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IMPROVEMENT OF WHEAT- JUTE-T. AMAN RICE CROPPING PATTERN FOR INCREASING SYSTEM PRODUCTIVITY IN LEVEL BARIND TRACT

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ABSTRACT

Increasing system productivity in a planned way is an important base for attaining food security. Improvement of the existing pattern through changing with high yield potential modern crop varieties can enhance the system productivity of that cropping system. Keeping this view in mind, a field trial was conducted at the farmers' field in Level Barind Tract of Joypurhat districts of the two consecutive years 2014-15 and 2015-16 to improve Wheat-Jute-T.aman cropping pattern by including modern high yielding varieties. There were two treatments i.e, T1: Existing cropping pattern: Wheat (BARI Gom-24)-Jute (Local/Indian)-T.aman (GutiSwarna) and T2: Improvedcropping pattern: Wheat (BARI Gom-26)-Jute (O-9897)-T.aman (BRRI dhan49). The introduced improved cropping pattern produced the higher system productivity based on rice equivalent yield, REY (17.78 t ha-1), than the existing cropping pattern (15.25 t ha-1), which is higher than the existing pattern. Production efficiency was increased by 17.84% in the improved pattern. The marginal return and marginal cost were calculated as Tk 51865 ha-1 yr-1 Tk 18079 ha-1 yr-1 which together contributed to the marginal benefit-cost ratio (MBCR) of 2.87 in the improved cropping pattern over the existing cropping pattern. The replacement of the local varieties by high-yielding ones played a significant role in increasing the system productivity as well as farm profitability.

INTRODUCTION

The annual sequence, temporal and partial arrangement of plants in a given area is a cropping pattern. It depends on physical, cultural, economic, social, and institutional factors and government policies (Agrawal and Kassam, 1976). Climate change, population expansion, food shortages, poverty, and famine are the main challenges of the 21st century and include accelerated land coverage and environmental damage (Neamatollahi et al., 2017). Around 1 billion people in the world continue to starve because of insufficient food supplies and by 2050 this will rise to 2 billion by 2050 (FAOSTAT, 2014). This situation is stressing the growing momentum in agricultural production with more than 70% increase in the next few decades for the developing countries of Asia and Africa (Neamatollahi et al., 2017). Improved crop patterns and improved management practices are essential to increase agricultural productivity. The population and urbanization are rapidly changing, land and water resources have become very limited. In the future, an improved crop pattern was developed to exploit the net profit that is subject to some limitations, to determine the optimum use of available resources (Osama et al., 2017). The crop patterns and changes depend on numerous factors such as climate, soil type, rainfall, irrigation, agricultural and other input technology, marketing and transport installations, and agro-industry expansion (Gadge, 2003; Rashid et al., 2005).

Bangladesh is a highly populous country with approximately 200 million people living there. Moreover, the crops are on a decreasing trend and are approximately 1 percent per year. Bangladesh covers approximately 14.84 million ha of total earth, of which 3.74 million ha (25 percent) are not suitable for cultivation due to urban deployment, commercial constructions, rural homes, and roads, etc. (Quasem, 2011). Therefore, we need to produce huge food on a small amount of land to declare food safety for increasing populations in the future. Improve cropping patterns can play a potential role in achieving country's food security. With this view to increase crop productivity, production efficiency, and economic return through intensifying cropping intensity as well as crop diversity by transforming three crops pattern, this experiment was conducted. Wheat–Jute-T.*aman* rice is one of the major cropping patterns in the Joypurhat area. Most of the farmers cultivate BARI Gom 24 of wheat, local/Indian of jute, and Gutiswarna/Mamun/BR-11 of T.aman variety which all are of low yield potential than the modern crop variety. These varieties are not only lowered yielders but also are susceptible to stress and pests. Recently BARI, BJRI, and BRRI developed new varieties of wheat, jute, and T.aman respectively. Replacing the local cultivars with modern varieties such as BARI Gom-26/28 for wheat, O-9897 for jute and BRRI dhan49 for T.aman may contribute to a 10-20% higher yield than the existing one. Improved patterns were 9%-18% higher yield compared to that of farmers' pattern with only 3% extra cost (Kamruzzaman *et. al.*, 2015). Therefore, the experiment was undertaken to improve the existing cropping pattern by replacing traditional varieties with a modern one.

MATERIALS AND METHODS

The study was conducted in the farmers' field at a multi-location testing site, Joypurhat under the Level Barind Tract agro-ecological zone during 2014-15 and 2015-16 to improve Wheat-Jute-T.*aman* cropping pattern through replacing the existing cultivars with high potential modern variety for higher yield, system productivity as well as economic return.

Climatic condition & soil characters

The climate of the experimental site is subtropical monsoon with high rainfall from May to September. The annual average rainfall is 2086 mm, of which 93% occurs from May to October. Monthly average temperature ranges 18.2°C in January to 28.6°C in August, with maximum and minimum values of 34.4°C and 11.6°C in April and January, respectively (Table 1). The soil of the experimental site was sandy and silty alluvium, rich with weatherable minerals with slightly alkaline in reaction (FRG, 2012). Initial soil was collected from the plot before starting the experiment and analyzed accordingly. The soil status showed that organic matter was very low, nitrogen was limiting whereas, K, S, Zn, and B status were very low to medium (Table 2).

The experiment was laid out in a randomized complete block design with six dispersed replications. There were two treatments i.e, T_1:Existing Cropping Pattern: Wheat (BARI Gom-24)-Jute (JRO-524)-T.*aman* (Gutiswarna) andT_2: Improved Cropping Pattern: Wheat (BARI Gom-26)-Jute (O-9897)-T.*aman* (BRRI dhan49). The unit plot size was 1320 m^2. All agronomic activities including sowing/transplanting, harvesting, spacing, fertilizer dose are presented in Table 3. Recommended fertilizer package following Fertilizer Recommendation Guide-2012 (BARC, 2012) along with the application methods were done to support the normal growth of the crops. Intercultural operations were followed by the standard method. No remarkable pest was observed in wheat and Jute. In T.aman rice, stem borer and sheath blight was observed in some plots. Folicure (Tebuconazole) 0.5 ml/Lwas sprayed to control sheath blight and Virtako (Thiomethazm) 40 WG @ 1.5g/10 L for stem borer.

Grain yield was determined by harvesting a 16 m^2 (4m × 4m) area in the center of each plot. The grain was manually threshed and fresh grain and straw weights were determined. Rice equivalent yield (REY) was calculated to compare system productivity by converting the yield of each component crop into equivalent rice yield using the formula: REY (of crop x) = Y× (Px /Pr) Where, Y\x is the yield of crop 'x' (tons harvested product ha^{-1}), P\x is the price of crop, x and Pr is the price of rice (Biswas et al., 2006). The production efficiency (PE) value was calculated by dividing the total grain production ha^{-1} in a sequence with the total duration of crops in a sequence (Tomar and Tiwari, 1990). The total field duration of a cropping system expressed in the percentage of 365 days was taken as the land-use efficiency, LUE of the system (Tomar and Tiwari, 1990). The cost and return analysis are included gross return, total variable cost (TVC), gross margin, and marginal benefit-cost ratio (MBCR). The gross return for each cropping pattern was calculated by multiplying the market price with crop yield while the gross margin for each cropping pattern was calculated by subtracting the TVC from gross return. The MBCR of improved cropping pattern over farmers existing patterns can be computed as the marginal value product (MVP) over the marginal value cost (MVC). as manually threshed and fresh grain and straw weights were determined.

For economic comparison between two crop sequences, the yield of all crops was converted into rice equivalent yield based on the prevailing market price of individual crops. The economic indices i.e. gross return, gross margin, and benefit-cost ratio were also calculated considering the prevailing market price of the commodities. Relevant data were taken and analyzed statistically following Gomez and Gomez, 1984.

RESULTS AND DISCUSSION

Performance of existing and improved cropping pattern

The yield of component crops under the existing pattern is presented in Table 4. In the existing pattern, the yield of wheat, Jute, and T.*aman* was lower than that of the respective crops cultivated in the improved pattern due to the use of earlier varieties. BARI Gom-24 an earlier released variety of wheat, locally adopted JRO-524 (Jute) and Guti Swarna (T.*aman* rice) contributed to the economic yield of 3.25, 2.33, and 4.78 t ha^{-1}in 2014-15 and 3.23, 2.73 and 4.73 t ha^{-1}in 2015-16, respectively. Lower yield in the local cultivar under the existing pattern might be due to lower yield potentiality or more susceptibility to stress and pests or the use of imbalanced fertilizers by the farmers for crop production. The yield of component crops under the improved pattern is presented in Table 5. In the improved pattern, the yield of wheat, Jute, and T.*aman* was higher than that of the respective crops cultivated in the existing pattern due to the use of modern high yield potential variety. BARI Gom-26 a drought and heat tolerant variety of wheat, higher yield potential jute variety (O-9897), and BRRI dhan49 (T. *aman* rice) contributed to higher economic yield 4.15, 2.76, and 5.26 t ha^{-1}in 2014-15 and 4.12, 3.12 and 5.21 t ha^{-1}in 2015-16, respectively which are averagely 27.62%, 16.21%, and 10.09% higher than the respective crop varieties used in the existing pattern. Higher yield of the new varieties might be due to yield potentiality, tolerance to heat and drought stress as well as balanced use of fertilizers.

As for the comparison between existing and improved cropping patterns, it was revealed that the improved system gave a better performance for the improved characteristics of the varieties of the selected crops in the cropping pattern. According to (Al-Musa et al., 2013), BARI Gom-26 produced the highest yield than other wheat varieties of BARI, and BARI Gom-24 produced the lowest yield. Results showed that the various cultivars had varying stress tolerances for per hectare production. In our experiment, it was also revealed that BARI Gom-26 gave more yield than BARI Gom-24. Further, according to (Debnath et al., 2018), O-9897 provided the highest seed and plant population which ensure more fiber than JRO-524 which was also proved by our experiment. Furthermore, BRRI dhan49 could be grown with a 20% higher grain yield than other varieties (BRRI Annual Report, 2009-10). As per discussion and references, the improved cropping pattern can be easily replaced in the existing cropping pattern due to its high yield performance.

System productivity, production efficiency and land use efficiency

System productivity was measured by assessing the rice equivalent yield of the crop sequences and presented in Table 6. The rice equivalent yield of the existing pattern was 14.75 t ha^{-1} and 15.75 t ha^{-1}in 2014-15 and 2015-16 respectively which was increased to 17.33 t ha^{-1} in 2014-15 and 18.24 t ha^{-1} in 2015-16 cropping year. The mean REY was increased from 15.25 t ha^{-1} in the existing pattern to 17.78 t ha^{-1} in the improved cropping pattern. Overall system productivity was increased by 16.59% due to the introduction of new varieties and the use of balanced fertilizer doses in the improved cropping pattern. Although production efficiency was lower in the existing pattern (46.14 $kgha^{-1}day^{-1}$) but it had increased by 17.84% in the improved cropping pattern (54.37 $kgha^{-1}day^{-1}$) due to inclusion of high yield potential varieties instead of traditional cutivars. Both the patterns resulted in around 90% land use efficiency and there was no significant diferrence between the cropping patterns. MI Nazrul (2016) reported that the pattern with improved management practice provided a 31% higher yield of T.aman rice and also contributed more rice equivalent yield compared to farmer practice. There was a tendency among the farmers of using more nitrogenous fertilizer for crop production but they were not conscious enough about the application of other fertilizers

Economics

Table 7 displayed the cost and return information. Although increased cultivation costs were approximately 14% more, the gross return of improved pattern was nearly 17% greater than that of the existing pattern. Increased cultivation costs rose from the use of balanced fertilizer and optimum crop management techniques since farmers have generally been used to apply lower doses of fertilizer than crop production except for urea requirements. It was supported by the data that a gross margin of Tk. 56142/ha was obtained for the cropping pattern (T. Aman-wheat-Jute) by Paul PLC et al. 2016. Higher gross return resulted in the marginal return of 51865Tk ha^{-1} against the marginal cost of 18079Tk ha^{-1}which consequently contributed to a marginal benefit-cost ratio of 2.87 in the improved pattern which was supported by the findings of (Uttam et. al., 2020).

CONCLUSION

Considering the rice equivalent yield, production efficiency and economic return, the improved cropping pattern: The improved Wheat (BARI Gom-26)-Jute (O-9897)-T.aman (BRRI dhan49) pattern is superior to the existing cropping pattern; Wheat (BARI Gom-24)-Jute (Local/Indian)-T.aman (GutiSwarna). It may thus be inferred that the improvement through varietal substitution and modern crop management approaches can increase system production by 17 percent in the existing Wheat-Jute-T. Aman cropping pattern.

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TABLES

Table 1. Meteorological data recorded at the experimental site during the study period (2015-16)

Months	Average Temperature (0C)		Average Relative Humidity (%)	Average Rainfall (mm)
	Max.	Min.		
January	24.50	12.02	93.89	0.22
February	28.83	16.20	91.76	0.0
March	32.45	20.77	87.56	0.5
April	32.26	22.62	85.62	7.52
May	34.36	25.34	84.37	6.98
June	33.64	26.86	86.21	2.86
July	32.90	26.86	93.31	1.69
August	32.41	26.17	94.42	1.47
September	33.38	25.96	94.53	1.05
October	33.50	23.42	93.72	0.09
November	31.16	18.95	93.99	0.0
December	25.75	14.01	93.21	0.0

Table 2. Soil analysis values of different samples collected from multi-location testing (MLT) sites at under Joypurhat district

pH	OM (%)	Total N (%)	meq/100g soil	mg/g soil			
			K	P	S	Zn	B
5.74	1.72	0.09	0.15	7.2	17.6	0.64	0.28
Slightly acidic	L	VL	L	VL	M	L	L

Table 3. Crop management practices of existing and improved cropping patterns at Joypurhat during 2014-15 and 2015-16 cropping year.

Parameters	**Existing Cropping Pattern**			**Improved Cropping Pattern**		
Crop	Wheat	Jute	T.*aman*	Wheat	Jute	T.*aman*
Variety	BARI Gom-24	JRO-524	GutiSwarna	BARI Gom-26	O-9897	BRRI dhan49
Sowing date	15-20/11/14 21-23/11/15	7-11/4/15 15-17/4/15	8-15/8/15 05-10/8/16	15-20/11/14 18-20/11/15	7-11/4/15 10-17/4/16	11-15/8/15 05-10/8/16
Spacing	Broadcast	Broadcast	Irregular planting	20 cm x solid row	Broadcast	20 cm × 15cm
Fertilizer dose (CD t ha^{-1}+NPKSZnB ($kgha^{-1}$)	4+130-25-60-25-2.5	86-12-26-14.4	95-10.5-41-10	5+120-30-66-20-2.69-1.27	95-7.4-33-15.6	90-11-41-11
Field duration	117	114	109	118	114	105
Turnaround time	8	10	7	7	12	8
Harvesting date	16-21/3/15 16-19/3/16	28-30/7/15 03-05/8/16	20-21/11/15 18-20/11/16	15-21/3/15 16-18/3/16	28-31/7/15 02-04/8/16	17-20/11/15 16-19/11/16

Table 4. The yield of component crops under the existing cropping pattern in the Joypurhat region

Parameters	Cropping year 2014-15			Cropping year 2015-16		
Crop	Wheat	Jute	T.*aman*	Wheat	Jute	T.*aman*
Grain/Fibre yield (t ha^{-1})	3.25	2.33	4.78	3.23	2.73	4.73
Straw/Stalk yield (t ha^{-1})	2.87	2.06	4.12	2.72	2.49	4.17

Table 5. The yield of component crops under the improved cropping pattern in the Joypurhat region.

Parameters	Cropping year 2014-15			Cropping year 2015-16		
Crop	Wheat	Jute	T.*aman*	Wheat	Jute	T.*aman*
Grain/Fibre yield (t ha^{-1})	4.15	2.76	5.26	4.12	3.12	5.21
Straw/Stalk yield (t ha^{-1})	2.95	2.41	4.95	3.11	2.81	4.95

Table 6. System productivity (REY*) between the existing and improved cropping pattern in the Joypurhat region

Pattern	Existing pattern		Improved pattern		t-Test	
Year	Cropping year 2014-15	Cropping year 2015-16	Cropping year 2014-15	Cropping year 2015-16	t-value	Significance level
REY (t/ha)	14.75	15.75	17.33	18.24	-	-
Mean REY (t/ha)	15.25		17.78		5.27	**
PE	46.14		54.37		11.23	**
LUE	90.55		89		2.07	NS

NB:REY=Rice equivalent yield, PE=Production efficiency, LUE=Land use efficiency

Table 7. Economic performance of the improved pattern over the existing pattern in the Joypurhat region

Pattern	REY (t/ha)	Gross return (Tk/ha)	Total variable cost (Tk/ha)	Marginal return (Tk/ha)	Marginal cost (Tk/ha)	MBCR
Improved pattern	17.78	364490	152633	51865	18079	2.87
Existing pattern	15.25	312625	134554	-	-	-
t value	5.27	5.27	4.37	-	-	-
Level of significance	**	**	**	-	-	-

Market price: Wheat @ 20 Tkkg-^{1}, Straw @ 1.5 Tkkg-^{1}, Jute (Fibre) @ 50.0 Tkkg-^{1}, Stalk @ 5.0 Tkkg-^{1} and T.aman @ 20.50 Tkkg-^{1}, Straw @ 2.0 Tkkg-^{1}