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Research Article

INTEGRATION OF HERBICIDES WITH MANUAL HAND WEEDING FOR CONTROLLING THE WEEDS IN PEARLMILLET BASED ON INTERCROPPING SYSTEM (*Pennisetum glaucum*)

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Abstract: A field experiment was conducted during March-June (*Kharif*), 2015 at Annamalai University Experimental farm, Department of agronomy, Tamilnadu, India to study the effect of management of weeds in pearl millet based intercropping system. The experiments were laid out in split-plot design replicated thrice with three main treatments *viz*., Sole pearl millet (M_1), Pearlmillet + Cluster beans (M_2) and Pearl millet + Moth beans (M_3) and four sub treatments *viz*., Unweeded control (S_1), Twice hand weeding (S_2), Pendimethalin 0.75kg ha^{-1} (S_3) and Alachlor 0.1 kg ha^{-1}(S_4). Among the cropping system Pearlmillet + Cluster beans influenced the growth and yield components of Pearl millet such plant height, LAI, drymatter production and recorded the lowest value of growth and yield components were recorded under sole Pearlmillet. Among the weed management practices, twice handweeding recorded the higher growth and yield components and the least weed population, weed biomass, highest weed control efficiency, weed smothering efficiency by weeds over the unweeded control. The growth, yield components and yield of both the intercrops such as plant height, LAI, DMP were high in twice hand weeding followed by Pendimethalin 0.75kg ha^{-1} over unweeded control.

Keywords: Intercropping, Pearlmillet, Weed management, Herbicides

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Introduction

Pearlmillet (*Pennisetum glaucum*) is the fourth most important food grain crop after rice, wheat and sorghum. As an arid and semiarid crop, traditionally it is the component of dryland system; usually grown on the soil with depleted fertility receiving less rainfall 150-750mm per annum .it is one of the stable food crops of quite a large population of India. India and Africa together account for 93.2 percent of the total pearl millet production of the world. It is generally used as a temporary summer pasture crop or in some areas as a food crop including Tamil nadu. Pearl millet constitutes an important staple crop, especially for marginalized households, for whom coarse cereals account for a larger share in daily diets than wheat and rice [3]. Its nutritious grain forms the principal maintenance ration for ruminant during the dry season. Grain of pearlmillet is highly used as feed for livestock and poultry, which contains 11-12%, 5-6% fat, 67% carbohydrate and also rich in minerals (phosphorus and iron) and vitamins (carotene, riboflavin and niacin). India is the largest producer of pearlmillet with an annual production of 10.05m tons from an area of 8.69 m ha and productivity of 1156 kg ha^{-1} [4]. Rajasthan ranks first in area (4.41m ha) and production (4.11 m tons). However, average productivity is 933 kg ha-1 which is still low compared to the national average [5].

Intercropping is a common practice in the low-level equilibrium farmers of semi-arid and arid tropics, whose primary concern is to insulate investment on labour and meagre capital against adversities of nature in order to sustain living. In consideration with mutualism and soil health, cereal and legume mixture is ideal one. Hence, it is worthwhile to find out best combination of pearlmillet intercropped with legume crops. Crop weed competition in pearl millet has been established as one the major causes for low yields. Pearl millet being a short duration crop, much of the soil, space and sunlight in the inter-row spaces left unutilized, allow weeds to grow luxuriantly causing acute crop-weed competition in early growth stages. Therefore, it is very crucial that weed free condition during germination phases is ensured for getting higher yields. Favourable temperature, light and moisture available to crop also permit rapid multiplication of weeds at the early stages and possess competition to pearlmillet crop. Due to un availability of labour, most farmers do not accord higher priority to weed management. Among the various technology developed for weed control herbicide application is one most successful method. Control leads to residue hazards, weed shift and build-up of resistance in weeds. In order to minimize the losses caused by weeds and also to reduce the sole independence on costly and controversial inputs such as herbicides, considerable interest has farmers, which is ecologically sound and socially acceptable. The recent awareness is to minimize the use of herbicides and adoption of eco-friendly approaches like cultural and biological methods for weed management. Intercropping not only given additional yield and economizes Pearl millet cultivation but also suppress weed growth and their interaction. Intercropping can go a long way in economizing pearlmillet cultivation with additional yields and their smothering effects on weeds though it invites careful selection of weed management. Cluster bean and moth bean may be suitably intercropped with Pearl millet and the intercrops economically and efficiently utilize the nutrients and radiant light thus intercropping can be a potential biological agent to manage weeds. Therefore, the present investigation was carried out to evolve the appropriate integrated weed management practice for pearl millet with the following objectives.

1. To evolve a suitable integrated weed management practice in pearl millet + pulse intercropping system.
2. To study the effect of alachlor and pendimethalin on weed control in pearl millet + pulse intercropping system.
3. To find out the nutrient uptake pattern by intercropping system.
4. To work out the economics of different weed management practices.

Materials and methods

The field experiment was conducted at Experimental farm, Department of agronomy, Annamalai University, Annamalai nagar, Tamilnadu during March - June (*Kharif*) 2015 to evaluate the effect of weed control measures on the growth and yield of pearlmillet based on intercropping system. The experiment site is situated at 11°24'N Latitude and 79°44'E Longitude at an altitude of 5.79 m above mean sea level. the weather at Annamalai nagar is moderately warm with some amount of rainfall. The maximum temperature of 29.3°C to 35.2°C with mean of 32.82°C. The minimum temperature ranges from 22.7°C to 25.0°C with a mean of 24.2°C. The relative humidity ranges from 81 to 96 percent with a mean of 85.78 percent and crop received a rainfall of 98.4 mm distributed over four rainy days. The soil of experimental site was sandy loam in texture having available N 210 kg/ha, available P_2O_5 25.4 kg/ha, available K_2O 375 kg/ha, available sulphur 14 kg/ha, pH 8.1 and EC 0.41dS/m. The experiment was laid out in split-plot design replicated thrice with three main treatments *viz*., sole pearl millet (M_1), Pearlmillet + Cluster beans (M_2) and Pearl millet + Moth beans (M_3) and four sub treatments *viz*., unweeded control (S_1), Twice hand weeding (S_2), pendimethalin 0.75kg ha-1(S3) and alachlor 0.1 kg ha^{-1}(S_4). Pearl millet variety 'CO-7' was sown at 45x15cm spacing with seed rate of 4 kg/ha at the onset of monsoon during the year 2018.One row each of cluster beans and moth beans were sown subsequently in between the two rows of pearl millet as per the treatments. pendimethalin 0.75kg/ha and alachlor 0.1 kg/ha was applied as pre-emergence by Knapsack sprayer to soil surface on the next day after sowing using 500L spray volume of water as per the treatments. The crop was fertilized with 80 kg N/ha, 40kg P_2O_5 ha,40kg K_20/ha in the form of urea, diammonium phosphate, muriate of potash. Half of the quantity of nitrogen and whole dose of phosphorus and potasium were applied as a basal application in the furrows at the time of sowing and remaining half dose of nitrogen was top dressed 25 days after sowing. Thinning of excess plants was done on 20th days after sowing (DAS) with 10cm distance between two plants. The field was irrigated by borewell and Uppanar channel. Initial irrigation was given immediately after sowing of seeds, the life irrigation was given on third day after sowing and subsequently irrigations were given as per the crop requirement. Biometric observations on weed count, weed dry weight, weed control efficiency at 30 and 60 DAS were recorded. Observations on growth components of pearl millet *viz*., Plant height, LAI and DMP yield components like no. of grains per head, Test weight were recorded. Yield parameters of grain and stover yield of from each net plot of pearl millet and intercrops was recorded and expressed in Kg ha^{-1}.Chemical analysis of crop and weed samples of nitrogen, phosphorus and potassium content was carried out for the computation of nutrient uptake by crops and nutrient removal by weeds. The values were expressed in Kg ha^{-1}. The expenditure incurred from sowing to harvest was worked out as cost of cultivation and expressed in Rs. ha^{-1}. Total income obtained from grain stover yield was calculated for individual treatments. Gross and net returns were worked out and presented. The observations collected during the experiments in respect of crop and weeds statistically analyzed using the procedure outlined by Panse and Sukhantme [1]. WCI values were transformed by angular transformation and that of the weeds counts by the formula $\sqrt{(x+0.5)}$ before statistical analysis for significant results, the critical difference was worked out at 5 percent probability level to draw statistical conclusions. The weed control efficiency (WCE) and Weed smothering efficiency (WSE) were calculated using the following formulas respectively.

$$\text{WCE (\%) =- } \frac{DWC-DWT}{DWC} \text{X100}$$

Where, DWC=Dry weight of weeds in unweeded plot (kg/ha), DWT=Dry weight of weeds in treated plot (kg/ha)

$$\text{WSE (\%)=- } \frac{DWC-DWT}{DWC} \text{X100}$$

Where, MDW = Dry weight of weeds in sole main crop plot (kg/ha), IDW = Dry weight of weeds in intercropped plot (kg/ha).

The experimental field was infested with monocot weeds *viz*., *Cyanodan dactylon*, Cyperus rotendus, the Dicot weeds *viz*., *Trianthema portulacastrum*, *Cleome viscose* and *Phyllanthus niruri.*

Results and discussion

Effect of intercropping and weed management practices on weeds

Among the cropping system, intercropping with pearlmillet + cluster beans recorded the lowest weed biomass of 45.19 g/m^2 at 60 DAS, which was followed by Pearlmillet + moth beans recorded 50.31g/m^2 at 60 DAS [Table-1]. And pearl millet-based cluster beans inter cropping system registered the highest WCE of 92.12 percent at 60 DAS. Pearlmillet + moth beans registered the lowest WCE compared to Pearlmillet + cluster beans with 91.11 percent at 60 DAS [Table-1]. And intercropping of cluster bean with pearl millet resulted in the greatest weed smothering efficiency of 45.48 percent on 60 DAS. Pearl millet +moth beans registered the lowest WSE compared to pearlmillet + cluster beans with 27.31 percent at 60 DAS.

Studies on pearl millet:

The plant height of pearl millet in all stage of the crop growth varied between sole and intercropping system. The taller plant height of 174.47cm at Harvest were recorded in pearl millet + cluster beans intercropping system (M_2). This was followed by pearl millet + moth beans intercropping system (M_3) with 170.92 cm at harvesting. The least plant height was recorded in the sole crop of pearl millet (M_1) with 164.89cm at harvesting [Table-2]. And the pearl millet + cluster beans intercropping system (M_2) was recorded the highest LAI of 6.07. This was followed by (M_3) which recorded 5.57. The least LAI was recorded in sole crop of pearl millet (M1) which recorded 5.53. And the highest Dry matter production of 5167.30 kg/ha at harvest were recorded in pearl millet + cluster beans (M_2). The least DMP was observed in sole pearl millet (M_1) which recorded 3498.21 kg/ha at harvesting. Pearl millet + cluster beans inter cropping system registered the least weed biomass, because of the less weed count due to suppressing nature of intercrop of cluster beans by way of filtering the sunlight to reach the ground level. Pearlmillet + moth beans intercropping system also recorded the least biomass of weeds compared to sole pearlmillet. And also weed control efficiency was increased under pearl millet + cluster beans intercropping system and this might be achieved due to greater reduction of weed population and weed biomass. And the highest weed smothering efficiency calculated under pearlmillet + clusterbeans intercropping system 45.48 percent at 60 DAS showed the weed smothering ability of cluster beans as inter crop in pearlmillet could able to suppress the weeds to a greater extent by its competitive ability. Quick growth and crop canopy to cover the interface area in between two pearl millet rows. Pearlmillet + moth beans also performed better to obtain more weed smothering efficiency than sole pearl millet. Under the growth components of pearl millet, the growth and yield of pearl millet was significantly influenced due to the intercropping of moth and cluster beans. Intercropping of pearlmillet + cluster beans showed a positive influence on pearl millet yield followed by pearl millet+ moth beans. Taller plants of pearl millet were obtained in association with cluster beans due to complementary interaction between base crop of pearl millet and intercrop of cluster beans and it was followed by pearl millet+ moth beans. This may be due to complementary interaction between base crop of pearl millet and intercrop of cluster and moth beans and WSE over the sole pearl millet. And the better smothering effect of intercrop of clusterbeans helped to accumulate more photosynthates and produced the highest LAI at flowering. It was followed by pearl millet + moth beans. This agrees with the findings of Ram and Singh, (2001) reported that growing pearlmillet along with cluster beans recorded the increasing LAI over sole pearl millet due to increasing in number of functioning leaves. Pearlmillet + cluster beans intercropping system recorded the highest DMP of pearl millet owing to increased plant height and LAI, obtained in this system. Pearlmillet + moth beans intercropping system also registered more DMP of pearl millet next to pearlmillet + cluster beans. The reason for obtained more DMP of pearl millet was due to more WSE compared to sole pearlmillet. Regarding the weed management practices, twice hand weeding registered the lowest weed biomass of 4.06 g/m^2 at 60 DAS followed by application of pendimethalin registered 4.46g/m^2 at 60 DAS [Table-2]. Unweeded control recorded the highest wed biomass 161.82 g/m^2 at 60DAS.The interaction effect between cropping system and weed management was found to be significant. The highest weed biomass was recorded is 180.47 in sole pearl millet with un weeded control.

Table-1 Weed biomass (g/m²) on 60 DAS, weed control efficiency on 60 DAS (%) and Weed smothering efficiency on 60 DAS (%) for pearlmillet, pearlmillet + cluster bean and Pearlmillet + moth bean

eed biomass (g/m²) on 60 DAS					Weed control efficiency on 60 DAS (%)				Weed smothering efficiency on 60 DAS (%)			
Sub Treatments	Main treatments				Main treatments				Main treatments			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	180.47	146.22	158.77	161.82	_	_	_	_	_	18.97	12.02	15.49
S_2	6.21	1.89	3.92	4.06	96.56	98.70	97.64	97.70	_	64.73	41.90	53.31
S_3	6.92	2.44	4.02	4.46	96.16	98.33	97.46	97.31	_	69.56	36.87	53.21
S_4	42.37	30.22	34.54	35.71	76.50	79.33	78.24	78.02	_	29.67	18.48	15.07
Mean	58.99	45.19	50.31		89.74	92.12	91.11		_	45.48	27.31	
	MAIN	SUB	MXS	SXM					_			
S.ED	2.10	4.57	2.30	5.10					_			
CD (p=0.05)	4.42	9.60	4.72	0.42					_			

M_1 – Sole Pearlmillet; M_2 – Pearlmillet + Cluster bean and M_3 – Pearlmillet + Moth bean; S_1-Control; S_2-Twice hand weeding; S_3-Pendimethalin 0.75 kg ha^{-1} and S_4-Alachlor 1.0 kg ha^{-1}

Table-2 Plant height at harvest time (cm), LAI at flowering and DMP (kg/ha) for pearlmillet, pearlmillet + cluster bean and Pearlmillet + moth bean

Plant height at harvest (cm)					LAI at flowering				Dry matter production at harvest (Kg/ha)			
Sub	Main treatments				Main treatments				Main treatments			
Treatments	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	148.16	164.14	157.59	156.63	4.08	4.98	4.46	4.5	2576.77	4023.64	3894.23	3498.21
S_2	180.23	185.04	183.93	183.06	6.95	7.26	7.1	7.1	4842.33	5484.22	5175.36	5167.3
S_3	174.94	179.93	177.23	177.3	5.86	6.44	5.94	6.08	4346.72	4923.43	4672.54	4647.56
S_4	156.26	168.78	162.94	162.66	4.59	5.62	4.78	4.99	3364.23	4173.23	3642.3	3726
Mean	164.89	174.47	170.92		5.37	6.07	5.57		3782.51	4651.12	4364.1	
	MAIN	SUB	MXS	SXM	MAIN	SUB	MXS	SXM	MAIN	SUB	MXS	SXM
S.ED	2.1	4.57	2.3	5.1	0.12	0.08	0.17	0.15	72.42	47.42	102.78	84.43
CD (p=0.05)	4.42	9.6	4.72	0.42	0.33	0.18	0.43	0.32	143.82	94.6	212.16	167.6

M_1 - Sole Pearlmillet; M_2 - Pearlmillet + Cluster bean and M_3 -Pearlmillet + Moth bean, S_1-Control; S_2-Twice hand weeding; S_3-Pendimethalin 0.75 kg ha^{-1} and S_4-Alachlor 1.0 kg ha^{-1}

Table-3 Plant height, LAI and DMP at flowering and harvesting period of Cluster bean and moth bean

Treatments	Cluster bean					Moth bean				
	Plant height (cm)		LAI	DMP (Kg/ha)		Plant height (cm)		LAI	DMP (Kg/ha)	
	Flowering	Harvest	Flowering	Flowering	Harvest	Flowering	Harvest	Flowering	Flowering	Harvest
S_1	21.24	26.42	0.74	507.65	837.07	25.12	38.07	0.83	825.57	1347.36
S_2	30.12	40.47	1.21	786.63	1674.59	38.85	51.42	1.46	1324.62	2398.23
S_3	27.92	37.53	1.20	740.26	1540.32	36.93	49.54	1.32	1268.18	2251.89
S_4	23.08	30.98	0.94	581.29	1049.74	27.95	41.35	0.98	1006.28	1721.96
S. ED	0.79	1.06	0.02	17.84	47.74	0.82	0.88	0.03	26.18	60.94
CD (p=0.05)	1.78	2.37	0.06	40.67	106.37	1.83	1.97	0.08	58.34	135.78

S_1-Control; S_2-Twice hand weeding; S_3-Pendimethalin 0.75 kg ha^{-1} and S_4-Alachlor 1.0 kg ha^{-1}

And twice hand weeding recorded highest weed control efficiency of 97.70 percent at 60 DAS [Table-2). This was followed by application of pendimethalin with 97.31 percent at 60 DAS and twice handweeding recorded the highest weed smothering efficiency of 53.31. This was followed by application of pendimethalin. The lowest WSE was registered in unweeded control.

Studies on pearl millet regarding weed management:

Regarding the weed management practices at 60 DAS, the taller plant height of 81.77 cm was recorded in two hand weeding, and followed by pendimethalin 0.75 kg/ha application practices with 149.42 cm at 60 DAS and 177.3 cm das at harvesting. And two hand weeding (S_2) recorded the highest LAI of 7.10 and this was followed by pre-emergence application of pendimethalin (S_3) with 6.08. The unweeded control(S_1) recorded the least LAI of 4.50. Interaction effect between cropping system and weed management was found to be significant. The highest DMP was recorded at 60 DAS with 5482.22 kg/ha in pearlmillet + cluster beans with twice hand weeding (M_2S_2). The least dry matter was noticed in sole pearl millet along with un weeded control (M_1S_1) recorded 2576.77 kg/ha at harvesting [Table-2]. Among the weed management practices, twice hand weeding recorded the least weed biomass and followed by pendimethalin application. This could be because of the herbicide controlling the weed seed emergence and establishment initially and depleting the soil seed reserves leaving only very little for late emergence and exposure to supplemental weed control measures. Unweeded control due to the absence of any weed control measures registered the highest weed biomass and twice hand weeding recorded the highest WCE of 97.70 percent at 60 DAS. Pendimethalin also being selective herbicide for pearlmillet as well as intercrop of pulses and alachlor controlled the weeds very effectively under intercropping situation and twice hand weeding registered the highest weed smothering efficiency and it was followed by application of pendimethalin it might be due to effective control weeds.

Effect of weed control treatments on intercrops:

Cluster beans

Weed control treatments significantly influenced all stages of crop *viz*., plant height and twice hand weeding registered taller plant height of 30.12 cm at flowering and 40.47 cm at harvest and followed by pendimethalin application with 27.92 cm at flowering and 37.53 at harvesting. [Table-3] and the highest leaf area index recorded under two hand weeding (1.21). The un weeded control recorded the least LAI of 0.74 [Table-3]. And two hand weeding recorded the highest DMP of 786.63 kg/ha at flowering and 1674.59 kg/ha at harvesting then followed by pendimethalin 0.75 kg/ha herbicide application with 740.26 kg/ha at flowering and 1540.32 kg/ha at harvest. The unweeded control recorded the lowest DMP of 507.65 kg/ha at flowering and 837.07 kg/ha at harvest. The growth and yield of cluster beans as intercrop in pearl millet were positively influenced by various weed management practices. When weeds were Allowed to grow without any control, the growth of cluster beans suffered due to reduction in plant height, DMP under unweeded control. Adoption of weed management practices improved plant height, DMP, yield components and yield of cluster beans. Twice hand weeding on 30 DAS resulted in the highest cluster beans yield of 474 kg/ha. The results are in accordance with the findings of Sandhu [2].

Moth beans

Data regarding weed biomass, weed control efficiency and weed smothering

efficiency was furnished in [Table-3]. Weed control measures significantly influenced the plant height at all stages. Twice hand weeding registered taller plant height of 38.85cm and 51.42cm at flowering and harvest respectively followed by pendimethalin herbicide application with 36.93cm at flowering and 49.54cm at harvesting. The least plant height was recorded in unweeded control with 25.12cm at flowering and 38.07cm at harvesting. And the highest leaf area index was recorded under twice hand weeding (1.46) followed by pendimethalin herbicide application (1.32). The lowest values of 0.83 was recorded under unweeded control [Table-3]. And the highest DMP was registered with twice hand weeding 1324.62 kg/ha at flowering and 2398.23 kg/ha at harvest followed by application of pendimethalin with 1268.18 kg/ha at flowering and 2251.89 kg/ha at harvesting. The lowest DMP was registered under unweeded control with 825.57 kg /ha. The various weed control practices promoted the growth and yield of moth beans intercropped with pearl millet. This was due to improved resource use of moth beans and less weed competition in all the weed management treatments over unweeded control.

Application of research: The taller plant height was recorded because of twice hand weeding for moth beans due to effective weed control treatments. Unweeded control caused reduction in yield components and yield of moth beans in the intercropping system. The unweeded control recorded the grain yield of 244 kg/ha. Twice hand weeding resulted in the highest yield of moth bean. This might be due to higher WCE and WSE.

Research Category: Weed management, Intercropping

Abbreviations:
DAS : Days after sowing
LAI: Leaf Area Index
DMP : Dry Matter Production
Kg : Kilogram
Ha : Hectare

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