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Research Article

IMPACT OF INTEGRATED WEED MANAGEMENT PRACTICES ON WEED DYNAMICS, GROWTH AND YIELD OF PEARLMILLET [*Pennisetum glaucum* L. Br. Emend. Stuntz.]

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Abstract- In this research, the effects of integrated weed management practices on weed dynamics, growth and yield of pearl millet [*Pennisetum glaucum* (L.) Br. Emend. Stuntz.] were studied at different growth stages. Weed density and dry weight were recorded thrice at 25 and 50 DAS and at harvest. The lowest density and dry weight of weeds were observed with hand weeding twice at 20 and 40 DAS, which was at par with pre-emergence application of atrazine @ 750 g *a.i.*/ha *fb* hand weeding at 30 DAS. The observations on growth and yield attributes by plants were recorded at harvest. Hand weeding twice at 20 and 40 DAS and pre-emergence application of atrazine @ 750 g *a.i.*/ha *fb* hand weeding at 30 DAS recorded 86.5 and 83.8% higher grain yield over weedy check. Pre-emergence application of oxyfluorfen @ 100 g *a.i.*/ha resulted in poor weed control and grain yield and was reported to be phytotoxic to the crop. Integration of post-emergence herbicides *viz.,* ethoxysulfuron @ 37.5 g *a.i.*/ha or almix @ 8 g *a.i.*/ha at 25 DAS with any of the pre-emergence herbicides *viz.,* atrazine and oxyfluorfen did not have any significant effect on weed control and grain yield of pearl millet. Integration of pre-emergence application of atrazine with hand weeding effectively controlled the weed population and increased the grain yield of pearl millet, significantly over other integrated weed management practices.

Keywords- Atrazine, Hand weeding, Phytotoxicity, Oxyflourfen, Post-emergence, Pre-emergence

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Introduction

Pearl millet [*Pennisetum glaucum* (L.) Br. Emend. Stuntz.] is one of the important food crop for millions of people in tropics, particularly in Asia and Africa. Due to its short duration and drought tolerant ability, it is suitable under adverse weather conditions with outstanding nutritional properties and they are considered to be poor man's food. India, encompassing vast sub-tropical area is having an average pearl millet productivity of 1198 kg/ha. Besides various constraints regarding pearl millet productivity, severe infestation of weeds during rainy season sub-optimizes the production of pearl millet. Yield loss upto 40 % or even more in pearl millet during rainy season has been reported by [1] as weed emerge simultaneously with crop and cause severe competition for growth resources. Manual weeding being the conventional method of weed control in pearl millet is expensive and time consuming. Lately, labour scarcity during rainy season has accentuated the usage of herbicides indispensable for timely weed control. Manual weeding or spraying of recommended pre-emergence herbicides sometime difficult in rainy season for effective weed control, thus, brought the application of post-emergence herbicides into the discussion. So, integration of mechanical and chemical weed control strategies provides a better option for effective weed control in pearl millet. The present experiment was undertaken in pearl millet to find out an effective combination of weed control methods to increase productivity in pearl millet.

Materials and Methods

Experimental Details and Treatments

Experimental Details: A field experiment was conducted during *kharif,* 2014 at S. V. Agricultural College farm, Tirupati campus of ANGRAU, Andhra Pradesh. The soil was sandy loam in texture, low in organic carbon (0.39 %) and available N (232 kg/ha), medium in available P (27.3 kg/ha) and available K (247.6 kg/ha) with pH 7.23. Ten treatments of weed control were evaluated in randomized block design replicated thrice with hybrid PHB-306. The recommended dose of 60 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha was applied. Entire quantity of phosphorous and potassium and half of the nitrogen were applied as basal through single super phosphate and muriate of potash and urea, respectively. The remaining half of nitrogen was applied at 30 DAS. The test hybrid was sown with a spacing of 45 × 10 cm. Thinning and gap filling were done at 10 DAS.

Treatments: The treatments consisted of pre-emergence application of atrazine @ 750 g/ha (T_1) and oxyfluorfen @ 100 g/ha alone (T_2) or in combination with hand weeding (HW) at 30 DAS (T_3 and T_4) or post-emergence herbicides, such as; almix @ 8 g/ha (T_5 and T_6) or ethoxysulfuron @ 37.5 g/ha (T_7 and T_8), hand weeding twice at 20 and 40 DAS (T_9) and unweeded check (T_{10}). Pre-emergence herbicides were applied 1 day after sowing (DAS), while post-emergence herbicides were applied at 25 DAS uniformly by using spray fluid @ 500 L/ha with the help of knapsack sprayer fitted with flat fan nozzle. Hand weedings were carried out in the respective treatments at 20, 30 and 40 DAS.

Statistical analysis: Weed density and dry weight were recorded thrice at 25 and 50 DAS and at harvest by placing a quadrant of size 0.5 × 0.5 m randomly at three places in each plot and were subjected to square root ($\sqrt{x+0.5}$) transformation. Visual Phytotoxicity scoring was done in all the treatments on 10th and 5th day after pre and post-emergence herbicide application as per the method suggested by

[2]. Weed control efficiency (%) was computed using the dry weight of weeds [3]. The observations on growth and yield attributes were recorded at harvest. The statistical analyses were done by using WASP- Web Agri Stat Package 2.0.

Results

Weed flora: The predominant weed species found in the experimental site were sedges like *Cyperus rotundus* L. (30.7%) and *C. iria* L. (17.0%), grasses like *Digitaria sanguinalis* L. (9.8%), *Echinochloa colona* L. (7.5%) and *Celosia argentia* L. (5.2%), broad leaved weeds like *Commelina benghalensis* L. (4.8%) and *Phalaris minor* L. (4.3%).

Effects on weed: The lowest weed count and dry weight was recorded with HW twice at 20 and 40 DAS during all the stages of observations, which was in parity with pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS at 50 DAS and at harvest. At 25 DAS, pre-emergence application of oxyfluorfen recorded significantly lower density and dry weight of weeds over pre-emergence application of atrazine. At later stages of observations, pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS resulted in better control of weeds over treatments involving pre-emergence application of oxyfluorfen @ 100 g/ha [Table-1]. Pre-emergence application of oxyfluorfen @ 100 g/ha provided lesser weed control due to its phytotoxic effect on crop. Among the different post-emergence herbicides applied, ethoxysulfuron @ 37.5 g/ha controlled annual sedges and broad leaved weeds, where as almix @ 8 g/ha controlled the grasses, effectively [4]. But overall, post-emergence herbicides were not effective as compared to hand weeding at 30 DAS. The highest density and dry weight of weeds was registered with weedy check. Among the weed management practices tried, HW twice at 20 and 40 DAS resulted in the highest weed control efficiency, which was statistically similar with pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS.

Table-1 *Effect of weed management practices on weed density at 25, 50 DAS and at harvest and weed dry weight and weed control efficiency*

Treatments	Weed density (No./m²)												Weed dry weight (g/m²)			WCE (%)
	25 DAS			50 DAS			At harvest			Total			Grasses	Sedges	BLWs	
	Grasses	Sedges	BLWs	Grasses	Sedges	BLWs	Grasses	Sedges	BLWs	25 DAS	50 DAS	At harvest				
T_1: PE atrazine @ 750 g/ha	7.66 (2.94)	85.00 (9.27)	9.66 (3.26)	18.33 (4.39)	98.33 (9.94)	24.00 (4.99)	21.00 (4.69)	95.66 (9.82)	22.00 (4.79)	102.32 (10.16)	140.66 (11.90)	138.66 (11.81)	26.08 (5.20)	35.89 (6.07)	35.52 (6.03)	56.0 (48.4)
T_2: PE oxyflourfen @ 100 g/ha	4.66 (2.37)	69.66 (8.40)	6.00 (2.64)	19.00 (4.47)	99.33 (10.66)	24.66 (5.06)	39.33 (6.34)	100.33 (10.05)	34.66 (5.97)	80.33 (9.01)	143.00 (12.00)	174.66 (13.23)	20.49 (4.63)	36.76 (6.14)	43.73 (6.68)	45.9 (42.6)
T_3: PE atrazine @ 750 g/ha + HW at 30 DAS	8.33 (3.05)	87.66 (9.41)	9.33 (3.21)	3.33 (2.07)	8.66 (3.10)	3.33 (2.06)	7.64 (2.93)	18.33 (4.39)	7.66 (2.94)	105.33 (10.31)	15.33 (4.04)	33.66 (5.86)	26.65 (5.25)	4.10 (2.25)	8.64 (3.10)	89.2 (70.8)
T_4: PE oxyflourfen @ 100 g/ha + HW at 30 DAS	5.00 (2.44)	68.33 (8.32)	5.66 (2.58)	7.66 (2.94)	48.00 (6.98)	7.66 (2.93)	40.00 (6.39)	88.66 (9.46)	32.66 (5.80)	79.00 (8.94)	63.33 (8.00)	161.33 (12.74)	19.86 (4.56)	16.41 (4.16)	40.26 (6.42)	50.1 (45.0)
T_5: PE atrazine @ 750 g/ha + PoE almix @ 8 g/ha	9.00 (3.16)	83.33 (9.17)	10.33 (3.36)	11.33 (3.51)	97.33 (9.91)	14.00 (3.81)	21.00 (4.69)	95.00 (9.78)	21.66 (4.75)	102.66 (10.17)	122.66 (11.11)	137.66 (11.76)	26.23 (5.21)	31.46 (5.71)	34.77 (5.98)	56.9 (49.0)
T_6: PE atrazine @ 750 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	8.00 (2.99)	86.33 (9.34)	10.00 (3.31)	16.33 (4.16)	65.66 (8.32)	15.33 (4.03)	35.00 (5.99)	78.00 (8.88)	20.66 (4.65)	104.33 (10.26)	100.00 (10.04)	133.66 (11.60)	26.54 (5.24)	26.12 (5.20)	33.71 (5.89)	58.2 (49.7)
T_7: PE oxyflourfen @ 100 g/ha + PoE almix @ 8 g/ha	5.33 (2.50)	69.33 (8.38)	6.33 (2.70)	11.66 (3.55)	99.66 (10.02)	14.66 (3.95)	23.33 (4.93)	118.00 (10.89)	34.00 (5.91)	81.00 (9.04)	126.00 (11.26)	165.66 (12.89)	20.48 (4.63)	32.45 (5.78)	43.41 (6.66)	46.2 (42.8)
T_8: PE oxyflourfen @100 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	5.00 (2.44)	66.66 (8.27)	6.66 (2.76)	16.00 (4.12)	65.66 (8.16)	15.33 (4.04)	49.00 (7.05)	81.00 (9.05)	33.33 (5.85)	78.33 (8.91)	97.00 (9.89)	163.33 (12.81)	19.65 (4.54)	26.50 (5.24)	40.62 (6.44)	49.7 (44.8)
T_9: HW twice at 20 and 40 DAS	1.33 (1.52)	7.33 (2.88)	1.33 (1.52)	2.66 (1.91)	8.30 (2.99)	2.33 (1.82)	7.33 (2.85)	17.33 (4.27)	7.33 (2.88)	10.00 (3.30)	13.00 (3.77)	32.00 (5.73)	2.53 (1.84)	3.53 (2.12)	8.29 (3.04)	89.7 (71.3)
T_{10}:Weedy check	43.33 (6.64)	128.6 (11.4)	28.00 (5.36)	82.00 (9.08)	185.33 (13.60)	59.00 (7.72)	86.66 (9.36)	177.33 (13.33)	71.66 (8.49)	200.00 (14.17)	326.33 (18.09)	335.66 (18.33)	48.27 (7.01)	83.69 (9.20)	80.84 (9.04)	-
SEm±	0.13	0.17	0.12	0.16	0.19	0.14	0.17	0.29	0.16	0.18	0.20	0.26	0.07	0.08	0.09	0.85
CD (P=0.05)	0.40	0.50	0.35	0.50	0.57	0.42	0.53	0.86	0.50	0.54	0.61	0.80	0.22	0.24	0.28	2.5

*Figures in parentheses represent square root transformed values of the original data

Effects on crop: All the growth parameters *viz.,* plant height and dry matter production were significantly higher with HW twice at 20 and 40 DAS, which were comparable with pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS. The treatments involving pre-emergence application of oxyfluorfen @ 100 g/ha recorded in lower values of the above growth parameters due to the phytotoxic effect of oxyfluorfen on pearl millet with the phytotoxicity score recorded upto "4" [5]. HW twice at 20 and 40 DAS recorded the highest yield attributes *i.e.* effective tillers/plant, grain and straw yield of pearl millet, which were statistically similar to pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS. The treatments associated with pre-emergence application of oxyfluorfen @ 100 g/ha resulted in reduced yield attributes and yield in pearl millet due to poor growth and mortality of pearl millet. Post-emergence application of either ethoxysulfuron @ 37.5 g/ha or almix @ 8 g/ha did not produce any significant increase in grain and straw yield due to failure in controlling broad spectrum of weeds. Weedy check recorded the lowest grain and straw yield and grain yield was 53.5 % lower as compared to weed free condition.

Economics: HW twice at 20 and 40 DAS resulted in the highest gross returns, which was in parity with pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS. However, the latter treatment recorded the highest net returns and benefit-cost ratio [Table-2]. The treatments with pre-emergence application of oxyfluorfen @ 100 g/ha recorded lesser gross, net returns and benefit-cost ratio due to lower yield level and higher cost of cultivation. The lowest gross, net returns and benefit-cost ratio were realized with weedy check due to the lowest yield associated with it.

Discussions

Pre-emergence application of oxyfluorfen @ 100 g/ha controlled the weeds during

initial stages mainly due to effective suppression of the highly populated sedges owing to the fumigating mode of action of oxyfluorfen [6]. Oxyfluorfen effectively controlled the early emerging weeds due to accumulation of protoporphyrin IX, a photosensitizing porphyrin, leading to membrane destruction and ethane production resulting in killing of weeds [7]. During later stages, pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS controlled the broad spectrum of weeds owing to effective weed control by atrazine during the critical period of crop-weed competition and by hand weeding at the later stages of crop growth of the crop ontogeny. Pre-emergence application of oxyfluorfen @ 100 g/ha proved to be less effective in suppressing weeds due to its phytotoxicity on pearl millet, thereby reducing the crop growth and plant population resulting in better availability of growth resources to the weeds. Post-emergence application of ethoxysulfuron @ 37.5 g/ha along with any of the pre-emergence herbicide resulted in better suppressing ability of annual sedges and broad leaved weeds. The treatments involving post-emergence application of almix @ 8 g/ha resulted in satisfactory control of grasses and broad leaved weeds, which might be due to inhibition of cell division in target plants. These results were supported by [8]. But, failure in controlling the broad spectrum of weeds by the post-emergence herbicides has limited the usage of these herbicides in pearl millet.

Table-2 *Effect of weed management practices on Growth and Yield attributing characters of pearlmillet and Economics of the treatments*

Treatments	Plant height (cm)	Dry matter production (kg/ha)	Phytotoxicity score	Effective tillers/plant	Straw yield (kg/ha)	Grain yield (kg/ha)	Net returns (Rs./ha)	B:C Ratio
T_1: PE atrazine @ 750 g/ha	204.9	8919	0	2.36	5097	2289	27789	2.74
T_2: PE oxyflourfen @ 100 g/ha	179.9	7313	4	1.96	4245	1860	19438	2.20
T_3: PE atrazine @ 750 g/ha + HW at 30 DAS	228.8	10449	0	2.80	6158	2936	36115	2.82
T_4: PE oxyflourfen @ 100 g/ha + HW at 30 DAS	188.3	7901	4	2.13	4646	2055	19298	1.96
T_5: PE atrazine @ 750 g/ha + PoE almix @ 8 g/ha	205.7	9391	0	2.46	5148	2339	27858	2.65
T_6: PE atrazine @ 750 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	211.8	9459	0	2.53	5244	2398	28339	2.63
T_7: PE oxyflourfen @ 100 g/ha + PoE almix @ 8 g/ha	181.6	7592	3	2.00	4368	1915	19634	2.15
T_8: PE oxyflourfen @100 g/ha + PoE ethoxysulfuron @ 37.5 g/ha	184.6	7606	4	2.06	4556	2007	20814	2.18
T_9: HW twice at 20 and 40 DAS	235.6	10674	0	0.81	6368	2976	33737	2.46
T_{10}:Weedy check	162.3	6151	0	1.71	3701	1595	15247	1.99
SEm±	5.33	285.9	-	0.072	149.5	77.5	1350	0.072
CD (P=0.05)	15.8	849	-	0.21	447	232	4042	0.21

Pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS resulted higher growth parameters and higher yield attributes which might be due to weed free condition for a longer period during the crop ontogeny increasing the availability of growth resources to the crop. The results are in accordance with [9]. Atrazine controlled the weeds by blocking the Hill reaction and producing reactive singlet oxygen species in photo-system II due to inhibition of ATP formation [10] and weed free condition effectively increased the translocation of photosynthates from source to the sink resulting in better yield attributes and thereby better grain yield. Pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS recorded the highest net returns and benifit-cost ratio due to its lower cost of cultivation compared to other weed management practices.

Conclusions

In conclusion, though HW twice at 20 and 40 DAS resulted the highest yield, but in terms of economics, pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS was found to be the best integrated weed management practice in this investigation. Evaluation of other post-emergence herbicides should be given preference in order to find out suitable post-emergence herbicide for pearl millet to avoid the problem of labour scarcity in future.

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Abbreviations: HW- Hand weeding, *fb*- followed by, PE –Pre-emergence, PoE-Post-emergence, DAS-Days after sowing

Conflict of Interest: None declared

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