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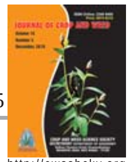

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Study the combined effect of brown manuring with post emergence herbicide on weed management in planted sugarcane

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ABSTRACT

Field experiments were conducted to study the combined effect of brown manuring with post emergence herbicide on weed management in planted sugarcane.Weeds are one of the major biotic stress and its management was the very costliest agronomic input in the successful crop production. In sugarcane, weeds alone causes yield reduction up to 40%. Indiscriminate use of herbicides can accelerate weed flora shift and resistance besides causing environmental pollution and non-target toxicities. Brown manuring is a no till version of green manuring using a post emergence herbicide. BM had multiple benefits including weed management. In Sugarcane its wider inter row space and its initial slow growth would allow to formulate an integrated weed management (IWM) module with brown manuring and herbicide. In this study, for Brown Manuring (BM), Sesbania aculeate was grown as intercrop with sugarcane for initial 35 days, and then, knocked down by spraying of 2,4-D.Treatments included BM of sesbania and in- situ incorporation of sesbania, with one intercultural operation at 90 DAP (Hand hoeing or Post emergence application of Metribuzin or halosulfuron). In addition, three controls, namely atrazine 1 kg a.i. ha^{-1} + power weeeding at 45 and 75 DAP, hand weeding twice and unweeded control were also adopted and the experiments were laid out in a randomized block design with three replications. A pre-emergence application of pendimethalin 2.0 kg a.i.ha^{-1} was made in all sesbaniaraisedplots.The results showed that application of pendimethalin 2.0 kg ha^{-1} + Sesbania (brown manuring) + hand hoeing at 90 DAP recorded minimum number of weeds and weed dry weight.The higher weed control efficiency (78.96 %), cane yield (100.5 t ha^{-1}) and benefit cost ratio (2.72) were found with PE application of Pendimethalin + Sesbania (Brown manuring) + hand hoeing at 90 DAP compared to POE herbicides and in situ incorporation of Sesbania.

***Keywords**:* Brown manuring, *halosulfuron*, *metribuzin*, planted sugarcane, *sesbania*, weed management.

Sugarcane (*Saccharumofficinarum*) is the most adaptable crop under varied agro ecological conditions. Weeds are the major threat in crop cultivationin tropical region. Sugarcane productivity is more in tropics (80 t ha^{-1}) when compared to sub-tropics, it is around 50 t ha^{-1} (Nair, 2011). Many researchers reported that there is a wide yield gap between the potential yield and actually harvested yield of sugarcane and the estimated gap was around 21per cent (Singh *et al.*,2009). In India, sugarcane was cultivated on 2.8 per cent of gross cropped area. Today India maintains the second position in sugarcane and sugar production next to Brazil and largest consumer of sugar (15.93%) in the world. Sugarcane being a long duration crop and due to its initial slow growth it takes longer time for ground coverage. So crop faces tough competition with weeds upto 120 Day After Planting (DAP) which causes cane yield reduction ranging from 40 per cent (Kadam *et al.*, 2011).

In the current agriculture scenario, developing eco-friendly approach of weed management is more desirable one so as to protect the natural resources such as soil flora and fuana in a holistic manner. In this context, in India brown manuring is emerged as an advanced weed management strategy. Brown Manuring (BM) aimed at suppressing the weeds without affecting the physical chemical and biological properties of soil. By using different appropriate weed management practices, farmers have more options for controlling weeds, thereby reducing the possibility of escapes and adaptation of weeds to any single weed management tactic.By adopting any single weed management approach, it cannot be keep weed population below the threshold level of economic damage. Hence, adoption of integrated weed management is essential for weed check in sugarcane. The use of green manure crop having bio herbicidal characteristic or weed smothering capability would have the additional benefit of adding biomass to soil. In order to devise an integrated weed management strategy for sugarcane, studies need to be done on brown manuring in combination with herbicides. Since not much work have been done in this field, this experiment was conducted to evaluate the effect of brown manuring and herbicides in controlling and enhancing sugarcane productivity.

MATERIALS AND METHODS

A field experiments were conducted during 2016–17 and 2017-18 at farm of Agricultural College and Research Institute, Madurai which is located at 13°10'N latitude 77° 37' E longitude with 976 m altitude.The soil

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was sandy loam and having organic carbon content of 0.38% and pH 8.2 Initial nutrient status of the soil was low in nitrogen (195kg ha^{-1}), medium in phosphorus (12.4 kg ha^{-1}) and low in potassium (387 kg ha^{-1}). The treatment consists on nine treatments *viz.*,

T_1 - PE Pendimethalin + Sesbania (Brown Manuring)+ hand hoeing at 90 DAP

T_2- PE Pendimethalin+ Sesbania *(Insitu* incorporation) + hand hoeing at 90 DAP

T_3- PE Pendimethalin + Sesbania(Brown Manuring) + Metribuzin at 90 DAP

T_4- PE Pendimethalin + Sesbania *(Insitu incorporation)* + Metribuzin at 90 DAP

T_5- PE Pendimethalin + Sesbania (Brown Manuring) + Halosulfuron at 90 DAP

T_6- PE Pendimethalin +Sesbania (*Insitu* incorporation) +Halosulfuron at 90 DAP

T_7- PE Atrazine + Power weeding at 45 & 75 DAP

T_8- Hand weeding twice (30& 60 DAP) and

T_9- Weedy check.

Pendimethalin 2 kg a.i. ha^{-1} and atrazine 1 kg a.i. ha^{-1} was applied on 3 DAP as pre emergence herbicide whereas Metribuzin 1 kg a.i. ha^{-1} and halosulfuron 67.5 g a.i ha^{-1} was applied as post emergence on 90 DAP as per treatment schedule. In brown manuring treatments plots, 25 kg of sesbania (*Sesbaniaaculeata*) seeds are broad casted on inter row space of sugarcane on the same day of planting of sugarcane and then, it was knocked down with the use of 2, 4-D @ 0.5 kg ha^{-1} on 35 DAS. *In-situ* incorporation of sesbania also been done at 35 DAS.

The experiment was conducted in randomized block design with three replications during the spring season under irrigated condition. Sugarcane crop (variety Co86032) was planted in the second week of December at 120 cm row spacing and harvested in the last week of November during all the year of experimentation. Recommended doses of N, P and K (300: 100: 200 kg ha^{-1}) were applied. Urea, super phosphate and muriate of potash were taken as sources of nitrogen, phosphorus and potassium respectively. Full dose of P and quarter the dose of N and K were applied basal at the time of planting and the rest of N and K in three equal splits on 30, 60 and 90 DAP in each year. Package of practices recommended in TNAU crop Production guide was adopted for conducting field experiments. Weed populations were recorded in all the plots using a quadrat of 0.5 x 0.5 m area and expressed in no.m^{-2}. Then, weeds were categorized into grasses,sedges broad-leaved and total weeds. They were sun-dried for 2 days and kept in an oven at 70^0 C for 48 hrs for dry weight estimation. Dry weight was expressed as g m-^{2}. Data on weed density and dry weight having greater coefficient of variation than 20%, were subjected to transformed through square-root (x+0.5) method and the transformed data were used for the ANOVA analysis (Pal and Sarkar 2015).

Weed control efficiency was determined by using the formula:

$$WCE\,\% = \frac{DWC - DWT}{DWC}$$

Where, WCE = Weed control efficiency (%) DWC= Dry matter production of weeds in the untreated plot (control) (g m^{-2}) DWT = Dry matter production of weeds in the treated plot (g m^{-2})

The data on growth, yield attributes, yield and quality of sugarcane were recorded by following the standard procedures. Economic analysis was done based on pooled yield data and considering price of input and output of the last year of study. The net income was calculated by deducting the total cost of cultivation from the gross income. The benefit: cost ratio was calculated as ratio of gross income to cost of cultivation. Finally the data were analysed as per the standard statistical methods.

RESULTS AND DISCUSSION

Effect on weeds

All weed species namely grasses, sedges and broad leaved weeds were found in the experimental field. The composition of broad leaved weed was found to be the highest followed by grasses and sedges. The major broad-leaved weeds in the experimental field comprised of *Commelina benghalensis, Trianthem aportulacastrum, Digeraarvensis, Amaranthus viridis, Cleome gynandra* and *Ipomea* spp. Predominant grassy weeds were *Dactyloctenium aegyptium, Echinochloa colonum* and *Dinebraretro flexa*. *Cyperus rotundus* and *Cyperus esculentus* were the predominant sedges in experimental field.

There was a significant reduction in total density due to PE pendimethalin + brown manuring + hand hoeing at 60 and 120 DAP (Table 1). The reduction was comparable with PE pendimethalin +sesbania (brown manuring) + Metribuzin treatment. Hand weeding twice at 30 and 60 DAP could not control the weeds effectively at 120 DAP. But, thePEpendimethalin +sesbania (brown manuring) + hand hoeing resulted in 85 -90% reduction of weed as compared to the unweeded control. The physical interference of sesbania, occupying interspace early, and/or allelopathic effects might have played roles.

Integrated weed management practices in sugarcane showed significant variation on weed density and drymatter production of weeds (Table 1). PE pendimethalin+ Sesbania (BM) + hand hoeing at 90 DAP resulted in the minimum number of weed, followed by Pendimethalin+ Sesbania (BM) + Metribuzin at 90 DAP, while the highest density of weeds was observed with

Table 1 : Effect of different weed management methods on total weed density (No. / m^2),Weed dry weight (g/m^2)and weed Control Efficiency (WCE) (pooled of 2years data)

Treatment		Total weed density			Total weed dry weight			WCE (%)
		60 DAP	**90 DAP**	**120 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	
T_1	PE Pendimethalin + Sesbania (BM) + hand hoeing at 90 DAP	10.17(101.3)	5.61 (29.4)	4.72 (20.2)	8.18 (65.0)	3.22 (8.4)	3.32(9.05)	82.3
T_2	PE Pendimethalin + Sesbania(*IC*) + hand hoeing at 90 DAP	10.92(117.3)	6.00 (34.0)	4.97 (22.7)	9.60 (90.3)	3.70(11.7)	3.99(13.9)	72.9
T_3	PE Pendimethalin + Sesbania(BM) + Metribuzin at 90 DAP	10.55(109.3)	5.94 (33.3)	4.99 (23.1)	8.47 (69.7)	3.39 (9.5)	3.62(11.1)	78.3
T_4 -	PE Pendimethalin + Sesbania (*IC*) + Metribuzin at 90 DAP	11.39(127.7)	6.37 (38.9)	5.40 (27.2)	9.29 (84.3)	3.77(12.3)	3.72(11.9)	76.8
T_5	PE Pendimethalin + Sesbania (BM) + Halosulfuron at 90 DAP	12.57(156.0)	7.79 (58.7)	5.55 (28.7)	8.89 (77.1)	3.63(11.2)	3.54(10.5)	79.5
T_6	PE Pendimethalin + Sesbania (*IC*) + Halosulfuron at 90 DAP	11.83(138.0)	6.54 (40.8)	6.55 (40.9)	9.44 (87.3)	3.95(13.7)	4.39(17.3)	66.2
T_7	PE Atrazine + Power weeding at 45 & 75 DAP	11.43(128.7)	6.98 (46.7)	6.48 (40.0)	9.21 (83.0)	3.92(13.4)	4.60(19.2)	62.5
T_8	Hand weeding twice (30 & 60 DAP)	8.41 (68.67)	5.16 (24.7)	5.16 (24.6)	6.72 (43.2)	3.06 (7.4)	3.72(11.9)	76.8
T_9	Weedy check	15.28(231.5)	10.78(114.3)	10.30(104.0)	12.26(148.4)	5.91(33.0)	7.29(51.2)	82.3
	SEm(±)	**0.13**	**0.19**	**0.19**	**0.48**	**0.34**	**0.23**	
	LSD(0.05)	**0.27**	**0.40**	**0.40**	**0.98**	**0.71**	**0.47**	

Figures in the parenthesis are original values, BM – Brown manuring; IC –Insitu incorporation, DAP – Days After Planting, PE – Pre emergence

Table 2 :Effect of different weed management methods on growth, yield and economics of sugarcane (pooled of 2years data)

Treatment		Millable canes ($x10^3$ ha^{-1})	Cane length (cm)	Stem girth (cm)	No. of inter nodes	Individual Cane weight (g)	Cane yield ($t.ha^{-1}$)	Net income ($Rs.ha^{-1}$)	B : C Ratio
T_1	PE Pendimethalin + Sesbania (BM) + hand hoeing at 90 DAP	128	149	9.3	17	750	100.5	145924	2.72
T_2	PE Pendimethalin + Sesbania*(IC)* + hand hoeing at 90 DAP	123	134	7.9	14	598	77.9	94909	2.13
T_3	PE Pendimethalin + Sesbania (BM) + Metribuzin at 90 DAP	118	136	8.1	16	729	97.6	140274	2.67
T_4	PE Pendimethalin + Sesbania *(IC)* + Metribuzin at 90 DAP	120	131	7.9	14	586	76.2	91649	2.10
T_5	PE Pendimethalin + Sesbania (BM) + Halosulfuron at 90 DAP	116	144	8.7	17	699	91.4	125534	2.48
T_6	PE Pendimethalin + Sesbania (*IC*) + Halosulfuron at 90 DAP	118	115	7.9	12	563	76.0	90849	2.09
T_7	PE Atrazine + Power weeding at 45 & 75 DAP	119	142	8.6	16	633	86.5	115403	2.38
T_8	Hand weeding twice (30 & 60 DAP)	116	144	8.6	15	650	81.6	104579	2.26
T_9	Weedy check	105	95.5	6.9	9	483	62.1	63244	1.80
	SEm(±)	**2.49**	**5.73**	**0.57**	**0.3**	**9.3**			
	LSD(0.05)	**5.30**	**6.91**	**0.82**	**0.75**	**19.7**			

weedy check plot. Results are in accordance with the findings ofSuganthi *et al*., (2019).They reported higher density of weeds at 60 DAP compared to later stages of the sugarcane crop. After 120 DAP the crop has dense foliage to cover the ground.

PE Pendimethalin+ Sesbania (BM) + hand hoeing at 90 DAP resulted in significantly lesser total weed dry weight. However, this treatment was comparable with POEMetribuzin or Halosulfuron at 90 DAP. Significant reduction was observed with total dry weight of weeds in brown manuring of sesbania plots. Reduction in the density of total weeds would have resulted in lower dry weight.

Dry weight of weed is the most important factor to measure the weed competitiveness for the crop productivity. Less number of weeds with higher drymatter might have more competitiveness with crop than more number of weeds with lesser drymatter. Chongtham (2015) stated that pre-emergence spray of pendimethalin 1kg ha^{-1} followed by brown manuring of Sesbania by 2, 4-D @ 0.50 kg ha^{-1} at 25 days after sowing (DAS) and combination of pre emergence spray of pendimethalin 1 kg ha^{-1} followed by EPOE bispyribac 0.025 kg ha^{-1} followed by brown manuring of Sesbania by 2, 4-D @ 0.50 kg ha^{-1}at 25 DAS significantly lowered dry matter of all weeds in direct-seeded rice.

Weed management practices followed in this study influenced the weed control efficiency. PE pendimethalin + Sesbania (BM) + hand hoeing at 90 DAP resulted in higher WCE of 82.3%.

Brown manuring was more effective in suppressing the weed, which might be due to allelopathic effect or biotic interference from brown manure crops. Suppression of weeds due to allelopathic effect was noticed when crops are intercropped with legumes (Singh *et al.,* 2011).Lower weed dry weight is a reflection of lesser density and biomass accumulation, which has further contributed for higher weed control efficiency. Lesser weed density and weed dry weight as well as higher weed control efficiency in brown manure treatment might be due to early space occupation, higher biomass accumulation and larger ground cover by sesbania. That could lead to better weed suppression particularly late emerging weeds through live mulch of sesbania. Besides pre emergence application of pendimethalin controlled early flushes of broad spectrum of weeds that had germinated simultaneously with sugarcane. Later application of 2,4 D for knocking down of sesbania plant could also control broad leaved weeds.

Effect on crop

Different weed management practices evolved in this study influenced the growth, yield parameter and yield of cane. The PEpendimethalin+ sesbania (BM) + hand hoeing at 90 DAS, PE pendimethalin + Sesbania (BM) + Metribuzin at 90 DAS and PEpendimethalin+ sesbania (BM) + Halosulfuron at 90 DAS treatments (Table 2) gave 38,36 and 32% higher cane yield, respectively than the unweeded control (62.1 t ha^{-1}), and the cane yields were comparable. Higher cane yield in these treatment mainly attributed through production of more number of millable cane, increased cane length, cane girth and more number of internodes which leads to higher individual cane yield under the brown manuring treatment.

Sesbania offered greater interference against weed but less interference on sugarcane during the initial stages of growth and it providing competitive advantage to the sugarcane crop against weeds. Generally, legume residue undergo faster decomposition than cereal residue.In this study, sesbania intercropped with sugarcane produced enough biomass within 35 DAS. In brown manuring, knocking down of sesbania by 2,4 D application fasten the decomposition and release of nutrient present in sesbania as compared to *in-situ* incorporation. Sesbania could add C and N into soil which facilitate for favorable microbial action (Biswaranjan Behera and Das, 2019). Also during decomposition of sesbania, certain organic acids, allele-chemicals are released which might offer some depressive effect of weed seed bank. Enhanced soil fertility as well as lesser weed competition under brown manuring treatment leads to higher productivity in sugarcane. Sharma *et al.* (2017) reported that the direct-seeded rice with brown manuring of sesbania gave grain yield of 3.65 tha^{-1} which was comparable with conventional transplanting (3.69 t ha^{-1}) and significantly higher than direct-seeding without brown manuring (3.24 t ha^{-1}).

Economic analysis

PE pendimethalin + sesbania (BM) + hand hoeing at 90 DAS recorded higher net return (Rs.1,42359 ha^{-1}) and BCR (2.72) followed by brown manuring of sesbania with POE metribuzin at 90 DAP (Rs.1,40,274 ha^{-1} and 2.67 of net returns and BCR respectively) as compared to rest of the treatments. Lowest net return (Rs.63244 ha^{-1}) and BCR (1.80) was recorded in weedy check. All the weed management practices implemented in this study gave higher net income of 30 to 57 per cent over weedy check. (Table 2).

The reason attributed to the higher net return and B:C was effective weed management practices which reduced the weed density, dry weight and nutrient removal by weeds and positively influenced the growth attributes, yield parameters and yield of sugarcane. The weed free environment leads to increased availability of resources to the crop with better utilization leading to good growth ultimately resulted in increased crop yield attributes and yield (Kaur *et al.,* 2015).Unweeded control had lower values compared to other treatments, which might due to establishment of many weeds with higher weed dry weight. Ramachandran and Veeramani(2012) reported that in maize crop pre emergence application of alachlor 1.0 kg ha^{-1} + brown manuring of sesbania was significantly lowered the weed density and have higher weed control efficiency of 89.6%, higher net returns and benefit cost ratio which was on par with PE alachclor 1.0 kg ha^{-1} + Sesbania as intercrop with *in-situ* incorporation on 35 DAS. Kumar and Mukherjee (2011) also reported similar results that the preplant surface application of butachlor 1.5 kg ha^{-1} + brown manuring with *Sesbaniarostrata* treatment resulted in highest net returns and BCR in rice.

Lowest density as well as dry weight of total weeds were recorded with pre emergence application of pendimethalin @ 2.0 kg a.i ha^{-1} + Sesbania (brown manuring) + hand hoeing at 90 DAP. The higher weed control efficiency, cane yield and benefit cost ratio were also found higher with PE application of Pendimethalin + Sesbania (Brown manuring) + hand hoeing at 90 DAP compared to other herbicides and *insitu* incorporation of Sesbania.

The overall positive effect of brown manuring on weed management might be due to early occupation of wider inter row space in sugarcane and higher biomass accumulation that leads to better suppression of weed, especially late emerging weeds through live mulching ofsesbania. Pre emergence application of pendimethalin@ 2.0 kg a.i. ha^{-1} + brown manuring of sesbania + hand hoeing at 90 DAP could lowered weed density and weed dry weight; and increased weed control efficiency, yield parameters and cane yield of sugarcane. Also this weed management practices provide profitable income. Hence, it could beconcluded that brown manuring along with PE pendimethalin@ 2.0 kg a.i. ha^{-1}+one hand hoeing at 90 DAS was viable weed management option for sugarcane to get higher productivity and profitability.

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