Original Research Article

Evaluating Weed Management Strategies and the Differential Effects of Herbicides on Weed dynamics and crop performance of foxtail millet [Setariaitalica (L.) Beauv] grown under the irrigated conditions of Rayalaseema

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ABSTRACT

At the wetland farm of S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India, a field experiment was carried out during the (rainy season) kharif 2020 to evaluating weed management strategies and the differential effects of herbicides on weed dynamics and crop performance of foxtail millet [Setariaitalica (L.) Beauv] grown under the irrigated conditions of Rayalaseema. The current study has shown that the application of PE pretilachlor 500 g ha^{-1} fb intercultivation at 20 DAS was followed by HW twice at 20 and 40 DAS and it led to the highest WCE, including foxtail millet's nutrient uptake, and the lowest weed density and dry weight. In unweeded check, a heavy weed infestation reduced the amount of nitrogen, phosphorus, and potassium absorbed by crop by 45.67, 18.03, and 35 kg ha^{-1}, respectively. Grain production was increased by hand weeding twice, however the benefit-cost ratio lagged behind the most effective weed management strategy, which is applying PE of pretilachlor 500 g ha^{-1}fb intercultivation at 20 DAS.

Keywords: [Broad-spectrum, Pre-emergence herbicides, Pretilachlor, Intercultivation, Hand weeding, Nutrient uptake}

1. INTRODUCTION

Foxtail millet [Setariaitalica (L.) Beauv] is cultivated in India as a rain-fed Kharif crop. Appropriate weed control is regarded as a crucial component of agronomic procedures because to significant losses brought on by weed infestation (Munirathnam and Sawadhkar 2007) [4]. The highly diverse weed flora associated with foxtail millet varies according to the season, the state of the agro-ecological system, and the degree of control. During its early growth, foxtail millet is vulnerable to weed competition due to its slow-growing canopy. In general, especially in the early phases of the crop, minor millets are less competitive with weeds for growth resources. Foxtail millet has a severe weed invasion because of its initial delayed development during the rainy season. The first four to six weeks following seedling emergence were thought to be crucial for weed eradication (Nanjappa and Hosmani, 1985) [5]. According to Ning et al. (2015) [6], the presence of weeds during the crop season on calcareous soils caused a 56% reduction in the grain production of foxtail millet. Major millets have larger seeds and are sown at a deeper depth than minor millets, pre-emergence herbicides increase the efficiency of productivity and weed control in major millets (Mishra 2016) [3]. Very little research has been done on the topic of chemical weed control in foxtail millet. Farmers are now more likely to use herbicides in minor millet fields to effectively manage weeds because hand weeding has become more expensive in recent years. Hence, the present study was undertaken to evaluate weed management strategies and the differential effects of herbicides on weed dynamics and crop performance of foxtail millet [Setariaitalica (L.) Beauv] grown under the irrigated conditions of Rayalaseema.

2. MATERIAL AND METHODS

At the wetland farm of S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India, a field experiment was carried out during the kharif 2020 rainy season. The texture of the soil was sandy clay loam, with a neutral reaction, low levels of accessible nitrogen and organic carbon, and medium levels of available potassium and phosphorus. Eleven treatments were included in the randomized block design trial, which was conducted three times. On August 14, 2020, foxtail millet was sowed with a 30 x 10 cm spacing. Pre-emergence application (PE) of 500, 500, and 15 g/ha of pretilachlor, isoproturon, and pyrazosulfuron-ethyl, respectively, as well as twice-hand weeding and un-weeded check were the weed management treatments (Table 1). Twenty days after sowing (DAS), intercultivation or post-emergence application (PoE) of penoxsulam 20 g/ha was added to all pre-emergence herbicides. Herbicides for pre-emergence were treated at 1 DAS, whereas penoxsulam, an inter-cultivation/post-emergence herbicide, was applied at 20 DAS. Applying all pre- and post-emergence herbicides required the use of a knapsack sprayer with a 500 L/ha spray volume and a flat fan nozzle. All of the plots received an equal dosage of 20 kg N and 20 kg P in the form of urea and single super phosphate, respectively. The complete dose of phosphorous was administered as basal at the time of sowing, and the nitrogen was treated in two splits: half the dose was applied as basal and the other half as top dressing at 30 DAS. The recommendations of the Acharya N.G. Ranga Agricultural University were followed in adopting the remaining packages of practices. Using a 0.25 m^2 quadrat, category-specific weed density and biomass were randomly recorded. To standardize the distribution of the weed density and biomass data, a square root ($\sqrt{X + 0.5}$) transformation was applied. Based on the methodology proposed by (Mani et al. 1973) [2], the efficiency of weed suppression was calculated. At harvest, every component of yield was documented. The benefit-cost ratio was computed by dividing the cost of cultivation by the gross returns. November 5, 2020, was the harvest date of the crop. The statistical analysis of the weed and crop data was conducted using the analysis of variance for randomized block design, as recommended by Panse and Sukhatme (1985) [9]. At harvest in foxtail millet, the nitrogen uptake (kg ha^{-1}) by weeds and crop was determined using the techniques recommended by Subbiah and Asija (1956) [12] and Olsen et al. (1954) [7], respectively. Following the normal protocol, data on plant height, dry matter production, yield qualities, and grain yield and straw yield were recorded at harvest. The net returns were calculated by taking the gross returns for each treatment and subtracting the cultivation cost. The benefit-cost ratio was computed by dividing the cost of cultivation by the gross returns.

3. RESULTS AND DISCUSSION

3.1 Dry weight and weed density

Weed management significantly influenced rainfed foxtail millet. Hand weeding twice and pre-emergence pretilachlor at 500 g ha^{-1} were most effective, except at 20 DAS. Hand weeding twice at 20 and 40 DAS might have controlled all the categories of weeds including perennial sedge Cyperus rotundus L. These results are in agreement with the findings of Jawahar et al. (2020) [1] with HW twice on 20 and 40 DAT in kodo millet.Pretilachlor 500 g ha^{-1} followed by intercultivation (W_4), which was at par with PE pyrazosulfuron-ethyl 15 g ha^{-1}fbintercultivation (W_6) and isoproturon 500 g ha^{-1} fb intercultivation (W_5) in order of ascent, at all the stages of observation (Table 1). This might be due to broad spectrum weed control by the PE herbicides supplemented with intercultivation at 20 DAS. These results are in agreement with the findings of Patil et al. (2013) [10]. Isoproturon 500 g ha^{-1} followed by penoxulam 20 g ha^{-1} (W_8) showed the higher dry weight and density of total weeds due to its poor performance in controlling all the categories of weeds associated with foxtail millet. These outcomes agree with those of Mishra et al. (2016) [3]. The highest dry weight and weed density were found in the unweeded check. The most effective method of controlling weeds was hand weeding twice at 20 and 40 DAS (W_{10}). The only exception was pre-emergence application of pretilachlor at 500 g ha^{-1} with intercultivation at 20 DAS had a higher WCE than other pre-emergence herbicides.

Table-1: Weed density m^{-2}, dry weight (g m^{-2}) and Weed control efficiency (%) as influenced by different weed management practices in foxtail millet

Treatments	Dose (g ha^{-1})	Time of application (DAS)	Weed density m^{-2}			Weed dry weight (g m^{-2})			WCE (%)		
			20 DAS	60 DAS	At harvest	20 DAS	60 DAS	At harvest	20 DAS	60 DAS	At harvest
Pretilachlor	500	1	47.67 (6.67)	100.87 (10.06)	(131.67) 11.49	11.13 (3.32)	79.70 (9.12)	(94.37) 10.06	85.01	29.18	27.34
Isoproturon	500	1	63.53 (7.86)	102.17 (10.13)	(133.33) 11.57	24.25 (4.97)	81.27 (9.21)	(95.93) 10.14	67.35	27.78	26.13
Pyrazosulfuron-ethyl	15	1	76.35 (8.92)	101.33 (10.09)	(132.50) 11.53	36.15 (6.05)	80.93 (9.19)	(95.60) 10.12	51.32	28.08	26.39
Pretilachlor *fb* IC	500	1+20	48.00 (6.75)	52.33 (7.27)	(69.33) 8.36	12.60 (3.57)	15.47 (3.99)	(32.07) 5.70	83.03	86.26	75.31
Isoproturon*fb* IC	500	1+20	63.67 (7.89)	55.00 (7.45)	(72.00) 8.51	24.61 (5.01)	19.10 (4.39)	(36.77) 6.07	61.47	83.03	71.69
Pyrazosulfuron-ethyl *fb* IC	15	1+20	76.00 (8.86)	53.67 (7.36)	(70.00) 8.40	35.21 (5.95)	18.77 (4.32)	(35.73) 6.01	52.59	83.32	72.48
Pretilachlor *fb* penoxsulam	500 + 20	1+20	48.33 (6.87)	80.63 (9.01)	(104.33) 10.24	12.40 (3.54)	58.40 (6.60)	(68.40) 7.39	83.30	48.10	47.33
Isoproturon*fb* penoxsulam	500+ 20	1+20	63.50 (7.85)	124.17 (11.15)	(161.00) 12.70	25.21 (5.07)	100.77 (10.29)	(117.27) 11.56	66.05	10.46	9.70
Pyrazosulfuron-ethyl *fb* penoxsulam	15+ 20	1+20	77.01 (8.89)	81.00 (9.03)	(106.50) 10.34	35.81 (6.01)	58.80 (6.67)	(69.60) 7.45	51.78	47.75	46.41
Hand weeding		20+40	136.67 (11.71)	18.33 (4.34)	(21.33) 4.67	72.13 (8.50)	2.90 (1.84)	(8.50) 2.98	-	97.42	93.45
Unweeded check			137.27 (11.74)	163.83 (12.82)	(192.33) 13.89	74.27 (8.64)	112.53 (11.58)	(129.87) 13.20	-	-	-
LSD (p=0.05)			0.88	0.92	1.06	0.57	0.73	0.84			

Data given in parenthesis are original values. Original data subjected to square root transformation.
WCE: weed control efficiency; IC: Intercultivation;*fb*: followed by

3.2 Crop growth parameters

3.2.1 Phytotoxicity and Plant population m^{-2}

Isoproturon at 500 g ha^{-1} (W_2, W_5, W_8) exhibited mild phytotoxicity, (Table 2) disappearing within 20 days. On average, it reduced initial and final plant population by 18.55% and 20.50%. Pre-emergence pretilachlor at 500 g ha^{-1} and pyrazosulfuron-ethyl at 15 g ha^{-1} showed no phytotoxicity. Post-emergence penoxulam at 20 g ha^{-1} at 20 DAS resulted in severe crop injury and stunted growth exhibited phytotoxicity ratings of '1' and '5', respectively, on a 0-10 scale. Penoxsulam inhibit the acetolactate synthase enzyme activity, a key enzyme responsible for biosynthesis of branched chain amino acids, which inturn making crop plants deficit in protein synthesis in meristematic tissues lead to discolouration of foliage and stunted growth.These outcomes agree with Prasuna and Rammohan (2015) [11] findings with PE application of pretilachlor 0.75 kg ha^{-1}fb PoE application of penoxsulam 25 g ha^{-1} at 20 DAS in aerobic rice.

3.2.2Plant height and LAI

Pre-emergence pretilachlor at 500 g ha^{-1} with intercultivation (W_4) showed optimal growth parameters, akin to pre-emergence pyrazosulfuron-ethyl at 15 g ha^{-1} with intercultivation (W_6) and isoproturon at 500 g ha^{-1} with intercultivation (W_5). Notably effective among pre-emergence herbicides, pretilachlor at 500 g ha^{-1} performed comparably to pyrazosulfuron-ethyl (W_3). During the key phase of crop-weed competition, which results in enhanced plant height and dry matter production, as well as higher crop uptake of nutrients, these three weed management practices provided broad-spectrum weed control. These outcomes agree with those of Pandey et al. (2018) [8]. However, sequential isoproturon at 500 g ha^{-1} followed by penoxulam at 20 g ha^{-1} at 20 DAS (W_8) exhibited reduced growth due to penoxulam phytotoxicity, falling behind the unweeded check (W_{11}), which displayed significantly lower growth parameters than other weed management practices.

Table-2: Crop growth parameters as influenced by different weed management practices in foxtail millet

Treatments	Dose (g ha^{-1})	Time of application (DAS)	Phytotoxicity scoring		Plant population m^{-2}		Plant height (cm)	Leaf area index
			PE herbicides	PoE herbicides	Initial	Final		
Pretilachlor	500	1	0	-	30.67	30.00	105	1.76
Isoproturon	500	1	1	-	26.67	25.67	105	1.70
Pyrazosulfuron-ethyl	15	1	0	-	31.67	31.00	105	1.74
Pretilachlor *fb* IC	500	1+20	0	-	31.67	31.67	117	1.91
Isoproturon*fb* IC	500	1+20	1	-	26.67	25.33	116	1.88
Pyrazosulfuron-ethyl *fb* IC	15	1+20	0	-	31.67	31.00	116	1.90
Pretilachlor *fb* penoxsulam	500+ 20	1+20	0	5	31.67	30.00	77	1.36
Isoproturon*fb* penoxsulam	500+ 20	1+20	1	5	25.67	24.33	67	1.31
Pyrazosulfuron-ethyl *fb* penoxsulam	15+ 20	1+20	0	5	31.33	31.00	76	1.32
Hand weeding		20+40	-	-	31.33	31.00	128	2.16
Unweeded check			-	-	32.23	32.00	93	1.55
LSD (p=0.05)					3.17	3.01	10	0.047

3.3.3 Yield and Yield components

The highest yield was produced by hand weeding twice at 20 and 40 DAS (W_{10}) followed by pre-emergence application of pretilachlor 500 g/ha with inter-cultivation at 20 DAS (Table 3) because there was less competition for growth resources, which increased photosynthates translocation to developing grains. These outcomes concurred with the direct-seeded finger millet research conducted by Yathisha et al. (2020) [13]. The unweeded check (W_{11}) outperformed sequential pre-emergence herbicides with penoxulam at 20 g ha^{-1} (W_7, W_9, W_8) due to penoxulam phytotoxicity and poor weed control efficiency.

Table-3: Yield and Yield components as influenced by different weed management practices in foxtail millet

Treatments	Dose (g ha^{-1})	Time of application (DAS)	Number of panicles (m^{-2})	Dry matter production (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Gross returns (₹ha^{-1})	Net returns (₹ ha^{-1})	B:C

Pretilachlor	500	1	47.00	4617	1309	3008	30.37	40775	18815	1.86
Isoproturon	500	1	47.00	4604	1182	2962	28.02	36947	14900	1.68
Pyrazosulfuron-ethyl	15	1	47.00	4611	1284	2978	30.12	39996	18363	1.85
Pretilachlor *fb* IC	500	1+20	62.67	5754	1961	3592	35.42	60637	35077	2.37
Isoproturon*fb* IC	500	1+20	56.00	5298	1660	3348	33.55	51460	25813	2.11
Pyrazosulfuron-ethyl *fb* IC	15	1+20	58.33	5380	1745	3435	33.75	54067	28834	2.14
Pretilachlor *fb* penoxsulam	500+ 20	1+20	37.33	3297	779	2438	24.22	26999	2241	1.09
Isoproturon*fb* penoxsulam	500+ 20	1+20	32.00	3220	690	2250	23.47	25317	472	1.02
Pyrazosulfuron-ethyl *fb* penoxsulam	15+ 20	1+20	33.33	3256	724	2397	22.92	25914	1483	1.06
Hand weeding		20+40	70.00	6496	2353	3944	37.47	72547	34867	1.92
Unweeded check			2.292	3951	861	2881	22.92	27257	7077	1.35
LSD (p=0.05)			6.72	4617	315	419	4.11	3220	4634	0.17

Hand weeding twice (W_{10}) resulted in the highest gross returns, followed by pre-emergence pretilachlor at 500 g ha^{-1} with intercultivation (W_4), showing comparable net returns. However, hand weeding twice had a lower benefit-cost ratio due to increased weeding costs. The lowest gross and net returns, along with a lower benefit-cost ratio, were observed with pre-emergence isoproturon at 500 g ha^{-1} with penoxulam at 20 g ha^{-1} (W_8), significantly lower than the unweeded check (W_{11}) in terms of net returns and benefit-cost ratio but comparable in gross returns.

3.3.4 **Nutrient uptake by weed and crop**

Outperforming other treatments, hand weeding twice (W_{10}) reduced weeds' intake of nutrients (Table 4) and maximised the crop uptake of nutrients. Intercultivation after pre-emergence pretilachlor at 500 g ha^{-1} (W_4) successfully decreased weeds' nutrient outflow and increased the crop uptake of nutrients. This could be because these weed management techniques eliminated all weeds, which decreased the dry weight of all weeds and hence reduced nutrient intake. These outcomes agree with those of Pandey et al. (2018) [8]. Nutrient absorption by weeds was enhanced by isoproturon at 500 g ha^{-1} and penoxulam at 20 g ha^{-1} (W_8). In comparison to other techniques, the unweeded check (W_{11}) had the maximum nutrient uptake by weeds, with losses of 45.67, 18.03, and 35 kg ha^{-1} of nitrogen, phosphate, and potassium, respectively.

Table-4: Nutrient uptake (kg ha^{-1}) by weeds and crop as influenced by different weed management practices in foxtail millet

Treatments	Dose (g ha^{-1})	Time of application (DAS)	Nutrient uptake by weeds (kg ha^{-1})			Nutrient uptake by crop (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Pretilachlor	500	1	30.00	13.33	22.67	41.33	11.17	48.33

Isoproturon	500	1	32.33	14.00	24.17	36.67	10.33	46.00
Pyrazosulfuron-ethyl	15	1	30.50	13.00	23.67	40.00	11.00	45.67
Pretilachlor *fb* IC	500	1+20	11.67	6.00	12.00	63.33	16.93	57.00
Isoproturon*fb* IC	500	1+20	14.20	6.67	14.17	59.67	15.83	55.00
Pyrazosulfuron-ethyl *fb* IC	15	1+20	13.33	7.00	13.33	62.00	16.33	55.00
Pretilachlor *fb* penoxsulam	500 + 20	1+20	24.67	10.33	19.00	25.67	6.00	29.33
Isoproturon*fb* penoxsulam	500+ 20	1+20	36.33	16.23	30.67	21.00	5.33	26.67
Pyrazosulfuron-ethyl *fb* penoxsulam	15+ 20	1+20	26.33	10.63	19.33	23.00	5.00	28.33
Hand weeding		20+40	5.00	2.00	5.67	73.00	19.67	64.67
Unweeded check			45.67	18.03	35.00	25.33	6.17	31.00
LSD (p=0.05)			2.53	1.07	2.37	4.51	1.27	4.60

4. CONCLUSION

In order to effectively manage weeds in foxtail millet, the field experiment showed that pre-emergence pretilachlor at 500 g ha followed by intercultivation at 20 DAS produced higher grain production and benefit-cost ratio. The grain yield was higher when hand weeding twice, but the benefit-to-cost ratio was not as high as it would have been with the ideal pre-emergence pretilachlor technique. In areas with abundant and economical labour for hand weeding, it remains a viable option. Notably, pre-emergence isoproturon at 500 g ha^{-1} and post-emergence penoxsulam at 20 g ha^{-1} at 20 DAS exhibited phytotoxicity ratings of '1' and '5', respectively, on a 0-10 scale.

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