INTERCROPPING OF MUKHIKACHU AND PAPAYA WITH PINEAPPLE

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ABSTRACT

The experiment was carried out at the farmers' field condition under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during 2016-18 and 2018-20 to find out suitable intercropping system for increasing crop productivity and profitability of pineapple + mukhikachu + papaya intercropping system. The treatments were viz. T_1 = Pineapple (100%) + Mukhikachu (40%), T_2 = Pineapple (100%) + Papaya (66%) and T_3 = Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4 = Pineapple (100%), T_5 = Mukhikachu (100%), T_6 = Papaya (100%). Pineapple (Honey queen), Mukhikachu (Bilashi) and Papaya (Shahi) were used as test materials. The experiment was laid out in a randomized complete block design with six dispersed replications. Pineapple was the main crop, mukhikachu and papaya were intercrop in the study. Among three intercropped treatments, pineapple (100%) + papaya (66%) + mukhikachu (40%) within two paired rows of pineapple (T_3) showed higher equivalent yield of pineapple, mukhikachu and papaya 70.37, 46.91 and 58.64 tha^{-1}, respectively which provided yield advantages of 57, 138 and 92 % over their respective sole crops. The highest land equivalent ratio (1.83), gross return (Tk 7,03,700 ha^{-1}) and benefit cost ratio (2.04) were achieved in this treatment (T_3) compared to other cropping systems. The higher values of all competition functions were also exhibited in Pineapple (100%) + Papaya (66%) + Mukhikachu (40%) intercropping system. Thus, it could be stated that papaya (66%) and mukhikachu (40%) in between two paired rows of pineapple was the most productive and profitable intercropping system for the farmers of Madhupur Tract (AEZ-28).

Keywords: Intercropping, Equivalent yield, Aggressivity, Competitive ratio.

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Received: 11.03.2023 *Accepted: 07.06.2023*

INTRODUCTION

Agriculture is the single largest producing sector of the Bangladeshi economy and contributes about 13.02% to the total Gross Domestic Product (GDP). Majority of the farmers are marginal and smallholders and their land size is on an average 0.05 to 2.49 acres and 1.50 to 2.49 acre, respectively (MOA, 2021). On top of that, demand for food has been increasing with the rapid population increase while land accessibility has been diminishing. Thus, the only way to increase agricultural production is to increase yield per unit area (Hirpa, 2014). Increasing food demand for the over population is creating challenge to the country for increasing productivity of the limited land. Now cultivation of long duration crops is discouraged and simultaneously short duration crops, mixed crop and intercrops are emphasized for cultivation to ensure food security for a large number of populations. Consequently, intercropping is a time demanding technology for cultivation of long duration crops. In Madhupur tract (AEZ-28), pineapple has been considered as the best component in most of intercropping system. So, intercropping of mukhikachu and papaya with pineapple will help to retain vegetable and fruit crops in existing cropping pattern. Intercropping is an effective and the economical production system as it not only increases the production per unit area and time, but also increases the resource use efficiency and economic stock of the growers (Bhatti et al., 2013). Presently, intercropping is gaining acceptance among small holder farmers as it provides a yield advantage compared to sole cropping through yield stability and helps achieve diversified domestic needs (Bhatti et al., 2013). Intercropping practices have some benefits such as improving yield (Sadeghpour and Jahanzad, 2012) and increasing biological activities in the soil, and decreasing pests (Smith and McSorley, 2000). Different crop combination ratio for intercropping of pineapple, mukhikachu and papaya have conflicting experimental results on the potential productivity advantage of mixed cropping over monoculture. Similarly, the yield advantage of intercropping has not been so marked in several situations possibly due to the use of supra-optimal plant population proportions and in some cases, to the use of sub-optimal population proportions for component crops (Refay et al., 2013).

Pineapple is a long duration (15-18 months) wide spaced crop. It is also partial shade loving crop. So, farmers can easily grow short duration crop as intercrop with pineapple at early growth stage. Pineapple is an important cash crop of Madhupur hilly area of Tangail. In these area farmers sporadically cultivate papaya, banana, mukhikachu, ginger etc. with pineapple as intercrop. It will also play an important role to ensure the highest productivity per unit area as well as supply vegetable and fruit in our food menu. There is scope to cultivate mukhikachu and papaya as intercrop with pineapple. Therefore, the study was conducted to find out the suitable intercropping combination and also to increase productivity and profitability of mukhikachu and papaya with pineapple intercropping system.

MATERIALS AND METHODS

The experiment was conducted at the farmers' field of Madhupur MLT stie, under On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Tangail during 2016-18 and 2018-20 to find out a suitable intercrop combination of mukhikachu and papaya with pineapple for higher productivity and profitability. The experimental site situated at approximately $24^0 64^/$N latitude and $90^0 09^/$E longitude with the altitude of 19 m above sea level. Mean annual precipitation was 2212 mm, most of which (90%) was received during May to September due to monsoon. The experiment consisted of six treatments viz. T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%), T_3 Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Pineapple (100%), T_5=Mukhikachu (100%) and T_6= Papaya (100%). Pineapple (Honey queen), Mukhikachu (Bilashi) and Papaya (Shahi) were used as the experimental materials.

The experiment was laid out in a randomized complete block design with six dispersed replications. The unit plot size was 400 m^2. Pineapple was the main crop, mukhikachu and papaya were the intercrop in the study. Mukhikachu and papaya were intercropped in between pineapple row @ 40 and 60% population. Fifty-centimeter distance between two paired rows and 100 cm distance between paired rows to paired rows were maintained in pineapple plantation. Plant to plant 40 cm and row to row 3 m (single row) distance was followed for mukhikachu planting. In papaya, plant to plant 2 m and row to row (single row) 3 m distance was considered. The crops pineapple, mukhikachu and papaya were planted on 15-20 November 2016 and 17-21November 2018, 10-14 April 2017 and 12-16 April 2019 and 19-23 March 2017 and 16-21 March 2019, respectively. The recommended fertilizer doses at the rate of 225-85-150-30-2 kg NPKSZn ha^{-1} along with cowdung 5 t ha^{-1}, 30-27-105 kg NPK ha^{-1} and 115-80-16-45-3-10 kg NPKSB along with cowdung 5 t ha^{-1}, respectively were applied separately in monoculture pineapple, mukhikachu and papaya. In pineapple, all of cowdung, P, S and Zn were applied as basal during final land preparation 3 to 4 days prior to planting. The N and K were applied in five equal splits as side dressing at one month interval starting from 4-5 months after planting and mixed thoroughly with the soil followed by irrigation. For mukhikachu and papaya all fertilizer were applied in pits. Mulching, Weeding, irrigation and crop protection measures were taken properly for normal growth of the crops. Mukhikachu was harvested on 10-14 October 2018 and 11-15 October 2019. Papaya was harvested on November 2017 to October 18 and November 2019 to October 2020 in two consecutive years. Pineapple was also harvested on 15 June to 15 September 2018 and 20 June to 20 September in successive years. The yield contributing characters of pineapple was recorded from 10 randomly selected plants in both the years.

Yield of individual crop was converted into equivalent yield on the basis of the prevailing market price of individual crop (Prasad and Srivastava, 1991).

Pineapple equivalent yield (PiEY) = Yield of intercrop pineapple + $\frac{Yim \times Pm}{Ppi} + \frac{Yip \times Pp}{Ppi}$ Mukhikachu equivalent yield (MEY) = Yield of intercrop mukhikachu + $\frac{Yipi \times Ppi}{Pm} + \frac{Yip \times Pp}{Pm}$ and Papaya equivalent yield (PEY) = Yield of intercrop papaya + $\frac{Yipi \times Ppi}{Pp} + \frac{Yim \times Pm}{Pp}$

Where, Yim= Yield of intercrop mukhikachu, Pm= Price of mukhikachu, Yip= Yield of intercrop papaya, Pp= Price of papaya and Yipi= Yield of intercrop pineapple and Ppi= Price of pineapple

Relative yields (RY) based on grain yields were calculated according to the formula (De Wit and van den Bergh, 1965)

Relative Yield of Pineapple (RYpi): $\frac{Yipi}{Yspi}$ Relative Yield of Mukhikachu (RYm): $\frac{Yim}{Ysm}$ Relative Yield of Papaya (RYp): $\frac{Yip}{Ysp}$ and Relative yield total (RYT): RYpi + RYm + RYp

Where, Yipi= Intercrop yield of pineapple, Yspi= Sole yield of pineapple,

Yim= Intercrop yield of mukhikachu,

Ysm= Sole yield of mukhikachu,

Yip = Intercrop yield of papaya and Ysp = Sole yield of papaya.

On the other hand, various competition functions like land equivalent ratio (LER) (Mead and Willey, 1980), land equivalent coefficient (LEC) (Adetiloye et al., 1983) area time equivalent ratio (ATER) (Hiebsch, 1987), replacement value of intercropping (RVI) (Moseley, 1994), monetary advantage index (MAI) (Ghosh, 2004), competitive ratio (CR) (Willey and Rao, 1980), aggressivity index (A) (Dhima et al., 2007), relative crowding coefficient (K) (Willey and Rao, 1980), system productivity index (SPI) (Odo, 1991) were worked out by using standard procedures to find out the benefit of intercropping and the effect of competition between the treatments used in this experiment.

Pooled analysis was done as there was no significant difference in yield and yield contributing characters between two years. The collected data on different parameters were statistically analyzed using analysis of variance technique with the help of computer package MSTAT-C and mean comparison among the treatments was made by LSD test at 5% level of significance (Gomez and Gomez, 1984).

Economic analysis was done on the basis of prevailing market price of the commodities. The inputs used included seed, fertilizer, labour and insecticides. The two years average results were analyzed for economic benefits using the methodology prescribed by CIMMYT (1988).

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Total cost}}$$

RESULT AND DISCUSSION

Effect of intercropping on yield and yield attributes of pineapple

Yield and yield attributes of pineapple were significantly influenced by intercropping with mukhikachu and papaya (Table 1). The highest fruit length (18.93cm) and breadth (38.58 cm) were recorded from sole pineapple (T_4) due to minimum crop competition. The lowest fruit length (14.71cm) and breadth (35.51 cm) were recorded from pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired lines of pineapple intercropping system (T_3) treatment due to maximum crop competition. The maximum individual fruit weight (1.93 kg) was found in sole pineapple (T_4) treatment and the minimum individual fruit weight (1.51 kg) was recorded from pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired lines of pineapple intercropping system (T_3). The highest number of fruits (21965 ha^{-1}) was obtained from sole pineapple (T_4) and the lowest number of fruits (18589 ha^{-1}) was recorded from pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired lines of pineapple intercropping system (T_3).

Table 1. Yield attributes and fruit yield of pineapple as influenced by intercropping with mukhikachu and papaya during 2016-18 and 2018-20

Treatment	Fruit length (cm)	Fruit breadth (cm)	Individual fruit wt. (kg)	No. of Fruits ha^{-1}	Yield (t ha^{-1})
T_1	15.87	36.98	1.66	20419	35.68
T_2	15.00	36.57	1.65	21087	34.82
T_3	14.71	35.51	1.51	18589	32.75
T_4	18.93	38.58	1.93	21965	44. 93
T_5	-	-	-	-	-
T_6	-	-	-	-	-
$LSD_{0.05}$	0.99	0.58	0.32	1943.20	7.16
CV (%)	6.10	5.80	9.40	7.40	11.00

T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%) and T_3= Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Pineapple (100%), T_5=Mukhikachu (100%), T_6= Papaya (100%).

Fruits yield of pineapple showed almost similar pattern to its yield contributing characters observed in sole and intercropping systems. The highest fruit yield (44.93 tha^{-1}) was obtained from sole pineapple (T_4) due to cumulative effect of yield attributes followed by pineapple (100) + mukhikachu (40%) treatment (35.68 t ha^{-1}) and pineapple (100) + papaya (66%) treatment (34.8 tha^{-1}). The lowest fruit yield (32.75 tha^{-1}) was recorded from pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired lines of pineapple intercropping system. Sole pineapple produced higher fruits yield compared to different intercropping system might be due to less competition among the plants for sun light, nutrients, water and space than intercropped situation. Less competition among plants lead to better growth and development of plants as well as fruits yield in monoculture.

Yield of components crops and economic return of pineapple intercropping system

The highest pineapple, mukhikachu and papaya yields were recorded from sole crops. Pineapple gave 21 to 27, mukhikachu gave 51 to 60 and papaya gave 21-30% higher yield in monoculture as compared to their corresponding intercropped yield due to less competition among the plants for sun light, nutrients, water and space in sole crops than intercropped situation.

Table 2. Yield of component crops, pineapple equivalent yield (PEY) and economics of pineapple, mukhikachu and papaya intercropping system during 2016-18 and 2018-20 (average of two years)

Treatment	Yield (tha^{-1})			Gross return ($Tk\ ha^{-1}$)	Total cost ($Tk\ ha^{-1}$)	Gross margin ($Tk\ ha^{-1}$)	BCR
	Pineapple	Mukhikachu	Papaya				
T_1	35.68	9.60	-	500800	280784	211016	1.78
T_2	34.82	-	24.18	638360	332191	306169	1.92
T_3	32.75	7.88	21.50	703700	344363	359337	2.04
T_4	44. 93	-	-	449300	257612	191680	1.74
T_5	-	19.70	-	295500	187510	107990	1.58
T_6	-	-	30.58	366960	215713	151247	1.70

Input and output Price (Tk kg^{-1}): Urea= 16/-, TSP= 23/-, MoP=16/-, Gypsum= 10/-, Zinc sulphate= 180/-, Boric acid=220/-, Pineapple= 10/-, Mukhikachu=15/- and Papaya=12/-

On the basis of two years average result, all intercrop combinations gave monetary advantages over sole crops. The highest gross margin (Tk. 359337 ha^{-1}) was found in Pineapple (100%) + Papaya (66%) + Mukhikachu (40%) in pineapple intercropping system (T_3) which gave an additional income of (Tk.167657,208090 and 251347ha^{-1}) over pineapple, papaya and mukhikachu sole cropping, respectively. Total cultivation cost was lower in sole crops than intercropping treatments might be due to inclusion of component crops. Intercropping of mukhikachu and papaya brought about an increase in return per taka investment. It was evident that intercropping was beneficial and recorded higher benefit cost ratio (BCR) than monoculture of pineapple, mukhikachu and papaya. Among the intercropping systems the highest BCR (2.04) was obtained from Pineapple (100%) + Papaya (66%) + Mukhikachu (40%) intercropping system which further indicated the superiority to T_3 over other treatments (Table 2). These results are in agreement with the findings of Islam et al. (2016).

Equivalent yield and relative yield

All the intercropping systems gave higher pineapple, mukhikachu and papaya equivalent yield than that of respective sole crop (Table 3). It's indicated that higher biomass production and consequently more efficient use of land and available resources under intercropping than sole cropping. The highest pineapple, mukhikachu and papaya equivalent yield 70.37, 46.91 and 58.64 tha^{-1} were recorded from Pineapple (100%) + Papaya (66%) + Mukhikachu (40%) in between two paired rows of pineapple (T_3) which covered the yield advantages of 57, 138 and 92% over their respective sole crops. Such yield advantage might be due to combined yield of both the crops. The partial relative yields of intercropped pineapple, mukhikachu and papaya varied from 0.73 to 0.79, 0.40 to 0.49 and 0.70 to 0.79, respectively (Table 3). Pineapple yield was reduced 27 to 21%, mukhikachu yield was reduced 60 to 51% and papaya yield was reduced 30 to 21% among the intercropping system. The yield was reduced due to lower plant population. The result showed that T_3 was well accommodative in competitiveness in pineapple + mukhikachu + papaya intercropping system (Table 3). The results are in agreement with the finding of Islam et al. (2016).

Table 3. Equivalent yields, relative yields and land equivalent ratio of pineapple intercropping with mukhikachu and papaya during 2016-18 and 2018-20

Treatments	Pineapple equivalent yield (t ha^{-1})	Mukhikachu equivalent yield (t ha^{-1})	Papaya equivalent yield (t ha^{-1})	Partial Relative yield			Total Relative Yield (LER)
				Pineapple	Mukhikachu	Papaya	
T_1	50.08	33.39	41.73	0.79	0.49	-	1.28
T_2	63.84	42.55	53.20	0.78	-	0.79	1.57
T_3	70.37	46.91	58.64	0.73	0.40	0.70	1.83
T_4	44.93	29.95	37.44	1.00	-	-	1.00
T_5	29.55	19.70	24.63	-	1.00	-	1.00
T_6	36.70	24.46	30.58	-	-	1.00	1.00

Note: - T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%) and T_3= Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Pineapple (100%), T_5=Mukhikachu (100%), T_6= Papaya (100%).

Land Equivalent Ratio (LER)

The values of LER in different intercropping systems were found greater than unity indicating higher land use efficiency of intercropping systems over the respective monoculture (Table 3). Yield advantages occurred in intercropping was mainly due to development of both temporal and spatial complementarities. However, total LER value (1.83) was the highest in pineapple (100%) + papaya (66%) + mukhikachu (40%) in between pineapple lines (T_3), where pineapple, papaya and mukhikachu achieved 73, 70 and 40% of their sole yields, respectively indicating higher biological and economic efficiency. It also expressed that by intercropping pineapple with papaya and mukhikachu a farmer can produce 32.75 tons pineapple, 21.50 tons papaya and 7.88 tons mukhikachu in one hectare of land instead of growing them separately as sole crop. The results were in agreement with observations made by Ali et al. (2016) who reported that relative yield total (RYT) values of intercropping were higher than that of monocrop corn and soybean.

Effect of intercropping on competition functions

Land Equivalent Coefficient (LEC)

The LEC measure mixture productivity which also measures intercrop interaction proved to be a superior index for the evaluation of mixture performance. Land equivalent coefficient values ranged from 0.20 to 0.61 (Table 4). The highest LEC (0.61) value was found in growing pineapple with papaya in intercropping system 100% Pineapple: 66% papaya). These results probably due to yielding ability of 100% pineapple + 66% papaya (T_2) was more constant through the coordination of the interaction for above and/or below ground competition than other intercropping system. These results show that competitive pressure between pineapple and papaya was lower than mukhikachu when grown together in the same field indicating a substantial land use advantage of intercropping. Thus, mukhikachu was less competitive to adverse effects of pineapple shading by increasing plant density per unit area. These results are in the same context of those obtained by Metwally et al. (2018).

Area Time Equivalent Ratio (ATER)

The ATER included the duration of the intercrops in intercropping systems in the field and also evaluated the crop yield per day basis. ATER values were found greater than unity in pineapple (100%) + Papaya (66%) and pineapple (100%) + papaya (66%) + mukhikachu (40%) intercropping systems. Pineapple (100%) + papaya (66%) + mukhikachu (40%) intercropping system (T_3) recorded the higher ATER value (1.14) which was 3.64 and 22.25 % higher than ATER values obtained from pineapple (100%) + papaya (66%) intercropping system (T_2) and pineapple (100%) + mukhikachu (40%) intercropping system (T_1) which indicating higher per day yield (Table 4). ATER values also similar to LER were higher in pineapple (100%) + papaya (66%) + mukhikachu (40%) proportion of sowing. So, the intercropping system was found to be advantageous in comparison to monoculture. This was achieved due to the development of temporal as well as spatial complementary. Khan et al. (2018) reported that ATER was higher in maize (100%) + garden pea (66%) in between two rows of maize which corroborated the findings of the present investigation.

Replacement Value of Intercropping (RVI)

The RVI value of intercropping is one of the better measures of economic advantage of intercropping system. Higher value (3.67) of RVI was observed in pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired rows of pineapple (T_3) intercropping system (Table 4). This implies that farmers practice intercropping of papaya (66%) + mukhikachu (40%) in between two paired rows of pineapple (T_3) could be making 267% more profit than the farmers who are involved in pineapple, mukhikachu and papaya monocropping. Islam et al. (2016) recorded higher RVI values due to intercropping turmeric-sesame as compared to their monoculture which corroborated the present findings.

System Productivity Index (SPI)

The SPI which standardized the yield of the secondary and tertiary crops in terms of the main crop (pineapple) and also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance (Tajudeen, 2010). The SPI values ranged from 57.57 to 70.35. The results showed that pineapple (100%) + papaya (66%) in between two paired rows of pineapple (T_2) intercropping system gave the highest SPI value (70.35) than other intercropping systems (Table 4). The values of SPI were higher and largely determined by pineapple intercrop yields which were not much reduced by intercropping with papaya. This result is supported by the findings of Islam et al. (2016) in turmeric-sesame intercropping.

Monetary Advantage Index (MAI)

The MAI values were positive in all intercropping systems (Table 3). The result also gives an indication of the yield and economic advantages in pineapple + mukhikachu + papaya intercropping systems over their sole cropping. The highest MAI (Tk. 3,19,165 ha^{-1}) was obtained in pineapple (100%) + papaya (66%) + mukhikachu (40%) in between pineapple lines (T_3), which implied that the planting pattern was highly economical and advantageous for the mixtures. The results are in agreement with the finding of Islam et al. (2016) who reported that higher MAI values found in turmeric-sesame intercropping systems compared to sole cropping system.

Table 4. Land equivalent coefficient, area time equivalent ratio, replacement value of intercropping, system productivity index and monetary advantage index of pineapple, mukhikachu and papaya in intercropping system during 2016-18 and 2018-20.

Treatment	LEC	ATER	RVI	SPI	MAI (Tk ha^{-1})
T_1	0.39	0.93	2.61	57.57	109550
T_2	0.61	1.10	3.33	70.35	229155
T_3	0.20	1.14	3.67	59.00	319165
T_4	-	-	-	-	-
T_5	-	-	-	-	-
T_6	-	-	-	-	-

T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%) and T_3= Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Sole pineapple, T_5= Sole mukhikachu and T_6= Sole papaya.

Aggressivity

The competitive ability of the component crops in an intercropping system is determined by its aggressivity value. Regardless of the intercropping system, there was a positive sign indicating dominant crop (+ve) and a negative sign appeared as dominated crop (-ve). Data showed positive aggressivity for mukhikachu at pineapple (100%) + mukhikachu (40%) and positive aggressivity for papaya at pineapple (100%) + papaya (66%) in between two pineapple lines intercropping system (Table 4). Higher aggressivity value was calculated with pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two pineapple lines planting pattern while it proved less competitive and was dominated by pineapple (100%) + papaya (66%) + mukhikachu (40%) intercropping system.

Competitive Ratio (CR)

The competitive ratio values showed variation among the intercropping indicating differential competitive ability of component crops as influenced by intercrops of mukhikachu and papaya (Table 4). Papaya showed higher value of CR (1.31-1.55) followed by mukhikachu (1.16-1.55) and pineapple (0.64-0.70) indicating papaya and mukhikachu as the better competitor than pineapple. Lower value of difference in CR indicated more similarities of competitiveness but higher value of difference indicated more dissimilarities of competitiveness among the species grown in mixture. Consequently, pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired rows of pineapple (T_3) intercropping system with higher difference of CR (1.77) exhibited dissimilarities competitiveness between the component crops. However, Pineapple (100%) + mukhikachu (40 %) and Pineapple (100%) + papaya (66%) in between two paired rows of pineapple (T_1 and T_2) intercropping system with lower difference of CR (0.91) showed merely similar competitiveness between the component crops. The results expressed that similar competitiveness with minimum CR between component crops provided complementary utilization of growth resources for better performance of intercropping with higher productivity. These results are in agreement with the findings of Islam et al. (2016).

Table 5. Aggressivity index, competitive ratio and relative crowding coefficient pineapple, mukhikachu and papaya in intercropping system during 2016-18 and 2018-20

Treatment	Aggressivity (A)			Competitive ratio (CR)			
	Pineapple	Mukhikachu	papaya	Pineapple	Mukhikachu	papaya	Difference
T_1	-0.424	0.424	-	0.64	1.55	-	0.91
T_2	-0.423	-	0.423	0.64	-	1.55	0.91
T_3	-1.340	-1.070	-0.660	0.70	1.16	1.31	1.77
T_4	-	-	-	-	-	-	-
T_5	-	-	-	-	-	-	-
T_6	-	-	-	-	-	-	-

T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%) and T_3= Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Pineapple (100%), T_5=Mukhikachu (100%), T_6= Papaya (100%).

Relative Crowding Coefficient (K)

Total relative crowding coefficient is a measure of the relative dominance of one species over the other in a mixture. The crop component that a higher coefficient was said to be dominant. Total relative crowding coefficient value of pineapple, mukhikachu and papaya was more than unity indicating greater non-competitive interference than the competitive one. The intercropped papaya had higher relative crowding coefficient values (5.02 to 5.72) than the intercropped mukhikachu (2.38 to 2.77) and pineapple (1.54 to 2.85). Positive K values were obtained in all intercropping system (Table 6). In this study, 100% pineapple + 40% mukhikachu + 66% papaya (T_3) had the maximum K value (39.63) after that 100% pineapple + 66% papaya (T_3) and100% pineapple + 40% mukhikachu (T_1) with 12.98 and 3.67 were recorded, respectively. This result is supported by the findings of Islam et al., (2016) in turmeric-sesame intercropping.

Table 6. Relative crowding coefficient (K) of pineapple, mukhikachu and papaya in intercropping system during 2016-18 and 2018-20

Treatment	Relative Crowding Coefficient (K)			
	Pineapple (K_p)	Mukhikachu (K_m)	Papaya (K_{pa})	Total
T_1	1.54	2.38	-	3.67
T_2	2.27	-	5.72	12.98
T_3	2.85	2.77	5.02	39.63
T_4	-	-	-	-
T_5	-	-	-	-
T_6	-	-	-	-

T_1= Pineapple (100%) + Mukhikachu (40%), T_2= Pineapple (100%) + Papaya (66%) and T_3= Pineapple (100%) + Papaya (66%) + Mukhikachu (40%), T_4= Pineapple (100%), T_5=Mukhikachu (100%), T_6= Papaya (100%).

CONCLUSION

Two years average result indicated that intercropping pineapple with mukhikachu and papaya gave higher productivity as well as economic return than monoculture of component crops. The equivalent yields, relative yields, land equivalent ratio and economic return were found higher in 100% pineapple +66% papaya +40% mukhikachu intercropping system. The competitive functions also showed that intercropping had a major advantage over sole cropping. Thus, it could be concluded that a planting pattern comprising on pineapple (100%) + papaya (66%) + mukhikachu (40%) in between two paired rows of pineapple intercropping system should be adopted for better productivity and to get maximum profit. So, the farmers of Tangail regions at Madhupur Tract (AEZ-28) could be suggested to cultivate pineapple with papaya and mukhikachu as intercropped instead of sole cropping.

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