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Effect of Spacing and Weed Management Practices on Barnyard Millet (*Echinochloa frumentaceae*) under Rainfed Condition

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A B S T R A C T

Field experiment was carried out to assess suitable spacing and weed management practices under rainfed condition that can suppress weeds and enhance the growth of Barnyard millet (*Echinochloa frumentaceae*) during *Rabi* season of 2018 at Tamil Nadu Agricultural University, Killikulam, Tamil Nadu. Weed flora observed in experimental field consists of *Echionocloacolonum* under grasses, *Cyperus rotundus* under sedges and *Amaranthus viridis, Boerhavia diffusa, Cleome viscosa, Commelina bengalensis, Phyllanthus niruri* under Broad leaved weeds. Irrespective of weed management practices, total density, total dry weight of weeds and weed control efficiency were higher in weed free check (T_{11}) which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) *fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) and spacing of 30 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_5) over unweeded control (T_{12}). Grain and straw yield (1681 and 3975kg/ha, respectively) were significantly higher with weed free check (T_{11}) as compared to Unweeded control (T_{12}). The net return and B: C ratio (Rs. 26502 per ha and 2.17, respectively) were significantly higher with weed free check (T_{11}) which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) *fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) and spacing of 30 cm x 10 cm with hand weeding twice on 20 and 40 DAS(T_5). Unweeded control (T_{12}) recorded significantly minimum net returns (Rs.6933 per ha) and benefit: cost ratio (Rs.1.34). The result shows that both spacing and weed management practices had the ability of suppressing weeds. Hand weeding twice and narrow spacing had strong and negative effects on weed biomass and positive effects on crop biomass and yield.

Introduction

Barnyard millet (*Echinochloa frumentaceae*) is cultivated and grown as cereal with nativity of Eurasia. It is important minor millet belonging to the family Poaceae. It is a grain crop of lesser importance. It is drought tolerant crop capable of withstanding waterlogged conditions. It is a fastest multi-purpose crop, which yields food and forage in

a short duration and at low inputs even under adverse climatic conditions. In India, Japan and China, Barnyard millet was often used as a substitute for rice when the paddy crop fails. In the U.S.A. it is grown primarily for forage, and can produce up to eight harvests a year. It does not require more irrigation. Barnyard Millet is considered the least important of cereals, with annual production less than 2% of the world's grain. It is found in most of the southern and central states in India especially wherever annual rainfall is below 350 mm, whereas no other cereal crop can grow under such moisture stress.

Nutritionally, Barnyard millet is an important crop. It is a rich source of protein (11.8%) and crude fibre (9.8%). Out of the total protein; it also consists of 16.6% of amino acid leucine, which is twice the quantity of Rice, which is highly digestible and is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions. The grains of barnyard millet are low in phytic acid and rich in iron and calcium contents (Sampath *et al.*, 1990). The carbohydrate content is low and slowly digestible, which makes the Barnyard millet a natural designer food. In the present days of increased diabetes mellitus, Barnyard millet could become an ideal food.

In the year of 2014-2015, the total production of minor millets in India is 6.83 lakh tonnes, cultivated in area about 6 lakh hectares with an average productivity of 630 kg ha^{-1}. In Tamil Nadu small millets are cultivated in an area of 32000 ha with a production of about 35000 t. The average productivity of small millets is about 1086 kg ha^{-1} (Agricultural statistics at a Glance, 2015). Appropriate inter-row spacing will help the crop to compete with weed. Several reports indicated that crops planted in narrow row spacing suppress weed growth more than in wide row spacing because high density of crop in narrower inter row spacing resulting in lower weeds infestation which was suppressed by crops. It is a need of determining suitable inter-row spacing for suppression of weeds with effective weed management practices either by herbicide application or manual or mechanical weeding to increase the crop yield, crop quality and reduce production cost.

Materials and Methods

Field experiment was carried out during *Rabi* season of 2018 at Tamil Nadu Agricultural University, Killikulam, Tamil Nadu. The soil of the experimental field was sandy clay loam soil in texture with low in available organic carbon (5.6 g/kg soil) and available nitrogen (230 kg/ha) but medium in available phosphorus (22 kg/ha) and potassium (256 kg/ha) with a pH of 7.8. The experiment consisting of 12 treatments and were factorially arranged and laid out in a Randomized Complete Block Design with three replications. The experiment was conducted in randomized block design replicated thrice with twelve different weed management practices viz., broadcasting (seeds of 10 kg ha^{-1}) + Hand weeding twice on 20 and 40 DAS (T_1), spacing of 25 cm × 10 cm + Hand weeding twice on 20 and 40 DAS (T_2), spacing of 25 cm × 10 cm + one Hand weeding twice on 20 + one Mechanical weeding on 40 DAS (T_3), spacing of 25 cm x 10 cm + PE Pendimethalin@ 1kg ai ha^{-1} followed by Hand weeding on 40 DAS (T_4), spacing of 30 cm × 10 cm + hand weeding twice on 20 and 40 DAS (T_5), spacing of 30 cm × 10 cm + one hand weeding twice on 20 + one Mechanical weeding on 40 DAS (T_6), spacing of 30 cm × 10 cm + PE Pendimethalin @ 1kg ai ha^{-1} followed by hand weeding on 40 DAS (T_7), spacing of 40 cm × 10 cm + hand weeding twice on 20 and 40 DAS (T_8), spacing of 40 cm × 10 cm + one hand weeding twice on 20 DAS + one Mechanical weeding on 40 DAS (T_9), spacing

of 40 cm × 10 cm + PE Pendimethalin @ 1kg ai ha^{-1} followed by hand weeding on 40 DAS (T_{10}),Weed-free check(T_{11}), Unweeded control (T_{12}).

The variety used for the experiment was MDU 1. A recommended dose of fertilizers (40:20:0 N: P_2O_5: K_2O kg/ha) was applied equally to each plot. Nitrogen was applied in two splits. Half dose of N (20 kg/ha) along with full dose of P_2O_5 (20 kg/ha) were applied as basal and remaining N (20 kg/ha) was applied as top dressing after 30 days of sowing. The source for nitrogen and phosphorous were urea, di-ammonium phosphate respectively. Weed counts (No. m^{-2}) and dry weight (g m^{-2}) were recorded by putting a quadrate (25 cm x 25 cm) at two random spots in each plot at 45 DAS of the crop. Weed control efficiency (WCE) was also calculated on the basis of dry matter production of weeds. The experimental data recorded for growth, yield attributes and yield were statistically analysed. Data on weed density and dry weight of weeds were transformed using square root transformation (√X+0.5) before statistical analysis.

Results and Discussion

Effect on weeds

Weed flora observed in experimental field were classified as Grasses, Sedges and Broad leaved weeds. There were seven species belonging to seven families. Weed flora consists of *Echionocloa colonum* under grasses, *Cyperus rotundus* under sedges and *Amaranthus viridis, Boerhavia diffusa, Cleome viscosa, Commelina bengalensis, Phyllanthus niruri* under Broad leaved weeds as reported by Gowda *et al.*, (2012).

Weed free check (T_{11}) significantly reduced the density of grasses, sedge and broad leaved weeds (0.43 No.m^{-2}, 1.0 No.m^{-2} and 1.1No. m^{-2}, respectively) at 45 DAS which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) *fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) and spacing of 30 cm x 10 cm + hand weeding twice on 20 and 40 DAS (T_5). Among weed management practices, weed free check (T_{11})had significantly reduced dry weight of grasses, sedges and broad leaved weeds(0.20 g m^{-2}, 0.34g $m^{-2}$and 0.59g m^{-2}, respectively) at 45 days after sowing which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) *fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) as compared to other treatments. Whereas, unweeded control (T_{11}) recorded significantly higher weed population and weed dry weight, respectively. The reduction in the weed population and weed dry weight in these treatments was mainly due to effective control of weeds at all stages of crop growth period. These results are in conformity with the findings of Sanjoy Saha (2005) and Madhu Kumar *et al.,* (2013). However, the weed control efficiency (98.18%) was also highest with weed free check (T_{11}) given in Table 1. This was mainly due to better control of weeds right from sowing to45 DAS, which is the critical period for crop weed competition. These results are in conformity with the findings of Pradhan *et al.*, (2010).

Effect on growth and yield attributes of crop

All weed management practices significantly improved the growth and yield attributes of Barnyard millet over unweeded control (Table 2). Plant spacing plays an important role on growth, development and yield of crops. In general, yield of millets is greatly affected by the plant population and higher yield could be

achieved with increasing plant population to a greater extent. Barker (1996) reported that when millet is grown in narrow spacing, lower weed pressure and weed composition was observed as compared to wider spacing.

Table.1 Effect of spacing and weed management practices on weed density, weed dry weight and weed control efficiency at 45 DAS in barnyard millet under rainfed condition

Treatments	Weed density (No.m^{-2})			Weed dry matter production (g m^{-2})			WCE(%)
	Grasses	Sedges	Broad leaved weeds	Grasses	Sedges	Broad leaved weeds	
T_1: Broadcasting 10 kg seeds /ha+ 2 HW on 20 and 40 DAS	4.39(2.21)	6.33 (2.72)	4.4 (2.21)	1.21	2.13	2.35	89.43
T_2: Spacing of 25 cm x 10 cm + 2 HW on 20 and 40 DAS	1.27(1.33)	2.13 (1.62)	2.1 (1.63)	0.43	0.70	1.42	96.08
T_3: Spacing of 25 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	3.51 (2.00)	5.97 (2.54)	4.4 (2.23)	1.36	2.01	2.37	90.20
T_4: Spacing of 25 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	2.97 (1.87)	5.53 (2.46)	3.2 (1.92)	1.16	1.76	1.75	91.74
T_5 : Spacing of 30 cm x 10 cm +2 HW on 20 and 40 DAS	3.10 (1.90)	5.40 (2.43)	3.2 (1.92)	1.19	1.75	1.76	91.88
T_6: Spacing of 30 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	3.88 (2.09)	6.80 (2.70)	3.7 (2.06)	1.68	2.24	2.06	89.85
T_7 : Spacing of 30 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	4.30 (2.19)	6.77 (2.70)	4.5 (2.24)	1.65	2.29	2.43	89.08
T_8: Spacing of 40 cm x 10 cm +2 HW on 20 and 40 DAS	4.42 (2.22)	7.93 (2.90)	3.8 (2.08)	1.85	2.57	2.18	88.66
T_9: Spacing of 40 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	5.11 (2.37)	6.97 (2.73)	3.3 (1.96)	2.13	2.93	1.79	89.15
T_{10}: Spacing of 40 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	4.03 (2.13)	7.27 (2.79)	4.6 (2.25)	1.57	2.78	2.42	88.87
T_{11}: Weed free check	0.43 (0.97)	1.00 (1.22)	1.1 (1.28)	0.20	0.34	0.59	98.18
T_{12}: Unweeded control	34.91 (5.95)	71.60 (8.48)	36.4 (6.07)	13.92	23.2	20.9	0.00
SEd	0.03	0.09	0.09	0.25	0.24	0.21	
CD(P=0.05)	0.07	0.19	0.19	0.53	0.50	0.44	

Actual figures are transformed to $\sqrt{X+0.5}$ and population figures are given in Parenthesis.

Table.2 Effect of spacing and weed management practices on growth and yield attributes of barnyard millet under rainfed condition

Treatments	Plant height (cm) at harvest	LAI at 60 DAS	Number of productive tillers (m^{-2})	Length of panicle(cm)
T_1: Broadcasting 10 kg seeds /ha+ 2 HW on 20 and 40 DAS	111.28	4.56	103.5	12.2
T_2: Spacing of 25 cm x 10 cm + 2 HW on 20 and 40 DAS	129.12	8.42	176	14.5
T_3: Spacing of 25 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	106.34	6.57	132	13.8
T_4: Spacing of 25 cm x 10 cm + PE Pendimethalin 1 kg ai ha^{-1} fb1 HW on 20 DAS	122.00	7.09	163	14.0
T_5 : Spacing of 30 cm x 10 cm +2 HW on 20 and 40 DAS	121.47	7.02	131	13.7
T_6: Spacing of 30 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	110.68	6.43	124	13.6
T_7 : Spacing of 30 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb1 HW on 20 DAS	112.75	6.28	134	13.3
T_8: Spacing of 40 cm x 10 cm +2 HW on 20 and 40 DAS	106.25	5.21	104	13.1
T_9: Spacing of 40 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	107.32	5.98	110	12.7
T_{10}: Spacing of 40 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb1 HW on 20 DAS	104.68	5.13	105	12.6
T_{11}: Weed free check	129.69	8.53	176	14.6
T_{12}: Unweeded control	96.73	3.52	97	11.8
SEd	0.76	0.16	5.32	0.08
CD(P=0.05)	1.59	0.36	11.04	0.17

Table.3 Effect of spacing and weed management practices on yield and economics of barnyard millet under rainfed condition

Treatments	Grain yield(kg ha^{-1})	Stover yield(kg ha^{-1})	Cost of cultivation (☐. ha^{-1})	Gross return (☐. ha^{-1})	Net return (☐. ha^{-1})	B:C ratio
T_1: Broadcasting 10 kg seeds /ha+ 2 HW on 20 and 40 DAS	1075	3049	22563	36579	14016	1.62
T_2: Spacing of 25 cm x 10 cm + 2 HW on 20 and 40 DAS	1678	3944	22563	48834	26271	2.16
T_3: Spacing of 25 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	1096	3412	22658	36912	14254	1.63
T_4: Spacing of 25 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	1290	3594	22627	40914	18287	1.81
T_5 : Spacing of 30 cm x 10 cm +2 HW on 20 and 40 DAS	1289	3592	22563	40887	18324	1.81
T_6: Spacing of 30 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	1109	3443	22658	37293	14635	1.65
T_7 : Spacing of 30 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	1179	3419	22627	38199	15572	1.69
T_8: Spacing of 40 cm x 10 cm +2 HW on 20 and 40 DAS	1006	3337	22563	35112	12549	1.56
T_9: Spacing of 40 cm x 10 cm +1 HW on 20 DAS + 1 Mechanical Weeding on 40 DAS	986	3095	22658	33405	10747	1.47
T_{10}: Spacing of 40 cm x 10 cm + PE Pendimethalin 1 Kg ai ha^{-1} fb 1 HW on 20 DAS	1010	3273	22627	34788	12161	1.54
T_{11}: Weed free check	1681	3975	22563	49065	26502	2.17
T_{12}: Unweeded control	837	2449	20316	27249	6933	1.34
SEd	48.24	57.71	NA	NA	NA	NA
CD(P=0.05)	100.04	119.70	-	-	-	-

The highest values of plant height (129.69 cm at 90 DAS), leaf area index (5.69 at 60 DAS), number of productive tillers (176 m^{-2} at maturity), length of panicle (14.6 cm at maturity) were recorded under weed free check (T_{11}) which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) *fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) and spacing of 30 cm x 10 cm + hand weeding twice on 20 and 40 DAS (T_5). The enhancement of crop growth and yield attributes 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 sowing through pre-emergence application of herbicides and late emerged weeds through manual weeding. Similar results were reported by Prashanth Kumar *et al.,* (2015) and Prithvi *et al.,* (2015).

Effect on yield of crop

Data pertaining to Yield of Barnyard millet, in which weed free check (T_{11}) recorded significantly higher grain and stover yield (1681 kg/ha and 3975 kg/ha, respectively) among different weed management practices which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2) as compared to unweeded control (T_{12}) (Table 3). The minimum grain and straw yield in unweeded control could be due to the severe weed competition as evidenced by the maximum weed density, weed dry matter which resulted in less number of tillers, lower plant dry matter and plant height. Reduction in grain yield of Barnyard millet was due to weed competition was reported by Prashanth Kumar *et al.,* (2015) and Prithvi *et al.,* (2015).

Effect on economics

A critical analysis of data on economics revealed that the highest gross returns (Rs.49065 ha^{-1}) was obtained with weed free check(T_{11}). But higher cost of cultivation in weed free check (Hand weeding twice) due to engagement of more labourers for weeding. This confirms the finding of Tuti *et al.,* (2016).Spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS (T_4) compared to weed free check(T_{11}). Maximum net return (Rs.26502ha^{-1}) and benefit: cost ratio (2.17) were obtained with weed free check (T_{11}) which was on par with spacing of 25 cm x 10 cm with hand weeding twice on 20 and 40 DAS (T_2)*fb* spacing of 25 cm x 10 cm with Pre emergence application of Pendimethalin @1 kg ai ha^{-1} + hand weeding on 20 DAS(T_4) (Table 3). This confirms the finding of Khaliq *et al.,* (2011). On the basis of result obtained, it can be concluded that hand weeding twice with narrow spacing of 25 cm × 10 cm (T_2) found to be best as weed management practice for better weed control efficiency, crop growth, higher productivity and profitability in line sown rainfed barnyard millet.

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