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भा.कृ.अनु.प.- केन्द्रीय पटसन एवं समवर्गीय रेशा अनुसंधान संस्थान

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FOREWORD

The global importance of jute as a potential substitute for synthetics, particularly under increasingly polluted environment and eco-friendly awareness among the masses needs no emphasis. On the way of successful and economic jute production system, weeds are the main obstacle that not only reduce yield and quality but also adds cost of production by about 50% more, and thereby reduce profitability from the jute farming. Search for an updated referred documentation on the weed management methods and technologies for jute crop was overdue to cater the growing needs of the farmers, research workers, entrepreneurs, the jute industry started growing & planning to grow jute of their own and similar other stakeholders in the wake of rapid diversification and global demand of jute products. India, being a global leader both in acreage and in production of jute fibres, the primary responsibility of this sub-continent (including Bangladesh) in enhancing the productivity of the crop consistent with quality cannot be overlooked. This document embodies precisely all the improved and proven weed management technologies generated so far to improve the productivity and fibre quality of jute with considerable saving in cost of production and reduction of drudgery of jute farmers from inhuman manual weeding under the scorching sun with excessive humidity of early jute growing season. I convey my heartfelt thanks to Drs. Sitangshu Sarkar, Bijan Majumdar, Ranjan Kumar Naik, Gouranga Kar, Sanjoy Saha, Sourav Ghosh and Debarati Datta, for this meticulously prepared technical bulletin, which will surely serve the very purpose of this document for all the concerned persons and organizations engaged and interested in raw jute production.

Place : Barrackpore

(Gouranga Kar)
Director, ICAR-CRIJAF

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1. Introduction

Jute (*Corchorus olitorius, Tossa* Jute and *Corchorus capsularis*, White Jute; Family: Malvaceae) is a stupendously important commercial fibre crop of West Bengal, Assam, Bihar, Jharkhand, Meghalaya, Odisha, and mesta (*Hibiscus cannabinus*, Kenaf and *Hibiscus sabdariffa*, Roselle; Family: Malvaceae) is very important for Andhra Pradesh. In industrial parlance jute and mesta together is called 'raw jute'. In India about 0.8 million ha is covered annually by this crop with an annual average production of 1.5 million tonnes of fibre. Jute farming involves four million farm families and generates employment to the tune of 10 million paid man-days. Jute fibre productivity has increased from mere 1138 kg/ha in 1947-48 to around 2600 kg/ha in 2021-22, indicating a rise of 228%. However, the difference between the realisable potential yield and farmers' yield has remained as much as 14 q/ha. The yield gap can be narrowed down through adoption of improved package of practices (Siddiq, 1999) which include sound weed management for jute and mesta. From the time immemorial, weed control has been one of the major concerns in successful crop husbandry. In the modern agriculture, development of efficient and effective weed management measure has assumed a greater role in not only achieving higher crop yield and greater returns but also keeping global environment clean and healthy.

2. Jute associated weeds and their ecology

Jute is prone to heavy weed infestation during the early stages of its growth. The weed flora associated with jute includes all three categories of weeds, viz. grasses, sedges and broadleaved. Grasses and sedges are the main competing weed flora, however, day by day in number of cases broadleaved weeds are also becoming serious problem of jute.

To have a comprehensive list of jute weeds, Kundu (1980) did a massive survey of weed flora over five jute growing states of India namely West Bengal, Assam, Odisha, Bihar and Uttar Pradesh. It was found that there were 190 different species of weeds, which belong to 37 families. The important families were Poaceae *(Cynodon dactylon, Echinochloa colona, Eleusine indica, Paspalum scrobiculatum, Brachiaria reptans, Imperata cylindrica)*, Cyperaceae *(Cyperus rotundus, Kyllinga monocephalla, Fimbristylis diphyla)*, Compositae *(Eclipta alba)*, Leguminosae *(Cassia tora)*, Amaranthaceae *(Amaranthus viridis, Amaranthus spinosus)*, Euphorbiaceae (*Croton sparsiflorus, Phyllanthus niruri)*, Labiateae *(Leucas linifolia)*, Solanaceae *(Solanum nigram)*, Capparaceae *(Cleome viscosa)*, Commelinaceae *(Commelina benghalensis)*, Chenopodiaceae *(Chenopodium album)*, Stercultaceae *(Melocia corchorifolia)* and Tiliaceae *(Corchorus acutangulus)*. From an extensive survey on *pre-kharif* weeds of West Bengal, Das *et al*., (1997), reported that the jute crop of West Bengal is mainly infested by weeds like *Cyperus rotundus, Cynodon dactylon, Cleome viscosa, Phyllanthus niruri, Corchorus acutangulus, Cassia tora, Melochia corchorifolia, Digitaria sanguinalis, Physalis minima, Euphorbia hirta, Croton sparciflorus, Scoparia dulcis, Eclipta alba* etc. The occurrence of weeds in jute fields from the time of land preparation to harvest of the crop for fibre or seed under various agroclimatic and edaphic conditions was also studied by Saraswat (1980).

Photo 1. Jute is prone to heavy weed infestation

Photo 2. Hand weeding is always costly

The predominant weeds were annual grasses namely *Axonipous compressus, Brachiaria ramose, Brachiaria reptans, Cynodon dactylon, Dactyloctenium aegyptium, Digitaria sanguinalis, Echinochloa colona, Eleusine indica, Eragrostis tenella, Eragrostis unioloides, Imperata cylindrica, Leptochloa chinensis, Panicum repens, Paspalum commersoni, Paspalum scrobiculatum, Setaria glauca and Sporobolus diander and sedges were Cyperus alulatus, Cyperus rotundus, Cuperus iria, Fimristylis aestivalis, Fimbristylis dichotoma and Eclipta alba, Euphorbia hirta, Launea sarmentosa, Portulaca oleracea, Phyllanthus niruri, Tridax procumbens* were in broadleaved group. Kundu (1980) reported that broad-leaved weeds pose minimum problem in jute as compared to grasses and sedges. The weed seeds germinate along with the jute, compete with the crop and mature before the crop is harvested. The graminaceous and cyperaceous weeds exhibit the greatest frequency, dry matter accumulation and production of seeds by individual plants, although great variation exists between different weed species and within the same species. Studies on the habitat of weeds in jute, showed a wide variation not only in the habitat but also in the life span of different weed species. It was also reported that *Cyperus rotundus* was prevalent in all jute-growing areas, present abundantly in light-textured upland soils, but rare in heavy low land soils (Saraswat and Mukherjee, 1983). From a multilocation trial Saraswat (1973a, b) reported that *Eleusine indica, Dactyloctenium aegyptiacum, Echinochloa colonum* and *Cyperus rotundus* were dominant weeds in almost all places except the lowlands of the JARI (at present ICAR-CRIJAF) farm, Barrackpore. He further reported that 126 weed species infested in jute; the most dominant were annual grasses and sedges, which outnumbered the broadleaved weeds. Among the weeds associated with *Corchorus capsularis* (cv. JRC 212) and *C. olitorius* (cv. JRO 632), *Borreria articularis* and *Cyperus compressus* were the most dominant weeds in *Corchorus olitorius* on highlands and *C. compressus* and *Fimbristylis diphylla* in *C. capsularis* on medium highlands of Tripura state (Datta and Chakraborti, 1983; Chakraborti, 1983; Chakraborti, 1985). Experiments at CRIJAF, Barrackpore also noticed that the extent of grass weed population in jute field may reach 90 % in general (Ghorai *et al*., 2004) or even up to 98% at 3 weeks after sowing (Sarkar *et al*., 2005). In another study (Kumar *et al*., 2013) at Barrackpore, West Bengal it was reported that the category-wise associated weeds in jute are as follows (Table 1):

Table 1. Category-wise associated weeds in jute

Grass weeds	Broadleaved weeds	Sedge weeds
Brachiaria reptance (L.) Gard & C.E. Hubb. (Running grass)	*Ageratum conyzoides* L. (Goat weeds)	*Cyperus rotundus* L. (Purple nutsedge)
Cynodoc dactylon (L.) Pers. (Bermuda grass)	*Amaranthus viridis* L. (Pig weed)	*Cyperus difformis* L. (Common sedge)
Dactyloctenium aegyptium (L.) Willd. (Cow foot grass)	*Cleome viscosa* L. (Cleome)	*Cyperus compressus* L. (Annual sedge)
Digitaria sanguinalis (L.) Scop. (Large crabgrass)	*Digera arvens Forsk*. (Digera)	*Fimbristylis miliacea* (L.) Vahl. (Globe fingerush)
Echionochloa colonum (L.) Link. (Jungle rice)	*Euphorbia hirta* L. (Leafy spurge)	
Echionochloa crusgalli (L.) P. Beauv (Barnyard grass)	*Malacra Capitate* L. (Brazil jute)	
Eleusine indica Gaertn. (Crow foot grass)	*Phyllanthus niruri* L. (Phyllanthus)	
Leptochloa chinensis Retz. (Red sprangle top)	*Physalis minima* L. (Wild goose berry)	
Setaria glauca (L.) Beauv. (Giant green foxtail)	*Portulaca oleracea* L. (Purslane)	
S*etaria verticillata* (L.) P. Beauv. (Bristly foxtail)	*Trianthema portulacastrum* L. (Horse purslane)	

The growth behaviour of grass weeds in jute varied over time in a sigmoidal curve and the maximum dry biomass of grass weed was observed at 112 days in *capsularis* jute (187 g/m2) cv. JRC-698 and at 87 days in case of *olitorius* jute (114 g/m2) cv. JRO-8432 (Sarkar and Bhattacharya, 2005b). Jute being a C3 plant (Palit and Bhattacharyya, 1984) cannot compete with C4 weeds of jute field during the initial critical growth phase. Many of the persistent weeds of jute are C4 plants. Some common C4 weeds are *Cyperus, Cynodon, Echinochloa, Elusine, Sorghum, Imperata, Chenopodium, Digitaria, Convolvulace, Amarenthus* etc. (Elmore and Paul, 1983).

Photo 3.
Trianthema portulacastrum

Photo 4.
Euphorbia microphyla

Photo 5.
Portulaca oleracea

3. Crop-weed competition in jute

Crop-weed competition is a natural powerful force in eliminating the weaker plants in the association for which the economic plants should be saved from the clutch of the harmful weeds at the critical period. Datta and Chakraborti (1983) reported that weed infestation, as evidenced by population data and nutrient uptake, caused enormous competition to the jute crop. Gogoi and Kalita (1992), reported that critical period of crop-weed competition in *capsularis* jute ranges between 15 and 60 days after sowing.

Sarkar (2003a) reported that the fibre yield of jute (Y) was inversely correlated with the dry weight of weeds (X). The relation for *olitorius* jute (cv. JRO 66) was Y= 3.47-0.016 X (r = -0.66) and for *capsularis* jute (JRC-698) it was, Y = 2.53 –0.012 X (r= -0.61).

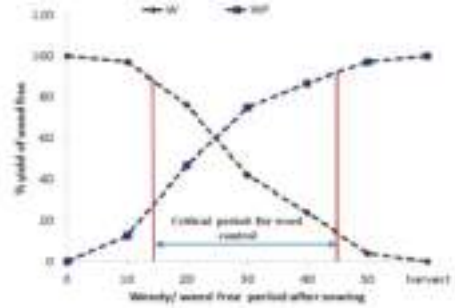

Fig 1. Critical period of crop-weed competition in jute

In a study in jute, 10-45 days after seedling emergence has been found critical period and therefore post-emergence intercultural or herbicides application should not be delayed beyond this period (Fig. 1). Weed emergence after 45 days of jute sowing did not reduce the yield. Hence, season long intercultural operations or herbicides application is not required. Presence of weeds in jute caused 40-70% of yield loss if not controlled properly (Kumar *et al*., 2013).

4. Losses caused by weeds in jute

If the weeds are not kept under control during the critical period, total crop failure in jute is not uncommon. Sahoo and Saraswat (1988), from an exhaustive study reported that 75.5% of fibre yield may be lost in jute due to presence of weeds in un-weeded plots as compared to the yield obtained from weed free condition. They also estimated the loss of fibre yield (due to weeds) in production terms amounting to 700.9 thousand tonnes of jute fibre annually in India due to weeds only, which is a huge loss to the national exchequer.

Losses due to the presence of weeds in jute field was also studied by Datta and Chakraborti (1983), where they reported that yield loss due to weed was 63.15% in *olitorius* (JRO 632) and 51.92% in *capsularis* (JRC 212) jute. Mishra (1997) reported that 50-80% fibre yield loss has occurred in jute due to the presence of weeds during the critical period of 30-46 days after sowing. In normal cultivation condition, weedy situation or inadequate weeding in *capsularis* jute can reduce yield by 55.16% and in *olitorius* jute the yield reduction varies from 59.70 to 70.75% (Ghorai, *et al*., 2003; Sarkar and Bhattacharya, 2005a; Sarkar *et al*., 2005). It was estimated that the manual energy required for weeding in jute (543 MJ /ha) is 4.5 times greater than the energy requirement for land preparation (Borkar *et al*., 1999). As reported by Saraswat (1980), about 35% of the total cost of cultivation of jute goes to weeding alone if done manually.

Biswas and Das (1987) quantified the yield reduction due to competition from weeds in jute. The regression equation between the weed dry weight (X) at 30 DAS and the fibre yield (Y) was, Y= 3038.77 – 8.52 X, which showed that at 30 DAS rise of every kilogram of weed dry weight reduced the fibre yield by 85 kg/ha. The same equation at 45 DAS was, Y= 2563.29 – 0.057 X, proving thereby the yield reduction was only 0.57 kg/ha due to increase of every kilogram of weed biomass.

Sarkar and Majumdar (2013) reported that weeds in jute field at 45 DAS removed 16.59 kg N, 3.67 kg P2O5 and 33.88 kg K2O/ha. Nutrient contents were much higher in sedge weeds (1.01% N, 0.34% P2O5 and 2.63% K2O) than the grasses (0.81% N, 0.09% P2O5 and 1.22% K2O). From another study it was found that weeds in jute harness about 30-50 kg N, 10-25 kg P and 50-60 kg K/ha from soil depending upon nature and intensity of weeds, duration of weeds infestation and environmental conditions (Kumar *et al*. 2013). Therefore, it is well established that weeds remove huge amount of plant nutrients from soil and thereby jute suffers from reduced availability of essential plant nutrients.

5. Resources involved in the weeding of jute

The maximum share in the operation wise cost to the tune of 37% was on weeding and thinning in jute as per an estimate of Das and Hazra (2002). It was reported by Saraswat (1974) that for weeding in a hectare of jute field, about 120 manual labourers are required. He further reported that about 35% of the total cost of cultivation of jute goes to weeding alone if done manually (Saraswat, 1980). The manual weeding in jute is not only tedious and time consuming but also very costly affair as the wages for manual labourers are increasing sharply with the advent of increasing demand of work force for infrastructure development all around and other city/town-based work-force need.

6. Methods of weed management

Number of investigators worked for years on different aspects of weed management in jute comprising of chemical, cultural, mechanical and other methods solely or in combination to find out a suitable and technologically sound method of weed management as this particular problem considerably increases the cost of production and thereby reduces the profitability in jute cultivation. It is of great concern that till date no single method or few numbers of methods could prove successful in this crop, which might be attributed to the inherent weaknesses of jute besides the typical edapho-climatic factors of jute growing environment favouring excessive weed growth.

The concept of weed management instead of control is very important in jute. Because weeds are a major but temporal problem which intensifies the inter-specific competition between jute plant and weeds during the early growth phase up to 45 days. Weed control aims at putting down the weeds already present in jute field, where as weed management is a system approach where planning is done in advance to minimise the invasion of aggressive weeds and give jute plant a strong competitive advantage over the undesirable fauna in the system.

6.1. Crop husbandry / cultural methods

Proper crop husbandry practices essentially play an important role in prevention and management of weeds in jute field.

6.1.1. Use of farmyard manure (FYM) from non-contaminated (by weed seeds) pits

For ages, jute cultivation seldom received proper management from the resource poor small and marginal farmers as they were growing the crop traditionally like their ancestors. However, with the increasing demand of natural fibres, jute is also gaining footing steadily in the arena and progressive farmers are paying more attention to this crop by providing critical inputs like recommended dose of manures & fertilizers and 1-2 or even more life-saving irrigations also. Use of weed seed contaminated FYM will aggravate the annual weed problem in jute cultivation because of the presence of viable weed seeds in the dung of farm animals, as well as direct addition of weed seeds (such as *Amaranthus viridis* and A. *spinosus*) to the compost pits as farm waste. So, proper care has to be given to select the source of FYM to be used for application in the jute fields.

6.1.2. Use of weed free jute seeds

Jute seeds are minute in size (1000 seed weight is 2 g) and there is always a chance of weed seed admixture in the seed lot. Sowing of jute seeds having weed seed as admixture will obviously intensify the existing weed problem in jute farming. As per Indian Minimum Seed Certification Standards (1988) the maximum permissible limit for weed seed contamination in jute seed is only 10 and 20 weed seeds per kg for foundation and certified jute seed respectively (Tunwar and Singh, 1988).

6.1.3. Sowing time

Final land preparation and sowing of jute with minimum time lapse has to be practised as this husbandry method gives upper hand to the jute plant. Being a predominantly rainfed crop, jute is sown by exerting the soil moisture obtained from the pre-monsoon showers received during late March or early April. By the time major weeds germinate with the break of monsoon, the jute seedlings are well up and can easily compete with the germinating weeds. If sowing of jute is delayed by even 2-3 weeks it has to cope with the vigorous flush of weeds which appear with the onset of monsoon.

6.1.4. Sowing method

It is always advisable to sow jute seeds in line as it facilitates mechanical weeding and better management of the crop for faster growth resulting competitive advantages over the associated weeds. However, recent field studies showed that in some very specific cases specialized broadcasting might be appropriate for easier management of weeds. Mechanical weeder (CRIJAF nail weeder) is capable of creating rows in broadcast jute field resulting like line sown jute crop.

6.1.4.1. Stale seedbed method

In areas with severe weed problem during early crop growth stages, stale seedbed technique is useful for controlling weeds. This technique is most appropriate to reduce the weed seed bank in the soil. In this method, sowing of jute should withheld for at least 15 days after the final land preparation to allow germination of weed seeds and then emerging weeds are controlled either by shallow tillage with rotavator (cultivated stale seed bed technique) or by applying non-selective herbicide like paraquat or glyphosate (chemical stale seed bed technique) before final seeding of jute. It helps to reduce the early weed thrust remarkably by controlling the early emergent annual grasses and sedges. Jute crop can be sown immediately where 'cultivated stale seed bed technique' adopted while a gap of 3-7 days should be kept in areas where 'chemical stale seed bed adopted'. It was reported that stale seedbed with glyphosate 1.75 kg/ha + pretilachlor 1.0 kg/ha may be practiced for effective weeds control specially *Cyperus rotundus*, higher productivity and income in jute cultivation (Kumar *et al*., 2018).

6.1.4.2. Sowing of jute seed mixed with sand in low density sowing method

Jute seed (@ 1.9-2.6 kg/ha) is mixed with sand or soil in the ratio of 1:3-4 (seed: sand) and scattered/ broadcasted on the field, as even as possible, followed by planking. The jute seed-sand mixture should be broadcasted in levelled jute field in double crisscross (East to West followed by North to South) way for uniform seed distribution and desirable plant stand. This should follow one post sowing irrigation and spraying of pre-emergence herbicide, namely pretilachlor 50EC @ 0.9 l/ ha at 48 hours of sowing with irrigation. This method of jute sowing proved to be very effective in managing weeds, reduced cost of manual weeding and production of comparable better fibre yield (Ghorai *et al*., 2020).

6.1.5. Crop stand

Proper spacing and uniform germination of jute seeds leads to optimum plant population (4.5-5.0 lakh/ha for fibre crop and 2.2-2.5 lakh/ha for seed crop) with optimum leaf area index permitting less light penetration up to the ground and thereby restricting weed growth. It was observed that the dry weights of weeds (DW) were directly correlated with the light transmission ratio (LTR) in jute (Sarkar, 2003b). At 60 days after sowing (DAS) the relation was, DW60 = 158.64 x LTR – 2.59 (r = 0.829). Similarly, the other relation was, DW90 = 814.89 x LTR + 5.92 (r = 0.934) for 90 DAS. The straight-line relation with high positive correlation values (0.83 to 0.93) between the weed growth and the LTR advocates that there should be both agronomic and breeding approach to optimize the LTR in jute resulting less competition from weeds.

Recent studies done at ICAR-CRIJAF and in number of farmers' fields at North 24 Parganas, Mushidabad and Paschim Medinipur districts showed that low-density jute planting (3-4 lakhs jute plants/ha i.e., 30-40 plants/m2) reduced man-days cost in weeding & thinning by about 63% as compared to traditionally followed high density (7-10 lakh/ha) planting by the farmers, which requires about 120 man-days for the same operations (Ghorai *et al*., 2020). Moreover, in fibre extraction also, the man-days reduction is about 25% as compared to the man-days required in conventional system (75 man-days,Table 2).

Table 2. Low density jute population (3-4 lakh/ha) versus high density population (7-10 lakh/ha) with respect to reduction in man-days in different operations.

Operations in jute	High density sowing (man-days/ha)	Low density sowing (man-days/ha)	Reduction of man-days/ha in low density sowing	% Reduction
1st weeding and thinning	75	30	45	60%
2nd weeding and thinning	45	15	30	67%
Sorting of plants after harvest	14	00	14	100%
Fibre extraction	100	75	25	25%
Total	234	135	114	-

Source: Ghorai *et al.*, 2020

6.1.6. Application of fertilizer

Timely application of recommended dose of fertilizers improves growth of jute plants. Nitrogenous fertilizers in split doses are better to increase N use efficiency as well as reducing weed growth. For both the species of jute, nitrogenous fertilizers should not be applied as basal dose. The N fertilizers are to be applied in 2 split doses, 50% N after 1st weeding and the rest 50% N after 2nd weeding. As per the native fertility status of the soil, the rate of N (and other) fertilizer application will vary. For medium fertile soil, the recommended N fertilizer dose is 60 kg/ha (130 kg urea), which means per hectare 65 kg urea is to be applied after 1 st weeding and another 65 kg urea is to be given after 2nd weeding when the soil is having recommended level of soil moisture, otherwise, farmer need to apply irrigation. In coarse soil, this 60 kg nitrogen should be given in 3 splits (20 kg N as basal, 20 kg after 2nd weeding or 21 DAS and 20 kg at 35-42 DAS). For low fertile soil, the recommended N dose for jute is 80 kg/ha (or 174 kg urea). Other than urea, any N containing commercial fertilizers can also be applied as per recommended dose of N in jute cultivation. It is now well established that application of N fertilizer as basal dose will aggravate the weed problem where soil moisture is not a limiting factor. Whereas, the full recommended dose of phosphatic and potassic fertilizers are to be applied at the time of final land preparation, i.e., as basal application (Sarkar, 2021).

6.1.7. Crop rotation

Some weeds are typically associated with specific rotational crops and are much less serious in other crops. These weeds increase rapidly in proportion if the same crop rotation is followed but can be suppressed by changing a rotational crop in the system. Field trials conducted for 6 years (1975-81) in fixed plots revealed that repeated applications of tetrapion- butachlor-nitrofen/ alachlor/ atrazine in jute-rice-wheat/ potato/ maize, respectively induced a shift in the

composition of the weed flora in jute from annuals to perennials (such as *Cyperus rotundus*). However, the interaction of the jute-rice-potato rotation and the direct effect of flupropanate in the jute crop-weed community caused a shift in the population balance in favour of jute. The maximum weed density was observed in jute rotated with wheat or maize. There was a little increase in the numbers of broadleaved weeds in jute when potato was included in the rotation (Biswas and Das, 1993). In a recent minimum-tillage study, it was observed that in cropping system such as jute-rice-lentil, jute-rice-mustard and jute-rice-wheat did not differ the weed density in jute (Saha *et al*., 2018).

6.1.8. Smother crop / mixed cropping

6.1.8.1. Smother crops

Smother crops grow quickly, form large canopy and are able to photosynthate efficiently in relatively shorter time. These crops can suppress the weeds by excluding light beneath. The weed suppression effect of red amaranth (seed rate of 10-30 kg/ha) was up to 54% with respect to manual weeding twice at 21 DAE (Ghorai *et al*., 2004). Mixed cropping system (red amaranth, summer radish and white amaranth) produced 35-37 quintal raw jute fibre along with 19-29 quintal red amaranth (21 DAE), 7.5-9.0 q white amaranth and 7.5-9.0 q summer radish (at 30-40 DAE), respectively. This system fetched a net return of ₹ 18,472 to ₹ 20,949 over only ₹ 16,147 under conventional manual weeding twice (Ghorai, 2008). Red amaranth (seed rate @ 50 kg/ha) suppressed the weed growth in jute field by 54% and produced a maximum of 64 q red amaranth (leafy vegetables)/ha at 21 DAE. This intercrop should be sown in early jute crop to fetch higher price in the market. If the soil is medium to low fertile, and if any N nutrient deficiency is observed in the crop, then the jute crop should be supplemented with additional quantity of nitrogen over the recommended dose of N fertilizer for sole jute crop. The natural delay to actualize revenue from jute till post-harvest operation will thus be reduced since weeding and thinning will turn into harvesting of valuable companion crops between 21-35 DAE. These intercrops are rich in nutrients, minerals and vitamins and therefore, nutrition for the resource poor farmers is ascertained. Excess growth (if any) of red amaranth from jute field can meet the fodder requirement in dairy, piggery, poultry and fishery sectors (Ghorai *et al*., 2003).

Photo 6. Weed suppression by red amaranth (*cv. Jabakusum*) in jute (cv. JRO 524) at 21 DAE

Photo 7. Weed suppression by green gram (cv. TMB-37) in jute (cv. NJ 7005) at 21 DAE

6.1.8.2. Intercropping of jute with green gram (1:1) for weed smothering

Jute (cv. NJ 7010 or JRO 204, row to row spacing 35- 40 cm) and green gram (cv. TMB-37, Pant moong-5 and RMG-62) grown in intercropping (1:1 ratio in lines) system suppressed 56% *Cyperus rotundus*, and produced 6-8 quintal pulse (with 2 tones pulse threshing waste) and 36.5-37.6 q jute fibre/ha . The jute equivalent yield in the intercropping system varied from 47 to 53 q /ha. In this method, initially butachlor or pretilachlor @ 1 kg/ha was applied as pre-emergence herbicide and one manual weeding was required (Ghorai *et al*., 2016). In 2010, intercropping (1:1) of jute (cv. JRO 204) row to row spacing 30 cm, with green gram (cv. Pant moong-5 and RMG-62) suppressed *Cyperus rotundus* from 56-76%, yielded 5.3-9.2 q pulse grain and 36.5-37.5 q jute fibre per hectare (Ghorai *et al*., 2010). At 45 DAS, the sun light entry at the base of jute and moong canopy is reduced by more than 90% (Ghorai *et al*., 2018). In this system, green gram varieties namely IPM 205-7 (Virat), WBM 29 (Sukumar) performed well with jute and suppressed weeds to a greater extent.

6.2. Physical methods

Physical methods are the oldest method of weed control ever since man began growing crops. In jute weed management, practices such as tillage, hoeing, hand weeding, mulching and soil solarisation may be deployed under this method of weed management.

6.2.1. Tillage

Weed control by conventional tillage in jute is achieved primarily by the burial of annual weeds through the soil turning action of the plough during land preparation. In jute, no tillage and no tillage with crop residue could not suppress weed growth as compared to the weed population observed in conventional tillage (Saha *et al*., 2018). In comparison to grass and broadleaved weeds, sedges such as *Cyperus rotundus* is difficult to control in most of the crop situations and especially true for jute also. In semi-mechanical control of *Cyperus rotundus*, during final land preparation by rotavator following primary tillage with cultivator uprooted tubers of *Cyperus rotundus*. Ridge formation in ridge-furrow sowing using 9-tyne cultivator, helped the *Cyperus* tubers to remain embedded shallow in ridges. Hand pulling of these germinating and very tiny sized *Cyperus rotundus* at 8-10 DAS were very easy with respect to flatbed sowing (Ghorai *et al*., 2010).

6.2.2. Hoeing / mechanical weeders

Weed management in jute by hoeing plays an important role. Wheel hoeing in inter-rows control the weeds, and enhances soil aeration (particularly in comparatively heavy textured soils). However, soil aeration in jute field may not be improved in light soils by wheel hoeing. Intercultural operations in jute consist mainly of light harrowing traditionally by '*bida*' (a locally available hoeing tool made of iron and bamboo) or wheel hoe. Wheel hoeing requires additional manual weeding for better control of weed in jute field. Additional hoeing in hand weeded plots at 25 and 35 DAS revealed that secondary tillage (wheel hoeing) destroys germinating seedling of annual weeds even before its' emergence. Wheel hoeing once coupled with one hand weeding is better than wheel hoeing twice as the former method gave 80% weed control. In a field experiment at Shillongani (Assam), jute (cv. JRO 524) was hoed 2, 3 and 4 weeks after sowing (WAS); 3, 4 and 5 WAS or

2, 3, 4 and 5 WAS, or manually weeded once 3 WAS or twice 3 and 4 WAS. Manual weeding at 3 and 4 WAS resulted in the lowest number and dry weight of weeds and the highest fibre yield and net return, followed by manual weeding at 3 WAS (Guha, 1999). As reported by Rahman and Gaffer (1990) from Mymensingh, Bangladesh, raking twice (15 and 25 days after sowing) and hand weeding once (25 DAS) resulted in fibre yield of *capsularis* jute (cv. CC 45) comparable to those obtained by raking once and hand weeding twice reducing the labour requirement by 23 man-days for a ha. Prusty *et al*., (1988), reported from an experiment with JRC 212 that hoeing at 15 DAS and 2 weedings in the 3 and 5 weeks gave best *capsularis* jute fibre yield (25.4 q/ha).

From field studies done during the last 6-7 years, it was proved that, wheel hoe, CRIJAF nail weeder (Ghorai *et al*., 2010), single wheel jute weeder (Naik *et al*., 2018) and scrappers are suitable as better weed control tools in jute, mesta and sunnhemp. At field capacity of soil, CRIJAF Nail weeder is suitable to control germinating composite weeds flora (at 2 leaf stage of weeds) i.e., at early stage of crop (4-8 DAE) both in line-sown and broadcast crop and reduces the loss of soil moisture by creating soil mulch through its operation (Ghorai and Kundu, 2016) and yielded jute fibre upto 40 q/ha with higer B:C ratio. In jute, mesta and sunnhemp simultaneous weed control, thinning, line development and soil moisture conservation is possible using CRIJAF nail weeder. It will reduce the manpower requirement by 65% over manual weeding twice. Modified nail weeder by dismantling the middle nail (the 3rd nail from each side) could able to remove weeds even within the rows in early phase of jute plant (say 8-10 cm height). Provisions have been kept in the design of the tool to attach other available tines and scrappers with it. Use of scrapper at 15-21 DAE is recommended to control established tough weeds. This controls 85-90% of the total weed flora in these crops. It minimises soil cracks, maintains 4-15 % more soil moisture by soil mulching, improves oxygen diffusion rate [ODR 303 µg $O_2/m^2/s$ in mulched soil over only 140 µg $O_2/m^2/s$ in non-mulched soil (ODR meter, Eijkelkamp, The Netherlands, Ghorai *et al*, 2017; Chakraborty *et al*., 2021)], reduces soil temperature by 1-5°C and improves fibre yield at least by 10-15%. However, often one hand weeding is required to control remaining weeds from within the rows. This mechanical method is cheaper than manual weeding twice at least by ₹15,000-20,000/ha depending on the weed situation in the jute field. These mechanical weeders namely CRIJAF nail weeder and single wheel jute weeder are useful to control composite weed flora in field crops, vegetable fields and other horticultural crops also while sown in between lines.

Photo 8. CRIJAF Nail Weeder

Photo 9. Modified CRIJAF nail assembly having 8 mm diameter nails with threads to fit with nail assembly bar by nuts and bolts

Photo 10. For weed control within rows (the middle nail dismantled)

Photo 11. Soil mulch in broadcast jute by CRIJAF nail weeder at 5 DAE (no soil crack and thus maintains more moisture)

Photo 12. No soil mulch in broadcast jute (showing huge soil cracks, a source of fast water loss in summer)

Photo 13. Soil mulching by CRIJAF Nail weeder (5 & 8 DAE) maintained 5-6% more moisture, kept the soil cooler (by 1-3°C) at 5-10 cm soil depth and helped the jute seedling to escape early drought stress (no rain till 30 days after sowing) [Source: ICAR-CRIJAF Annual Report, 2016-17]

Photo 14. *Trianthema* spp infestation in jute

Photo 15. *Trianthema* spp control at early stage by CRIJAF nail weeder

CRIJAF nail weeder: Structure, fittings and different uses

Photo 16. Single wheel jute weeder

Photo 17. Single wheel jute weeder in operation

6.2.3. Herbicide applicator

This is a tool to apply nonselective herbicides (total vegetation killer) generally in between crop rows and sometimes in broadcast jute (with specialized technique) to control composite weed flora. Like CIJAF Nail Weeder, simultaneous weed control, thinning, crop-row or line making is possible using CRIJAF herbicide applicator in jute, mesta, sunnhemp, lentil, coriander, wheat, and mustard etc. It was recorded that the herbicide applicator can control 85% of the total weed flora in those crops. One hand weeding is required to control the remaining survived weeds within the rows. The usual wind-drift hazard is completely eliminated in this herbicide applicator. Non-selective herbicides like glyphosate @ 1.6 kg SL to 2.46 kg SL/ha with or without paraquat dichloride @ 0.36 kg SL/ha at 15 DAE to 21 DAE controlled composite weed flora in between jute and mesta crop. Application of Glufosinate ammonium through it has also been found to be successful for weed control, thinning and line arrangement in broadcast jute at very early stage (5-8 DAS).

Photo 18. CRIJAF Herbicide Applicator

Photo 19. Composite weed control by CRIJAF Herbicide Applicator

This method produced about 36-38 q of jute fibre per hectare (Ghorai *et al*., 2016). This herbicide applicator method is cheaper than manual weeding twice by about ₹15,000-20,000/ha. It (with non-selective herbicides) is also suitable in controlling composite weed flora in other line-sown field and horticultural crops (Ghorai *et al*., 2010.).

6.2.4. Hand weeding by small tools

In conventional method of weed control, removal of weeds by hands using *khurpi* (a small hand tool having sharp iron head fixed to a wooden handle to hold by the operator) is very common among the jute farmers. This method is effective but at the same time it increases the cost of weeding and thereby reduces the profitability from jute farming. In the recommended practices for jute, sole hand weeding is not advised. However, in some specific situation one hand weeding is permitted along with herbicidal or mechanical or cultural method of weed management. Gogoi *et al*., 1992, reported that the highest weed control efficiency, better crop growth and the maximum fibre yield of jute was observed in Assam under hand weeding done at 21 and 42 days after sowing and this treatment was significantly superior to all other herbicidal treatments.

6.2.5. Mulching

Mulches stunt, inhibit, or kill the weeds by impeding sunlight from them. It reduces weed pressure, maintain better hydrothermal regime of soil, improves soil quality and increases crop productivity. Rice straw as mulch to control weed in jute field was tested in the recent past. For mulching in jute, the soil should be well drained and alluvial to coarse textured in nature. Rice straw

mulch @ 10-15 t/ha (i.e., 1.0-1.5 kg/m^2), reduced the weed dry matter by 68-82% as compared to manual weeding twice and yielded jute fibre of 39 q/ha. The second manual weeding became redundant/ minimized due to mulching in jute field. Mulched plots maintained better hydrothermal regime of soil, were relatively cooler (6-8ºC) and maintained more soil moisture (18 to 23.4%) than bare soil (12.6-18%) cultivation (Ghorai *et al*., 2008).

Photo 20. Smothering of weeds by rice straw mulch (10 t /ha) and mixed cropping of red amaranth and summer radish in jute at 21 DAE

This is highly remunerative over conventional method of manual weeding twice. This system fetched a net return of ₹32,848 to ₹34,360 over only ₹16,147 under conventional manual weeding twice. The total variable cost of this system was much less than manual weeding twice. It is important to mention that about 55-man days/ha were necessary to mulch jute field in between rows. The benefit cost ratio of this system varied between 2.19 and 2.32 over only 1.50 in case of manual weeding twice.

6.2.6. Soil solarization

Soil solarization promotes rise of soil temperature lethal to germinating weeds, microbes etc. Transparent or black polythene (200-400 gauge) is used to cover the moist top soil for 30 days, which kills all germinating annual grasses. Soil solarization by this method raised the soil temperature up to 48-54° C in 0-5 cm soil profile at 14:00 hrs as compared to 38-40° C under bare soil condition. Solarization for 30 days killed sprouted weed seedlings of *Echinochloa colona*, *Digitaria spp*, *Brachiaria spp, Phyllanthus niruri, Trainthema spp* and *Cyperus rotundus*. At 21 DAE, solarization by transparent polyethylene, recorded 46% lower weed population in jute field over unweeded check and yielded 44 q/ha jute fibre. Solarization by black polyethylene and mixed cropping with red amaranth reduced weed emergence by 61% over unweeded check (Ghorai, 2007). Total weed population at 21 DAE was reduced significantly by solarisation and smothering processes. In sequence, it reduced the sedge weed emergence in mustard field too. However, due to the high cost of polyethylene in the market, soil solarisation in jute is not economically viable at present in spite of its merit for weed management.

Photo 21. Weed suppression by soil solarization

Photo 22. Etiolation of weeds by soil solarization

6.3. Biological method

Biological weed control involves utilization of natural enemies for the control of certain weeds. The objectives of biological weed control are not eradication in true sense, rather, the reduction and regulation of weed population below the threshold limit of economic damage. In a recent survey it was found that the nutgrass weevil, *Athesapeuta cyperi* caused 47-85% dead hearts in *Cyperus rotundus* in the jute ecosystem. This study throws a hope of using this weevil as a potential biocontrol agent against the most notorious weed the nut grass, which has been gradually developing resistance against many of the commonly used herbicides (Ghorai and Ramasubramanian, 2010; Gotyal *et al*., 2020). However, so far little progress has been made in this direction of biological weed control in jute crop. Although, this method has ample scope for development of strategy for cultivation of organic jute, which is gaining footing rapidly due to its raising demand around the globe. Drenching of spore suspension (4.10 x 106 spores/ml) of *Fusarium oxysporum* in soil killed 98% of *Cyperus rotundus* including its nuts in pot culture. A linear relationship (r = 0.976) between percent death of C. *rotundus* and concentration of inoculation was recorded (Ghorai, *et al*., 2005).

6.4. Chemical methods

Use of herbicide as a technique in modern farming has resulted in increased productivity through prevention of losses caused by weeds and reducing the wastage of resources and energy. In the developed countries, herbicides are used in more than 80% of the cultivable area. Today on a global scale, the sale of herbicides exceeds the sale of other pesticides put together. However, in developing countries like India herbicide sale are just 10-15% of the total pesticides.

From the past findings on weed management in *capsularis* and *olitorius* jute, it was quite clear that chemical method alone could not able to manage weeds in jute field. Only adoption and integration of more than one type of methods were needed to combat the weed menace in both the species of jute.

6.4.1. Pre-emergence herbicides

Pre-plant and pre-emergence application of butachlor (50% EC or 5G) from 7 days before sowing to 72 hours within sowing of jute controlled annual grasses and broadleaved weeds for 3-4 weeks. The granular butachlor formulation has to be mixed thoroughly with soil under proper moist

condition. Pretilachlor 50% EC @ 0.90 kg ai/ha (45-48 hours after sowing of jute with irrigation) performed well in jute field and produced jute fibre yield upto 40 q/ha. When applied 45-48 hours after jute sowing, pretilachlor 50% EC has been found effective in controlling *Trainthema* spp in jute field and keeps the jute field free from weeds for about four weeks. These two herbicides effectively reduced *Cyperus difformis* species also in jute field. One manual weeding or wheel hoeing following this or after new flush of weed emergence is essential. In Assam, it was found that pendimethalin @ 0.75 kg/ha applied on soil at one day before sowing of jute + one hand weeding at 35 DAS provided good weed control in tossa jute (Das *et al*., 1994).

Photo 23. Pre-emergence weed control in jute using butachlor @ 1kg ai/ha

The highest fibre yield (40.1 q/ha) in *olitorius* jute was recorded with two hand weeding (at 21 and 35 DAS) treatment which was at par with the fibre yield (37 q/ha) obtained with fluchloralin + one hand weeding (at 35 DAS). In case of *capsularis* jute, the highest fibre yield of 29 q/ha resulted from two hand weeding (at 21 and 35 DAS) which was at par with the fibre yield (28 q/ha) from fluchloralin + one hand weeding (at 35 DAS) (Sarkar, 2003a). The highest net return per rupee investment (NRPRI) in *olitorius* jute was 2.70 with fluchloralin + one hand weeding (at 35 DAS) treatment, which was closely followed by the NRPRI (2.69) in one hand weeding (at 21 DAS) treatment. Whereas, in *capsularis* jute the highest NRPRI was 1.64 in fluchloralin + one hand weeding (at 35 DAS) treatment which was closely followed by the NRPRI (1.61) in one hand weeding (21 DAS) treatment (Sarkar and Bhattacharya, 2005a).

Earlier it was reported that pre-plant soil incorporation of trifluralin at 0.75 kg a.i/ha one day before sowing of jute seeds is found effective to control most of the grassy (Poaceae) and some of the broadleaved weeds generally found in jute field. If the grass community was killed in greater degree by applying higher dose of grass killing herbicides, the weed community was then shifted to a mixed population dominated by sedges (62%), followed by grass (26%) and broadleaved weeds (12%). Trifluralin may give as high as 90% weed control efficiency up to 35-42 DAS if the predominant weeds are mainly grasses and some are broadleaved. In case of very dry soil, trifluralin (and some other pre-emergence herbicides) should not be used because moisture stress may hamper germination of jute seeds. At higher dose (> 1.0 kg a.i. /ha) germination of jute is also reduced in light textured soil. Within the recommended dose of trifluralin, there is no problem of residue in soil as evidenced from oat (*Avena fatua*) bioassay and HPLC studies (Sarkar *et al*., 2005).

In a recent study (Sarkar *et al*., 2023), it was found that application of ipfencarbazone @120 g/ha (PE) + CRIJAF nail weeder at 21 DAS produced higher jute fibre yield (34.2 q/ha) closely followed by and at par fibre yield recorded with ipfencarbazone @120 g/ha (PE) + CRIJAF single wheel jute weeder at 21 DAS (32.0 q/ha) under south Bengal condition. Non-phytotoxic effect of ipfencarbazone was reported in jute (Ghorai *et al*., 2018) under wide range of soil moisture regime (rain fed to irrigated) when sown in line using CRIJAF multi-row seed drill or broadcasted, usually followed in jute.

The sedge weeds which may pose serious problem in some specific situation of jute could not be easily managed by the use of commonly used pre-emergence herbicides. It was found that pre-emergence application of s-metolachlor @ 0.50 kg a.i./ha (often with one hand weeding) could effectively control the weeds in jute if the weed complex is dominated by sedges and resulted in higher fibre yield (Sarkar, 2007).

Photo 24. *Trianthema* spp infestation in jute

Photo 25. *Trianthema* spp control by pretilachlor @ 0.9 kg/ha (at 45 hrs after sowing) in jute field

6.4.2. Post-emergence herbicides

Jute crop is primarily sown under rainfed situation coinciding with the pre-monsoon shower received during the late March or first fortnight of April. If this pre-monsoon shower is available, regularly in time, pre-emergence herbicides may be used. However, under purely rainfed situation, the farmers sow jute crop early to get the full benefit of the pre-monsoon shower and it may not be possible to delay the sowing even by a single day as often required in case of pre-emergence herbicides. In such situation, selective post-emergence herbicides, which do not affect jute crop, have greater role to combat the weed problem in jute.

Application (spray) of grass killing post emergence herbicide, quizalofop ethyl 5% EC (45-60 g a.i. /ha) or quizalofop ethyl 10% EC (38 g ai /ha) + adjuvant @ 1.0 ml l^{-1} at 15-21 days after emergence (DAE) and one hand weeding was found very effective for control of grass weed in jute. Quizalofop ethyl 5% EC if applied in time with suitable adjuvant may control the grasses by 95-100% (Ghorai *et al*, 2004; Bhattacharya *et al*., 2004). For early grass weed control at 8-10 DAE,

quizalofop ethyl 5% EC @ 30 g a.i./ha is effective. It should preferably be applied in the early morning or late afternoon hours with flood jet nozzle wetting the grasses properly for its maximum effect. Quizalofop ethyl along with one manual weeding produced 40 q fibre/ha as compared to fibre yield obtained from two manual weeding (37 q/ha) and left no phytotoxic effect on jute, rice and mustard crops in sequence. If the dominated weeds are grasses in a particular jute field, quizalofop ethyl is adequate and no hand weeding is required. In recent studies it was found that quizalofop ethyl (5% EC) @ 45 g a.i. /ha at 15 DAE (+ adjuvant) along with one hand weeding may yield 46.5 q/ha of jute fibre (Ghorai *et al*., 2006). One hand weeding/ wheel hoeing was followed at 7-10 days after spray (when the grasses have already withered), to remove non-targeted broad-leaved and sedge weeds. So, this method of post-emergence herbicide was cheaper by ₹ 10,000 to 15,000/ha as compared to the conventional two manual weeding. From residual analysis of soil and plants it was observed that the quizalofop ethyl herbicide residue in soil and plant were below detectable limit even 8 days after spray (Ghorai *et al*., 2008; 2014 and 2016).

Photo 26. Unweeded control plot of jute

Photo 27. Grass weed control of jute by quizalofop ethyl (@ 45 g ai/ha (adjuvant @ 1 ml/l) at 15 DAE

Other post-emergence herbicides were also tested and found that fenoxaprop-p-ethyl at 75 g a.i./ha showed good WCE (86.55%). Post-emergence application of fenoxaprop-p-ethyl @ 75 g a.i./ha at 21 days after sowing (when the grass weeds are at four leaf stage) could effectively control the grasses in jute producing higher fibre yield of 40.4 q/ha resulting in net return per rupee investment of 2.0 (Sarkar, 2006). It was also found that application of grass-killing post-emergence herbicides such as propaquizafop 10% EC @ 150 g ai/ha and clodinafop propagryl @1g/lit after 15 days of jute emergence followed by one hand weeding was found effective for weed control in jute and yielded 35-41 q fibre/ha (Ghorai *et al*., 2012). In Assam fluazifop butyl at 400 g/ha applied at 21 DAS + 1 hand weeding (HW) at 35 DAS gave more effective control of weeds of jute (cv. JRO 212) than 600 g of fluazifop butyl applied at 21 DAS + 1 HW (Borgohain *et al*., 1990). In Odisha, fluazifop-p-butyl @ 0.4-0.6 kg/ha proved quite effective for grass weed control in *capsularis* jute (Mishra and Bhol, 1996).

Application of butachlor @ 1 kg ai/ha after sowing of jute and spray of glyphosate @ 0.82 kg SL/ha at 25 DAS in between jute lines using directed spray (mike nozzle guarded by plastic bottles, 10 cm x 10 cm) effectively controlled composite weed flora in jute (cv. JRO 524) field. This system of weed management produced fibre yield of 30 q/ha when harvested at 110 DAS (Ghorai, *et al*; 2013). Other non-selective herbicides can also be used using this technic.

Photo 28. Directed application of glyphosate @ 0.82 kg SL/ha and urea 2% or parquat @ 0.48 kg SL/ha in between jute rows (30-45 cm) using plastic bottle guarded mike nozzle to control composite weed flora

6.4.3. Effect of herbicides on microbes of jute soil

It was observed that initial depression of total soil bacteria (52.3-57.1%), actinomycetes (29.1-31.6%) and fungi (47.7-50.3%) had occurred due to application of fluchloralin. However, after 14-21 days of herbicide application the microbial population reached its normal level i.e., 11.8-13.6 x 106 CFU of bacteria, 79.8-90.4 x 10^5 CFU of actinomycetes and 10.9-12.1 x 10^4 CFU of fungi in one g of dry soil (Sarkar, 2003[b]). Field experiments were conducted to find out the effect of pre-emergence (trifluralin and fluchloralin) and post emergence herbicide (quizalofop ethyl) applied to jute crop on microbial dynamics in soil. It was found that while the total microbial population (bacteria, fungi and actinomycetes) in soil decreased significantly with all the herbicides compared to control, hand weeding and initial population after 7 days of their application but the same started recovering after 15 days of application and recovered to the tune of initial population near the time of jute harvest. However, the *Azotobacter* and *Azospirilum* population in the soil reduced even after 7 and 15 days of application of herbicides and then recovered but could not cope with their respective initial population (2.2 x 104, 6.7 x 10^4). Among the herbicides tested, Trifluralin was less harmful to *Azotobacter* and *Azospirillum* population in the soil (Majumdar *et al*., 2008; Majumdar *et al*., 2010). In comparatively recent studies, it was observed that, pre-emergence herbicides such as trifluralin and metolachlor either singly or in combination reduced the total soil bacteria count by 36.2 - 69.1% at 7 days after application. At 45 DAS, the total bacterial count was reduced to the tune of 64.9, 62.4 and 58.9% by post-emergence herbicides such as quizalofop ethyl, cyhalofop butyl and fenoxapropp-ethyl, respectively. At harvest of jute (120 DAS), in all the herbicide treatments the bacterial population was comparable with the control treatment. The total actinomycetes population was reduced initially by the application of pre-emergence herbicides. The depression was in the order trifluralin + S-metolachlor (60.9%) > trifluralin (52.7%) > S-metolachlor PE (49%) > S-metolachlor PPI (46.6%). At harvest, the detrimental effect of pre-emergence herbicides on actinomycetes population was nullified. S-metolachlor as pre-emergence application did not affect the total fungi population. At harvest, there were not much difference in the total fungi population among the different weed management treatments (Sarkar and Majumdar, 2013).

6.5. Integrated weed management

In the integrated weed management system in jute, integration of different methods like sanitation, crop husbandry methods, mechanical methods and use of herbicides at a recommended level are made in order to keep the weeds below the threshold limit causing economic yield and fibre quality reduction. Based on the published work on different approaches of weed management in jute, it may be summarized that-

- Use of non-contaminated FYM, use of weed free jute seed, timely sowing, sowing of seeds in line in optimum condition, maintaining optimum plant population, use of nitrogenous fertilizers in split doses and following of recommended crop rotation are the key components of cultural methods in the integrated weed management in jute.
- Rice straw mulch @ 10-15 t /ha (just after sowing of jute) along with one hand weeding (at 35 DAE) was effective to control all category of weeds in jute field and yielded 38 q fibre/ ha. If rice straw is locally available at a cheaper rate, this method is acceptable for organic jute cultivation.
- Red amaranth suppressed the weed growth by 54% and mixed cropping produced (additional amount) a maximum of 64 q red amaranth (leafy vegetables) per ha at 21-40 DAE along with 36 q jute fibre/ha.
- It was proved that (i) CRIJAF nail weeder (and with attachments), (ii) Single wheel jute weeder suitable as better weed control tools in jute. CRIJAF Nail weeder is suitable to control germinating composite weeds flora (at 2 leaf stage of weeds) i.e., at early stage of crop (4-8 DAE) in line-sown crop and reduces the loss of soil moisture by creating soil mulch through its operation. Both the machines singly can control 80-85% of the total weed flora in jute. Scrapper attached with nail weeder at 15-21 DAE is recommended to control established tough weeds. However, in both the cases often one hand weeding is required to control remaining weeds from within the rows. These mechanical methods are cheaper than manual weeding twice by ₹15,000-20,000/ha at present, depending on the degree of weed infestation in the jute field.
- Pre-plant and pre-emergence application of butachlor (50%EC or G) from 7 days before sowing to 72 hours within sowing of jute controlled annual grasses and broadleaved weeds for 3-4 weeks. Pretilachlor 50% EC @ 0.90 kg ai/ha (45-48 hours after sowing with irrigation) performed well in jute field and produced jute fibre yield up to 40 q/ha. When applied 45-48 hours after jute sowing, pretilachlor 50% EC has been found effective in controlling *Trainthema* spp in jute field and keeps the jute field free from weeds for about four weeks. Application of ipfencarbazone @120 g/ha (PE) + CRIJAF nail weeder at 21 DAS produced higher jute fibre yield (34.2 q/ha) closely followed by and at par fibre yield recorded with ipfencarbazone @120 g/ha (PE) + CRIJAF single wheel jute weeder at 21 DAS (32.0 q/ha) under south Bengal condition. The sedge weeds may pose serious problem in some specific situation of jute where commonly used pre-emergence herbicides are not effective. In such specific situation, pre-emergence application of S-Metolachlor @

0.50 kg a.i./ha (sometimes with one hand weeding at 35 DAS) could effectively control the weeds in jute if the weed complex is dominated by sedges and resulted in higher fibre yield.

- Post-emergence herbicides retained a firm footing in the weed management strategy of jute. Application (spray) of grass killing post emergence herbicide, quizalofop ethyl 5% EC (45-60 g a.i./ha) or quizalofop ethyl 10% EC (38 g ai /ha) + adjuvant @ 1.0 ml l-1 at 15-21 days after emergence (DAE) and one hand weeding was found very effective for control of grass weed in jute (90-95%). Other grass killing post emergence herbicides such as Fenoxaprop-p-ethyl can also be used for controlling the weeds in jute if the grass weed population dominates in the weed complex. It was also found that application of other grass-killing post-emergence herbicides such as propaquizafop 10% EC @ 150 g ai/ha and clodinafop propagryl @1g/lit after 15 days of jute emergence followed by one hand weeding was found effective for weed control in jute and yielded 35-40 q fibre/ha. These post-emergence herbicidal methods are cheaper than manual weeding twice by ₹15,000-20,000/ha at present, depending on the degree of weed infestation.

6.6. Economics of weed management

About 35-40% of the total cost of production of jute goes to weeding alone if done manually which require at least 120-man days and at the same time 60-80% fibre yield loss may occur due to presence of weeds during the critical period of 10-45 DAS. Use of pre-emergence herbicides such as butachlor (50% EC) or pretilachlor or post-emergence herbicides such as quizalofop ethyl or propaquizafop, clodinafop propagryl, fenoxaprop ethyl can save ₹ 15,000-20,000 at present, thereby reduce the weeding cost by 80% as compared to manual weeding twice (₹ 30,000). Its net return was higher (₹ 57,500/ha) over conventional manual weeding twice (₹ 37,500/ha). Mulching with paddy straw (if locally available at a cheaper rate) or growing summer radish with jute is highly effective in weed suppression and remunerative over conventional method of manual weeding twice. Due to the high cost of polyethylene, soil solarisation in jute is not economically viable at present in spite of its merit for weed management in jute.

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