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Spinoffs in Mechano - Chemical Approach of Weed Management Practices in Tossa Jute (*Corchorus olitorious*)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PB and SM designed the study and wrote the protocol. Authors AC and RB performed the statistical analysis and wrote the first draft of the manuscript. Authors SB and AC managed the analyses of the study. Authors AC and RB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

One of the most important pre-*kharif* crop in eastern plains is jute. Weed can deplete 70-80% of the crop yield. An experiment was conducted at Mondouri Research Farm of Bidhan Chandra Krishi Viswavidyalaya, India, during summer season of 2018 and 2019. The design of experiment was Randomized block design with 3 replications and 7 treatments with variety JRO-524 (Navin) for weed control comprised –T1: Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hrs of sowing + one hand weeding at 15 days after sowing, T2: Quizalofop ethyl 10 EC at 38 g/ha at 15 days after sowing + one hand weeding at 30 days after sowing, T3: Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100 g/ha at 15 days after sowing, T4: Propaquizafop 10 EC at 90 g/ha at 15 days after sowing+ one hand weeding at 30 days after sowing, T5: Nail weeder at 7 days after sowing + Quizalofop ethyl 5 EC at 60 g/ha at 30 days after sowing, T6: Un-weeded check and T7: Two hand weeding at 15 and 30 days after sowing. Sowing was done on 28th April 2018 and 30th April in 2019. Predominant monocot weeds were *Digiteria sanguinalis, Echinochloa colona, Elusine indica, Cyperus rotundus* and dicot weeds were–*Digera arvense, Cleome viscose* and *Physalis*

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minima. Among the treatments, twice hand weeding gave the highest fibre yield alongwith maximum Weed control efficiency, Weed control index, Crop resistance index, Herbicide efficiency index followed by nail weeder induced weed management at 7 days after sowing coupled with herbicide spray of Quizalofop ethyl 5 EC at 60 g/ha at 30 days after sowing which resulted in maximum net return (Rs. 110222/- per ha) with a corresponding highest benefit cost ratio (2.40) and enriched soil microbes population. Considering bio-efficacy of applied treatment, economics and microbial study, nail weeder along with post emergence herbicide application at 30 days after sowing can be advocated for higher revenue as well as better soil health replenishment.

Keywords: Nail weeder; weed biomass; WCE; HEI; WPI; soil microbes; yield; economics.

1. INTRODUCTION

Jute yarns are principally used for sacking natural, renewable, biodegradable and eco-friendly material, as a host of diversifications and offers livelihood to about four million farm families [1] in SAARC countries other than Pakistan and China and thus has becomean integral part of their farming. Besides having a comparatively short (100-120 days) LGP, it nourishes the soil health adding organic matter through huge amount of leaf fall during its growth [2] and stubble incorporation after harvest, both makes the crop promising to the farmers of eastern India to be fitted in the prevalent rice based cropping system during the pre-*Kharif* (summer) season even under rainfed condition. India has to increase jute productivity to 5.50 t/ha to contain projected demand [3].

Manual weeding operation itself maps to 16.3% of the total cost of cultivation [4] and along with retting it constitute 70% of the cost of cultivation [5]. Yieldlosses owing to weed competition can compromise 70-80% of the jute yield in hot humid tropics characterised periodic rainfall [6]. Congenial conditions of warm and humid delta results in a complex weed flora including grassy, sedge and broad leaf weeds in Jute. Under this scenario, exploring integrated weed management including an integration with nail weeder, an implement developed by ICAR-CRIJAF along with a recommended new approach on mechano- chemical approach for controlling weeds with different types of pre-emergence (PE) and post emergence (POE) combinations can open a window towards profitable jute cultivation. The present experiment was conducted to develop suitable weed management practices through effective integration of PE & POE herbicides with hand weeding (HW) and a novel treatment of nail weeding through Nail weeder developed by ICAR-CRIJAF which can control weed growth effectively at the very younger stage of the crop. This study also bears a purpose to fill up the scanty information regarding various weed indices for the better understanding of different treatment efficacies in jute.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at Mondouri Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India, located at 89° E, 23° N with an elevation of 10 m above the sea level, during pre-*kharif* season of 2018 and 2019.

2.2 Experimental Set-Up

The experimental site enjoyed a hot and humid sub-tropical climate with alluvial, sandy- loam soil having good drainage capacity. Variety of the jute used for experiment was JRO-524 (Navin). The experiment was laid in randomized block design having 7 treatments replicated thrice. A plot size of 20 m^2 was maintained. Spacing of the crop was 25 cm × 8 cm. The treatments for weed control comprised –T1: Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hrs of sowing + one hand weeding at 15 DAS; T2: Quizalofop ethyl 10 EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS; T3: Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100 g/ha at 15 DAS; T4: Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS; T5: Nail weeder (developed by CRIJAF) at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS. T6: Un-weeded check and T7: Two hand weeding (HW) at 15 DAS and 30 DAS. Sowing was done on 28th April 2018 and 30th April in 2019.

2.3 Data Collection

As the understanding of critical period of weed control (CPWC) is very much essential for making proper decision on weed control and

efficient use of herbicide [7,8], the treatments in this experiment, have been scheduled based on this. For evaluation ofefficacy of different herbicides and their combinations, each plot was sampled randomly at 45 DAS as the critical crop weed completion period for jute is upto 42 DAS [9]. Weed density and biomass were determined by placing three squares of 1 m^2 randomly in each plot. From each square, three categories of weeds i.e. grasses, sedges and broadleaves were separated by species, the number was counted individually and summed to get total weed density. Weed dry weight were recorded after 2 days of sun drying and then oven drying at 70°C. Several weed indices were calculated to compute the efficacy of herbicides [10,11]. The shortfall in yield due to weeds as compared to the weed-free plots were represented by the Weed index (WI).

1. Weed Index (WI) = $[(\mathrm{YWF} - \mathrm{YT}\ )/\mathrm{YWF}] \times 100$

Where, Y_{WF} is the grain yield in weed-free plot; Y_T is the grain yield in treatment plot.

2. Weed control efficiency (WCE) = $[(\mathrm{WDC} - \mathrm{WDT})/\mathrm{WD\ c}] \times 100$

Where, WD_C is the weed density (Population/m^2) in control plot; WD_T is the weed density (Population/m^2) in the treated plot.

3. Weed control Index (WCI) = $[(\mathrm{WDMC} - \mathrm{WDMT})/\mathrm{WDM\ c}] \times 100$

Where, WDM_C is the weed dry weight (g m^{-2}) in un-weeded control plot; WDM_T is the weed dry weight (g m^{-2}) in the treated plot.

4. Weed persistence index (WPI) = (Weed population in un-weeded control plot X Weed dry weight in treated plot)/ (Weed population in treated plot X Weed dry weight in un-weeded control plot).

This index indicates the resistance in weeds against the tested treatments and confirms the effectiveness of selected herbicides.

5. CRI = (Jute biomass in treated plot X Weed biomass in control plot)/ (Jute biomass in control plot X Weed biomass in treated plot)

Crop Resistance index (CRI) indicates the relationship between a proportionate increase in crop biomass and a proportionate decrease in weed biomass in the treated plots.

6. Weed infestation (%) = (Total number of weeds in unit area/ Total number of weeds and crop plants in the same area) X 100

It indicates how much percentage of crop area is infested by weeds.

7. Herbicide efficiency index (HEI) = $[\{(\mathrm{YT} - \mathrm{YC})/\mathrm{YC}\} \times 100] / \{(\mathrm{WDMT}\ /\mathrm{WDMC}) \times 100\}$

Where, Y_T and Y_C stands for the yields of treatment and un-weeded control respectively; while WDM_T and WDM_C are weed dry matter in treatment and un-weeded control, respectively. This index indicates the potential of herbicides for controlling weeds.

8. WMI = (Percent yield increase over check/ Percent control of weeds.)

Weed management index (WMI) is the ratio of yield increase over the weedy check due to weed management and percent control of weeds by the respective treatment.

At harvest, fibre yield and stick yield was also recorded and plant height along with basal diameter at final stage has been shown here. Cost of various inputs and crop management practices in producing the crops including the treatment cost and the price of the produce were estimated as per available market price. Cost of cultivation, value of produce, net return and benefit: cost ratios of the crop for various treatments were then calculated.

Soil microbial assay was done by collecting composite samples from inter row space of each plot at a depth of 0-15 cm before sowing (Initial), at 30 DAS and at 45 DAS each after application of respective treatments. Specific media viz. for total bacteria, Thornton's agar medium [12] for actinomycetes, Jensen's agar medium [13] and for fungi, Martin's rose bengal streptomycin agar medium [14] were used for plating of diluted soil samples. The soil microbial population was enumerated on agar plates following serial dilution technique and pour plate method [15]. The counts were taken at the 3rd day of incubation of the plates at 30°C.

2.4 Data Analysis

The statistical analysis of the recorded data on crop and weeds was done through test of significance at probability level of 0.05 and online

OPSTAT Statistical Software Package for Agricultural Research [16]. The ANOVA across the year showed no significant variation (*P*= 0.05) between the years of experiment, among the treatments and year × treatment interactions. Hence, the pooled data over two years have been presented here.

3. RESULTS AND DISCUSSION

Predominant weed flora present in the experimental field throughout the crop growing season in the year 2018 and 2019 were *Digiteria sanguinalis, Cynodon dactylon, Echinochloa colona, Elusine indica Dactyloctenium aegyptium* under grassy weeds, *Cyperus rotundus* under sedge, *Digera arvense, Cleome viscosa* and *Physalis minima, Amaranthus viridis, Alternenthera philoxeroides* under BLWs. Similar findings were reported by Masum et al. [17] and Mukherjee et al. [18].

3.1 Crop and Weed indices

At the terminal end of crop weed completion period, weed density (weed population/m^2) in two year pooled value, was significantly lowest (40.27) (Table 1a) in twice hand weeded plotsat15 and 30 DAS followed by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5) with the value of 57.60. Similar kind of result has been reported by Datta et al. [19].

Weed control efficiency (WCE) was also maximum (75.57%) (Table 1a.) for twice hand weeded plots, followed by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS treated plots (65.06).

Among the treatments, weed biomass was minimum for two hand weeding (HW) at 15 DAS and 30 DAS (6.70 g/m^2) (Table 1a.) keeping statistically at par value (7.78 g/m^2) with Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS treated plots. Pretilachlor being a pre-emergence herbicide, was effective for all type of weeds in earlier growth stages but at 45 DAS registered comparatively higher weed biomass (27.45 g/m^2) lower than only un-weeded control plots (61.05 g/m^2). These findings are similar with the findings of Jena et al. [5] where PE and POE herbicides were used.

In the study, the highest weed control index (WCI) (Table 1a.) was observed in pooled value of twice hand weeding at 15 and 30 DAS (T7)(89.03 %) which was statistically at par with Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5) (87.26%). The weed control efficiency of Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 days after sowing (T1) (55.04%),Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100 g/ha at 15 DAS (T3) (66.01%) were less due to not treated after 15 DAS. Similar types of findings were reported by Sarkar et al. [20] and Jena et al. [5] regarding the performance of herbicides.

Weed persistence is a function of both weed count and dry biomass of weeds which is significantly reduced by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5)

Table 1a. Effect of integrated weed management practices on different weed management indices in jute (at 45 DAS)

Treatment	Weed density (Population /m^2)	Weed Control Efficiency (WCE) (%)	Total weed biomass (g/m^2)	Weed Control Index (WCI) (%)	Weed Persistence Index (WPI)
T_1	117.30	28.85	27.45	55.04	0.63
T_2	100.80	38.86	17.21	71.81	0.46
T_3	115.45	29.97	20.75	66.01	0.49
T_4	78.36	52.47	10.72	82.44	0.37
T_5	57.60	65.06	7.78	87.26	0.36
T_6	164.86	0.00	61.05	0.00	1.00
T_7	40.27	75.57	6.70	89.03	0.45
S.Em (±)	0.99	0.60	1.28	1.13	0.007
CD(P=0.05)	3.08	1.86	3.99	3.41	0.020

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T_4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

Table 1b. Effect of integrated weed management practices on crop resistance index, weed infestation (%) and herbicide efficiency index different weed management indices in jute

Treatment	Plant population /m^2	Plant biomass (g/m^2)	Crop Resistance Index (CRI)	Weed Infestation (%)	Weed index (WI) (%)	Herbicide efficiency index (HEI)	Weed Management Index (WMI)
T_1	50.00	216.70	3.10	70.11	23.30	0.99	1.55
T_2	51.33	228.19	5.04	66.26	14.85	2.15	1.56
T_3	50.33	233.61	4.60	69.64	28.09	1.05	1.19
T_4	49.67	229.04	8.33	61.20	21.03	2.79	0.93
T_5	50.33	240.46	13.42	53.37	4.14	6.35	1.54
T_6	49.00	151.11	1.00	77.09	47.00	-	-
T_7	50.33	249.26	16.11	44.45	0.00	8.08	1.17
S.Em (±)	0.57	0.75	0.19	0.26	0.36	-	-
CD (P=0.05)	NS	2.33	0.62	0.81	1.13	-	-

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T_4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

treated plots showing significantly minimum value of 0.36 WPI (Table 1a.) and was in statistical parity with Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS (T4)(0.37). Probably Propaquizafop had a better control over grassy weeds and subsequent hand weeding at 30 DAS controlled rest types of weeds successfully showing lesser WPI.

Difference of plant population (m^{-2}) across weed control methods was not significant.As evident from the two year pooled plant biomass data, maximum dry matter accumulation (249.26 g/m^2) (Table 1b) was observed where in twice hand weeded plots was closely followed by nail weeded plots with the value of 240.46 g/m^2.

In case of weed index, integrated weed control including nail weeder in 7 DAS with POE herbicide application at 30 DAS (T5) registered best result with 47.00% (Table 1b.). Data regarding crop resistance index (CRI) and Herbicide efficiency index (HEI), represented comparatively higher values (16.11 and 8.08 respectively) in twice hand weeding at 15 and 30 DAS (T7) treated plots. Nail weeder along with Quizalofop ethyl 5 EC at 30 DAS registered little lower values for CRI (13.42) and HEI (6.35) than T7 (Table 1b). Nonetheless the values of both the indices in Nail weeder along with Quizalofop ethyl 5 EC at 30 DAS treated plots were significantly higher than the other treatments complementing the efficiency of Nail weeder in combination with herbicide application as an effective control of all types of weeds throughout the crop weed completion period.

Weed infestation values from respective treatments reflected degree of infestation (%) and here also Nail weeder along with Quizalofop ethyl 5 EC at 30 DAS (T5) showed lesser values (53.37) (Table 1b.), just after twice hand weeding at 15 and 30 DAS (T7) treated plots (44.45) having the least weed infestation. In case of Weed management index (WMI), highest value (1.56) was recorded with Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS (T2) which was closely followed by T1 (1.55) and T5 (1.54).

3.2 Growth Attributes

Plant height and basal diameter are important characteristics which contribute to fibre yield. Pooled data revealed highest plant height (346.21 cm) (Table 2.) at harvest with two hand weeding at 15 DAS and 30 DAS followed by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS which yielded 345.83 cm being statistically at par with twice hand weeding treatment. The corresponding pooled data for basal diameter were 1.61 cm for two hand weeding at 15 DAS and 30 DAS (T7) and 1.55 cm for Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5) respectively.

3.3 Fibre Yield and Stick yield

At harvest, among the treatments, significantly highest fibre yield (3.96 t/ha) (Table 2.) was recorded in two HW at 15 DAS and 30 DAS (T7) followed by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha (T5) (3.80 t/ha)

Table 2. Effect of weed management practices on growth and yield attributes of Jute

Treatment	Plant height (Final) (cm)	Basal diameter (Final) (cm)	Fibre yield (t/ha)	Stick yield (t/ha)
T_1	291.26	1.20	3.04	8.80
T_2	292.92	1.31	3.38	10.10
T_3	264.90	1.24	2.85	8.86
T_4	261.34	1.17	3.13	9.41
T_5	345.83	1.55	3.80	11.70
T_6	211.96	0.97	2.10	6.16
T_7	346.21	1.61	3.97	12.40
S.Em (±)	6.08	0.02	0.77	3.23
CD(P=0.05)	18.26	0.072	2.31	9.72

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

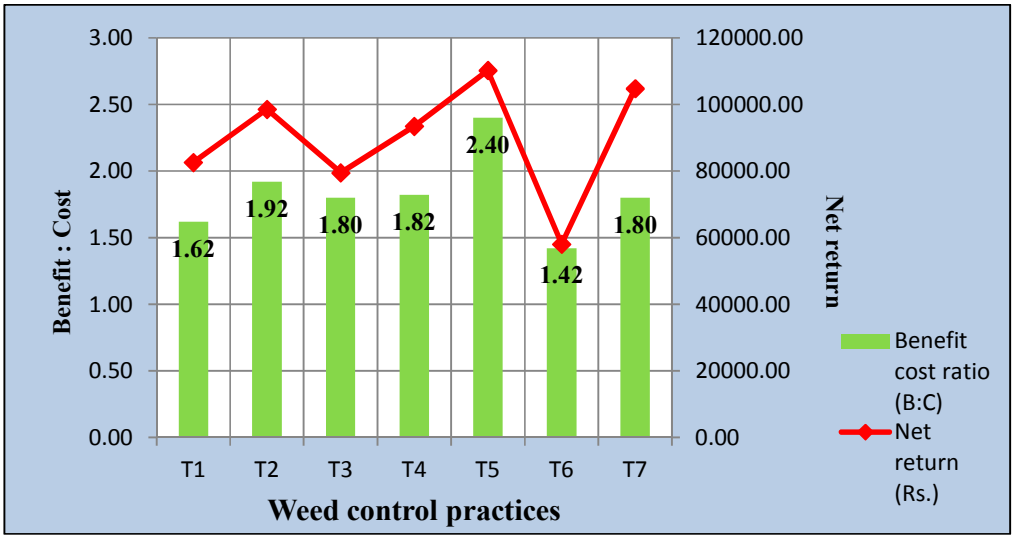

Fig. 1. Effect of weed control practices on economics of jute

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T_4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

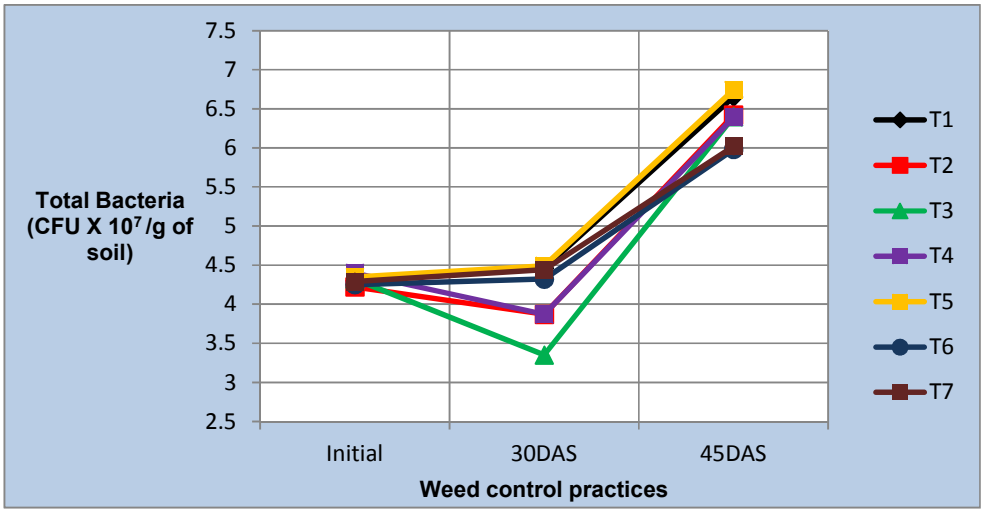

Fig. 2. Effect of weed control practices on total bacteria count in soil

keeping statistical parity with T7 in pooled analysis. The lowest fibre yield (2.10 t/ha) was recorded in un-weeded check (T6). The trend was similar also for stick yield. At harvest, among the treatments, maximum stick yield (12.39 t/ha) was recorded in two hand weeding at 15 DAS and 30 DAS (T7) followed by Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha (T5) (11.70 t/ha) resulting themselves as statistically at par. Similar types of findings were reported by Majumdar et al. [21].

3.4 Economics

The economics was calculated resorting input costs and price of jute fibre of 2018. The Jute price published by CACP 2018 was used for the purpose. The fibre and stick yield were maximum in case of two hand weeding at 15 DAS and 30 DAS (T7) so the gross return was also maximum in this case (Rs.163032) but in T7 treatment, variable cost was also maximum (Rs.17500) because of high labour requirement

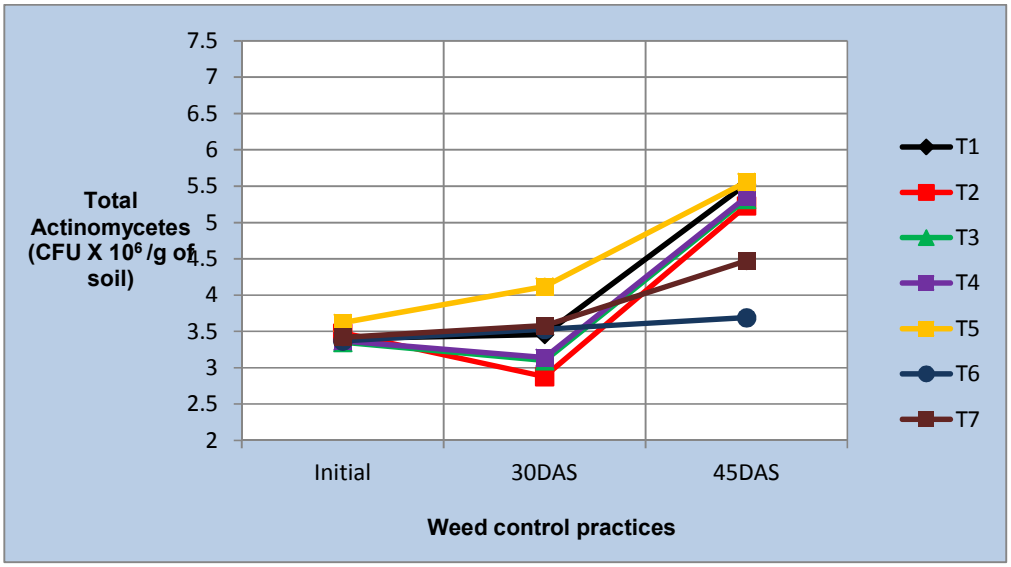

Fig. 3. Effect of weed control practices on total actinomycetes count in soil

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T_4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

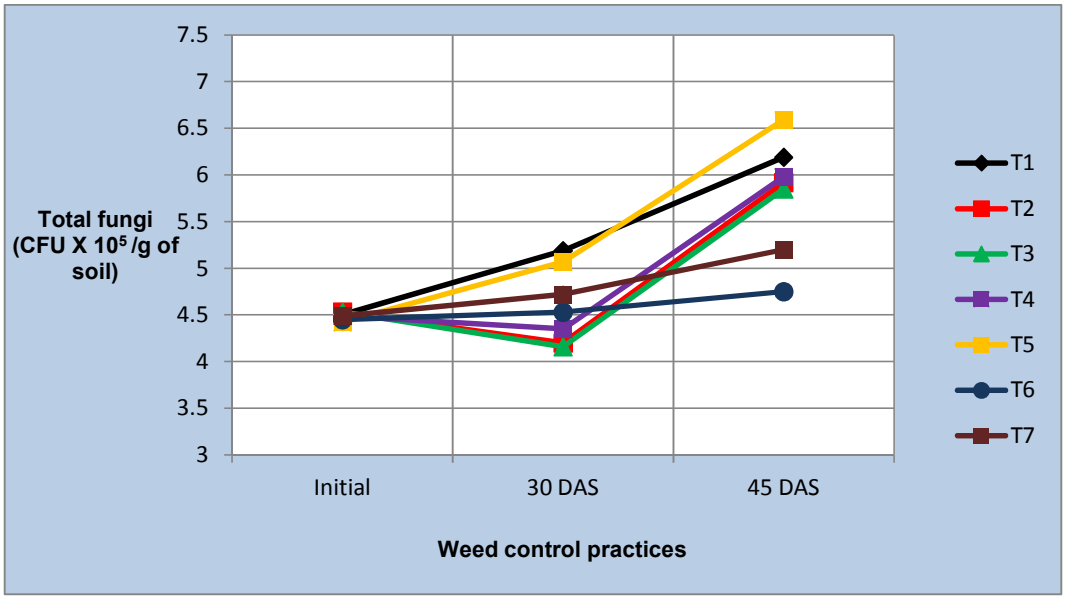

Fig. 4. Effect of weed control practices on total fungi count in soil

T_1 = Pretilachlor 50 EC at 900 ml/ha with irrigation after 48 hours of sowing + one hand weeding at 15 DAS, T_2= Quizalofop ethyl 10% EC at 38 g/ha at 15 DAS + one hand weeding at 30 DAS, T_3 = Quizalofop ethyl 5 EC at 60 g/ha + Ethoxysulfuron 10 EC at 100g/ha at 15 DAS, T_4 = Propaquizafop 10 EC at 90 g/ha at 15 DAS+ one hand weeding at 30 DAS, T_5 = Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS, T_6 = Un-weeded check, T_7 = Two hand weeding (HW) at 15 DAS and 30 DAS

for two hand weeding. On the other hand nail weeder required70% less labour than hand weeding, so in case of Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha (T5) variable cost was low (Rs.5200) and consequently had a higher net return of Rs.110222.38 which was

maximum among the treatments. The table of economics reveals that the best economics was provided by the Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5) having benefit cost ratio (B:C) 2.40.

3.5 Soil Microbial Population

There was no significant variation in each of the microbes population in initial soil. Later on, data revealed that across the herbicidal treatments, there was an initial depression in the all the microbe types followed by an upsurge of the corresponding at 45 DAS. The variation was more pronounced with the bacterial count. Ghosh et al. [22] also had similar results. This depression and upsurge owing to herbicide action has been also corroborated by Mondal et al. [23] for transplanted *kharif* rice. Applied herbicides, before degradation in soil, show toxic effects on the metabolism of the microbes which hinders their multiplication and usual activities that is reflected in their low count in the early stage. Gradually microbes start utilizing the degraded herbicide molecule as their carbon food reserve and multiply vigorously which leads to an enriched microbe-diversity. Mondal et al. [23].

Significantly better values have been observed with nail weeded plots along with POE herbicide application. Nail weeder, apart from efficient weed control, also provides advantages of soil mulch in crop field, which might have resulted in better moisture conservation [24] and regulated soil temperature [25] which might be reflected in gradual microbes build up upto 45 DAS. Several reports [26], Sharma and Bhardwaj [27] in support of mulching effects on soil health had been already registered. Thus the total count of each of the three microbes turned out maximum in case of Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS (T5) keeping statistical parity with the Pretilachlor treated plot in count of bacteria and actinomycetes. This was because the PE applied plots had more time available for the microbes to multiply upto 45 DAS revealing better count.

4. CONCLUSION

Among the treatments twice hand weeding applied plots came up with highest fibre yield along with maximum weed control efficiency (WCE), weed control index (WCI), crop resistance index (CRI) and Herbicide efficiency index (HEI) and lowest weed infestation. Nail weeder induced weed management at 7 DAS stage coupled with herbicide spray of Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS had lowest weed persistence index (WPI) (0.36), highest weed index (WI) of 47.00% and very close values in every weed index viz. WCI, WCE, HEI and CRI. The fibre yield was also at par for nail weeder in combination with herbicide spray of Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS. The gross return from fibre yield and stick yield was maximum in twice hand weeding approach yielding Rs. 163032 per ha; owing to the more implied cost of human labour, requiring 300-350% more cost than nail weeding. Nail weeder at 7 DAS + Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS resulted in maximum net returns (Rs. 110222/- per ha) with a corresponding highest benefit cost ratio (B:C) (2.40) among the treatments. Additionally, Nail weeded plots along with spray of Quizalofop ethyl 5 EC at 60 g/ha at 30 DAS had its own benefits with at an enriched soil microbial population with special emphasis on bacteria. So we can infer that the combine use of nail weeder and herbicide is more profitable both in terms of economics and soil health replenishment, than hand weeding as well as sole application of herbicides.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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