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Cropping System Intensification under Rice Based System for Increasing Crop Productivity in Salt-Affected Coastal Zones of Bangladesh

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The field trial was conducted at farmers' field at Bandra village in Amtali upazila of Barguna district and Pankhali village in Dacope upazila of Khulna district in Bangladesh during two consecutive years (2016-17 and 2017-18) starting from monsoon (*aman*) season of 2016. The experiment areas face slight to moderately drought and saline prone and salinity exists at later part of winter season and beginning of summer. Farmers generally cultivate only single transplanted *aman* (T. *aman*) rice during monsoon season a year in south and south-western coastal saline areas. However, the lands remain fallow in other seasons of the year. In this respect, the experiment was designed to increase the cropping intensity as well as crop productivity through crop intensification under rice based cropping systems. In Amtali (Barguna), treatments of the experiment were five cropping patterns *viz*., CP_1 = T. *aman* - Potato - Mungbean - T. *aus*, CP_2 = T. *aman* - Mustard - Mungbean - T. *aus*, CP_3 = T. *aman* - Gardenpea - Mungbean - T. *aus*, CP_4 = T. *aman* - Spinach - Mungbean - T. *aus*, and CP_5 = T. *aman* - Fallow - Fallow (Farmers' practice). Whereas in Dacope (Khulna) six cropping patterns were: CP_1 = T. *aman* - Wheat - Fallow, CP_2 = T. *aman* - Mustard - Fallow, CP_3 = T. *aman* - Gardenpea - Fallow, CP_4 = T. *aman* - Spinach - Fallow, CP_5= T. *aman* - Potato - Fallow, CP_6 = T. *aman* - Fallow - Fallow (Farmers' practice). Research findings showed that the cropping patterns can be established by judicious application of irrigation with comparatively low salinity content surface water (canal/pond). In Amtali, Barguna, T. *aman* - Potato - Mungbean - T. *aus* cropping pattern gave the highest (20.18 t ha^{-1}) rice equivalent yield (REY) (360% higher REY over the farmers' practice). However, in Dacope, Khulna, T. *aman* - Spinach - Fallow registerd the highest REY (13.99 t ha^{-1}) that increased REY by 211% compared to farmers' practice. The improved cropping patterns can be practiced within the polder (embankment for water control) with suitable irrigation water for increasing crop productivity and profitability in salt-affected coastal zones of Bangladesh.

(***Key words:*** *Coastal zone, Crop productivity, Cropping system intensification, Salinity)*

In global climate risk index, Bangladesh has ranked seventh amongst the countries mostly affected by extreme weather events in 20 years since 1998 (Eckstein *et al*., 2019). The anticipated climate change impacts are salinity, sea level rise, flooding, drought, extreme weather condition, erratic rainfall, cyclone and storm surges, which are considered as the major constraints for sustaining agricultural production particularly in the vulnerable southern and south-western regions of Bangladesh. The most vulnerable areas are located outside the polder (embankment for water control) in Patuakhali, Pirojpur, Barishal and Jhalakati districts (IWM-CEGIS, 2007). The master plan for agricultural development in the southern region of Bangladesh focused on improving water management and rejuvenating productivity of degraded lands towards increasing agricultural productivity (MoA and FAO, 2013). Out of 2.86 million hectares of coastal and off-shore lands about 1.056 million ha of arable lands are affected by varying degrees of salinity. Salinity intrusion increased by 27% (0.22 million ha) from 1973 to 2009 in coastal areas (SRDI, 2010). However, lands affected by salinity in southern and south-western regions are about 0.84 million ha. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The factors

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which contribute significantly to the development of saline soil are, tidal flooding during wet season (June - October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November - May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. The stress environment of the south and south-western parts of the country received very little attention in the past. Perennial water-logging due to inadequate drainage and faulty operation of sluice gate facilities restricts potential land use for crop production within the polders (Haque, 2006). The use of agricultural land in the coastal areas is therefore very poor. The average cropping intensity of Bangladesh was 194% in 2015-16, whereas the cropping intensities in greater coastal districts like Patuakhali and Khulna were 146% and 148%, respectively (BBS, 2018).

The cropping systems of southern and south-western regions of Bangladesh are mainly rice based, where most of the lands remain fallow during dry season. Development of climate smart and/or innovative agricultural technologies is essential for sustaining the crop productivity towards improving the food security of the vulnerable people. In the coastal saline area, only 100% cropping intensity is existed where only the T. *aman* - Fallow - Fallow is practiced. In the recent years, cultivation of a wide range of crops such as maize, sunflower, watermelon, wheat, mustard and vegetables after the T. *aman* rice harvest has been expanding around some surface water sources and shallow wells with low salinity water. Adoption of salt tolerant crop varieties along with component technologies on salinity management can increase the cropping intensity and crop productivity remarkably in the coastal saline areas of Bangladesh that would generate employment and additional income for the rural poor. In this respect, the experiment were undertaken to increase the cropping intensity and productivity through crop intensification in rice based cropping system in the salt affected coastal zones of Bangladesh.

MATERIALS AND METHODS

The field experiments were conducted in two consecutive years (2016-17 and 2017-18) on year round basis at Sikanderkhali village (Latitude 22° 07′ 45.842′′ N and longitude 90° 13′ 44.04′′ E) under Amtaliu pazila of Barguna district and at Pankhali village (Latitude 22° 34′ 19.92′′ N and longitude 88° 30′ 39.96′′ E) under Dacopeupazila of Khulna district which belong to the southern and south-western coastal regions of Bangladesh (Figs. 1 and 2).

The experiments were started from July, 2016 through transplanting of monsoon rice (cv. BRRI dhan62 and cv. Benapole Local in Amtali and Dacope respectively).Theexperimentalareaisslighttomoderately drought and saline prone, and face salinity at later part of winter season and beginning of summer. Five cropping patterns *viz*., CP_1 = T. *aman* - Potato - Mungbean - T. *aus*, CP_2 = T. *aman* - Mustard - Mungbean - T. *aus*, CP_3 = T. *aman* - Gardenpea - Mungbean - T. *aus*, CP_4 = T. *aman* - Spinach - Mungbean - T. *aus* and CP_5 = T. *aman* - Fallow - Fallow (Farmers' practice) were the treatment in Amtali, Barguna. Besides, the treatments for Dacope, Khulna were CP_1 = T. *aman* - Wheat - Fallow, CP_2 = T. *aman* - Mustard - Fallow, CP_3 = T. *aman* - Garden pea - Fallow, CP_4 = T. *aman* - Spinach - Fallow, CP_5 = T. *aman* - Potato - Fallow and CP_6 = T. *aman* - Fallow - Fallow (Farmers' practice). The unit plot size was 4m × 5m. After harvesting of T. *aman* rice, the next crops were sown as per cropping sequences of the

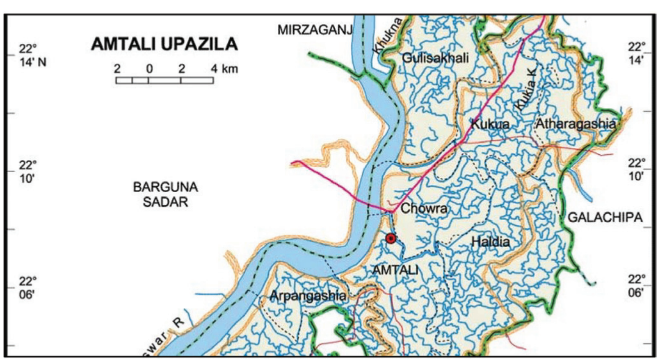

Fig. 1. Map showing the experimental site of Amtali, Barguna

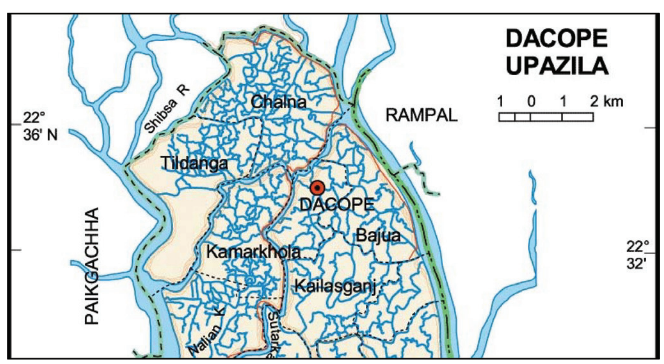

Fig. 2. Map showing the experimental site of Dacope, Khulna

Table 1. *Dates of sowing/planting and harvesting of crops under five cropping patterns in Amtali (2016-17 and 2017-18)*

Cropping patterns	Season	Crop	Variety	Spacing	Sowing/ planting date	Harvesting date
T. *aman* -Potato -Mungbean -T. *aus*	Monsoon	T. *aman*	BRRI dhan62 BRRI dhan39	20 × 15 cm	28 Jul 2016 18 Aug 2017	8-10 Oct 2016 15-18 Nov 2017
	Winter	Potato	Cardinal BARI Alu-72	60 × 25 cm	26 Nov 2016 27 Nov 2017	19 Feb 2017 27 Feb 2018
	Summer	Mungbean	BARI Mung-6	30 cm × 5 cm	23 Feb 2017 1-2 Mar 2018	6 May 2017 10-12May 2018
	Summer	T. *aus*	Parija BRRI dhan48	15 cm × 15 cm	11 May 2017 20-21May 2018	10 Aug 2017 20 Aug 2018
T. *aman* -Mustard -Mungbean -T. *aus*	Monsoon	T. *aman*	BRRI dhan62 BRRI dhan39	20 × 15 cm	28 Jul 2016 18 Aug 2017	8-10 Oct 2016 15-18 Nov 2017
	Winter	Mustard	BARI Sarisha-14	30 cm × 5 cm	26 Nov 2016	19 Feb 2017
	Summer	Mungbean	BARI Mung-6	30 cm × 5 cm	23 Feb 2017 1-2 Mar 2018	6 May 2017 10-12May 2018
	Summer	T. *aus*	Parija BRRI dhan48	15 cm × 15 cm	11 May 2017 20-21May 2018	10 Aug 2017 20 Aug 2018
T. *aman* -Gardenpea -Mungbean -T. *aus*	Monsoon	T. *aman*	BRRI dhan62 BRRI dhan39	20 × 15 cm	28 Jul 2016 18 Aug 2017	8-10 Oct 2016 15-18 Nov 2017
	Winter	Gardenpea	BARI Matorshuti-3	30 × 5 cm	26 Nov 2016	10 Feb 2017
	Summer	Mungbean	BARI Mung-6	30 cm × 5 cm	23 Feb 2017 1-2 Mar 2018	6 May 2017 10-12May 2018
	Summer	T. *aus*	Parija BRRI dhan48	15 cm × 15 cm	11 May 2017 20-21May 2018	10 Aug 2017 20 Aug 2018
T. *aman* -Spinach -Mungbean -T. *aus*	Monsoon	T. *aman*	BRRI dhan62 BRRI dhan39	20 × 15 cm	28 Jul 2016	8-10 Oct 2016
	Winter	Spinach	BARI Palongshak-1	Broadcast	26 Nov 2016 28 Nov 2017	29 Jan 2017 31 Jan 2018
	Summer	Mungbean	BARI Mung-6	30 cm × 5 cm	23 Feb 2017 1-2 Mar 2018	6 May 2017 10-12May 2018
	Summer	T. *aus*	Parija BRRI dhan48	15 cm × 15 cm	11 May 2017 20-21May 2018	10 Aug 2017 20 Aug 2018
T. *aman* -Fallow -Fallow (Farmers' practice)	Monsoon	T. *aman*	BRRI dhan62 BRRI dhan39	20 × 15 cm	28 Jul 2016 18 Aug 2017	8-10 Oct 2016 15-18 Nov 2017

treatment. The crop varieties for Amtali, Barguna and Dacope, Khulna have been summarized in Tables 1 and 2, respectively. Different agronomic practices (like seed/seedling sowing/transplanting, fertilizer management, weeding, mulching, irrigation, plant protection etc.) were done as recommended by standard local best managemet practices (BARI, 2011; FRG, 2012; BARI, 2017) for optimum plant growth and higher yields. The initial soil samples (0-15 cm and 15-30 cm) were collected from the experimental sites for determining the chemical properties. The water and soil salinity as well as weather data were recorded during the crop growing period. The soil and water salinity levels at both the experiment locations (Amtali and Dacope) increased gradually from the month of November but attained the peak in March/April (Figs. 3 and 4). The irrigation water salinity of pond was comparatively higher in Dacope than that at Amtali (Fig. 4), but application of this irrigation water reduced the severe effect of salinity on crop yield particularly in Amtali, Barguna. Besides,

Table 2. *Dates of different ativities under six cropping patterns in Dacope, Khulna (2016-17 and 2017-18)*

Cropping patterns	Season	Crop	Variety	Spacing	Sowing/ planting date	Harvesting date
T. aman -Wheat -Fallow	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017
	Winter	Wheat	BARI gom-25	20 × 5 cm	25 Nov 2016 03 Dec 2017	20 Mar 2017 29 Mar 2018
T.aman -Mustard - Fallow	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017
	Winter	Mustard	BARI sarisha-14	30 × 5 cm	25 Nov 2016 03 Dec 2017	20 Feb 2017 27 Feb 2018
T. aman – Garden pea - Fallow	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017
	Winter	Garden pea	BARI matorshuti-3	30 × 5 cm	25 Nov 2016 03 Dec 2017	12 Feb 2017 20 Feb 2018
T. aman - Spinach - Fallow	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017
	Winter	Spinach	Local	30 cm × Continuous	25 Nov 2016 03 Dec 2017	30 Jan 2017 07 Feb 2018
T. aman - Potato - Fallow	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017
	Winter	Potato	Diamant	60 ×25 cm	25 Nov 2016 03 Dec 2017	20 Feb 2017 28 Feb 2018
T. aman -Fallow -Fallow (Farmers' practice)	Monsoon	T. aman	Benapole local	20 × 15 cm	08 Aug 2016 10 Aug 2017	22 Oct 2016 20 Nov 2017

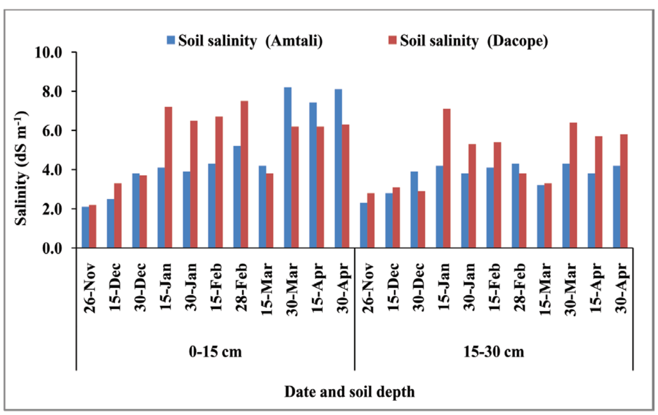

Fig. 3. *Variation of soil salinity at different time periods in 0-15 and 15- 30 cm soil depths during the cropping season at Amtali and Dacope*

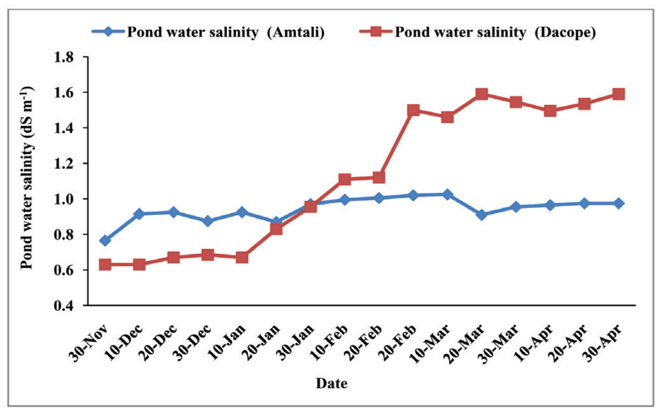

Fig. 4. *Seasonal variation in salinity of pond water used for irrigation in crops at Amtali and Dacope*

rainfall occurred from late March to April and it reduced the soil and water salinity slightly (Fig. 5a & b).

The crops were harvested when the main products attained the physiolocal maturity or harvestable stages. Data were recorded accordingly on different activities as well as parameters of the growing crops. The rice equivalent yield (REY) was calculated to compare system performance by converting the yield of non-rice crops into equivalent rice yield on a price basis, using the formula:

$$REY = Y_x (P_x / P_r)$$

where, Y_x is the yield of non-rice crops (kg ha^{-1}), P_x is the price of non-rice crops and P_r is the price of rice (Lal *et al.*, 2017). In case of rice equivalent yield, data

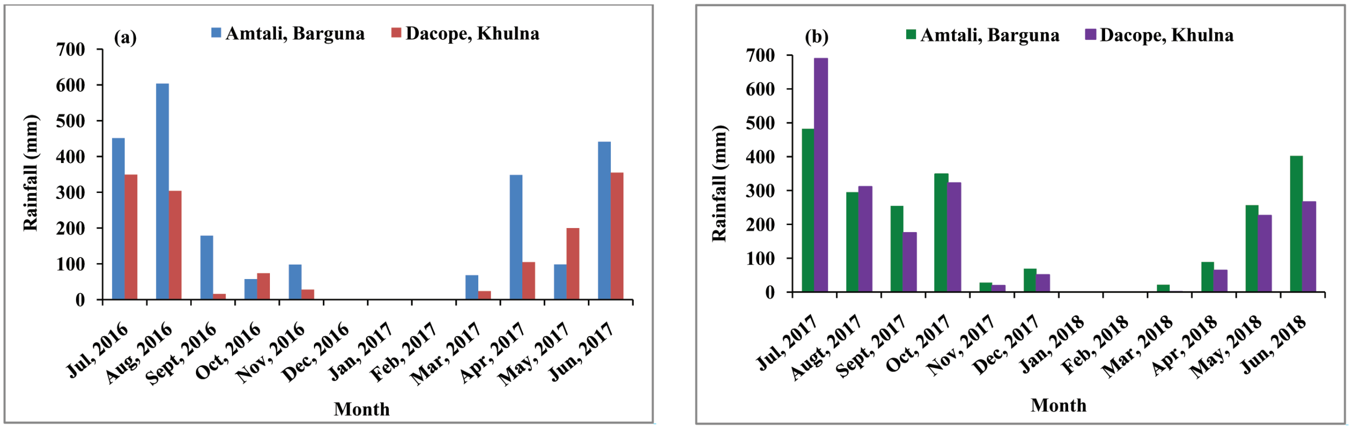

Fig. 5. *Monthly rainfall during the cropping seasons of (a) 2016-17 and (b) 2017-18 at Amtali, Barguna and Dacope, Khulna*

were analyzed statistically and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

In Amtali, Barguna, the five cropping patterns (CP_1 = T. *aman* - Potato - Mungbean - T. *aus*, CP_2 = T. *aman* - Mustard - Mungbean - T. *aus*, CP_3 = T. *aman* - Gardenpea - Mungbean - T. *aus*, CP_4 = T. *aman* - Spinach - Mungbean - T. *aus*, and CP_5 = T. *aman* - Fallow - Fallow) were established following the date of activities as mentioned in Table 1. The grain yields of T. *aman* rice were 3.75 and 5.02 t ha^{-1} in 2016-17 and 2017-18, respectively (Table 3). The T. *aman* rice variety BRRI dhan62 used in 2016-17 gave comparatively lower yield. However, rice variety BRRI dhan39 produced higher yield in 2017-18 due to its higher yield potential than that of BRRI dhan62. Rice variety BRRI dhan62 matured earlier and had yield loss due to attack by insect-pests and birds. Farmers in the research area were

Table 3. *Yields of different crops under five cropping patterns at Amtali, Barguna (2016-17 & 2017-18)*

Cropping patterns	Season	Crop	Product yield (t ha^{-1})		
			2016-17	2017-18	Average
T. aman - Potato - Mungbean - *T. aus*	Monsoon	T. *aman*	3.75	5.02	4.39
	Winter	Potato	18.43	12.50	15.47
	Summer	Mungbean	0.54	0.42	0.48
	Summer	T. *aus*	3.76	3.86	3.81
T. aman - Mustard - Mungbean - *T. aus*	Monsoon	T. *aman*	3.75	5.02	4.39
	Winter	Mustard	1.61	1.04	1.33
	Summer	Mungbean	0.56	0.42	0.49
	Summer	T.*aus*	3.76	3.86	3.81
T. aman - Garden pea - Mungbean - *T. aus*	Monsoon	T. *aman*	3.75	5.02	4.39
	Winter	Garden pea	2.43	2.51	2.47
	Summer	Mungbean	0.50	0.42	0.46
	Summer	T. *aus*	3.76	3.86	3.81
T. aman - Spinach - Mungbean - *T. aus*	Monsoon	T. *aman*	3.75	5.02	4.39
	Winter	Spinach	12.70	12.33	12.52
	Summer	Mungbean	0.41	0.42	0.42
	Summer	T. *aus*	3.76	3.86	3.81
T. aman - Fallow - Fallow (Farmers' practice)	Monsoon	T. *aman*	3.10	5.02	4.39

not interested to sacrifice the yield of their staple crop T. *aman* rice any more, and therefore rice variety BRRI dhan62 was excluded from the research programme in 2017-18. Under different cropping patterns, yields of winter crops like potato, mustard and spinach were higher except garden pea in 2016-17.

In summer season, mungbean cultivated under different cropping patterens gave yield ranges from 0.41 to 0.56 t ha^{-1}. In 2016-17, local T. *aus* rice variety Parija was used under the cropping patterns and gave comparatively lower yield (3.76 t ha^{-1}) but in 2017-18, modern variety of T. *aus* rice namely BRRI dhan48 was used as planting material and produced highest yield of grain (3.86 t ha^{-1}). In case of farmers' practice, T. *aman* rice varieties BRRI dhan62 and BRRI dhan39 produced yields of 3.10 and 5.02 t ha^{-1}, respectively. Farmers in the experiment area generally grow only a single T. *aman* rice a year.

In Dacope, Khulna, the six cropping patterns (CP_1 = T. *aman* - Wheat - Fallow, CP_2 = T. *aman* - Mustard - Fallow, CP_3 = T. *aman* - Garden pea - Fallow, CP_4 = T. *aman* - Spinach - Fallow, CP_5 = T. *aman* - Potato - Fallow, and CP_6 = T. *aman* - Fallow - Fallow) were set up following the date of activities as described in Table 2. The average yield of wheat was 3.07 t ha^{-1}, mustard gave yield of 0.77 t ha^{-1}, green pod yield of garden pea was 4.79 t ha^{-1} and green biomass yield of spinach was 27.5 t ha^{-1} during 2016-17. During 2017-18 season, the average yield of wheat was 1.19 t ha^{-1}, mustard 0.36 t ha^{-1}, green pod of garden pea 2.10 t ha-1, green biomass of spinach 15.20 t ha^{-1} and potato tuber yield was 10.04 t ha^{-1} (Table 4).

In winter season, soil salinity caused remarkable yield reduction of the crops under different cropping patterns. The crop yields from the cropping patterns were comparatively low than that of their potential yields due to soil and water salinity as well as drought. Siringam *et al*. (2011) indicated that soil salinity is one of the serious abiotic stresses that reduce plant growth, development and productivity. Similar results were also reported by SRDI (2010) that the level of soil salinity in southern coastal region generally remains the minimum in monsoon season but it attains to the peak in the month of March/ April. If the sowing time gets delayed as compared to its optimum, then the crop might encounter soil salinity during active vegetative stage and onward that affects the plant growth as well as yield of the crops. *Khan et al*. (2008) observed that irrigation water with EC upto 0.75 dS m^{-1} is suitable for irrigation but above 0.75 dS m^{-1} is not suitable for irrigation for crop production. In this present experimentation, application of saline water with EC above 0.75 dS m^{-1} reduced the yield of winter crops.

Yield contribution and rice equivalent yield under different cropping patterns

In Amtali, Barguna, the rice equivalent yield (REY) of non-rice crops under different cropping patterns was for potato 10.61 t ha^{-1}, mustard 4.56 t ha^{-1}, garden pea 3.53 t ha^{-1}, spinach 10.73 t ha^{-1} and mungbean 1.37, 1.40 and 1.20 t ha^{-1} (Table 5). The computed

Table 4. *Yields of different crops under six cropping patterns in Dacope, Khulna (2016-17 & 2017-18)*

Cropping patterns	Season	Crop	Product yield (t ha^{-1})		
			2016-17	2017-18	Average
T. aman - Wheat - *Fallow*	Monsoon	T. *aman*	4.99	4.00	4.50
	Winter	Wheat	3.07	1.19	2.13
T. aman - Mustard - *Fallow*	Monsoon	T. *aman*	4.99	4.00	4.50
	Winter	Mustard	0.77	0.36	0.57
T. aman - Garden pea - *Fallow*	Monsoon	T. *aman*	4.99	4.00	4.50
	Winter	Garden pea	4.79	2.12	2.45
T. aman - Spinach - *Fallow*	Monsoon	T. *aman*	4.99	4.00	4.50
	Winter	Spinach	27.50	15.20	21.35
T. aman - Potato - *Fallow*	Monsoon	T. *aman*	4.99	4.00	4.50
	Winter	Potato	9.61	10.47	10.04
T. aman - Fallow - Fallow (Farmers' practice)	Monsoon	T. *aman*	4.99	4.00	4.50

Table 5. *Yield contribution and rice equivalent yield (REY) under different cropping patterns in Amtali, Barguna (average of 2016-17 and 2017-18)*

Cropping pattern	Crop yield (t ha^{-1})							REY (t ha^{-1})	REY increase over FP (%)
	T. aman	Potato	Mustard	Garden pea	Spinach	Mung	*T. aus*		
T. *aman* - Potato - Mungbean - T. *aus*	4.39	15.47 (10.61)	-	-	-	0.48 (1.37)	3.81	20.18a	360
T. *aman* - Mustard - Mungbean - T *aus*	4.39	-	1.33 (4.56)	-	-	0.49 (1.40)	3.81	14.16b	323
T. *aman* - Garden pea - Mungbean - T. *aus*	4.39	-	-	2.47 (3.53)	-	0.46 (1.31)	3.81	13.04b	197
T. *aman* - Spinach - Mungbean - T. *aus*	4.39	-	-	-	12.52 (10.73)	0.42 (1.20)	3.81	20.13a	359
T. *aman* - Fallow - Fallow	4.39	-	-	-	-	-	3.81	4.39c	-
CV (%)	-	-	-	-	-	-	-	5.22	-
Level of sig.	-	-	-	-	-	-	-	**	-

**Significant at 1% level of probability; values in parenthesis indicate the rice equivalent yield
Product price: Rice Tk. 17.5 kg^{-1}, potato Tk. 12 kg^{-1}, mustard Tk. 60 kg^{-1}, garden pea Tk. 25 kg^{-1}, spinach Tk. 15 kg^{-1}, mungbean Tk. 50 kg^{-1}

REYs of T. *aman* - Potato - Mungbean - T. *aus* (CP_1), T. *aman* - Mustard - Mungbean - T. *aus* (CP_2), T. *aman* - Garden pea - Mungbean - T. *aus* (CP_3), T. *aman* - Spinach - Mungbean - T. *aus* (CP_4) and T. *aman* - Fallow - Fallow (Farmers' practice) (CP_5) cropping patterns differed significantly. T. *aman* - Potato - Mungbean - T. *aus* cropping pattern showed the highest REY (20.18 t ha^{-1}), which was statistically similar to that of T. *aman* - Spinach - Mungbean - T. *aus* cropping pattern (REY 20.13 t ha^{-1}). The lowest REY (4.39 t ha^{-1}) was obtained from T. *aman* - Fallow - Fallow (Farmers' practice). The increased percentages of REYs under T. *aman* - Potato - Mungbean - T. *aus*, T. *aman* - Mustard - Mungbean - T. *aus*, T. *aman* - Garden pea - Mungbean - T. *aus*, and T. *aman* - Spinach - Mungbean - T. *aus* were 360%, 323%, 197% and 359%, respectively over the farmers' practice T. *aman* - Fallow - Fallow cropping pattern.

In Dacope, Khulna, the two year's average (2016-17 and 2017-18) yield of T. *aman* rice was 4.50 t ha^{-1} under different cropping patterns (Table 6). The T. *aman* - Wheat - Fallow cropping pattern gave the grain yield of wheat 2.13 t ha^{-1} (REY 1.94 t ha^{-1}). T. *aman* - Mustard - Fallow cropping pattern produced the mustard yield of 0.57 t ha^{-1} (REY 1.50 t ha^{-1}). The yield for garden pea (green pod), spinach (green biomass) and potato (tuber) were 3.45, 21.35 and 10.04 t ha^{-1} in T. *aman* - Garden pea - Fallow, T. *aman* - Spinach - Fallow, and T. *aman* - Potato - Fallow, respectively. The REY varied significantly in different cropping patterns as studied under this experiment. The REY was highest (13.99 t ha^{-1}) in T. *aman* - Spinach - Fallow cropping pattern followed by T. *aman* - Potato - Fallow (8.96 t ha^{-1}). Besides, T. *aman* - Garden pea - Fallow, T. *aman* - Wheat - Fallow, and T. *aman* - Mustard - Fallow showed the REYs of 8.32, 6.44 and 6.00 t ha^{-1}, respectively. However, the lowest REY (4.50 t ha^{-1}) was obtained from T. *aman* - Fallow - Fallow cropping pattern (farmers' practice). The REY increased the highest (211.12%) due to practicing of T. *aman* - Spinach - Fallow cropping pattern over the T. *aman* - Fallow - Fallow cropping pattern (farmers' practice). The T. *aman* - Potato - Fallow, and T. *aman* - Garden pea - Fallow cropping patterns also increased the REY remarkably (99.22% and 85.09%, respectively). It can be noted that spinach crop inheritantly and potato variety BARI alu-72 can tolerate soil salinity to some extent. The REY increased the lowest (33.48%) by T. *aman* - Mustard - Fallow cropping pattern followed by T. *aman* - Wheat - Fallow (43.27%). Lal *et al*., (2017) noted that rice-rice system and rice fallows are no longer sustainable for South Asian countries. Crop and varietal diversification of the rice-based cropping systems may improve the productivity and profitability of the systems. Diversification is also a viable option to mitigate the risk of climate change. In coastal saline

Table 6. *Yield contribution and rice equivalent yield under different cropping patterns in Dacope, Khulna (average of 2016-17 and 2017-18)*

Cropping pattern	Crop yield (t ha^{-1})						REY (t ha^{-1})	REY increase over FP (%)
	T. *aman*	Wheat	Mustard	Garden pea	Potato	Spinach		
CP_1 = T. *aman* - Wheat - Fallow	4.50	2.13 (1.94)	-	-	-	-	6.44c	43.27
CP_2 = T. *aman* - Mustard - Fallow	4.50	-	0.57 (1.50)	-	-	-	6.00c	33.48
CP_3 = T. *aman* - Garden pea - Fallow	4.50	-	-	3.45 (3.82)	-	-	8.32b	85.09
CP_4 = T. *aman* - Spinach - Fallow	4.50	-	-	-	-	21.35 (9.49)	13.99a	211.12
CP_5 = T. *aman* - Potato - Fallow	4.50	-	-	-	10.04 (4.46)	-	8.96b	99.22
CP_6 = T. *aman* - Fallow - Fallow	4.50	-	-	-	-	-	4.50d	-
CV (%)	-	-	-	-	-	-	4.86	-
Level of sig.	-	-	-	-	-	-	**	-

**Significant at 1% level of probability; values in parenthesis indicate the rice equivalent yield

Price: Rice grain Tk. 22.5 kg^{-1}, wheat Tk. 20 kg^{-1}, mustard Tk. 60 kg^{-1}, garden pea Tk. 25 kg^{-1}, potato Tk.10 kg^{-1}, spinach Tk. 10 kg^{-1}, 1 Bangladeshi Taka = 85 US Dollar

areas, sufficient residual soil moisture is available in rice fallow system in the post-rainy season (November - December), which can be utilized for establishment of winter crops for intensification of rice-based cropping systems. If planting is delayed then the winter crops may face the drought as well as salinity stresses.

Profitability of the cropping patterns

The profitability analysis of the studied cropping patterns was done by computing the gross return, total variable cost, net return and benefit cost ratio. In Amtali, T. *aman* - Potato - Mungbean - T. *aus* showed the highest gross return, total variable cost and net return followed by T. *aman* - Spinach - Mungbean - T. *aus*. The later cropping pattern gave the highest benefit cost ratio (1.91). T. *aman* - Garden pea - Mungbean - T. *aus* also gave comparatively higher gross return, net return as well as benefit cost ratio (Table 7). On the other hand, T. *aman* - Fallow - Fallow (Farmers' practice) contributed the lowest gross return, total variable cost, net return and benefit cost ratio. In Dacope, the highest gross return, net return and benefit cost ratio were obtained in T. *aman* - Spinach - Fallow cropping pattern followed by T. *aman* - Potato - Fallow (Table 8). Similarly, T. *aman* - Fallow - Fallow (Farmers' practice) recorded the lowest values of all the computed parameters. Introduction of all potential crops and varieties into the existing cropping systems increased the profitability of the improved cropping patterns.

Farmers in Amtali, Barguna opined that the tested cropping patterns have created an opportunity to cultivate more crops in a year. Earlier farmers of this area had no idea about the improved cropping pattern and that is why they used to cultivate only single rice crop (T. *aman* rice) in monsoon and the land remained fallow during rest period of the year. The improved cropping patterns will increase their total crop production and economic return which will ultimately improve their livelihood. Farmers in Dacope, Khulna opined that potato, garden pea, wheat, mustard and spinach gave the satisfactory yield. Therefore, the farmers are interested to cultivate this winter crops after harvest of T. *aman* at that location.

From the two year's experimental results of Amtali, Barguna, it can be concluded that T. *aman* - Potato - Mungbean - T. *aus* (CP_1), T. *aman* - Mustard - Mungbean - T. *aus* (CP_2), and T. *aman* - Spinach - Mungbean - T. *aus* (CP_4) cropping patterns might be suitable. However, different winter crops may be grown successfully during rabi season in Dacope, Khulna for increasing cropping intensity and productivity in southern coastal area of Bangladesh.

Table 7. *Profitability of different cropping patterns in Amtali, Barguna*

Cropping pattern	Gross return (Tk)	Total variable cost (Tk)	Net return (Tk)	Benefit cost ratio
T. *aman* - Potato - Mungbean - T. *aus*	454050	258762	195288	1.75
T. *aman* - Mustard - Mungbean - T. *aus*	318600	187623	130977	1.70
T. *aman* - Garden pea - Mungbean - T. *aus*	293400	157631	135769	1.86
T. *aman* - Spinach - Mungbean - T. *aus*	452925	236591	216334	1.91
T. *aman* - Fallow - Fallow (Farmers' practice)	98775	64285	34490	1.54

Table 8. *Profitability of different cropping patterns in Dacope, Khulna*

Cropping pattern	Gross return (Tk)	Total variable cost (Tk)	Net return (Tk)	Benefit cost ratio
T. *aman* - Wheat - Fallow	114750	87467	27283	1.31
T. *aman* - Mustard - Fallow	111600	76315	35285	1.46
T. *aman* - Garden pea - Fallow	142425	82871	59554	1.72
T. *aman* - Spinach - Fallow	242100	93719	148381	2.58
T. *aman* - Potato - Fallow	190350	121823	68527	1.56
T. *aman* - Fallow - Fallow (Farmers' practice)	90000	65136	24864	1.38

*1 US Dollar = 85 Bangladeshi Taka (Tk)

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