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WEED MANAGEMENT OF KENAF (*Hibiscus cannabinus*) THROUGH INTERCROPPING LEAFY VEGETABLES AND CULTURAL PRACTICES

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ABSTRACT

A field experiment was conducted at Jute Research Experimental Station, Manikganj, Bangladesh during 2017 and 2018 cropping seasons to study the feasibility of intercropping leafy vegetables at early stage of the fibre crop: kenaf along with conventional weeding methods for better weed suppression and higher productivity. A Randomized Complete Block Design (RCBD) was followed consisting of eight treatments with three replications. Three leafy vegetables: red amaranth, jute *shak* and kangkong were used as intercrop with kenaf following 1 hand weeding and 1 hand hoeing alternately. Sole kenaf (weeded twice) was also grown as control. The total weed vegetation was comprised of grasses 49%, broadleaved 33% and sedge only 18%. Performance of kangkong as intercrop was found better in terms of weed suppression. Hand weeding was found more efficient as a cultural weeding method in reducing weed density. Although intercropping resulted in significant yield reduction of kenaf but increased net return and benefit-cost ratio (BCR) by increasing kenaf equivalent yield (KEY). The land equivalent ratio (LER) was found higher in all intercropping treatments than sole kenaf which indicated more efficient utilization of land under intercropping. Red amaranth intercropping+1 hand weeding resulted the maximum gross return (TK.1,36,200 ha^{-1}) while the highest gross margin (Tk. 59,390 ha^{-1}) and BCR (1.78) was obtained from jute *shak* intercropping+1 hoeing. Considering the production cost, monetary return and productivity, Kenaf intercropped with Jute *shak*+1 hoeing was found better than other intercropping treatments.

Keywords*:* Fibre crop, Intercropping, Leafy vegetables, Productivity, Weed suppression.

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INTRODUCTION

Kenaf (*Hibiscus cannabinus* L. Malvaceae) is a warm season annual fibre crop related to cotton and okra but shows similar characteristics with White Jute (*Corchorus capsularis* L.). It is an industrial crop holding high cellulosic fibre content, predominantly grown in Asia and Africa (Ayadi et al., 2011; Niu et al., 2015). Kenaf is an appealing fibre source for paper pulps, fabrics, textiles, building materials, bio-composites, bedding material, oil absorbents etc. Because of its versatile uses and wide environmental adaptability, its cultivation is gradually increasing in South Asian countries i.e., Bangladesh, India, Pakistan and Nepal. In Bangladesh, around 0.08-0.09 million tons of kenaf is produced from 0.04 million hectares of land (Islam, 2019). In the course of cultivation, weed is one of the most important pests in kenaf. Aluko and Ayodeli (2017) reported that delayed weeding and weedy kenaf fields might significantly reduce its fibre and seed yield by 50 to 80 % while net return could be reduced by 86% in weedy plot and therefore recommended early and effective Kenaf weed control by farmers for optimum production of the crop. Hence, in order to achieve an economic and large-scale production of kenaf, weed management is essential in kenaf cultivation.

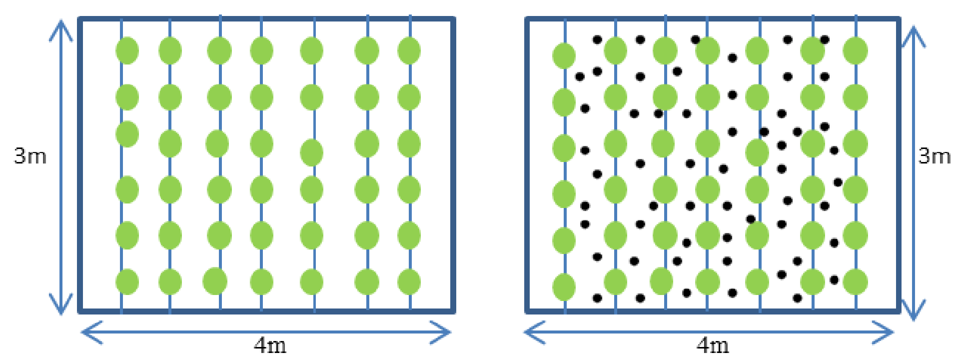
Bangladesh is a densely populated country with rapidly declining cultivable lands which is subjected to be cultivated technically. Intercropping can be a viable approach in this situation. Intercropping is a cropping system which involves the intensification and diversification of cropping in time and space dimensions (Francis 1986). Ahmad et al. (2018) reported that mixed/inter/multiple cropping may ensure proper utilization of resources towards increased production per unit area and time on a sustainable basis. It is a traditional but important approach of cropping system for increasing total productivity as well as farmer’s income particularly in South Asian developing countries including Bangladesh.

Although intercropping is practiced to maximize land use, it has also a significant effect in suppressing weed growth. Colbach et al. (2014) reported that cropping systems composed of a diversity of crops with different life cycles are a great option to manage weeds and critical component of integrated weed management. Weed interference in crop fields are critical during the early crop plant establishment and growth reported by Chikoye et al. (2004). Kenaf is a long duration (110-130 days) and wide spaced (30-40 cm) crop. Leafy vegetables such as red amaranth, kangkong and jute *shak* being short structured and quick growing can be easily intercropped between two rows of kenaf at early growth stage.

Manual weeding is an effective means of controlling weeds (Fischer and Hill, 2004). Hand weeding and hand hoeing are two predominant methods of manual weeding used by smallholder farmers in Bangladesh. In this study, these two cultural weeding methods are considered as treatments along with intercropping systems, since intercropping system alone is not sufficient to ensure adequate weed management practices because of diverse canopy coverage occurred by intercrop. Sustainable kenaf production requires effective weed management strategy which is ecologically friendly and economically profitable. Very little information is available in this regard. Therefore, the present study aims at finding the combined result of intercropping and cultural weeding practice on weed management of Kenaf and thereby increasing the crop productivity.

MATERIALS AND METHODS

The experiment was conducted in JAES, Jagir, Manikganj station (23°53'01.2" N 90°02'13.5" E) of Bangladesh during April to August for two consecutive years 2017 (1st April to 2nd Aug) and 2018 (4th April to 5th Aug). The soil was silt loam to silty clay loam in texture which belongs to the Young Brahmaputra and Jamuna floodplain soils (AEZ 8). The type of land was medium high and soil was slightly acidic (pH 5.9-6.4). Soil fertility was moderate and organic matter content was low. Temperature and Relative humidity in both years ranges between 37°C to 28°C and 74-78% respectively. The crop was grown rainfed. Total rainfall was 2376 mm in 2017 and 2332 mm in 2018. Randomized complete block design was followed with three replications with unit plot size 4m×3m. Space between plot to plot and between replications was 60 cm and around the field was 1.0m. Seeds of kenaf variety was sown in row of 30cm apart after broadcasting the seeds of leafy vegetables (red amaranth, kangkong and jute leafy vegetable) according to the treatments. Other intercultural practices were followed as per recommendation.



(a) Sole kenaf

(b) kenaf in rows + broadcasted leafy vegetables

Figure 1. Orientation of main crop (kenaf) and intercrop (leafy vegetables) in the field plots (a) and (b)

Among the leafy vegetables red amaranth was harvested 20 DAS, both of jute shak and kangkong were harvested 30 DAS. After harvesting of vegetables (30DAS) all the treatment plots were weeded by two cultural weeding practices: hoeing and hand weeding as per treatments. The number of weeds/m^2 was taken along with the weed species composition 30 days (1 month) after weeding. Kenaf (main crop) was harvested 120 DAS. At maturity, 10 randomly selected plants were uprooted from inner rows of each plot for recording data on yield and yield contributing characters.

Data of two years were analyzed statistically using MSTAT-C for stable recommendation and mean comparison was done by DMRT (Duncun's Multiple Range Test) test at 5% level of significance. The relative yield was obtained by dividing the intercrop yield of a crop with the respective sole crop yield of that crop using the following formula of Dewit and Vander (1965).

$$\text{The relative yield of a crop} = \frac{\text{Yield of sole crop}}{\text{Yield of component crops}}$$

Kenaf equivalent yield (KEY) was calculated by converting yield of intercrops on the basis of prevailing market price of individual crop following the formula of Anjaneyulu et al., (1982).

$$\text{KEY} = \text{Yield of intercrop Kenaf} + \frac{\text{Yi x Pi}}{\text{Price of Kenaf}}$$

Where, Yi = yield of intercrops (leafy vegetables) and Pi = Price of intercrop (leafy vegetables).

Land equivalent ratio (LER) values were determined from the yield data of the crops according to Mian (2008).

$$LER = RY_k + RY_i = \frac{K_{IY}}{K_{SY}} + \frac{K_{EYCC}}{K_{SY}}$$

Where,

RY_k= Relative yield of kenaf (main crop)

RY_i= Relative yield of intercrops (leafy vegetables)

K_{IY} = Intercrop yield of kenaf

K_{SY} = Sole crop yield of kenaf

K_{EYCC} = Kenaf equivalent yield of component crops {(component crop yield in intercrop × price of component crop)/price of Kenaf}.

Variety: kenaf: HC-95, red amaranth: BARI lalshak-1, Kangkong: BARI gimakalmi-1 and jute shak: BJRI deshi patshak-1.

Treatments:

T_1 = Sole kenaf with hand weeding

T_2 = Kenaf + Red amaranth with 1 hoeing (After harvest of Red amaranth)

T_3 = Kenaf + Kangkong with 1 hoeing (After harvest of Kangkong)

T_4 = Kenaf + Jute *shak* with 1 hoeing (After harvest of Jute *shak*)

T_5 = Kenaf + Red amaranth with 1 hand weeding (After harvest of red amaranth)

T_6 = Kenaf + Kangkong with 1 hand weeding (After harvest of Kangkong)

T_7 = Kenaf + Jute *shak* with 1 hand weeding (After harvest of Jute *shak*)

T_8 = Sole kenaf (No weeding).

(a) (b)

Figure 2. Pictorial view of the experiment: (a) 20 Days old Kenaf crop intercropped with leafy vegetables; (b) Kenaf crops after harvesting of intercrops.

Benefit-cost Analysis

A Benefit cost analysis was also carried out to determine the most economically acceptable treatment practice. The prevailing wage rates paid for labor were used to estimate the labour costs. Economic data from cost of inputs and farm operations used for each treatment were used to estimate the total cost of production (TCP). The gross income (GI) was a product of the total yield (Kenaf yield and KEY) and prevailing price of fibre and stick which was TK.32 per kg and TK.4 per kg respectively. The GI minus TCP is the net income.

RESULTS AND DISCUSSION

Weed flora composition and density

The total weed vegetation in the experiment comprised of grasses 49%, broadleaved 33% and sedge 18% (Fig. 3). Buhler (1999) reported that weed population in a specific area depends on several factors and within different species composition, 70% - 90% of the total species is usually found dominating. In this study, grass weeds (49%) were found to be dominating.

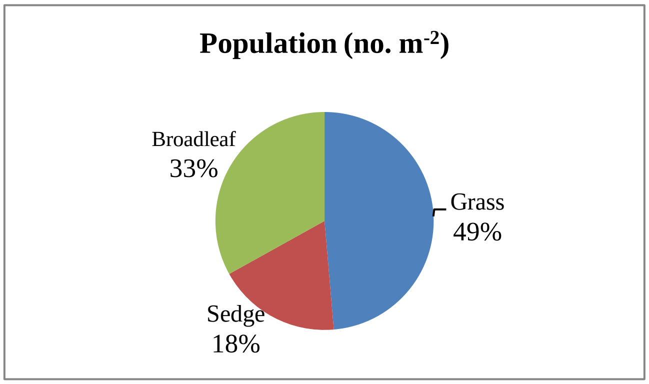


Figure 3. Population (%) of different types of weeds found in kenaf-leafy vegetable intercropping systems in cropping season 2017 and 2018.

Only 10 weed species from 7 families were found in both years of the study, majority of which belonged to the Poaceae family (Table 1). According to the population, *Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa colonum*, *Anhydra fluctuans* and *Amaranthus viridis* were found to be the major weed in this experiment.

Table 1. Weed species found in different intercropping treatments in 2017 and 2018

Weed species name	Family	Common name	Morphology
Cyperus rotundus	Cyperaceae	Nutsedge	Sedge
Cynodon dactylon	Poaceae	Bermuda grass	Grass
Echinochloa colonum	Poaceae	Jungle rice	Grass
Anhydra fluctuans	Asteraceae	Hingcha	Broadleaf
Amaranthus viridis	Amaranthaceae	Green amaranth	Broad leaf
Physalis heterophylla	Solanaceae	Clammy groundcherry	broadleaf
Euphorbia hirta	Euphorbiaceae	Garden spurge	Broadleaf
Elusine indica	Poaceae	Goose grass	Grass
Phyllanthus niruri	Euphorbiaceae	Corn spurge	Broadleaf
Corchorus acutangulus	Malavaceae	Wild jute	broadleaf

The weeded, intercropped and non-weeded plots were evaluated for the number of weed species/m^2 present in the experiment (Table 2). The highest weed density was found in unweeded sole kenaf and the lowest was recorded in control treatment in both years. The author also found that weed flora composition was influenced by the treatments of the study. The control treatment had only 5 weed species, while 10 species was found in unweeded plots. Both species composition and weed density were found comparatively lower in hand weeded plots than the hoeing plots. This is because the efficiency of manual weeding was higher than mechanical weeding reported by Abbas et al. (2018).

Table 2. Density of weeds found in different intercropping treatments in 2017 and 2018

Treatments	Types of cultural weeding practice	Weed Density ($No.m^{-2}$)	No. of species
T_1 (weed free sole kenaf)	2 hand weeding	26.00	5
T_2 (Kenaf + Red amaranth)	1 Hoeing (30 DAS)	71.67	8
T_3 (Kenaf + Kangkong)		67.83	6
T_4 (Kenaf + Jute *shak*)		88.17	7
T_5(Kenaf + Red amaranth)	1 Hand weeding (30 DAS)	36.00	6
T_6 (Kenaf + Kangkong)		41.83	7
T_7 (Kenaf + Jute *shak*)		43.17	7
T_8 (unweeded sole kenaf)	No weeding	136.70	10

Moreover, Kangkong was found to be better than other intercrops in terms of reducing weed density. Liebman and Davis (2000) reported that intercropping is also indicated as an alternative to the use of herbicides, by reducing or suppressing weed growth.

Kenaf yield influenced by different treatments

Significant variation was found in all the yield contributing parameters under the treatments, except for plant population (Table 3). Results showed that the tallest kenaf plant (2.88m), the highest base diameter (19.96 mm) and the highest fibre yield (0.296 kgm^{-2}) were recorded in control treatment in both years of the trial which were statistically similar to all the intercropping treatments except T_2 (Kenaf-Red amaranth intercropping with 1 hoeing). The lowest yield was recorded in unweeded sole kenaf treatment (T_8).

Table 3. Yield and yield contributing characters of kenaf under kenaf-leafy vegetables intercropping systems for cropping seasons 2017 and 2018

Treatments	Plant pop^n (m^{-2})	Plant Height (m)	Base Diameter (mm)	Fiber yield (kgm^{-2})	Stick yield (kgm^{-2})
	2017-18	2017-18	2017-18	2017-18	2017-18
T_1 (weed free sole kenaf)	27.23	2.88a	19.96a	**0.296a**	0.565a
T_2 (Kenaf + Red amaranth with 1 hoeing)	26.16	2.72ab	18.20ab	0.270b	0.514ab
T_3 (Kenaf + Kangkong with 1 hoeing)	27.93	2.62ab	17.26b	0.277ab	0.522ab
T_4 (Kenaf + Jute *shak* with 1 hoeing)	27.20	2.63ab	18.16ab	**0.285ab**	0.539a
T_5(Kenaf + Red amaranth with 1 hand weeding)	26.53	2.71ab	18.70ab	0.276ab	0.517ab
T_6 (Kenaf + Kangkong with 1 hand weeding)	27.90	2.70ab	18.66ab	0.277ab	0.514ab
T_7 (Kenaf + Jute *shak* with 1 hand weeding)	27.10	2.64ab	17.83b	0.278ab	0.522ab
T_8 (unweeded sole kenaf)	28.53	2.53b	17.00b	0.246c	0.473b
LSD (0.05)	NS	**0.254***	**1.652***	**0.019****	**0.047***
CV (%)	8.22	5.45	5.18	4.17	5.23

*significant ** highly significant

Values having same lowercase letters in a column do not differ significantly at P< 0.05 by Duncan’s multiple range tests. Different letters e.g., a and b after the numerical values in each column indicate significant differences (P≤0.05) according to Duncan's Multiple Range test.

Among the intercropping treatments, the highest fibre yield (0.285 kgm^{-2}) was obtained in Kenaf intercropped with Jute *shak* with 1 hoeing and the lowest fibre yield (0.270 kgm^{-2}) was found in Kenaf intercropped with red amaranth with 1 hoeing (Table 3).

Reduction in kenaf component yield from weed invasion may be aggravated under limited soil nutrients reported by Aluko and Ayodeli (2017). Hence, the introduction of intercrops to smother weeds may be responsible for the reduction in kenaf yield and yield contributing parameters compared to the maximum from the control plots.

Table 4. System productivity (expressed as kenaf equivalent yield), percent increase of productivity and land equivalent ratio of kenaf-leafy vegetables intercropping systems for cropping seasons 2017 and 2018

Treatment	Yield of component crop (kgm^{-2})	KEY (Kenaf Equivalent Yield (kgm^{-2})	Percent (%) increase of KEY over sole kenaf	LER (Land Equivalent Ratio)
	2017-18	2017-18	2017-18	2017-18
T_1 (Sole kenaf + 2 hand weeding)	--	0.373	--	1.00
T_2 (Kenaf + Red amaranth + 1 hoeing)	0.308	0.431	15.54	1.15
T_3 (Kenaf + Kangkong + 1 hoeing)	0.320	0.411	10.18	1.10
T_4 (Kenaf + Jute *shak* with 1 hoeing)	0.326	0.434	16.35	1.16
T_5 (Kenaf + Red amaranth+ 1 hand weeding)	0.300	**0.435**	**16.62**	1.17
T_6 (Kenaf + Kangkong + 1 hand weeding)	0.310	0.403	8.04	1.08
T_7 (Kenaf + Jute *shak* + 1 hand weeding)	0.310	0.417	11.79	1.12
T_8 (Sole kenaf + no weeding)	--	0.302	--	0.81

Total productivity of each system was expressed as its kenaf equivalent yield (KEY) which was found to differ significantly among the various treatments tested (Table 4). The highest KEY (0.435 kgm^{-2}) was obtained in T_5 (Kenaf + Red amaranth + 1 hand weeding) followed by 0.434 kgm^{-2} found in T_4 (Kenaf + Jute *shak* + 1 hoeing), 0.431 kgm^{-2} found in T_2 (Kenaf + Red amaranth + 1 hoeing) and the lowest (0.302 kgm^{-2}) was in T_7 (Unweeded sole kenaf) (Table 4). The treatment of kenaf intercropped with kangkong gave lower KEY than the other intercropping treatments due to the lower market price of kangkong. In this study, the intercropping treatments increased 8-16% equivalent yield over sole kenaf. Begum S. A. and M. A. Kader (2018) found that pumpkin-leafy vegetables intercropping systems did not reduce pumpkin yield but increased system productivity by 39-120% over sole cropped pumpkin. Ahmed et al. (2013) reported 28 to 45% yield advantages in okra-vegetables intercropping system and Islam M. R. (2015) found 9-27% yield increase in brinjal-leafy vegetables/legumes intercropping system.

The highest land equivalent ratio (1.17) was found in T_5 (Kenaf + Red amaranth + 1 hand weeding) followed by 1.16 in T_4 (Kenaf + Jute *shak* with 1 hoeing), 1.15 in T_2 (Kenaf + Red amaranth with 1 hoeing) and the lowest (0.81) was in T_7 (sole kenaf with no weeding) (Table 4). Mazaheri and Overysi (2004) stated that any value greater than 1.0 indicates yield advantage for intercropping than monoculture. In this study, The LER values of different intercropping systems were greater than one in all the intercropping treatments which revealed that the land was more efficiently utilized under intercropping than under sole cropping of kenaf. Higher LER in intercropping compared to monocropping of kenaf was also reported by J. A. Raji (2008).

Cost benefit analysis

The simultaneous planting of cover/intercrop for weed suppression reduce cost of weed control and production in food crops was reported by Chikoye et al. (2000). The findings of the research also followed this trend. Intercropping combination of kenaf with leafy vegetables showed higher monetary return than the sole kenaf (control) in both years of the study (Table 5).

Table 5. Economic performances of kenaf-leafy vegetables intercropping systems for cropping season 2017 and 2018

Treatments	GI (Tk. ha^{-1})	TCP (Tk. ha^{-1})	GM (Tk. ha^{-1})	BCR
	2017-18	2017-18	2017-18	2017-18
T_1 (Sole kenaf +2 hand weeding)	1,19,360	75,000	44,360	1.59
T_2 (Kenaf+Red amaranth+1 hoeing)	1,37,920	78,000	59,920	1.77
T_3 (Kenaf+Kangkong+1 hoeing)	1,31,520	76,500	55,020	1.72
T_4 (Kenaf+Jute *shak* with 1 hoeing)	1,38,880	76,500	**62,380**	**1.82**
T_5 (Kenaf+Red amaranth+1 hand weeding)	**1,39,200**	81,000	58,200	1.72
T_6 (Kenaf+Kangkong+1 hand weeding)	1,28,960	79,500	49,460	1.62
T_7 (Kenaf+Jute *shak*+1 hand weeding)	1,33,440	79,500	53,940	1.68
T_8 (Sole kenaf no weeding)	96,640	55,000	41,640	1.76

GI (gross income), TCP (total cost of production), GM (gross margin), BCR (benefit-cost ratio)

1hactare (ha) =10,000 m^{-2}. Price: Kenaf: Tk. 32/kg (fibre); Tk. 4/kg (stick), Red amaranth: Tk. 10/kg, Jute (as leafy vegetable): Tk.8/kg, Kangkong: Tk.7/kg.

The highest gross income (GI) TK.1,39,200 ha^{-1} was recorded in T_5 (Kenaf + Red amaranth + 1 hand weeding) due to having higher market price of red amaranth. This was followed by TK. 1,38,880 ha^{-1} in T_4 (Kenaf + Jute *shak* + 1 hoeing), TK. 1,37,920 ha^{-1} in T_2 (Kenaf + Red amaranth + 1 hoeing) and the lowest GI (TK. 96,640 ha^{-1}) was obtained from T_8 (Unweeded sole kenaf). But the highest gross margin (Tk. 62,380 ha^{-1}) was obtained from T_4 (Kenaf + Jute *shak* + 1 hoeing) and this intercropping combination also gave the highest BCR (1.82) (Table 5). According to the results, all intercropping treatments were suitable as compared to sole treatments. It has been discovered that 25-40 people are needed to weed one hectare of maize farm and this may account for 50-80% of total labor budget (Darkwa et al., 2001). The mass migration from rural farm areas to urban centre increased cost of labour (Fischer and Hill, 2004). This in turn increases the cost of production which was minimized by intercropping systems. The results of increased productivity and returns and yield advantage of crop mixture compared to monoculture is also reported by Ahmed et al. (2013), Islam et al. (2015) and Rabeya et al. (2018). Considering the production cost, monetary return and productivity, Kenaf intercropped with Jute *shak* with 1 hoeing performed better than other treatment methods.

CONCLUSION

All the intercropping treatments performed better than sole cropping not only in weed management but also in productivity, land utilization and financial benefit. Hence it is clear from the experiment that intercropping kenaf with short duration leafy vegetables ensures initial weed suppression and guarantee profitable kenaf productivity. Intercropping kenaf with jute as leafy vegetable followed by 1 hoeing can be recommended for practicing at field level. This research can be further studied by intercropping with other short duration vegetables with or without including any cultural weeding practices for examining the level of weed suppression and profitability.

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CONFLICT OF INTEREST

All the authors do not have any possible conflict of interest.

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