Table 3. Effect of agri-silvicultural system on yield and yield attributes of clusterbean

Treatment	Number of Branches/plant		Number of pods/plant		Seeds/pod		Seed yield t/ha	
	2018	2019	2018	2019	2018	2019	2018	2019
Eucalyptus– clusterbean	3.07	2.93	13.77	13.43	5.70	5.47	0.85	0.83
Dek–	2.80	2.70	13.67	13.48	5.50	5.37	0.70	0.69
Poplar–clusterbean	2.90	2.70	13.73	13.57	5.53	5.33	0.74	0.71
Sole crop (clusterbean)	3.33	3.20	14.70	14.77	6.17	6.15	1.06	1.05
SEm±	0.07	0.063	0.22	0.19	0.14	0.12	0.04	0.04
CD (P=0.05)	0.34	0.29	NS	1.05	NS	0.57	0.12	0.10

However, days taken to 50% flowering and days taken to maturity slightly increased in crop planted under the tree species. This might be due to shade effect of tree species. Rathee *et al.* (2017) also observed significantly higher plant height in the control plot than fennel-poplar intercropping system. In case of greengram crop, it had less vegetative growth under the 4-year-old than the 3-year-old poplar canopy and in comparison to open area (Chauhan *et al.,* 2013)

Yield and yield attribute

Yield and yield attributes of clusterbean showed decrease in intercropped system in comparison to sole crop of *guar*. The reduction in crop yield under agro-forestry systems might be due to the competition for the light, water, nutrients and allelopathic effect (Carnell, 1990; Kaur *et al* 2017). Number of branches were significantly higher in sole *guar* crop as compared to intercrop system; however number of pods and seeds/pod were non-significant during the first year of investigation. During the 2nd year, data revealed that seed yield was significantly increased when clusterbean was taken as a sole crop. Number of branches, number of pods and number of seeds/pod also showed similar trend (Table 3). Number of pods per plant, pod weight and seed weight/plant reduced almost to half in 4-year-old plantation as compared to the control plot of greengram and turmeric crops (Chauhan *et al.,* 2013). Shading was more important than below-ground competition in an intercropping study (Wiley and Reddy, 2008) as it decreases the light interception, leaf-area index, photosynthesis rate etc of the field crops grown under tree species.

The present study showed that there was yield reduction in the intercropped crop (*guar*) in comparison to sole crops but being legume, *guar* is feasible to grow as an intercrop in this agri-silviculture system since it is eco-friendly and beneficial approach to apprehend the decline in soil fruitfulness. Also agroforestry (growing trees + crops) provides a viable option with opportunities for the diversification.

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Research Paper

Effect of integrated weed management on weeds, yield and economics of tossa jute (*Corchorus olitorius* L.) production

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ABSTRACT

A study was carried out during the pre-*kharif* season of 2018 and 2019 at Pundibari, Cooch Behar, West Bengal, to evaluate the efficacy of pre and post-emergence herbicides in tossa jute (*Corchorus olitorius* L.) over manual weeding. The experiment was laid out in a randomized complete-block design with 9 treatments, replicated thrice. The study results revealed that post-emergence herbicide-treated plots reduced the weed density by 74–96% and weed biomass by 72–93% compared to non-treated plots. Manual weeding twice-treated plots reduced the weed density by 82–92%. Pre-emergence herbicides failed to prove its efficacy over the manual weeding. Plots treated with quizalofop-ethyl + ethoxysulfuron followed by manual weeding achieved higher yield (3.46 t/ha) than manual weeding twice-treated plots (3.31 t/ha). Jute fibre yield and weed infestation showed a negative correlation. Yield reduction of 7.4–13.6 kg was recorded for every 1 kg increase in weed biomass, depending on time and method of the weed control. The study indicates that, ethoxysulfuron is a broad-spectrum herbicide. Combination of quizalofop-ethyl and ethoxysulfuron followed by manual weeding was found economically effective in controlling weeds as an alternative to labour consuming manual weeding.

Key words: Fibre yield, Integrated weed management, Jute, Weed density, Weed biomass

Jute is mainly grown in eastern and north-eastern parts of India, contributing around 62.2% of world total fibre production (Rajpoot *et al.,* 2019). The crop is cultivated mostly under rainfed condition with an unbalanced fertilizer schedule. Jute is grown in medium-high and high land situation with light-texture soil under warm-humid climate that favours weed growth. Weed problem is one of the major constraints in jute cultivation and causes 40–70% fibre yield loss (Ghorai *et al.,* 2013). Though weeds draw out most of the soil nutrients and water but weeding in this crop is often neglected by jute-growers. Greater crop-weed competition is mainly seen during the early stages of crop growth during 21–42 days after sowing (Kumar *et al.,* 2015a). Hence negligence of weed control in jute field will lead to slow crop growth, poor competition with weeds and consequently causes yield loss. Mostly, grassy weeds are predominant in jute field compared to sedge and broad-leaf weed (Bhattacharya, 2012).

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Jute with a weed-free environment during initial crop-growth period gives higher fibre yield. Tender weeds cannot be effectively controlled by hand-weeding or mechanical means only. Application of herbicides can create such environment by removing the weeds. Therefore, integrated weed management would be one of the main components of good agricultural practices in jute to increase the crop productivity and save important inputs like nutrients and water. Researches are being carried out to find an effective chemical method of weed control to replace costly, slow and tedious cultural methods. Out of total cost of cultivation, almost 30–40% cost is involved only for weeding operation (Islam, 2014). Weeds and jute seeds are germinated and occur at the same time of the season. The time of application would determine the efficiency of the herbicides (Maiti and Singh, 2019). For effective and economical weed management in field crops, the combined use of two or more herbicides is being increasingly practiced now-a-days. Therefore, broad-spectrum herbicide should be used to check a variety of weeds those are difficult to control by a single application (Singh *et al.,* 2016). Therefore, this study was framed to evaluate the impact of using sole and sequential application of herbicides and manual weeding on weed control and tossa jute fibre yield.

MATERIALS AND METHODS

The experiments were conducted in pre-rainy (*kharif*) season of 2018 and 2019, at farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The soil was sandy loam (62.1% sand 20.5% silt and 17.5% clay), with *p*H 5.7, organic carbon 0.59%, available nitrogen 150.53 kg/ha, available phosphorus 40.52 kg/ha and available potassium 110.85 kg/ha. During cropping season temperature was ranging from 21.7 to 32.5°C and rainfall received 621.4 mm and 2,035.7 mm in 2 years.

The experiment was laid out in a randomized complete-block design with 9 treatments and 3 replications. The plot size was 5 m × 4 m. The weed-control treatments were: pretilachlor 50% EC @ 450 g/ha followed by (fb) 1 manual weeding at 35 days after sowing (DAS), pretilachlor 50% EC @ 900 g/ha fb 1 manual weeding at 35 DAS, butachlor 50% EC @ 1,500 g/ha fb 1 manual weeding at 35 DAS, quizalofop ethyl 5% EC @ 60 g/ha fb 1 manual weeding at 35 DAS, ethoxysulfuron 15% WDG @ 100 g/ha fb 1 manual weeding at 35 DAS, quizalofop ethyl 5% EC @ 60 g/ha + ethoxysulfuron 15% WDG @ 100 g/ha fb one manual weeding at 35 DAS, manual weeding twice at 20 and 35 DAS, non-treated (weedy) and weed-free.

The tossa jute variety 'JRO 204' 'Suren' was used for this experiment with a seed rate of 5 kg/ha. The crop was sown on 18 March and 15 March in 2018 and 2019, respectively. Sowing was done using multi-row seed drill, at a spacing of 30 cm × 5–7 cm, with 2–3 cm depth. The tossa Jute was harvested on 30 June and 28 June in 2018 and 2019, respectively. A uniform dose of 40 kg each of P_2O_5 and K_2O/ha was applied to all the plots at the time of the last land preparation (as basal). Nitrogen (N) was applied @ 80 kg/ha in 2 equal splits–at 20 and 35 days after sowing (DAS). The herbicides were applied with flat-fan nozzle by using manual knapsack sprayer.

In both the years, treatment efficiency was evaluated @ 10 days after application of herbicides, i.e. at 30 and 45 DAS. Two quadrates of 50 cm × 50 cm were randomly placed in each plot to determine the density and biomass of weeds. Grass, sedge and broad leaf weeds were collected and counted. The samples were oven-dried at 70°C for 12 hr and dry weights were recorded. Weed density and weed-dry biomass were expressed as number and g per m^2, respectively. Plant height, basal diameter and fibre yield were recorded at the time of harvesting. The relationship between jute-fibre yield and weed biomass at 30, 45 and 60 DAS were assessed by regression analysis.

For impact assessment, interpretations and drawing appropriate conclusions in weed management of jute different weed indices were calculated by using the following equations as suggested by Awan *et al.* (2015).

Weed index (WI) signifies the yield reduction caused by weed in comparison with weed-free plots. It can be calculated as:

$$\text{WI} = \frac{\text{Yield in weed free plot} - \text{Yield in treated plot}}{\text{Yield in weed free plot}} \times 100$$

Weed-management index (WMI) denotes the ratio between yield increase over unweeded control plot due to weed management and per cent weed control by same treatment. It can be computed as:

$$\text{WMI} = \frac{\text{Percent yield increase over control}}{\text{Percent control of weeds}}$$

Agronomic management index (AMI) can be computed as:

$$\text{AMI} = \frac{\text{Percent yield increase} - \text{Percent control of weeds}}{\text{Percent control of weeds}} \times 100$$

Integrated weed-management index (IWMI) was calculated as:

$$\text{IWMI} = \frac{\text{Weed management index} + \text{Agronomic management index}}{2}$$

Considering the cost of cultivation and price of the produce, net returns (₹/ha) and benefit: cost (B: C) ratio were calculated. Cost of herbicides was estimated on the basis of their market price. Minimum support price (MSP) of tossa jute (₹37,000 and ₹39,500/t in 2018–19 and 2019–20, respectively) was used for calculating profitability of treatments in both the years. Labour wages for manual weeding twice were ₹80,132 and ₹89,401/ha in 2018 and 2019, respectively. Net returns were calculating by subtracting cost of cultivation from gross returns.

Statistical analysis was done using GenStat version 11.0 software. The comparisons of treatment means were based on Duncan's test at the probability level (P< 0.05). Analysis of variance (ANOVA) was done for plant weed density, weed biomass and jute-fibre yield. Weed data were subjected to square-root transformation [$\sqrt{(x + 0.5)}$] before analyses; however, results did not improve. Hence the non-transformed data were used for analysis.

RESULTS AND DISCUSSION

Weed density

Data showed that the density of the grassy weeds (63–67%) was more vigorous than that of sedge (21–23%) and broad leaf (10–12%) weeds (Table 1). All the weed-control treatments had significant influence on weed density over non-treated plots. The lowest weed density at 30 and 45 DAS was recorded in plots treated with quizalofop-ethyl + ethoxysulfuron fb manual weeding (MW), which was a 90% and 96% compared to weedy check. Plots treated with manual weeding only recoded 82% and 92% lower weed density at 30 and 45 DAS. Post-emergence herbicides fb manual weeding treatments showed greater efficiency than pre-emergence herbicides fb manual weeding in controlling weeds. Pre-emergence herbicides fb manual weeding, controlled 57–84% of total weed population, whereas post-emergence herbicides fb manual weeding reduced 75–96% of the total weed density. Ethoxysulfuron fb manual weeding treated plots reduced 84–95% grass, 76–88% sedges and 76–84% broad-leaf weeds, whereas quizalofop-ethyl fb manual weeding recorded 85–88% reduction of grass, 51–81% of sedges and 66–74% of broad-leaf weeds population. The critical weed-crop competition period of tossa jute was observed between 21 and 45 DAS (Sarkar and Bhattacharya, 2005). During this period, tossa jute competed more for its vertical development (Bhattacharya, 2012). Jute crop was mostly infested by grasses than sedge and broad-leaved weeds (Kumar *et al.,* 2017) and causes 60–70% reduction in fibre yield (Ghorai, 2008). Weed management in jute holds prime share of total production cost (Sinha *et al.,* 2009). Many pre- and post-emergence herbicides have been tested on jute for controlling the weed flora (Jena *et al.,* 2017). Due to unavailability of suitable herbicides farmers were adopted costly hand-weeding method for controlling the weeds (Rao, 2000). Higher weed-control efficiency and fibre yield could be achieved by application of hand-weeding twice in jute, but it was not cost effective (Kumar *et al.,* 2017).

Weed biomass

In both the years of experiments, weed biomass significantly affected by the weed-control treatments. The highest weed biomass were recorded in unweeded plots followed (fb) by pretilachlor (lower dose) fb manual weeding treatment. The lowest weed biomass was recorded in quizalofop-ethyl + ethoxysulfuron fb manual weeding treated plots which were followed by treatment with manual weeding only (Table 2). Pretilachlor applied in lower dose fb manual weeding reduced 44–53% weed biomass and with higher dose fb manual weeding, it reduced 53–66% of the total weed biomass. Plots treated with butachlor fb manual weeding reduced the biomass of grassy weeds by 58–61%, sedge biomass by 51–56% and broad-leaf weed biomass by 20–67%. Post-emergence herbicides fb manual weeding-treated plots reduced 74–96% biomass of grass, 63–91% of sedge and 75–89% of broad-leaf weeds compared to pre-emergence herbicides fb manual weeding treated plots (52–67%, 50–59% and 18–72% reduction in biomass of grass, sedge and broad-leaf weeds, respectively). The results revealed that, Pretilachlor controlled the grasses in initial stages of growth, but post-emergence herbicides (quizalofop-ethyl and ethoxysulfuron) outperformed the result of pre-emergence herbicides. These results are in agreement with the study in which quizalofop-ethyl fb hand-weeding recorded 23–53% lowest biomass than pretilachlor fb hand-weeding during the critical crop-weed competition period (Singh *et al.,* 2015). In another experiment, quizalofop-ethyl fb hand-weeding showed better control on weeds than pre-emergence herbicide treatments (Jena *et al.,* 2017). Ethoxysulfuron was reported as a broad-spectrum herbicide, which controls grass, sedge and broad-leaf weeds effectively in jute (Kumar *et al.,* 2015a).

Growth and yield attributes

Plant height and basal diameter are 2 vital traits which determine jute-fibre yield. The highest plant height recorded in the weed-free treatment, followed by plots treated with quizalofop-ethyl + ethoxysulfuron fb manual

Table 1. Impact of weed-control treatments on grass, sedge, broad-leaf weeds and total weed density in jute (pooled data of 2018 and 2019)

Treatment	Weed density (number/m^2)							
	30 DAS				45 DAS			
	Grass	Sedge	Broad-leaf	Total	Grass	Sedge	Broad-leaf	Total
Pret (L) fb MW	19.4	9.9	4.4	33.7	15.6	10.4	6.5	32.6
Pret (H) fb MW	11.3	7.6	4.3	23.2	12.0	9.0	4.5	25.5
Buta fb MW	12.8	10.7	7.3	30.7	20.2	11.4	8.4	40.0
Quiza + MW	7.4	8.9	3.4	19.8	12.2	6.3	4.2	22.8
Ethox fb MW	7.6	4.4	2.4	14.4	5.3	4.0	2.6	11.8
Quiza + ethox fb HW	4.0	2.6	0.8	7.3	2.0	2.0	1.2	5.2
MW	6.0	5.4	2.6	14.0	4.9	4.6	2.0	11.6
Non-treated (weedy)	49.6	18.5	10.0	78.1	104.1	33.5	16.2	153.8
Weed-free	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEm±	2.1	1.7	0.9	2.9	3.0	2.5	1.5	4.5
CD (P=0.05)	6.2	5.2	2.9	8.6	9.1	7.4	4.6	13.1

Pret (L), pretilachlor with lower dose; Pret (H), pretilachlor with higher dose fb, followed by; MW, manual weeding; Buta, butachlor; Q-ethyl, quizalofop-ethyl; ethox, ethoxysulfuron weeding (234.7 cm). Herbicide treatments recorded 24–33% higher plant height than the weedy check-plot, whereas in plots treated with manual weeding twice height the increment was 30% (Table 3). Higher basal diameter (11.04 mm) observed in quizalofop-ethyl + ethoxysulfuron fb manual weeding treated plots. The lowest plant height and basal diameter were recorded in non-treated plots. Plots received weed-management treatments resulted in better crop growth and plant height, whereas the weedy check plots recorded shortest plant height due to severe crop-weed competition. Therefore, weed density and crop growth have a negative correlation (Mandal and Mukherjee, 2018) and suitable weed-management techniques can improve crop growth (Sarkar, 2006).

Jute-fibre yield

During the study, weed-control treatments had significant effect (*P*< 0.05) on jute-fibre yield. The highest fibre yield (3.67 t/ha) was achieved in the complete weed-free plots (Table 3). Jute fibre was influenced by all the weed-control treatments and resulted in 65–195% higher yield than the weedy plots. Pre-emergence herbicides fb manual weeding recorded 65–93% higher yield than the unweeded plots, whereas post-emergence herbicides fb manual weeding showed 120–195% increase in fibre yield. Plots treated with manual weeding recorded 46–70% higher fibre yield than plots received pre-emergence herbicides fb manual weeding treatments. Post-emergence herbicide-treated plots resulted in higher fibre yield compared to plots treated with pre-emergence herbicides (Singh *et al.,* 2015).

Table 2. Impact of weed control treatments on grass, sedge, broad-leaf weeds and total biomass of weed in jute (pooled data of 2018 and 2019)

Treatment	Weed biomass (g/m^2) 30 DAS				45 DAS			
	Grass	Sedge	Broad-leaf	Total	Grass	Sedge	Broad-leaf	Total
Pret (L) fb MW	4.69	2.24	2.13	9.05	6.05	3.74	4.59	14.37
Pret (H) fb MW	3.28	2.00	1.30	6.57	4.95	3.09	4.19	12.23
Buta fb MW	3.85	2.08	1.53	7.45	5.36	3.67	4.48	13.50
Quiza + MW	2.54	1.71	1.07	5.32	3.07	1.75	1.36	6.18
Ethox fb MW	2.29	1.58	0.97	4.83	1.58	1.38	1.16	4.11
Quiza + ethox fb HW	0.68	1.01	0.52	2.20	0.44	0.67	0.58	1.69
MW	2.03	1.24	0.64	3.91	0.79	1.22	0.79	2.79
Non-treated (weedy)	9.98	4.73	4.65	19.35	12.82	7.61	5.60	26.02
Weed-free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	0.92	0.36	0.23	1.15	0.99	0.37	0.22	1.30
CD (P=0.05)	2.71	1.07	0.67	3.42	2.96	1.10	0.66	3.85

Abbreviations: Pret (L), Pretilachlor with lower dose; Pret (H), pretilachlor with higher dose fb, followed by; MW, manual weeding; Buta, butachlor; Q-ethyl, quizalofop-ethyl; ethox, ethoxysulfuron

Table 3. Impact of weed-control treatments on plant height, basal diameter, fibre yield, net returns, benefit: cost ratio and agronomic indices in jute (pooled data of 2018 and 2019)

Treatment	Plant height (cm)	Basal diameter (mm)	Fibre yield (t/ha)	Net returns (₹/ha)	Benefit: cost ratio	WMI	AMI	IWMI	WI (%)
Pret (L) fb MW	222.2	9.87	1.94	22,669	1.44	1.50	0.50	1.00	0.48
Pret (H) fb MW	220.1	9.98	2.26	36,535	1.73	1.72	0.72	1.22	0.39
Buta fb MW	226.5	9.57	2.15	30,628	1.59	1.72	0.72	1.22	0.42
Q-ethyl fb MW	227.6	10.23	2.58	52,941	2.15	1.57	0.57	1.07	0.30
Ethox fb MW	228.7	10.45	2.78	64,047	2.51	1.66	0.66	1.16	0.24
Q-ethyl + ethox fb MW	234.7	11.04	3.46	91,724	3.26	2.12	1.12	1.62	0.06
MW	229.3	10.66	3.31	41,921	1.49	2.07	1.07	1.57	0.10
Non-treated (weedy)	176.4	6.50	1.17	13,311	1.41	0.00	0.00	0.00	0.68
Weed-free	239.3	10.90	3.67	41,367	1.42	2.15	–	–	0.00
SEm±	11.19	0.76	0.16	–	–	–	–	–	–
CD (P=0.05)	33.53	2.27	0.47	–	–	–	–	–	–

Pret (L), Pretilachlor with lower dose; Pret (H), pretilachlor with higher dose fb, followed by; MW, manual weeding; Buta, butachlor; Q-ethyl, quizalofop-ethyl; ethox, ethoxysulfuron; B: C ratio, benefit: cost ratio; WMI, weed-management index; AMI, agronomic management index; IWMI, integrated weed-management index; WI, weed index.

This might be owing to better control of weeds (Jena *et al.,* 2017), which ultimately increased the plant height and basal diameter of the plants (Kumar *et al.,* 2012; Singh *et al.,* 2007). Application of post-emergence herbicides fb hand-weeding resulted in higher return over 2 times hand-weeded plots (Alam *et al.,* 2010; Jena *et al.,* 2017).

Correlation and regression of jute-fibre yield with weed biomass

A negative correlation was recorded between jute fibre yield and weed biomass. Outcome of regression analysis showed that, for every 1 kg increase in weed biomass resulted 13.6 kg, 9.4 kg and 7.4 kg reduction in fibre yield at 30, 45 and 60 DAS (Fig. 1). Previous studies revealed that, 1 kg increase in weed biomass resulted in 0.95–1.2 kg reduction in fibre yield (Jena *et al.,* 2017). These results corroborate the findings of Kumar *et al.* (2015b).

Agronomic indices in jute

Plots treated with quizalofop-ethyl + ethoxysulfuron fb manual weeding in both study years recorded higher weed-management index (WMI), agronomic management index (AMI), integrated weed management index (IWMI), and lower value of weed index (WI) (Table 3). The lowest value of WMI, AMI, IWMI and highest value of WI were recorded in the unweeded plots. High values of agronomic indices (WMI, AMI, IWMI) with higher weed-control efficiency should be considered for a better treatment. However, a lower value of weed index desirable for an ideal treatment (Awan *et al.,* 2015). Previous study revealed that post-emergence herbicide application fb hand-weeding recorded lower weed index value compared to pre-emergence herbicide-treated plots (Mandal and Mukherjee, 2018). Use of pre-and post-emergence herbicides reduced the production cost and increased economic return and benefit: cost ratio (Chakraborty *et al.,* 2020).

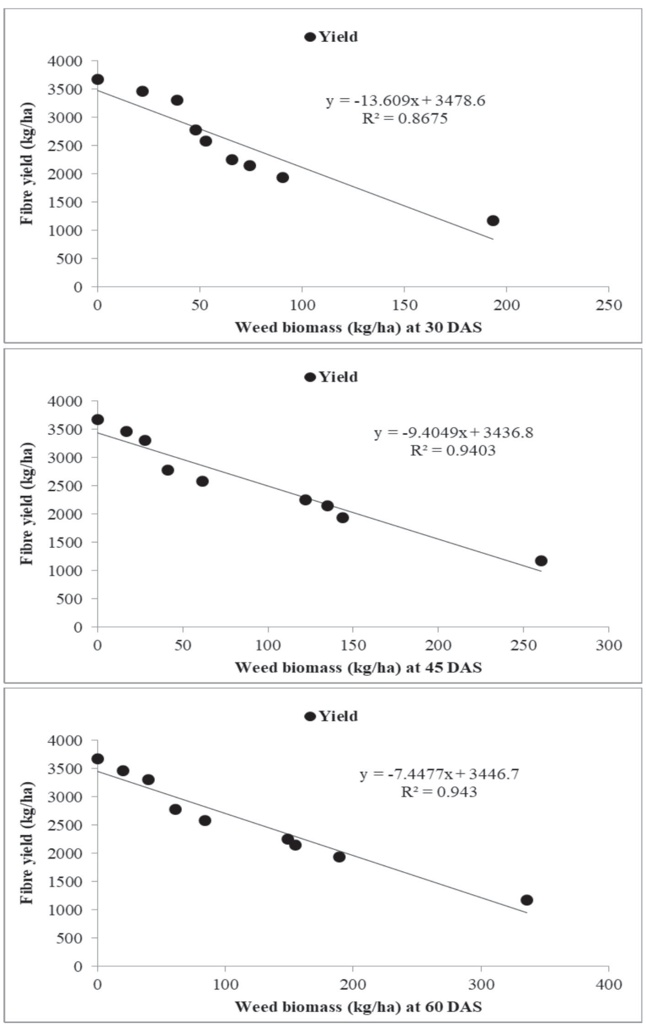

Fig. 1. Regression analysis of weed biomass and fibre yield of tossa jute (pooled data of 2018 and 2019)

Economics

Highest net returns/ha (91,724) and B: C ratio (3.26) were recorded in quizalofop-ethyl + ethoxysulfuron fb manually weeded plots, followed by ethoxysulfuron fb manual weeding (64,047 and B: C ratio 2.51). Among the herbicides treatments, pretilachlor (lower dose) fb manual weeding was recorded the lowest returns and B: C ratio. The highest cost of cultivation was found in weed-free treatment due to involvement of more numbers of labours (Table 3). Non-treated weedy plots showed the lowest net returns and B: C ratio. Highest net returns (134,284) and B: C ratio (1.67) were recorded with post-emergence herbicide and 1 hand-weeding (Mandal and Mukherjee, 2018) (Jena *et al.* 2017) reported that in jute, application of pre- and post-emergence herbicides + 1 hand-weeding gave higher return over the control.

Thus, ethoxysulfuron can effectively control all categories of weeds when applied alone or in combination with quizalofop-ethyl as post-emergence. Application of pre-emergence herbicides was found less effective in reduction of weed density. Higher fibre yield achieved in weed-free plots, followed by plots treated with quizalofop-ethyl + ethoxysulfuron fb MW, and the plots received manual weeding twice. Therefore, it can be concluded that post-emergence application of quizalofop-ethyl + ethoxysulfuron fb MW is the best option in controlling weeds in tossa jute. Farmers can apply pretilachlor as pre-emergence fb quizalofop-ethyl + ethoxysulfuron as post-emergence, depending on the density of grassy weeds in the initial growth stage of jute.

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