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Tillage, crop establishment and weed management in rice under conservation agriculture system

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ABSTRACT

Field experiments were carried out in wetland farm at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during 2012-13 to study the weed density, weed seed bank, yield and economics of rice under rice based conservation agriculture system. The main plot consisted six treatments with two crop establishment methods and three tillage practices over the seasons. Sub-plot treatments were having three weed management practices. Significantly minimum total weed density, weed seed count and higher grain yield, net returns were recorded in transplanted rice with conventional tillage in CT-CT-ZT system with pre-emergence treatment (PE) of butachlor 1.0 kg/ha for *Kharif*, pretilachlor 1.0 kg/ha PE for *Rabi* + inter crop with daincha (*Sesbania*) incorporation and mechanical weeding on 35 DAT during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013.

Key words: Conservation agrciculture, Rice establishment methods, Seed bank, Tillage, Weed management

Rice is the staple food of more than half of world's population. Among the rice growing countries, India has the largest area (44 million hectares) and it is the second largest producer (131 million tonnes) of rice next to China (197 million tonnes). Traditionally, rice is transplanted after puddling, which requires heavy amount of water and labours and it affects the soil health due to dispersion of soil particles, increase the soil compaction and make tillage operations difficult in succeeding crops requiring much energy. Compared to traditional agriculture, farmers can save up to 40% of time, labour and fuels in conservation agriculture

Therefore, over the past few years in many countries, there has been increasing trend towards conservation agriculture (Chhokar *et al.* 2007). Conservation Agriculture (CA) is an agricultural management practice in which there is minimum soil disturbance, retention of residue for soil cover and rotation of major crops. In conventional-tilled farming, weeds can be effectively controlled by tillage operations, which uproot and bury weeds deep into the soil. Due to lack of tillage, weeds grow and flourish in CA, if effective weed control measures are not taken. Weed control in CA is a greater challenge than in conventional agriculture because there is no weed seed burial by tillage operations and soil-applied herbicides are not incorporated resulting in reduced efficacy (Chauhan and Johnson 2009). Weed infestation, however continues to be a major bottleneck in dry-seeded rice compared to transplanted rice the weed problems may further be increased if dry-seeding of rice is done with zero tillage. Tillage operation can have a major impact on the distribution of weed seeds in the soil on survival (Lutman *et al*. 2002). Tillage as a filter or constraints that influences weed species and weed seed distribution in the soil seed bank. The type of tillage implement and concomitant cultivation can significantly impact the weed seed distribution and composition in soil surface. Direct drilling and shallow tillage can increase the proportion of weed seed retained near the soil surface, compared to conventional system of sowing in rice–wheat system (Yenish *et al.* 1992). The present investigation was undertaken quantify the impact of tillage, rice establishment and weed management methods on weed density, weed seed bank, yield and economics of rice under rice based conservation agriculture system.

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MATERIALS AND METHODS

Field experiments for weed management in rice based conservation agriculture system was carried out during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 wetland farm at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experimental location is situated in north western agro-climatic zone of Tamil Nadu at 11°N and 77°E with an altitude of 426.7 m above MSL. Normal climatic conditions (mean of past 50 years) of Coimbatore are as follows mean annual rainfall of 674 mm was received in 47 rainy days. Annual mean maximum and minimum temperatures

were 31.5 °C and 21 °C, respectively. Mean relative humidity was 84.9% (0722 hours) and 49.1% (1422 hours). Mean bright sunshine hour was 7.3 hours/day with a mean solar radiation of 429.2 cal/cm^2/day. Soil of the experimental fields was clay loam in texture classified taxonomically as 'Vertic Ustochrept', low in available nitrogen (197-216 kg/ha), medium in available phosphorus (12-16 kg /ha) and high in available potassium (420-511 kg /ha).

The experiments were laid out in strip plot design with three replications. Main plot consisted six treatments with two crop establishment and three tillage practices over the seasons. Main plot treatments were T_1-Transplanted rice with conventional tillage for *Kharif* rice - conventional tillage for *Rabi* rice - zero tillage for summer greengram, T_2- Transplanted rice with conventional tillage for *Kharif* rice - zero tillage for *Rabi* rice - zero tillage for summer greengram, T_3- Transplanted rice with zero tillage + crop residue for *Kharif* rice - zero tillage + crop residue for *Rabi* rice - zero tillage for summer greengram, T_4- Direct sown rice with conventional tillage for *Kharif* rice - conventional tillage for *Rabi* rice - zero tillage for summer greengram, T_5- Direct sown rice with conventional tillage for *Kharif* rice - zero tillage for *Rabi* rice - zero tillage for summer greengram and T_6 - Direct sown rice with zero tillage + crop residue for *Kharif* rice - zero tillage + crop residue for *Rabi* rice - zero tillage for summer greengram. Sub-plot treatments were the weed management practices, *viz.* W_1- Recommended herbicides (transplanted rice- butachlor 1.0 kg/ha for *Kharif*, pretilachlor 1.0 kg/ha for *Rabi* and direct-seeded rice - pretilachlor (S) 0.45 kg/ha), W_2 - Integrated weed management (transplanted rice - butachlor 1.0 kg/ha for *Kharif*, pretilachlor 1.0 kg/ha for *Rabi* + inter crop with daincha incorporation and mechanical weeding on 35 DAT) (direct seeded rice - PE pretilachlor (S) 0.45 kg/ha + inter crop with daincha (*Sesbania*) incorporation and mechanical weeding on 35 DAS) and W_3- Unweeded check. Rice varieties used foe experiments were '*ADT (R) 45*' for *Kharif* and '*CO 50*' for *Rabi*.

Conventional tillage comprised of one disc ploughing, two cultivators and then puddled with lugged wheel attached power tiller to obtain a soft puddle. The field operations for zero tillage comprised one puddled with lugged wheel attached power tiller to incorporation of crop residue. The main and sub-plots were formed with irrigation and drainage channels.

Seed rate of 60 and 40 kg of paddy seed was used in *Kharif* and *Rabi*. Paddy straw 5 tonnes applied in residue incorporation treatments. Manually operated rice drum seeder developed by Tamil Nadu Agricultural University, Coimbatore was used for direct sown rice. The seeder droped the seeds at 20 cm apart in continuous row. At a time, eight rows of rice seeds were sown. A seed rate of 60 kg/ha was adopted. Twenty one days old seedlings obtained from conventional wet nursery were transplanted at the rate of one seedling /hill at square planting of 25 x 25 cm spacing. Daincha (*Sesbania*) intercrop seeds were sown 25 kg/ha after transplanting/sowing of rice as per the treatment schedule on the day of transplanting/direct sowing.

Recommended rate of fertilizer (150 kg N + 50 kg P_2O_5+ 50 kg K_2O/ha), entire dose of phosphorus were applied as basal in addition to zinc sulphate 25 kg/ha. Nitrogen and potassium were applied in four equal splits at 15 DAS/T, active tillering, panicle initiation and heading stages. All other agronomic and plant protection measures were adopted as per the recommended packages as recommended by the TNAU to the farmers of Tamilnadu. The observations on total weed density was recorded at 30 DAS/T, 60 DAS/T and harvesting stages by using a quadrat of 0.25/m^2 sizes at 4 places in each plot and then species wise total weeds intensity and dry matter/m^2 were determined. For weed seed bank analysis, soil was sampled 1 kg using a 15 cm diameter metal core from 0-15 cm soil depth from each plot before sowing of both the crops. Bulked soil samples were partially air dried and then clods were broken by hands. The collected soil samples were well labelled. Samples were spread on 20 x 20 x 6 cm plastic tray separately in almost homogeneous and uniform layer. The plastic tray was marked for each treatment separately. After this, regular watering was done upto one season. The numbers of germinated weed seedlings were counted under each treatment at 7th, 14th, 21st 28th and 35th and after 35th days germinated weed seedlings were counted at 15 days interval upto 75 days. Finally, total weed seed counts of soil was worked out for each treatment. In case of observation on weeds, normality of distribution was not seen and hence, the values were subjected to square root transformation $\sqrt{x+0.5}$ prior to statistical analysis to normalize their distribution.

RESULTS AND DISCUSSION

Weed flora

General weed flora of the experimental rice field was observed in un-weeded check plots at 60 DAS/T. Weed flora of the experimental field predominantly consisted of three species of grass weeds, seven species of broad-leaved weeds and one sedge weed. The predominant among grass weeds were *Echinochloa colonum* and *Echinochloa crusgalli*. Among the broad-leaved weeds, *Ammania baccifera, Eclipta alba*, and

Marselia quadrifoliata were the dominant ones. *Cyperus difformis* was the only sedge present. Relative density of *Echinochloa colona* 24.9 to 53.3%, *Echinochloa crusgalli* 46.2 to 60.8%, *Ammania baccifera* 2.10 to 7.10%, *Eclipta alba* 1.26 to 3.35% and *Marselia quadrifoliata* 0.8 to 4.27%.

Effect of crop establishment methods on weeds and rice

Total weed density was recorded significantly lower in transplanted rice (TR) during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 (Table 1). This might be due to smothering effect of the larger canopy and early ground cover by transplanted rice than direct sown rice (DSR) during 30 DAT of crop and at later stages, weed management practices also reduced the grass weeds density in transplanted rice. Significantly higher total weed density was recorded in direct sown rice due to simultaneous germination of both the weed seeds and rice seeds when compared to other establishment methods tried during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. This finding is in line with the findings of Lourduraj *et al.* (2000) who reported reduced the weed density and biomass due to the smothering effect of closely spaced rice cultivation. Singh *et al.* (2008) reported highest density of weeds with direct seeding by zero-till-drill without tillage and lowest with transplanting method of rice establishment.

In soil weed seed bank spectrum, direct sown rice had higher weed seeds count on (0-15 cm) top layer of soil when compared to transplanted rice (Table 2). Conspicuously higher weed seeds count was noticed under direct sown rice with zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system. The increasing trend was observed in conspicuously higher weed seed population under direct sown rice with zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Transplanted rice with conventional tillage in

Table 1. Effect of tillage, crop establishment and weed management methods on total weed density (no./m^2) in rice

Treatment	*Kharif* 2012			*Rabi* 2012-13			*Kharif* 2013		
	30 DAS/T	60 DAS/T	Harvest	30 DAS/T	60 DAS/T	Harvest	30 DAS/T	60 DAS/T	Harvest
Tillage and crop establishment									
T_1- TR (CT-CT-ZT)	7.38 (66.3)	7.72 (72.7)	7.37 (68.5)	5.95 (43.4)	8.26 (84.6)	7.28 (63.1)	5.42 (32.1)	9.02 (96.0)	7.97 (75.2)
T_2- TR (CT-ZT-ZT)	8.44 (81.7)	8.80 (90.1)	8.39 (82.1)	6.82 (54.2)	9.55 (107.4)	8.49 (83.2)	5.64 (32.9)	9.93 (112.7)	8.68 (86.0)
T_3- TR (ZT+CR- ZT+CR-ZT)	9.78 (114.0)	10.12 (122.2)	9.39 (104.7)	7.64 (66.0)	10.61 (130.0)	9.39 (101.6)	6.23 (41.7)	11.14 (137.9)	9.67 (105.2)
T_4- DSR (CT-CT-ZT)	9.11 (95.8)	9.48 (104.2)	8.88 (94.5)	6.76 (54.3)	9.61 (107.6)	8.31 (79.7)	5.67 (35.4)	9.84 (108.3)	8.62 (84.5)
T_5- DSR (CT-ZT-ZT)	9.96 (112.7)	10.25 (119.1)	9.54 (103.6)	7.85 (67.9)	10.85 (133.2)	9.49 (100.7)	5.99 (36.4)	10.83 (130.7)	9.35 (96.1)
T_6- DSR (ZT+CR- ZT+CR-ZT)	11.54 (152.2)	11.63 (154.6)	10.66 (129.6)	8.46 (78.6)	11.67 (151.3)	10.25 (116.2)	7.46 (59.6)	12.39 (168.4)	10.93 (130.3)
LSD (P=0.05)	0.54	0.50	0.52	0.31	0.40	0.47	0.23	0.44	0.46
Weed management									
W1- Recommended herbicides	7.48 (56.0)	7.88 (61.6)	7.15 (50.8)	5.71 (31.4)	7.95 (62.3)	7.06 (48.6)	5.22 (25.7)	8.46 (70.8)	7.40 (53.8)
W2- IWM	5.71 (31.5)	5.82 (32.8)	5.33 (27.2)	4.50 (19.2)	6.34 (39.9)	5.65 (31.0)	4.12 (15.3)	7.10 (49.8)	6.08 (36.1)
W3- Unweeded check	14.93 (223.9)	15.43 (238.7)	14.63 (213.5)	11.53 (131.7)	15.98 (254.9)	13.90 (192.7)	8.87 (77.5)	16.02 (256.3)	14.13 (198.7)
LSD (P=0.05)	0.28	0.30	0.30	0.29	0.49	0.35	0.23	0.69	0.45

Figures in parentheses are mean of original values; Data subjected to square root transformation

TR : Transplanted rice
DSR : Direct sown rice
CT : Conventional tillage
ZT : Zero tillage
CR : Crop residue
W_1 : TR - Pre emergence treatment (PE) butachlor-*Kharif*, PE pretilachlor - *Rabi* DSR- PE pretilachlor (S)
W_2 : TR - PE butachlor-*Kharif*, PE pretilachlor – *Rabi* DSR- PE pretilachlor (S) + IC with daincha incorporation and mechanical weeding on 35 DAT/S
W_3 : Unweeded check

CT-CT-ZT system (T_1) resulted in perceptibly lesser weed seeds count during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. These results were in accordance with the findings of Legere and Sampson (1999) and Barberi and Blo Cascio (2001) who have observed higher weed biomass with more than 60 per cent of weed seedlings emerged from the surface soil layers in non-inversion chisel ploughing and no tillage systems.

Higher grain yield was recorded in transplanted rice with conventional tillage in CT-CT-ZT (T_1) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. However comparable higher grain yield was recorded in direct sown rice with conventional tillage in CT-CT-ZT (T_4) system. These were mainly due to lower weed density and higher weed control efficiency and this leads to higher grain yield. Direct sown rice with zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_6) produced consistently lower grain yield during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively.

Transplanted rice recorded lower cost of cultivation and higher net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. Whereas, direct sown rice registered in lower net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively (Table 3).

Effect of tillage practices on weeds and rice

Lower total weed density was recorded by conventional tillage in CT-CT-ZT (T_1) system tried during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 it was comparable total weed density was recorded in conventional tillage in CT-ZT-ZT (T_2) system *Kharif* 2012 and 2013 and conventional tillage in CT-CT-ZT (T_4) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. This might due to the inversion of surface soil and burial of weed seeds by disc ploughing and puddling. Zero tillage + crop residue in ZT+CR- ZT+CR-ZT system (T_6) was found to record higher grass weed density mainly due to deposition of more weed seeds and propagates of grass weeds seed near the soil surface during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Higher total weed seed densities in zero tillage systems may be the results of reduced herbicide availability because of adsorption to near-surface organic matter due to application of crop residues (Sadeghi and Isensee 1996). Greater deposition of weed seeds at the soil surface with zero tillage and minimum tillage than conventional tillage was also observed by Clements *et al.* (1996). Chauhan and Johnson (2009) stated that weeds were a greater problem in direct seeded rice than that in transplanted rice because of the absence of the crop seedling size advantage and standing water at the time of crop emergence.Tillage played a significant role in weed seed deposition and weed density rice- rice cropping system. Adoptions of non-inversion tillage practices tend to increase the total weed density.

Tillage practices showed significant difference with respect to weed seeds population. Conventional tillage in CT-CT-ZT system (T_1) resulted in perceptibly lesser weed seeds count. Whereas, conspicuously higher weed seed population was noticed under zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system. Rotation of conventional tillage – zero tillage in CT-ZT- ZT system (T_2) recorded lower weed seed count compared zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_3) system. Similar findings were also reported by Gangwar *et al.* (2009).

Significantly more grain yield was observed with conventional tillage in CT-CT-ZT (T_1) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. How-

Table 2. Effect of tillage, crop establishment and weed management methods on weed seeds count /kg of soil in rice (0-15 cm)

Treatment	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013
Tillage and crop establishment			
T_1- TR (CT-CT-ZT)	4.44 (19.22)	5.57 (37.00)	5.51 (36.11)
T_2- TR (CT-ZT-ZT)	4.77(21.89)	6.95(58.22)	6.65 (51.33)
T_3- TR (ZT+CR- ZT+CR-ZT)	5.66(32.33)	8.54(78.89)	7.99 (69.67)
T_4- DSR (CT-CT-ZT)	5.51(30.67)	6.86(55.22)	6.78 (53.11)
T_5- DSR (CT-ZT-ZT)	5.86(34.22)	9.42(99.67)	8.04 (70.11)
T_6- DSR (ZT+CR-ZT+CR-ZT)	6.56(43.22)	11.45(143.33)	9.70 (102.67)
LSD (P=0.05)	0.26	0.36	0.41
Weed management			
W_1- Recommended herbicides	5.02 (23.50)	6.23 (40.17)	5.97 (35.61)
W_2- IWM	4.10 (15.33)	5.43 (30.56)	4.83 (22.83)
W_3- Unweeded check	7.28 (51.94)	12.72 (165.44)	11.53 (133.06)
LSD (P=0.05)	0.18	0.40	0.30

Figures in parentheses are mean of original values; Data subjected to square root transformation

ever, it was comparable with zero tillage in CT-ZT-ZT (T_2). Zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_6) produced consistently lower grain yield during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Conventional tillage in CT-CT-ZT (T_1) system recorded lower cost of cultivation and higher net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. However it was comparable with conventional tillage in CT-ZT-ZT (T_2) system. Zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_3) system registered higher cost of cultivation compared to other treatments during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. Whereas, zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system registered in lower net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively (Table 3).

Effect of weed management methods on weeds and rice

Regarding weed management practices, PE of butachlor 1.0 kg/ha for *Kharif* and PE of pretilachlor 1.0 kg/ha for *Rabi* and PE pretilachlor (S) 0.45 kg/ha for direct sown rice + inter crop with daincha incorporation and mechanical weeding on 35 DAS/T (W_2) treatment recorded lower grass weed density at all the stages during both the years. This was mainly because of pre-emergence herbicides, which reduced the density of complex weed flora at early stages of crop. Mode of action of pretilachlor is by inhibition of cell division and protein synthesis. In later stage of critical crop weed competition in rice, inter crop with *Sesbania* incorporation and mechanical weeding at 35 DAS/T recorded lower grass weeds density of during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 which might be due to the reason that in mechanical weeding, all types of weeds especially grassy were removed. Bhanu Rekha *et al.* (2002) reported that hand weeding twice at 20 and 40 DAT resulted in significantly lower grass weed density and dry weight as compared to herbicide treatment and un-weeded check. Suganthi (2002) concluded that pretilachlor at 1.0 kg/ha followed by hand weeding at 40 DAT resulted in effective control of rice weeds and maximized the grain yield. Sunil *et al.* (2010) reported that pre-emergence application of bensulfuron methyl + pretilachlor (6.6 GR) 0.06 + 0.60 kg/ha, respectively + one inter-cultivation at 40 days after sowing recorded significantly lower weed population (Table 1).

Pre-emergence application of butachlor 1.0 kg/ha for transplanted rice and PE pretilachlor (S) 0.45 kg/ha for direct sown rice + inter crop with *Sesbania* incorporation and mechanical weeding on 35 DAS/T (W_2) attained its statistical supremacy by recording higher grain yield. Distinctly lower grain yield was obtained with under unweeded check (W_3).

Higher cost of cultivation and net return was incurred in integrated weed management (Transplanted rice - PE of Butachlor 1.0 kg/ha for *Kharif*, PE of Pretilachlor 1.0 kg/ha for *Rabi* + inter crop with daincha incorporation and mechanical weeding on 35 DAT) (direct seeded rice - PE pretilachlor (S) 0.45 kg/ha + inter crop with daincha incorporation and mechanical weeding at 35 DAS) during *Kharif* 2012 *Rabi* 2012-13 and *Kharif* 2013, respectively. Unweeded check (W_3) incurred lower cost of cultivation and net return during *Kharif* 2012 *Rabi* 2012-13 and *Kharif* 2013 (Table 3).

Table 3. Effect of tillage, crop establishment and weed management methods on yield, cost of cultivation and net returns in rice

Treatment	Yield (t/ha)			Cost of cultivation (x10^3 `/ha)			Net returns (x10^3 `/ha)		
	Kharif 2012	*Rabi* 2012-13	*Kharif* 2013	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013
Tillage and crop establishment									
T_1- TR (CT-CT-ZT)	5.10	5.59	5.05	35.86	35.29	36.29	36.62	36.89	43.02
T_2- TR (CT-ZT-ZT)	4.93	5.19	4.82	35.86	31.36	36.29	34.40	37.73	37.18
T_3- TR (ZT+CR-ZT+CR-ZT)	4.39	4.53	4.43	37.57	37.36	37.64	25.37	26.34	26.79
T_4- DSR (CT-CT-ZT)	4.67	4.78	4.73	33.14	33.68	33.16	33.62	34.14	34.79
T_5- DSR (CT-ZT-ZT)	4.17	4.15	4.13	33.14	29.18	33.16	26.51	30.28	26.31
T_6- DSR (ZT+CR-ZT+CR-ZT)	3.90	3.11	3.71	34.85	35.18	34.27	20.68	18.12	9.88
LSD (P=0.05)	0.30	0.34	0.28	-	-	-	-	-	-
Weed Management									
W1- Recommended herbicides	4.93	4.87	4.86	34.41	33.06	34.52	35.50	36.32	34.84
W2- IWM	5.46	5.78	5.56	37.01	35.67	37.06	40.46	43.34	44.49
W3- Unweeded check	3.19	3.02	3.01	33.78	32.30	33.83	12.64	12.09	36.32
LSD (P=0.05)	0.34	0.39	0.32	-	-	-	-	-	-

In conclusion, failure of weed management may result in severe losses in terms of yield and economic return. Present study revealed that transplanted rice under conventional tillage in CT-CT-ZT system with PE butachlor 1.0 kg/ha for *Kharif*, PE of pretilachlor 1.0 kg/ha for *Rabi* + inter crop with *Sesbania* incorporation and mechanical weeding on 35 DAT results in lower total weed density, higher grain yield and net returns.

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