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Integrated weed management practices with botanicals on weed control in cotton

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ABSTRACT

Integrated weed management is a system approach where by whole land use planning is done in advance to minimise the very invasion of weeds in aggressive forms and give crop plants a strongly competitive advantage over the weeds. Further, importance is given to involve more than one method of weed control in tackling the weeds so those broad spectrums of weeds are kept under check for longer period. A pre emergence herbicide take care of weeds only for a limited period and do not give long term weed control in a long duration crop like cotton where the problem of late emerging weeds arises and escape killing. So to attain a season long weed control, integration of chemical, mechanical and cultural methods holds a great promise in crop production. Hence, integrated weed management in cotton play important role in increasing crop production. Field experiments were conducted during 2013 and 2014, at Agricultural College and Research Institute, Madurai (Tamil Nadu Agricultural University) to study the effect of integrated weed management in rainfed cotton. The weed management practices consisted of pendimethalin (1.0 kg.ha^{-1}) and (*Calotropis gigantea* leaf extract spray at three concentrations (10%, 20%, and 30%) in combination with power weeder operation twice and manual weeding twice. From the results of the experiments, it could be recommended that the integrated weed management practices like, application of PE pendimethalin at 1.0 kg ha^{-1} + power weeding on 40 DAS (T_{11}) recorded higher seed cotton yield and economic return.

Key words: Economic return, weed density, weed dry weight, yield.

In India, cotton is grown under diverse agro-climatic conditions. Cotton crop contributing in 65% of total raw material needs of textile industry because it is the most important commercial crop in our country. India ranks first in global scenario occupying about 33 % of the world cotton area but with regard to production it ranks second, next to China. Cotton varieties are cultivated at wider spacing, which in turn invites multiple weed species infestation. Weed competition is severe during its initial growth stages. The high cost and unavailability of labour has been resulted in usage of herbicides in weed control. Hence, there is a need for selection of pre-emergence herbicides to control early emerging weeds during initial crop growth period. So to attain a season long weed control, integration of chemical, mechanical and cultural methods holds a great promise in crop production and leads to integrated weed management. One hoeing after spraying of pendimethalin resulted in improved soil moisture conservation and removal of weed population in cotton (Panwar *et al.*,1995). Brar *et al.* (1995) stated that pre emergence application of pendimethalin @ 1.5 kg ha-1 followed by one hoeing at 30 DAS was effective for the control of annual broad leaved and grassy weeds like Trianthema portulacastrum and Eleusine indica. The total weed density was reduced by 60-70 per cent with application of pendimethalin at 1.0 kg ha-1 + hand weeding on 30 DAS (Vivek *et al.*, 2002). Pendimethalin at 1.0 kg ha-1 as pre-emergence herbicide followed by one hand weeding at 30 DAS reduced the weed density and nutrient uptake by weeds (Chander et al., 1994). Application of pendimethalin (1.0 kg ha^{-1}) as pre emergence spray followed by one hand weeding resulted in maximum weed control in cotton (AICCIP, 1999). Velayutham (1996) reported that pre-emergence application of pendimethalin at 0.75 kg ha-1 followed by one hand weeding resulted in the enhanced kapas yield which was comparable with hand weeding twice. Highest seed cotton yield (2318 kg ha-1) was recorded with pre-emergence application of pendimethalin at 1.50 kg ha-1 followed by one hoeing and was 72 per cent higher than the unweeded control (Brar *et al.*, 1999). Rajavel *et al.* (2002) obtained higher seed cotton yield of 1217 kg ha-1 under integrated method of herbicide with manual weeding which was comparable with manual weeding twice (1205 kg ha-1) and this was supported by Ali et al. (2005). The highest seed cotton yield was obtained from application of pendimethalin 1.5 kg ha-1 followed by hoeing (Shaikh *et al.*, 2006). Deshpande *et al.* (2006) reported that the higher seed cotton yield and benefit: cost ratio were recorded with pre and post-emergence application of pendimethalin and glyphosate application followed by two hand weedings and two hoeings. Thus, integrated weed managemen play important role in cotton crop production.

MATERIALS AND METHODS

Field experiments were conducted at Agricultural College and Research Institute, Madurai during 2013 and 2014. Field trials were laid out in randomized block design with fourteen treatments replicated thrice. The weed management practices evaluated in the present study consisted of PE *Calotropis gigantea* at 30 % + one hand weeding on 40 DAS (T_1), PE *Calotropis gigantea* at 30 % + one power weeding (PW) on 40 DAS (T_2), PE *Calotropis gigantea* at 30 % + EPOE of *Calotropis gigantea* at 30 % (T_3) , PE *Calotropis gigantea* at 20 % + one hand weeding on 40 DAS (T_4), PE *Calotropis gigantea* at 20 % + one power weeding (PW) on 40 DAS (T_5), PE *Calotropis gigantea* at 20 % + EPOE of *Calotropis gigantea* at 20 % (T_6), PE *Calotropis gigantea* at 10 % + one hand weeding on 40 DAS (T_7), PE *Calotropis gigantea* at 10 % + one power weeding (PW) on 40 DAS (T_8), PE *Calotropis gigantea* at 10 % + EPOE of *Calotropis gigantea* at 10 % (T_9), PE Pendimethalin @ 1.0 kg.ha^{-1}+ one hand weeding on 40 DAS (T_{10}), PE Pendimethalin @ 1.0 kg.ha^{-1}+ one power weeding (PW) on 40 DAS(T_{11}), Two hand weeding at 20and 40 DAS (T_{12}), Two power weeding at 20and 40 DAS (T_{13}) were tested and compared with unweeded control (T_{14}). Leaf extracts of 10, 20 and 30 per cent concentrations were sprayed on 3 DAS as pre emergence (PE) and 10 DAS as early post emergence (EPoE) by using hand sprayer (Sripunitha, 2009). Weed management practices (hand and power weeding) were done on 40 DAS.

RESULTS AND DISCUSSION

Weed flora of the experimental field consisted of fourteen weeds and among these weeds, Cyanodon dactylon and Echinochloa colonum were the dominant grass, Cyperus rotundus was the only sedge, Trianthema portulacastrum, Corchorus trilocularis and Cleome viscose were the predominant broad leaved weeds.The results of the experiment revealed that the broad leaved weeds dominated over grasses and sedges in cotton during the initial growth stage. Among broad leaved weeds, Trianthema portulacastrum was the dominant weed flora during both the years. Dominance of broad leaved weeds in early stages was due to their faster growth and deep root system and thus promoted the absorption of soil moisture. Among the broad leaved weeds, Trianthema portulacastrum was the dominant weed flora during both the years of study. This might be due to the smothering effect of broad leaved weeds on monocots. The leaf area of the weed was more favourable for interception of brighter solar radiation. Nazar *et al.* (2008) reported that dominance of broad leaved weeds during the early stages of cotton was due to their fast growth and deep root system.

Effect on total weed density, total weed dry weight and weed control efficiency

Significant variation in total weed density was observed among the weed control methods. At 20 DAS, lesser and comparable level of total weed density was observed in the application of PE pendimethalin at 1.0 kg ha-1 + HW (T10) with 9.17 m-2; 4.68 m-2 and application of PE pendimethalin at 1.0 kg ha-1 + PW(T11) with 9.18 m-2; 4.31m-2 during 2012 and 2013, respectively. At 40 DAS, during 2012 and 2013, lesser density of total weed was observed with two hand weeding (T12), two power weeding (T13), application of PE pendimethalin at 1.0 kg ha-1 + HW (T10) and PE pendimethalin at 1.0 kg ha-1 + PW (T11) which were comparable with each other (Table 1). At 60 DAS, lesser total weed density was found in two hand weeding (T12) with 17.71 m-2; 6.82 m-2, PE pendimethalin at 1.0 kg ha-1+ HW (T10) with 18.04 m-2 ; 7.16 m-2, PE pendimethalin at 1.0 kg ha-1+

PW (T11) with 19.10 m-2 ; 7.66 m-2 and two power weeding (T13) with 21.35 m-2 ; 8.79 m-2 which were comparable with each other during 2012 and 2013, respectively. The cotton crop under unweeded check had higher total weed density at all the stages of observation in both the years.

Weed management practices imposed to cotton significantly influenced the total dry weight of weed. At 20 DAS, during 2012 and 2013, application of PE pendimethalin at1.0 kg ha^{-1} + HW (T_{10}) and PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) were comparable and recorded with lesser dry weight of total weed (Table 2). At 40 DAS, during 2012 and 2013, lesser dry weight of total weed was observed with two hand weeding (T_{12}), two power weeding (T_{13}), PE pendimethalin at 1.0 kg ha^{-1}+ HW (T_{10}) and PE pendimethalin at 1.0 kg ha^{-1}+ PW (T_{11}) which were comparable with each other. At 60 DAS, during 2012 and 2013, the lowest dry weight of total weed was registered with two hand weeding (T_{12}), PE pendimethalin at 1.0 kg ha^{-1}+ HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1}+ PW (T_{11}) and two power weeding (T_{13}) and were comparable. Unweeded check observed with higher density of total weed at all the stages of observation during both the years. During 2012, application of PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}) and PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) registered higher WCE of 74.73 and 74.33 per cent, respectively at 20 DAS (Table 3). During 2012, at 40 DAS, two hand weeding (T_{12}), two power weeding (T_{13}), PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}) and PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) recorded highest WCE of 68.73, 68.40, 65.94 and 65.65 per cent. At 60 DAS, two hand weeding (T_{12}), PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and two power weeding (T_{13}) were recorded with higher WCE of 88.25, 87.92, 87.66 and 87.32 per cent, respectively. During 2013, at 20 DAS, higher WCE of 89.37 and 89.35 per cent were recorded with the application of PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}). At 40 DAS, two hand weeding (T_{12}), two power weeding (T_{13}), PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}) and PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) recorded highest WCE of 77.84, 77.67, 74.73 and 74.44 per cent. At 60 DAS, two hand weeding (T_{12}), application of PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and two power weeding (T_{13}) were recorded with higher WCE. In the early stage of the crop growth (20 DAS), total weed density, total weed dry weight , were reduced greatly by the application of PE pendimethalin at 1.0 kg ha-1 + HW (T10) and PE pendimethalin at 1.0 kg ha-1 + PW (T11). Prabhu (2010) pointed out that broad spectrum action of pendimethalin recorded lesser density of grasses at 25 DAS due to the translocative nature of the herbicide. At 20 DAS, the sedge weeds were not satisfactorily controlled by pendimethalin 30 per cent EC formulation. It was supported by Nair et al. (1983) stating the failure of pendimethalin to control nutsedge.

Pre emergence application of pendimethalin effectively reduced Trianthema portulacastrum which was the predominant weed in the experimental site. This might be possibly due to the effective prevention of seed germination of broad leaved weeds. Nalini (2010) reported that pendimethalin effectively controlled annual weeds than perennial weeds. Das and Duary (1998) reported that the herbicidal effect of pendimethalin might be due to the inhibition of cell division and thus curtailed the density of weeds. The reduced weed dry weight could be due to the reduction in weed density at all the stages of crop growth. This might be attributed to rapid depletion of carbohydrate reserve of the weeds through rapid respiration as pointed out by Prakash *et al.* (1999). At 20 DAS, application of PE pendimethalin at 1.0 kg ha-1 + HW and PE pendimethalin at 1.0 kg ha-1 + PW recorded the highest WCE of 74.7; 89.35 and 74.33; 89.37 per cent in 2012 and 2013, respectively. But at later stages of crop growth (40 DAS), total weed density, total weed dry weight, were reduced by manual weeding twice (T12) and power weeding twice (T13). The underground root portions like tubers and stolens were effectively removed by mechanical methods of weed control than the chemical application. This was due to the imposement of first manual weeding on 20 DAS which avoided the competition by weeds with crop for nutrient and moisture (Prabhu, 2010). Shobana (2002) reported that Cynodon dactylon, was perennial in nature which was not much controlled by pendimethalin application. At this stage, manual weeding twice controlled the grass and sedge weed efficiently and favored the growth of cotton which influenced the crop and covered the field surface area much earlier than the weed.

At 60 DAS, both mechanical methods namely manual weeding twice (T12) and power weeding twice (T13) and integrated weed management viz., application of PE pendimethalin at 1.0 kg ha-1 + HW (T10) and PE pendimethalin at 1.0 kg ha-1 + PW (T11) effectively controlled all the weeds and reduced the dry weight of weeds ultimately lead to better weed control efficiency in the above treatments. Shobana (2002) reported that the mechanical methods were better in weed control due to better removal of perennial weeds at 20 and 40 DAS. The early emerging weeds were controlled by first hand weeding and late emerging weeds were removed by second hand weeding with better removal of underground root portions. The integrated weed management practice registered the broad spectrum weed control as a result of longer persistence in the soil profile. Similar finding was reported by Balasubramanian (1992) who found that the weed control efficiency was comparatively higher with the application of pendimethalin at 1.0 kg ha-1 as compared with 0.5 and 0.75 kg ha-1.

Nutrient removal by weeds

At 60 DAS, there was significant variation in N depletion by weeds among different weed management practices was found in both the crops (Table 4). In the first and second crop, at 60 DAS, two hand weeding (T12), PE pendimethalin at 1.0 kg ha-1+ HW (T10), PE pendimethalin at 1.0 kg ha-1 + PW (T11) and two power weeding (T13) were comparable and reduced the N removal by weeds markedly from 7.12 to 7.35 kg ha-1 in 2012 and 6.94 to 7.46 kg ha-1 in 2013 compared to other weed management practices. Unweeded control recorded with highest removal of N by weeds by 17.86 and 15.47 kg ha-1 during 2012 and 2013.

Weed control methods caused significant variation in P uptake by weeds in cotton. During 2012 and 2013, at 60 DAS, two hand weeding (T12), PE pendimethalin at 1.0 kg ha-1+ HW (T10), PE pendimethalin at 1.0 kg ha-1+ PW (T11) and two power weeding (T13) were comparable and analyzed with reduced P removal by weeds considerably from 3.71 to 4.09 kg ha-1 in 2012 and 2.58 to 2.89 kg ha-1 in 2013 as compared to control. During 2012 and 2013, at 60 DAS, unweeded control resulted in removal by weeds with 7.34 and 6.12 kg ha-1 in 2012 and 2013 (Table 4).

During 2012 and 2013, at 60 DAS, significant variations in K removal by weeds were observed among the weed management practices (Table 4). At 60 DAS, two hand weeding (T12), PE pendimethalin at 1.0 kg ha-1+ HW (T10), PE pendimethalin at 1.0 kg ha-1+ PW (T11) and two power weeding (T13) were found comparable and from 10.74 to 11.14 kg ha-1 in 2012 and from 7.96 to 8.32 kg ha-1 in 2013 with reduced K removal by weeds compared to other weed management practices. At 60 DAS, removal of potassium by weeds was highest under unweeded control with 21.06 and 17.13 kg ha-1in 2012 and 2013 respectively. The nutrient (NPK) removal by weeds was greatly reduced by two hand weeding (T12), PE pendimethalin at 1.0 kg ha-1 + HW (T10), PE pendimethalin at 1.0 kg ha-1 + PW (T11) and power weeding twice (T13). This might be due to fairly weed free condition at early stages of crop growth and the weed free environment created by the pre emergence herbicide with reduced weed DMP. The dry weight was another factor determining the nutrient removal by weeds. This finding is in line with the reports of Chander *et al.* (1994) who described that application of pendimethalin at 1.25 kg ha-1 followed by hand weeding reduced the nutrient removal by weeds which was comparable with hand weeding twice. Such positive effect was due to lower population and dry weight of weeds resulting from better control of the entire weed by two hand weeding.

Effect on yield attributes and seed cotton yield

Weed management practices did not significantly influence the number of monopodial branches plant^{-1} in both the years (Table 5 and 6). The data on number of sympodial branches plant^{-1}, number of bolls plant^{-1} and boll weight were recorded and presented under yield characters. Significant variation among the treatments was noticed for all the yield attributes (Table 5 and 6). The treatments such as two hand weeding (T_{12}), PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and two power weeding (T_{13}) were comparable and recorded with sympodial branches plant^{-1} of 19.36,19.11,18.96 and 18.23 in 2012 and 21.53.21.47,21.33 and 20.45 in 2013 (Table 5 and 6).

Unweeded control registered lesser number of sympodial branches plant^{-1} 8.41 and 10.37 in 2012 and 2013. The observation on boll number plant^{-1} showed that the weed management practices had significant effect on the boll production of cotton in the both the years of study. During 2012 and 2013, the treatments *viz.*, two hand weeding (T_{12}), PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and two power weeding (T_{13}) were comparable and recorded with higher number of bolls plant^{-1} (Table 5 and 6). Unweeded control registered lesser number of bolls plant^{-1} of 11.60 and 12.90 in 2012 and 2013. In both the years of study, two hand weeding (T_{12}) showed higher boll weight of 3.72 and 3.91 g which were on par with T_{10}, T_{11}, T_{13}, T_1, T_2, T_4, T_5, T_7 and T_8 treatments produced bolls with more weight during 2012 and 2013 respectively (Table 5 and 6). Unweeded control registered the lowest boll weight of 2.87 and 2.96 g boll^{-1} in both the years. But it was on par with T_3, T_6 and T_9 also.

In the present investigation, significant difference in seed cotton yield was observed among the various weed management practices with chemical, leaf extracts, manual mechanical methods and integrated weed management in both the years of study. During 2012, the maximum seed cotton yield of 2185 kg ha^{-1} was registered with two hand weeding (T_{12}) and the yield under this treatment was comparable with PE pendimethalin at 1.0 kg ha^{-1}+ HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and two power weeding (T_{13}) with the yield of 2123, 2087, 2045 kg ha^{-1} (Table 5 and 6). During 2013, two hand weeding (T_{12}) was comparable with PE pendimethalin at 1.0 kg ha^{-1}+ HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1}+ PW (T_{11}) and two power weeding (T_{13}) which registered higher seed cotton yield of 2293, 2232,2196 and 2174 kg ha^{-1} respectively. Unweeded control recorded lesser seed cotton yield of 1356 and 1517 kg ha^{-1} in both the years respectively.

Due to heavy infestation of weeds under unweeded check reduction in seed cotton yield was recorded. During both the years, growth character number of monopodial branches plant-1 was not significantly influenced by the weed management practices. The yield attributing characters viz., number of sympodial branches plant-1, number of bolls plant-1 and boll weight ultimately decide the seed cotton yield. During both the years, the treatments had significant effect on yield attributes and seed cotton yield. The yield attributes and seed cotton yield were more with manual weeding twice (T12), PE pendimethalin at 1.0 kg ha-1 + HW (T10), PE pendimethalin at 1.0 kg ha-1 + PW (T11) and power weeding twice (T13). This could be due to the enhanced plant height, dry matter production and nutrient uptake of the crop. This might also be due to the season long weed control which was favourable for better growth and enhanced leaf area contributing for the activated photosynthesis and translocation of more photosynthates to sink which increased the boll weight (Nalini, 2010). In the above treatments the yield increasing percentage over control was 61, 57, 54 and 51 per cent during 2012 and 51, 47, 45 and 43 per cent during 2013, respectively. Gnanavel and Babu (2008) also reported maximum seed cotton yield with pendimethalin combined with hand weeding as compared with control.

Economics

The cost of cultivation was highest in hand weeded twice (T_{12}) with Rs. 50,049 per hectare followed by T_1, T_4 and T_7 with Rs. 49,811 per hectare (Table 7 and 8). In both the crops, PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}), PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) and hand weeding twice (T_{12}) recorded maximum net return. The unweeded control recorded the lowest net return of Rs. 13,156/- ha^{-1} and Rs. 14,268/- ha^{-1} during 2012 and 2013. Highest benefit cost ratio (B: C ratio) was obtained with the application of PE pendimethalin at 1.0 kg ha^{-1} + PW (T_{11}) with 1.82 and 1.69 during 2012 and 2013. It was followed by PE pendimethalin at 1.0 kg ha^{-1} + HW (T_{10}) with 1.80 and 1.66 during the two years of study.

Weed management practices showed positive impact on net return and benefit-cost ratio. By considering the cost of cultivation, pre emergence application of pendimethalin at1.0 kg ha^{-1} + power weeding (T_{11}) resulted in higher net return of Rs.37,529/- during 2012 and Rs. 35,895/- during 2013 and benefit cost ratio of 1.82 and 1.69 during both the years, respectively. In the above treatment, the additional income obtained over unweeded control was Rs. 24,373/- and Rs. 21,627/- during 2012 and 2013 respectively.

Table 1. Effect of different weed management practices on total weed density in cotton

Treatments	Total weed density (No. m^{-2})					
	2012			2013		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	33.75 (5.81)	54.20 (7.36)	44.72 (6.69)	24.89 (4.99)	37.96 (6.16)	27.24 (5.22)
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	34.52 (5.88)	55.36 (7.44)	46.90 (6.85)	25.49 (5.05)	38.56 (6.21)	29.39 (5.42)
T_3 - PE Calotropis @ 30 % + EPoE Calotropis @ 30 %	32.02 (5.66)	51.11 (7.15)	109.78 (10.48)	23.66 (4.86)	35.82 (5.99)	82.34 (9.07)
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	46.79 (6.84)	72.23 (8.50)	54.44 (7.38)	31.05 (5.57)	50.57 (7.11)	38.33 (6.19)
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	47.70 (6.91)	72.87 (8.54)	56.92 (7.54)	31.78 (5.64)	51.00 (7.14)	40.19 (6.34)
T_6 - PE Calotropis @ 20 % + EPoE Calotropis @ 20 %	44.49 (6.67)	68.81 (8.30)	113.84 (10.67)	29.26 (5.41)	46.85 (6.84)	85.97 (9.27)
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	66.67 (8.17)	93.89 (9.69)	67.17 (8.20)	46.45 (6.82)	69.76 (8.35)	46.81 (6.84)
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	67.96 (8.24)	95.52 (9.77)	69.68 (8.35)	47.24 (6.87)	70.95 (8.42)	48.44 (6.96)
T_9 - PE Calotropis @ 10 % + EPoE Calotropis @ 10 %	62.85 (7.93)	91.65 (9.57)	120.44 (10.97)	43.54 (6.60)	65.06 (8.07)	90.20 (9.50)
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	9.17 (3.03)	29.04 (5.39)	18.04 (4.25)	4.68 (2.16)	13.76 (3.61)	7.16 (2.68)
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	9.18 (3.03)	29.73 (5.45)	19.10 (4.37)	4.31 (2.08)	14.41 (3.65)	7.66 (2.77)
T_{12} - HW on 20 and 40 DAS	81.19 (9.01)	23.36 (4.83)	17.71 (4.21)	58.87 (7.67)	9.74 (3.12)	6.82 (2.61)
T_{13} - PW on 20 and 40 DAS	80.49 (8.97)	25.47 (5.05)	21.35(4.62)	59.15 (7.69)	11.02 (3.32)	8.79 (2.96)
T_{14} - Unweeded control	81.19 (9.01)	109.29 (10.45)	134.17 (11.58)	59.67 (7.72)	79.37 (8.91)	99.00 (9.95)
S. Ed	**0.275**	**0.345**	**0.360**	**0.220**	**0.270**	**0.295**
CD (P = 0.05)	**0.55**	**0.69**	**0.72**	**0.44**	**0.54**	**0.59**

Figures in the parenthesis are transformed values

Table 2 . Effect of different weed management practices on total weed dry weight in cotton

Treatments	Total weed dry weight (kg ha^{-1})					
	2012			2013		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	146.07 (12.09)	209.29 (14.47)	98.08 (9.90)	112.61 (10.61)	154.40 (12.43)	76.34 (8.74)
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	145.99 (12.08)	209.71 (14.48)	99.41 (9.97)	112.91 (10.63)	154.87 (12.44)	77.16 (8.78)
T_3 - PE Calotropis @ 30 % + EPoE Calotropis @ 30 %	144.76 (12.03)	207.60 (14.41)	325.32 (18.04)	111.33 (10.55)	152.87 (12.36)	257.95 (16.06)
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	151.97 (12.33)	226.03 (15.03)	101.99 (10.10)	117.05 (10.82)	163.02 (12.77)	79.99 (8.94)
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	152.65 (12.36)	226.71 (15.06)	104.20 (10.21)	117.81 (10.85)	164.36 (12.82)	80.60 (8.98)
T_6 - PE Calotropis @ 20 % + EPoE Calotropis @ 20 %	151.14 (12.29)	221.59 (14.89)	328.86 (18.13)	115.41 (10.74)	160.23 (12.66)	260.90 (16.15)
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	206.03 (14.35)	348.29 (18.66)	110.55 (10.51)	170.10 (13.04)	258.11 (16.07)	83.26 (9.12)
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	209.73 (14.48)	355.56 (18.86)	112.24 (10.59)	171.07 (13.08)	268.40 (16.38)	84.52 (9.19)
T_9 - PE Calotropis @ 10 % + EPoE Calotropis @ 10 %	203.78 (14.28)	345.13 (18.58)	332.52 (18.24)	165.88 (12.88)	253.18 (15.91)	266.79 (16.33)
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	63.84 (7.99)	127.31 (11.28)	43.82 (6.62)	22.33 (4.73)	71.46 (8.45)	19.74 (4.44)
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	64.84 (8.05)	128.42 (11.33)	44.76 (6.69)	22.30 (4.72)	72.27 (8.50)	20.34 (4.51)
T_{12} - HW on 20 and 40 DAS	251.87 (15.87)	116.89 (10.81)	42.63 (6.53)	207.78 (14.41)	62.66 (7.92)	18.95 (4.35)
T_{13} - PW on 20 and 40 DAS	252.05 (15.88)	118.14 (10.87)	46.00 (6.78)	208.24 (14.43)	63.15 (7.95)	21.22 (4.61)
T_{14} - Unweeded control	252.61 (15.89)	373.82 (19.33)	377.80 (19.45)	209.70 (14.48)	282.79 (16.82)	377.80 (19.45)
S. Ed	**0.54**	**0.68**	**0.59**	**0.43**	**0.56**	**0.48**
CD (P = 0.05)	**1.07**	**1.36**	**1.17**	**0.86**	**1.11**	**0.96**

Figures in the parenthesis are transformed values

Table 3. Effect of different weed management practices on the weed control efficiency (WCE) in cotton

Treatments	Weed control efficiency (%)					
	2012			2013		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	42.17	44.01	72.97	46.30	45.40	73.20
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	42.21	43.90	72.60	46.16	45.24	72.91
T_3 - PE Calotropis @ 30 % + EPoE Calotropis @ 30 %	42.69	44.46	10.34	46.91	45.94	9.44
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	39.84	39.53	71.89	44.18	42.35	71.92
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	39.57	39.35	71.28	43.82	41.88	71.70
T_6 - PE Calotropis @ 20 % + EPoE Calotropis @ 20 %	40.17	40.72	9.36	44.97	43.34	8.41
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	18.44	6.83	69.53	18.88	8.73	70.77
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	16.97	4.88	69.07	18.42	5.09	70.33
T_9 - PE Calotropis @ 10 % + EPoE Calotropis @ 10 %	19.33	7.68	8.35	20.90	10.47	6.34
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	74.73	65.94	87.92	89.35	74.73	93.07
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	74.33	65.65	87.66	89.37	74.44	92.86
T_{12} - HW on 20 and 40 DAS	0.29	68.73	88.25	0.91	77.84	93.35
T_{13} - PW on 20 and 40 DAS	0.22	68.40	87.32	0.70	77.67	92.55
T_{14} - Unweeded control	-	-	-	-	-	-

Table 4. Nutrient removal by weed at 60 DAS as influenced by weed management practices in cotton

Treatments	N, P, K removal by weeds at 60 DAS (kg ha^{-1})					
	2012			2013		
	N	P	K	N	P	K
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	10.75	5.17	12.63	9.87	3.71	10.73
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	10.87	5.32	12.71	9.95	3.78	10.99
T_3 - PE Calotropis @ 30 % +EPoE Calotropis @ 30 %	16.81	6.89	19.69	14.59	5.75	16.09
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	12.34	6.83	15.13	11.59	4.66	12.32
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	12.82	6.91	15.34	11.69	4.75	12.56
T_6 - PE Calotropis @ 20 % +EPoE Calotropis @ 20 %	16.99	6.96	19.78	14.72	5.86	16.25
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	13.15	6.13	15.45	12.11	4.76	12.75
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	13.27	6.22	15.59	12.38	4.84	12.87
T_9 - PE Calotropis @ 10 % +EPoE Calotropis @ 10 %	17.34	7.13	19.83	15.01	5.91	16.54
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	7.22	3.88	10.89	7.15	2.71	8.09
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	7.29	3.96	10.96	7.32	2.80	8.15
T_{12} - HW on 20 and 40 DAS	7.12	3.71	10.74	6.94	2.58	7.96
T_{13} - PW on 20 and 40 DAS	7.35	4.09	11.14	7.46	2.89	8.32
T_{14} - Unweeded control	17.86	7.34	21.06	15.47	6.12	17.13
S. Ed	**0.56**	**0.25**	**0.72**	**0.50**	**0.20**	**0.57**
CD (P = 0.05)	**1.12**	**0.49**	**1.43**	**1.01**	**0.39**	**1.13**

Table 5. Effect of weed management practices on monopodial branches, yield attributes and yield of cotton in 2012

Treatments	Growth attribute	Yield attributes and yield of cotton			
	Monopodial branches plant^{-1} (Nos.)	Sympodial branches plant^{-1} (Nos.)	Bolls plant^{-1} (Nos.)	Boll weight (g boll^{-1})	Seed cotton yield (kg ha^{-1})
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	1.67	14.37	21.61	3.68	1884
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	1.67	14.31	21.33	3.68	1850
T_3 - PE Calotropis @ 30 % + EPoE Calotropis @ 30 %	1.33	8.99	12.01	3.16	1408
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	1.67	14.24	18.96	3.56	1638
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	1.67	14.19	18.89	3.56	1603
T_6 - PE Calotropis @ 20 % + EPoE Calotropis @ 20 %	1.33	8.76	11.95	3.09	1385
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	1.67	13.34	18.62	3.47	1589
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	1.67	13.25	18.56	3.47	1572
T_9 - PE Calotropis @ 10 % + EPoE Calotropis @ 10 %	1.33	8.65	11.78	2.96	1374
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	1.67	19.11	23.42	3.71	2123
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	1.67	18.96	23.18	3.71	2087
T_{12} - HW on 20 and 40 DAS	1.67	19.36	24.50	3.72	2185
T_{13} - PW on 20 and 40 DAS	1.67	18.23	22.92	3.69	2045
T_{14} - Unweeded control	1.00	8.41	11.60	2.87	1356
S. Ed	**0.40**	**0.63**	**0.82**	**0.15**	**80**
CD (P = 0.05)	**NS**	**1.25**	**1.63**	**0.30**	**159**

Table 6. Effect of weed management practices on monopodial branches, yield attributes and yield of cotton in 2013

Treatments	Growth attribute	Yield attributes and yield of cotton			
	Monopodial branches plant^{-1} (Nos.)	Sympodial branches plant^{-1} (Nos.)	Bolls plant^{-1} (Nos.)	Boll weight (g boll^{-1})	Seed cotton yield (kg ha^{-1})
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	1.67	18.96	20.12	3.70	2010
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	1.67	18.91	20.01	3.69	1998
T_3 - PE Calotropis @ 30 % + EPoE Calotropis @ 30 %	1.33	10.57	14.21	3.00	1582
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	1.67	18.75	17.43	3.67	1823
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	1.67	18.68	17.13	3.67	1811
T_6 - PE Calotropis @ 20 % + EPoE Calotropis @ 20 %	1.33	10.49	13.55	3.00	1560
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	1.67	17.86	16.75	3.65	1782
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	1.67	17.79	19.64	3.63	1759
T_9 - PE Calotropis @ 10 % + EPoE Calotropis @ 10 %	1.33	10.41	12.99	2.98	1541
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	1.67	21.47	26.18	3.86	2232
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	1.67	21.33	25.82	3.81	2196
T_{12} - HW on 20 and 40 DAS	2.00	21.53	26.30	3.91	2293
T_{13} - PW on 20 and 40 DAS	2.00	20.45	24.76	3.75	2174
T_{14} - Unweeded control	1.00	10.37	12.90	2.96	1517
S. Ed	**0.39**	**0.62**	**0.88**	**0.16**	**86**
CD (P = 0.05)	**NS**	**1.24**	**1.77**	**0.31**	**172**

Table 7. Economics of different weed management practices in cotton during 2012

Treatments	2012			
	Total cost of cultivation (Rs ha^{-1})	**Gross income (Rs ha^{-1})**	**Net income (Rs ha^{-1})**	**B:C ratio**
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	49811	75360	24549	1.48
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	48466	74000	24534	1.50
T_3 - PE Calotropis @ 30 % +EPoE Calotropis @ 30 %	46388	56320	8932	1.19
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	49811	65520	14709	1.29
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	48466	64120	14654	1.30
T_6 - PE Calotropis @ 20 % +EPoE Calotropis @ 20 %	46388	55400	8012	1.17
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	49811	63560	12749	1.25
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	48466	62880	13414	1.27
T_9 - PE Calotropis @ 10 % +EPoE Calotropis @ 10 %	46388	54960	7572	1.16
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	47296	84920	37624	1.80
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	45951	83480	37529	1.82
T_{12} - HW on 20 and 40 DAS	50049	87400	37351	1.75
T_{13} - PW on 20 and 40 DAS	46544	81800	35256	1.76
T_{14} - Unweeded control	41084	54240	13156	1.32

Table 8. Economics of different weed management practices in cotton during 2013

Treatments	2013			
	Total cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
T_1 - PE Calotropis @ 30 % + HW on 40 DAS	56235	80400	23065	1.40
T_2 - PE Calotropis @ 30 % + PW on 40 DAS	54530	79920	24290	1.44
T_3 - PE Calotropis @ 30 % +EPoE Calotropis @ 30 %	52308	63280	9872	1.18
T_4 - PE Calotropis @ 20 % + HW on 40 DAS	56235	72920	15585	1.27
T_5 - PE Calotropis @ 20 % + PW on 40 DAS	54530	72440	16810	1.30
T_6 - PE Calotropis @ 20 % +EPoE Calotropis @ 20 %	52308	62400	8992	1.17
T_7 - PE Calotropis @ 10 % + HW on 40 DAS	56235	71280	13945	1.24
T_8 - PE Calotropis @ 10 % + PW on 40 DAS	54530	70360	14730	1.26
T_9 - PE Calotropis @ 10 % +EPoE Calotropis @ 10 %	52308	61640	8232	1.15
T_{10} - Pendi. @ 1.0 kg ha^{-1} + HW on 40 DAS	53650	89280	35630	1.66
T_{11} - Pendi. @ 1.0 kg ha^{-1} + PW on 40 DAS	51945	87840	35895	1.69
T_{12} - HW on 20 and 40 DAS	56697	91720	35023	1.62
T_{13} - PW on 20 and 40 DAS	52352	86960	34608	1.66
T_{14} - Unweeded control	46412	60680	14268	1.31

CONCLUSION

From the above study, it could be concluded, that the integrated weed management practices like, application of PE pendimethalin at 1.0 kg ha^{-1} + power weeding on 40 DAS (T_{11}) could keep the weed density and dry weight reasonably at a lower level and recorded higher seed cotton yield and economic net return. The integrated weed management practices also performed equally effective as that of mechanical methods because of good control of early emerging weeds by the pre emergence herbicide application and better removal of late emerging weeds by mechanical methods of weed control.

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