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Effect of herbicides on growth and yield parameters of cotton (*Gossypium hirsutum*) under rice-fallow condition

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Abstract
The limited land resource in rice-fallow condition is to be efficiently utilized and cultivation of rice-fallow cotton is one such option. Weeds are the most dominant pests in rice-fallow cotton cultivation. To control the weeds effectively, a field experiment was conducted in rice-fallow cotton with different herbicides *viz.*, Pendimethalin, Quizalofop ethyl, Pyrithiobac sodium, Paraquat dichloride and their combinations. Results of field investigation revealed that all growth characters (plant height, LAI, DMP), chlorophyll content, sympods plant^{-1}, seed cotton yield and weed control efficiency were significantly higher in weed-free check (T_9) than others. Among treatments, Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS (T_2), Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence along with combination of Quizalofop ethyl @ 50g ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (T_4) and combination of Quizalofop ethyl @ 50g a.i. ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (T_5) registered significantly higher values of above measured parameters compared to all other weed management treatments and control. Hence, combined use of Pendimethalin and Quizalofop ethyl (or) Quizalofop ethyl and Pyrithiobac sodium (or) together use of these three herbicides effectively controls the weeds in rice-fallow cotton increases the growth and yield of cotton.

Keywords: LAI, rice-fallow cotton, seed cotton yield, sympods plant^{-1}, weed control efficiency

Introduction
Cotton (*Gossypium* spp.) is a major commercial bast fibre crop cultivated in India and plays a vital role in employment generation. Cotton is grown for its seed epidermal extensions (lint) which is the base material for cotton textile industry (Patel *et al*., 2016 and Sathishkumar *et al*., 2021) [20, 26] and contributes of about 25% of gross global fibre production.
Rice-fallow cotton is unique system, where seeds dibbled in between of rice stubbles without disturbing the soil which effectively utilized the residual soil moisture, improves water infiltration capacity and lowers soil erosion (Wilcut *et al*., 1993; Potter *et al*., 2008) [29, 22]. This rice based cropping system provided an opportunity to utilize residual water (Dixon *et al*., 2007; Ghosh *et al*., 2007; Dabin *et al*., 2016) [6, 8, 5]. Tillage practices were known to cause soil erosion, time consuming and also increased cost of cultivation. So there is increased trend of cultivation practices in fallow lands (Chauhan *et al*., 2012) [4]. With growing demand of food, fodder and fibre need to intensify the present day agricultural practices is must to meet the requirement and to create employment opportunity through cultivating crop under fallows is choice (Foley *et al*., 2011; Kumar *et al*., 2016) [7, 14]. Desirable characteristics of fallow crops to utilize limited water were fast growth, deep root system (Bandyopadhyay *et al*., 2016) [2]. Rice-fallow is a mono crop production system where sequential crop was sown after harvest of rice (Kumar *et al*., 2016; Kumar *et al*., 2018) [14, 15].
Sequential crop after rice in fallows is a challenge in post rainy season and often provoke with a chain of biotic and abiotic problem (Kumar *et al*., 2018) [15]. Among the major biotic problems, weeds cause severe loss to the crop productivity by competing with crops for resources and also acting as host for some insect pest during non-cropping season. So, there is need to control weeds in time (Zimdahl, 2013) [30].
Fallow condition of field and slow initial growth of cotton triggers the weed growth than crop and presence of rice stubble makes tough for hand weeding. This condition pushes to depend on herbicides for weed control (Ramesh and Rathika, 2015) [24]. Study has shown, adequate number of hand weeding was to be done at the optimal time to reduce the effect of weeds on

yield of crop (Prasad *et al*., 2008) [23]. In actual, fields were weeded seldom; due to many reasons *viz*., continuous rainy days, unavailability of labours at the time of weeding (Rashid *et al*., 2012) [25]. This made the dependence of herbicides for effective weed control (Gianessi, 2013) [9].

Though the combinations of herbicides are available in normal sown crop, it is needed to standardize in rice-fallow cotton. Hence the present study was undertaken.

Materials and Methods

A field experiment was conducted in wetland farms (Field No. J4) at Tamil Nadu Agricultural University, Coimbatore during summer season of 2021. The study field is located at western agro-climatic zone of Tamil Nadu at an latitude of 11.23˚N, longitude of 77.10˚E and at an altitude of 426.7 meters above mean sea level. Initial soil sample was collected and tested. It indicated that nitrogen was low (238.4 kg ha^{-1}), phosphorus was medium (11 kg ha^{-1}) and potassium was high (596.1 kg ha^{-1}).

Rice-fallow cotton, sowing was done after harvest of *rabi* rice near to the stubble without disturbing the soil. CO 17 variety was used as test cultivar in the present study. Zero monopodial branching and suitable for high density planting are the characteristics of CO 17 variety. Present study included with herbicides *viz*., Pendimethalin, Quizalofop ethyl, Pyrithiobac sodium and Paraquat dichloride.

Experiment was laid in randomized complete block design with nine treatments and three replications with plot size of 5 X 6 m^2. The treatments are T_1 - Pendimethalin @1.0 kg a.i. ha^{-1} as pre emergence and hand weeding, T_2 - Pendimethalin @1.0 kg a.i. ha^{-1} pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS, T_3 - Pendimethalin @ 1.0 kg a.i. ha^{-1} as pre emergence and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS, T_4 - Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence along with combination of Quizalofop ethyl @ 50g ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS, T_5 – combination of Quizalofop ethyl @ 50g a.i. ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS, T_6 - Quizalofop ethyl @ 50g a.i. ha^{-1} (before sowing) and mechanical weeding at 20 DAS, T_7 – Paraquat dichloride (before sowing) and mechanical Weeding at 20 DAS, T_8 – Weedy check and T_9 - Weed-free. In each treatment plot, five plants were randomly selected and tagged. Plant observations were taken in tagged plants at 120 DAS *viz*., plant height (cm), Leaf area index (LAI), drymatter production (kg ha^{-1}), Chlorophyll content (SPAD meter readings), number of sympods $plant^{-1}$ and yield (kg ha^{-1}). Weed observations included flora, was taken by placing 0.25 m^2 sized quadrat at random spots in each treatment at 60 DAS and weed control efficiency was recorded at 60 DAS.

Plant height was measured in centimetre from the base of plant to the top most leaf.

Leaf area index was measured by following formula.

$$LAI = \frac{\text{Leaf length x leaf breadth x number of leaves x K}}{\text{Spacing (cm}^2)}$$

Where, K= 0.775

Chlorophyll content was measured by using SPAD meter. For calculating drymatter production, 5 plants from each treatment were uprooted, dried to obtain constant weight and converted to one hectare.

Weed flora was recorded in weedy check at 60 DAS.

Weed control efficiency was calculated and expressed in per cent (Mani *et al*., 1973) [18].

$$WCE = \frac{W_2 - W_1}{W_2} X\ 100$$

Where,

W_1 - Dry weight of weeds in control plot

W_2 - Dry weight of weeds in treated plot

AGRES software was used to analyse the data using analysis of variance (ANOVA) under 5% significance.

Results and Discussion

Growth parameters

Plant height of treatments showed significant difference among various weed management methods mentioned in the Table 1. Taller plants were recorded in Pendimethalin @1.0 kg a.i. ha^{-1} pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS (89.6 cm) and Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence along with combination of Quizalofop ethyl @ 50g ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (88.2 cm) after weed free plot. This is because of grassy weeds were dominate flora under rice-fallow cotton which were effectively controlled by Quizalofop ethyl and reduced the weed competition, Higher WCE as evidenced in the present study also supports the results (Kumara *et al*., 2007; Iderawumi *et al*., 2018) [16, 11] and provided crop with favorable conditions for its growth and development.

Leaf area index of crop was significantly influenced by weed management practices included in the current study and noted in the Table 1. Pendimethalin @1.0 kg a.i. ha^{-1} pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS recorded higher value of LAI (3.0). This might be due to application of Pendimethalin and Quizalofop-ethyl in sequence was very effective in weed control might have facilitated the crop to utilize the solar radiation, nutrients, water effectively and ultimately leads to increased number of leaves and leaf area, this all resulted in higher LAI. Least leaf area index was observed with weedy check plot (1.01), because of lower weed control efficiency and shorter plants. Hallikeri *et al*. (2004) [10] and Bharathi *et al*. (2011) [3] reported that application of herbicides individually and in sequence gave higher weed control efficiency ultimately brought in to higher LAI.

Drymatter production was directly influenced by plant height, LAI and sympods $plant^{-1}$ and it was significantly influenced by weed management practices given in the Table 1. Drymatter production was recorded higher in Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence along with combination of Quizalofop ethyl @ 50g ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (11712 kg ha^{-1}) which is statistically on par with Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS (11490 kg ha^{-1}). This might be due to taller plants, higher LAI and higher sympods $plant^{-1}$ in these treatments. Weedy check showed lower DMP (5498 kg ha^{-1}) due to high weed competition for space, light and nutrients which made the plants with lower height, LAI and no. of sympods $plant^{-1}$. Amaregouda *et al*. (2013) [1] found similar kind of higher results in weed free plot in soybean with different herbicidal treatments. Oroka Frank and Omovbude, (2016) [19] also stated that weedy check recorded lower DMP in okra.

Chlorophyll content

Chlorophyll index used to measure the degree of phytotoxicity of herbicides to the crop photosynthetic apparatus. The treatments with different weed management practices have shown a significant difference in SPAD meter value, furnished in Table 1. Weed free treatment quantified with greater value (47.7). This may be due to lower competition for light among the vegetation as the light has major influence on chlorophyll development in plant system. Followed by Paraquat dichloride (before sowing) and mechanical weeding (46.8). This might be due Paraquat dichloride has no negative effect on chlorophyll development in crop plants. This results were supported by Amaregouda *et al*. (2013) [1]. Least value was recorded in the weedy check (43) might be due to weed flora shaded the crop plant and hinders the light penetration in to the crop canopy which ultimately reduced chlorophyll content (Kalaji *et al*., 2017) [12].

Sympods plant^{-1}

There is a significant difference in number of sympods plant^{-1}and it is mentioned in the Table 1.

Weed free check showed significantly higher no. of sympods plant^{-1} (14.5 plant^{-1}) is statistically on par with the treatments included with Quizalofop ethyl *viz*., T_2 (13.9 plant^{-1}), T_4 (13.7 plant^{-1}) and T_5 (13.6 plant^{-1}). This is due to effective control of dominant weed (*Echinochloa spp.)* by Quizalofop ethyl and left the field with favorable conditions for branching. Similar contributory work was done by Singh *et al*. (2016) [27] in cotton in regard of sympods using by Quizalofop ethyl showed better results. Least number of sympods plant^{-1} registered in weedy check (8.7 plant^{-1}). This is might be due to severe weed competition. Similar results were found in cotton weedy check recorded by Singh (1983) [28] and Singh *et al*. (2016) [27].

Seed cotton yield

A Significant variation was observed in seed cotton yield among different treatments and noted in the Table 1. Weed free plot recorded higher seed cotton yield (2790 kg ha^{-1}) followed by Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence along with combination of Quizalofop ethyl @ 50g ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (2219 kg/ha), Pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence and Quizalofop ethyl @ 50g ha^{-1} at 20 DAS (2179 kg/ha) and combination of Quizalofop ethyl @ 50g a.i. ha^{-1} and Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS (2102 kg/ha) noted statistically par seed cotton yield. This might be due lower weed competition, greater WCE and increased availability of growth factors reflected in higher seed cotton yield. Whereas weedy check (1093 kg/ha) showed lowest yield of all treatment plots. The supporting evidances found by Madhavi and Ramprakash, (2015) [17] and Kaur *et al*. (2019) [13]. This maybe due higher weed competition for growth resources and resulted in lower yield.

Table 1: Effect of different weed management methods of rice-fallow cotton on growth and yield parameters

Treatments	Plant height (cm)	Leaf area index	DMP (kg/ha)	SPAD	Sympods plant^{-1}	Seed cotton yield (kg/ha)
T_1	74.1	2.03	9700	45.4	12.1	1691
T_2	89.6	3.00	11490	44.1	13.9	2179
T_3	76.4	1.98	8767	45.2	12.7	1809
T_4	88.2	2.19	11712	44.0	13.7	2219
T_5	76.4	1.93	8700	43.9	13.6	2102
T_6	69.4	1.79	9177	45.0	12.0	1754
T_7	72.3	1.78	9523	46.8	10.4	1519
T_8	65.3	1.01	5498	43.0	8.7	1093
T_9	94.5	4.24	14767	47.7	14.5	2790
SEd	5.4	0.19	842	0.1	1.1	162
CD (0.05)	11.5	0.40	1786	0.2	2.3	343

Weed observations

Weed flora noted on 60 DAS, classified into grasses and broad leaved weeds. Single grassy weed (*Echinochloa colona*) prevails throughout the growing period as because of rice fallow situations, Broad leaved weeds includes *Alternanthera paronychioides*, *Ammannia baccifera*, *Portulaca oleracea*, *Phyllanthus niruri* and *Trianthema protulacastrum* are dominant weeds.

Weed control efficiency of different treatments shown a significant variation and mentioned in (Fig 1). Weed free plot showed greater weed control efficiency (83.69%). This is because of timely weeding was done in weed-free plot and also good crop growth. Patil *et al*. (2014) also reported similar results in weed free plot. Pendimethalin @ 1.0 kg a.i. ha^{-1} + Quizalofop ethyl @ 50g ha^{-1} + Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS recorded next higher WCE (46.43%). This might be due to broad spectrum control of weeds. Madhavi and Ramprakash. (2015) [17] and Kaur *et al*., (2019) [13] also concluded that higher weed control efficiency with combination of herbicides (Quizalofop ethyl and Pyrithiobac sodium).

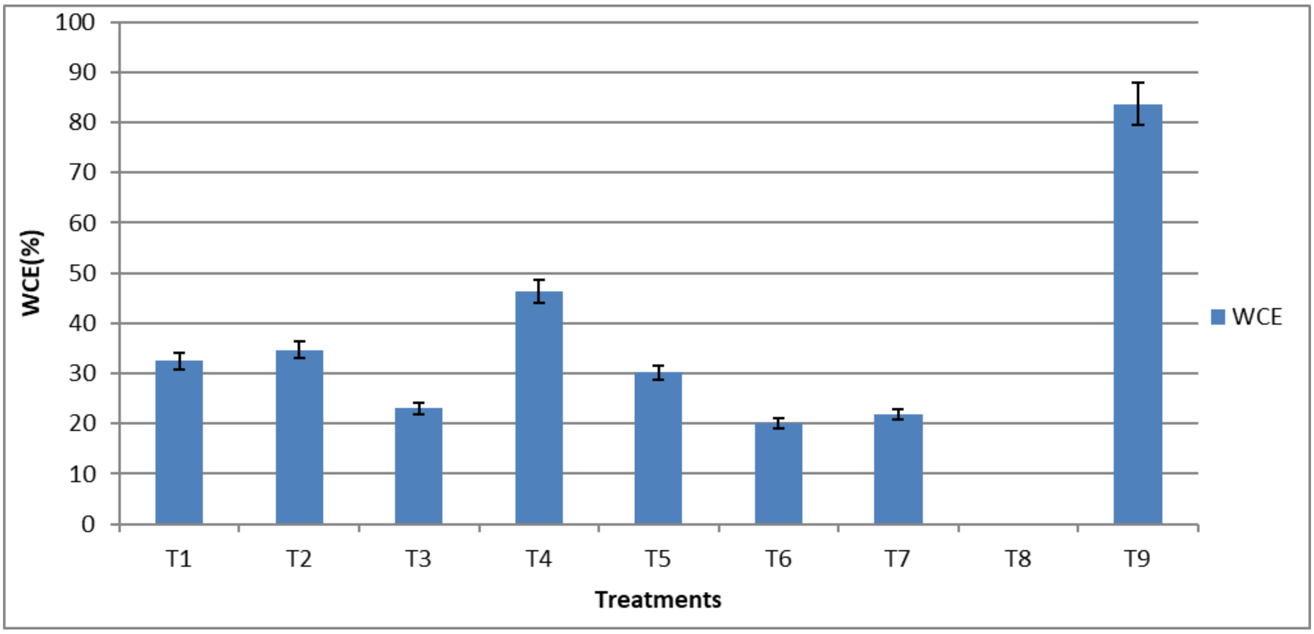

Fig 1: Effect of different weed management methods of rice-fallow cotton on weed control efficiency

Conclusion

From the current study, it can be concluded that the Pendimethalin and Quizalofop ethyl controls the dominant weed flora i.e., *Echinochloa colona* effectively and inclusion of Pyrithio bac sodium along with above two herbicides controls broad leaved weeds in rice fallow cotton. Therefore Pendimethalin @1.0 kg a.i. ha^{-1} + Quizalofop ethyl @ 50g ha^{-1} + Pyrithiobac sodium @ 62.5g a.i. ha^{-1} at 20 DAS is recommended to be very effective in control of broad spectrum weeds in rice-fallow cotton

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