheel hoe twice with one manual weeding (88.7 %). Grain yield was significantly higher in hand weeding twice (5460 kg/ha) followed by stale seedbed combined with inter cultivation twice (5365 kg/ha). The stale seedbed technique with inter cultivation twice at 20 and 35 DAP followed by hand weeding twice at 20 and 30 DAP recorded the highest net return and B:C ratio (Rs. 56,939 and 56,545/ha and 2.61, and 2.56, respectively).
Keywords: Organic, Stale seedbed, Inter cultivation, Weed index (WI), Weed control efficiency (WCE)

INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn.) ranks third in importance among millets in the country in both area (1.27 million ha) and production (1.91 million tonnes) after sorghum and pearl millet. Karnataka state shares 60.8 per cent of the area and two third of its production (68.4 per cent) [1]. Finger millet is an important dry land crop due to its resilience and ability to withstand aberrant weather conditions and generally grown in soils having poor water supplying capacity and nutrients. It is commonly referred as ragi in Karnataka, is one of the major staple food of farming communities of southern Karnataka. Apart from human consumption, straw is used as good fodder for cattle and the green straw is suitable for making silage.

Organic farming is being practiced in more than 130 countries of the world with a total area of 30.4 m. ha (0.65% of the total agricultural land) with 0.7 million number of organic farmers world over [14]. It is gaining momentum in India owing to the concerns expressed on the safety of environment, soil, water and food chain. In India it is estimated that 528,171 ha area is under organic with 44,926 certified farmers (0.3% of the total cultivated area) [10]. Cultivating crops organically, and at the same time maintaining higher production levels is a big challenge. Since chemical intervention is not permitted for weed management, non chemical weed management is the major limitation in field crops like ragi, paddy and other cereals under organic farming. A concern about the potential increase in weed population due to non use of herbicides is rated as serious problem in organic farming [4].In any organic agriculture system, adopting cost effective weed management practices is a major issue for achieving sustainable production levels. In organic agriculture weed management should simulate the principles of biological processes for desired suppression of weeds. Preventive weed management practices, higher plant population, manipulating crop geometry, stale-bed technique, competitive crop varieties, intercrops and cover crops, crop rotation are available at present which could be followed in an integrated manner where ever feasible. Weeding through non-chemical means have to be undertaken within the critical period of the crop. More dependence on the use of efficient mechanical weeding tools is also advocated in organic agriculture. Hence, the present study was initiated to find out effective and economical weed management practices in organic finger millet.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season 2012 at the Main Research Station, Hebbal, Bengaluru, to identify the suitable methods of managing weeds in organic finger millet. It was laid out

in Randomized Complete Block Design (RCBD) with three replications. The soil of the experimental field was sandy loam having pH of 6.55 with 236 kg N, 27.2 kg P_2O_5 and 176.2 kg K_2O/ha. The variety used for the experiment was GPU-28. The experiment comprised of twelve treatments Passing wheel hoe at 20, 30 and 40 DAP; Inter cultivation twice at 20 and 35 DAP; Stale seedbed technique; Passing wheel hoe at 20, 30 and 40 DAP + one hand weeding at 45 DAP; Inter cultivation twice at 20 and 35 DAP + one hand weeding at 45 DAP; Stale seedbed technique + Inter cultivation twice at 20 and 35 DAP; Organic mulching @10 t/ha after transplanting; Growing cover crops (Horse gram/cowpea) and mulching at 55 DAP; Directed spray of *Eucalyptus* leaf extract on weeds; Directed spray of cattle urine on weeds; Hand weeding twice at 20 and 30 DAP; Unweeded check. Seedlings were raised in nursery bed of size 7.5 m long, 1.2 m width and 10 cm height prepared one month before transplanting of the crop. Nursery bed was prepared and the FYM was mixed with soil. Seeds @ 5kg ha^{-1} were sown uniformly and light irrigation was given periodically. Neem cake was applied equivalent to 50 kg N/ha at the time of transplanting. Cattle urine was top dressed in three splits at 15, 30 and 40 DAP to meet remaining 50 kg N/ha. Stale seedbed treatment was initiated 15 days before transplanting of the crop. One irrigation was given to stale seedbed plots and weeds were allowed to germinate. The germinated weeds were removed by passing cultivator cris-cross one day before transplanting of the crop. Organic mulching was done with crop residues (paddy straw) and dried grasses @ 10 t/ha one week after transplanting. Seed mixture of cowpea and horse gram was sown in between two rows of finger millet. These cover crops were mulched between rows at 55 DAP.

RESULTS AND DISCUSSION

Weed flora:

Major weed flora observed in the experimental plot were *Cyperus rotundus* L. (among sedge); *Echinochloa colona* (L.), *Cynodon dactylon* (L.) Pers, *Dactyloctenium aegyptium* (L.) Beauv., *Digitaria marginata* (Retz.), *Eragrostis pilosa* (from initial stage) *Eleusine indica* (L.) Gaertn, (at later stages) (among grasses); among broad leaved weeds *Parthenium hysterophorus*, *Alternanthera sessilis*, *Sida acuta*, *Spillanthus acmella*, *Commelina benghalensis* L., *Ageratum conyzoides* Linn, *Ocimum canum*, *Cinebra didema* L. similar findings have been reported in the earlier studies at Hebbal, Bangalore [6,7,9].

Weed density and weed dry weight:

At 60 DAP the total weed density and weed dry weight was significantly lower in hand weeding twice at 20 and 30 DAP (26.32 and 6.4 g/m^2) treatment and was on par with stale seed bed technique + inter cultivation twice at 20 and 35 DAP (29.67 and 8.0 g/m^2) and T_1 + one hand weeding (41.26 and 10.7 g/m^2). Whereas, stale seedbed alone and spray of cattle urine on weeds were not significantly control the total weed density, which were on par with unweeded control (279.68 and 95.1 g/m^2). At harvest, total weed density and weed dry weight was significantly lower in hand weeding twice at 20 and 30 DAP (22.60 and 9.4 g/m^2) and was on par with stale seed bed technique + inter cultivation twice at 20 and 35 DAP (23.90 and 10.3 g/m^2). All the weed management treatments recorded significantly lower total weed density at harvest except stale seedbed technique alone and spray of cattle urine on weeds which were on par with unweeded control (245.90 and 105.1 g/m^2).

Table 1:- Total weed density and weed dry weight at different stages in finger millet as influenced by weed management practices.

Treatments	Weed density (number/m^2)		Weed dry weight (g/m^2)	
	60 DAP	At harvest	60 DAP	At harvest
T_1	1.72 (50.22)	1.68 (46.40)	1.62 (39.7)	1.67 (44.7)
T_2	1.92 (80.95)	1.79 (59.00)	1.76 (55.8)	1.76 (55.7)
T_3	2.25 (177.51)	2.23 (166.80)	1.91 (80.0)	1.96 (89.9)
T_4	1.64 (41.26)	1.64 (41.80)	1.10 (10.7)	1.55 (33.3)
T_5	1.69 (47.34)	1.68 (45.50)	1.65 (42.9)	1.63 (40.6)
T_6	1.50 (29.67)	1.41 (23.90)	1.00 (8.0)	1.09 (10.3)
T_7	2.10 (124.02)	2.04 (108.50)	1.74 (52.4)	1.78 (58.4)
T_8	1.89 (76.08)	1.83 (65.10)	1.74 (53.5)	1.67 (44.3)
T_9	2.22 (165.56)	2.18 (149.53)	1.92 (81.3)	1.94 (86.0)
T_{10}	2.27 (185.82)	2.21 (160.00)	1.84 (67.7)	1.93 (82.2)
T_{11}	1.45 (26.32)	1.39 (22.60)	0.92 (6.4)	1.06 (9.4)
T_{12}	2.45 (279.68)	2.39 (245.90)	1.99 (95.1)	2.03 (105.1)
CD(P=0.05)	0.20	0.19	0.06	0.11

Figures in parenthesis are original values; data analyzed using transformation =log(x+2)

Weed control efficiency (WCE):

The WCE was higher with hand weeding twice at different growth stage of the crop (92.8, 93.2 and 91.0 % at 30, 60 DAP and at harvest respectively) owing to the fact that it produced lesser weed dry weight. Similar findings were observed [5] in finger millet and in groundnut-finger millet cropping system [6], who observed hand weeding twice to be the best treatment having the lowest WI, highest WCE and higher yield. WCE of stale seedbed technique combined with inter cultivation twice (91.3, 91.6 and 90.1 % at 30, 60 DAP and at harvest respectively) and passing wheel hoe at 20, 30 and 45 DAP with one hand weeding (68.5, 88.7 and 68.3 % at 30, 60 DAP and at harvest respectively,). The results of this study are in concurs with earlier findings in finger millet [2,8]. Similar findings were also obtained in sesame [13] found that stale seedbed by cultivation significantly reduced the grasses, sedges and broad leaved weeds compared to conventional seedbed preparation.

Table 2:- Weed control efficiency at different growth stages and grain yield of finger millet as influenced by weed management practices.

Treatments	WCE % at 30 DAP	WCE % at 60 DAP	WCE % at harvest	Grain yield (kg/ha)
T_1	33.0	58.2	57.5	4095
T_2	18.6	41.3	47.0	3937
T_3	26.6	15.8	14.4	3397
T_4	68.5	88.7	68.3	5143
T_5	31.5	54.9	61.3	4222
T_6	91.3	91.6	90.1	5365
T_7	84.4	45.2	44.4	3778
T_8	8.5	43.7	57.8	3206
T_9	12.5	14.5	18.1	2921
T_{10}	18.5	28.8	21.8	3302
T_{11}	92.8	93.2	91.0	5460
T_{12}	0.0	0.0	0.0	2730
CD(P=0.05)	NA	NA	NA	945.6

NA – Not analyzed statistically

Growth parameters :

Hand weeding twice at 20 and 30 DAP produced significantly higher growth parameters *viz.*, taller plants (110.13 cm), higher LAI (3.3), number of tillers/hill (6.00) and dry matter accumulation (36.4 g/plant) than other treatments. However, it was on par with stale seedbed technique + inter cultivation twice and also with passing wheel hoe at 20, 30 and 45 DAP + one hand weeding. Significantly lowest plant height (86.2 cm), LAI (1.3), number of tillers/hill (3.47) and dry matter (22 g/plant) were obtained in unweeded control. The enhancement of crop growth components could be due to less competition by the weeds for crop these factors throughout the crop growth period due to control of early emerged weeds before transplanting through stale seedbed technique and late emerged weeds through inter cultivation. Our observation concurs with several earlier studies that have reported in maize, sunflower, dry seeded rice, and in maize [3,11,12].

Table 3: Growth parameters of finger millet as influenced by weed management practices at harvest.

Treatments	Plant height (cm)	No. of tillers	LAI	Total dry matter production (g/plant)
T_1	97.13	4.27	3.17	32.2
T_2	99.10	4.53	2.93	31.6
T_3	94.80	4.13	2.46	25.4
T_4	104.13	5.00	3.20	34.6
T_5	98.43	4.27	3.07	31.1
T_6	106.40	5.73	3.29	37.8
T_7	93.60	4.07	2.67	30.7
T_8	91.53	3.87	2.35	29.8
T_9	92.30	4.20	2.61	25.4
T_{10}	91.60	4.67	2.26	27.1
T_{11}	110.10	6.00	3.30	36.4
T_{12}	86.20	3.47	1.30	22.0
CD(P=0.05)	9.79	0.81	0.54	4.74

Leaf Area Duration (LAD) and Crop Growth Rate (CGR):

Significantly higher LAD was recorded in hand weeding twice at 20 and 30 DAP (123.3 days). Stale seedbed technique + Inter cultivation twice at 20 and 35 DAP (T6), T1 + one hand weeding (T4) accounted for 111.3 and 109.5 days respectively which were found to be on par with hand weeding twice at 20 and 30 DAP. While, unweeded control recorded lowest LAD (61.65). At 60 days to harvest significantly higher LAD was recorded in hand weeding twice at 20 and 30 DAP (125.25 days). However hand weeding twice at 20 and 30 DAP was on par with Stale seedbed technique + Inter cultivation twice at 20 and 35 DAP (T6) (114.3 days), T1 + one hand weeding (T4) (112.35 days) at 60 to harvest of crop growth stage. While unweeded control has recorded lowest LAD (58.5 days).

Significantly higher CGR was recorded in hand weeding twice at 20 and 30 DAP (18 g/m^2/ day). Stale seedbed technique + Inter cultivation twice at 20 and 35 DAP, T1 + one hand weeding, Organic mulching @10 t ha^{-1} after transplanting, Growing cover crops (Horse gram/cowpea) and passing blade hoe and passing wheel hoe at 20, 30 and 40 DAP were recorded 18.9, 15.4, 16.0, 15.6 and 15.3 g/m^2/ day CGR respectively which were statistically found to be on par with hand weeding twice at 20 and 30 DAP. Whereas stale seedbed alone, inter cultivation twice and spraying of eucalyptus leaf extract and cattle urine on weeds have not influenced the CGR significantly. While, lowest CGR was recorded in unweeded control (12 g/m^2/ day). At 60 to harvest of crop growth stage CGR did not differ significantly among the different weed management practices. However, highest CGR was observed in T1 + one hand weeding (9.67 g/m^2/ day) and lowest CGR was observed in unweeded control (5.0 g/m^2/ day^1).

Table 4:- Influence of weed management practices on LAD and CGR of finger millet at different growth stages

Treatments	LAD (Days)		CGR(g/m^2/ day)	
	At 30 to 60 DAP	At 60 to harvest	At 30 to 60 DAP	At 60 to harvest
T_1	98.25	106.65	15.3	8.89
T_2	97.95	103.35	15	7.67
T3	87.15	86.25	13.2	4.33
T4	109.05	112.35	15.4	9.67
T5	103.2	107.55	14.1	8.55
T6	111.3	114.3	18.9	8.55
T7	88.65	94.35	16.0	7.55
T8	69.15	80.25	15.6	8.67
T9	83.7	89.25	15.1	3.0
T10	82.8	82.8	12.1	7.11
T11	123.3	125.25	18.0	7.44
T12	61.65	58.5	12.0	5
CD(P=0.05)	15.51	13.74	3.4	NS

Grain yield:

Grain yield of finger millet was significantly higher in hand weeding twice at 20 and 30 DAP (5460 kg/ha) as compared to unweeded control. However, it was on par with stale seedbed technique + inter cultivation twice and also with passing wheel hoe at 20, 30 and 45 DAP + one hand weeding (5365 kg/ha). This higher yield might be due to better control of weeds at tillering stage of the crop resulted in higher yield of the crop [6,8,9]. Whereas, lower grain yield (2730 kg/ha) was obtained in unweeded control. This reduction in yield might be due to highest competition with the finger millet throughout the crop growth period.

Economics :

Highest gross return (Rs. 92,700/ha) was obtained in hand weeding twice followed by stale seedbed technique with inter cultivation twice (Rs. 91,775/ha). While, Highest net return (Rs. 56,645/ha) was obtained in Hand weeding twice at 20 and 30 DAP followed by stale seedbed technique combined with inter cultivation twice (Rs. 56319/ha). Whereas, the B:C ratio was higher in stale seedbed technique combined with inter cultivation twice (2.59) due to its lower cost of cultivation than hand weeding twice treatment. Hand weeding twice at 20 and 30 DAP did produced the highest gross and net return but B:C ratio was lower as compared to above treatment (2.57). However, lowest B:C ratio of 1.53 was found in unweeded control.

Table 5: Economics of finger millet as influence of different weed management practices

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C
T_1	35755	71275	35520	1.99
T_2	33715	68505	34790	2.03
T_3	32755	58305	25550	1.78
T_4	36955	87795	50840	2.38
T_5	36355	72630	36275	2.00
T_6	35455	91775	56319	2.59
T_7	33655	66120	32465	1.96
T_8	32340	57390	25050	1.77
T_9	31795	51715	19920	1.63
T_{10}	31675	57930	26255	1.83
T_{11}	36055	92700	56645	2.57
T_{12}	31255	47700	16443	1.53
CD(P=0.05)	NA	NA	NA	NA

NA – Not analyzed statistically

CONCLUSION

Hand weeding twice at 20 and 30 DAP is the best efficient method for the weed control which produces significantly highest yield and weed control efficiency. Since, the labour availability is a problem besides high cost involved in the hand weeding, stale seedbed technique in combination with inter cultivation twice at 20 and 35 DAP or passing wheel hoe at 20, 30 and 40 DAP with one hand weeding would be a viable alternative for weed management in organic finger millet production. Further there is need to carry out research on development and evaluation of power operated weeders for their efficacy in organic cultivation and evaluation of different mulching materials and cover crops need to be carried out for better weed control in organic condition.

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