ISSN 1025-7330

BANGLADESH RICE JOURNAL

VOL. 20 NO. 1 JUNE 2016

BANGLADESH RICE RESEARCH INSTITUTE
GAZIPUR 1701, BANGLADESH

BANGLADESH RICE JOURNAL VOL. 20 NO. 1 JUNE 2016

ISSN 1025-7330

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(Bangladesh Rice J.)

ISSN 1025-7330

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Bangladesh Rice J. 20 (1) : 1-10, 2016

Forecasting Aus Rice Area and Production in Bangladesh using Box-Jenkins Approach

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ABSTRACT

Forecasting of rice area and production is an essential procedure in supporting policy decision regarding food security and environmental issues. The main aim of this paper is to forecast Aus rice area and production in Bangladesh. Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) time-series methodology is considered for modeling and forecasting country's Aus rice area and production data commencing from 1971-72 to 2013-14. It was observed that ARIMA (1, 1, 5) and ARIMA (1, 1, 4) model were performed better than the other ARIMA models for forecasting Aus area and production respectively. The Aus rice areas were forecasted 1041.12 and 499.31 thousand hectares and for production it was 2059.642 and 1781.545 thousand metric tons in 2014-15 and 2023-24 respectively. The forecasted Aus rice area and production both were showed a decreasing trend. Government should create an enabling environment to develop HYV rice varieties for Aus rice crop to ensure ongoing food security by increasing cultivated area and production.

Key words: Aus rice, Box-Jenkins method, non-stationary, ACF and PACF

INTRODUCTION

Agro-based developing country like Bangladesh is striving hard for rapid development of its economy. The economic development of the country is mainly based on agriculture. The total cultivable area in Bangladesh is about 8.52 Mha and net cultivated area is 7.45 Mha and 0.47 Mha cultivable areas are unplanted. The contribution of agriculture sector in GDP is 19.29 percent. The crop sub-sector dominates with 13.44% from which rice contributes 46%. Almost 47.5% of manpower is directly involved in agriculture. In Bangladesh almost 66% of the labour force depends on agriculture for employment (BBS, 2012). Of all crops, rice plays the leading role by contributing 91% of total food grain production. More than 99% of the people eat rice as their main food @416 gm/person/day. Rice occupies about 76% of total cropped area from where modern varieties cover 84.67% and local varieties cover 15.33%. The present status of area and production of rice is 11.42 million ha and 34.43 million MT (BBS, 2012). The projected population is expected to be 189.85 M by 2030 and it would require 28 million MT of clean rice or 42.50 million MT of paddy (BBS, 2012).

Three major rice crops namely, Aus, Aman and Boro constitute 100% of total rice production and grow in three different seasons. Aus is typically planted in March-April and harvested in June-July and practically harmonized with the climatic season hot summer (March-May). Aus rice occupies about 8.97% of total cropped area from where modern varieties cover 6.65% and local varieties cover 2.32%. And 6.88% of total production comes from Aus rice where modern varieties cover 5.91% and local varieties cover 0.98%. The present status of total area and production of Aus rice is 1.02 million ha and 2.37 million MT (BBS, 2012). The Aus rice area and production is

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decreasing continuously comparing to Boro, which is dominated rice crop in Bangladesh. Boro rice cultivation fully depends on irrigation and the pressure of ground water is increasing day by day and ground water level is going down but Aus rice requires only 5% supplement irrigation and the pressure of ground water is required to be low for Aus than Boro. It is necessary to transfer Boro cultivated area to Aus and also make sure the food security of the country. So if we do forecast the Aus rice area and production then it would help the policy makers to formulate decision in this regard.

The autoregressive integrated moving average (ARIMA) methodology developed by Box and Jenkins (1976) have been used by a number of researchers to forecast demands in terms of internal production, consumption, imports and exports (Muhammed *et al.*, 1992; Shabur and Haque, 1993; Sohail *et al.*, 1994). The forecasting studies on rice using ARIMA model are available by (Raghavender, 2009, 2010; Ravichandran, 2012; Biswas and Bhattacharyya, 2013; Singh *et al.*, 2013; Jambhulkar, 2013) in India; (Pakravan, 2011) in Iran; (Suleman and Sarpong, 2012) in Ghana; (Rahman, 2010; Awal and Siddique, 2011; Hamjah, 2014) in Bangladesh. Keeping the above requirement in view, the present study was carried out to develop an empirical model for forecasting from the observed Aus rice area and production data based on Box-Jenkins ARIMA method.

MATERIALS AND METHODS

Data source

The time series data of Aus rice area and production of Bangladesh for the periods 1971-1972 to 2013-2014, collected from 'Year Book of Agricultural Statistics' is published by Bangladesh Bureau of Statistics (BBS), Bangladesh, used in this study.

Time series model. In this study the methodology first refers to use of ARIMA model as propounded by Box-Jenkins for forecasting of Aus rice area and production in Bangladesh. The Box-Jenkins methodology refers to the set of procedures for identifying, fitting, and checking models with time series data.

(1) A pth-order autoregressive model: AR(p), which has the general form

$$Y_t = \varphi_0 + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + ... + \varphi_p Y_{t-p} + \varepsilon_t$$

where, Y_t = Response (dependent) variable at time t

$Y_{t-1}, Y_{t-2}, ..., Y_{t-p}$ = Response variable at time lags t−1, t−2, . . . , t−p, respectively.

$\varphi_0, \varphi_1, \varphi_2, ..., \varphi_p$ = Coefficients to be estimated

ε_t = Error term at time t

(2) A qth-order moving average model: MA(q), which has the general form

$$Y_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - ... - \theta_q \varepsilon_{t-q}$$

where, Y_t = Response (dependent) variable at time t

μ = Constant mean of the process

$\theta_1, \theta_2, \ldots, \theta_q$ = Coefficients to be estimated

$\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q}$ = Errors in previous time periods that are incorporated in the response Y_t

ε_t = Error term at time t

(3) Autoregressive Integrated Moving Average Model: ARIMA (p,d,q), which has the general form

$$Y_t = \varphi_0 + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + ... + \varphi_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - ... - \theta_q \varepsilon_{t-q}$$

where, p, q and d denote the autoregressive, moving average and differenced order parameter of the process, respectively.

Diagnostic tests of residuals

Jarque-Bera test. The normality assumption is defined here using Jarque-Bera (1987) test, which a goodness of fit measure of departure from normality, based on the sample kurtosis (k) and skewness (s). The test statistics Jarque-Bera (JB) is defined as

$$JB = \frac{n}{6}\left(s^2 + \frac{(k-3)^2}{4}\right) \approx \chi^2_{(2)}$$

where n is the number of observations and k is the number of estimated parameters. The statistic JB has an asymptotic chi-square distribution with two degrees of freedom, and can be used to test the hypothesis of skewness being zero and excess kurtosis being zero.

Box-Pierce Q test. In order to check the adequacy of the model using a chi-square test, known as the Box-Pierce Q statistic, (Box and Pierce, 1970) on the autocorrelations of the residuals, the test statistic Q is defined as

$$Q_m = n(n+2)\sum_{k=1}^{n}(n-k)^{-1} r_k^2 \approx \chi^2_{m-r}$$

where, r_k = the residual autocorrelation at lag k,

n= the number of residuals,

m= the number of time lags includes in the test.

If the p-value associated with the Q statistic is small (p-value $< \alpha$), the model is considered inadequate.

RESULTS AND DISCUSSIONS

Original series

Figure 1 presents the yearly cultivated area and yearly production of rice in Bangladesh from 1971-72 to 2013-14 along with the best (adjudged through R^2 value) fitted trend. Both the curve shows decreasing pattern and also both the trend curve shows cubic trend (R^2=0.98 for area and R^2=0.89 for production and significant at 95% confidence limit).

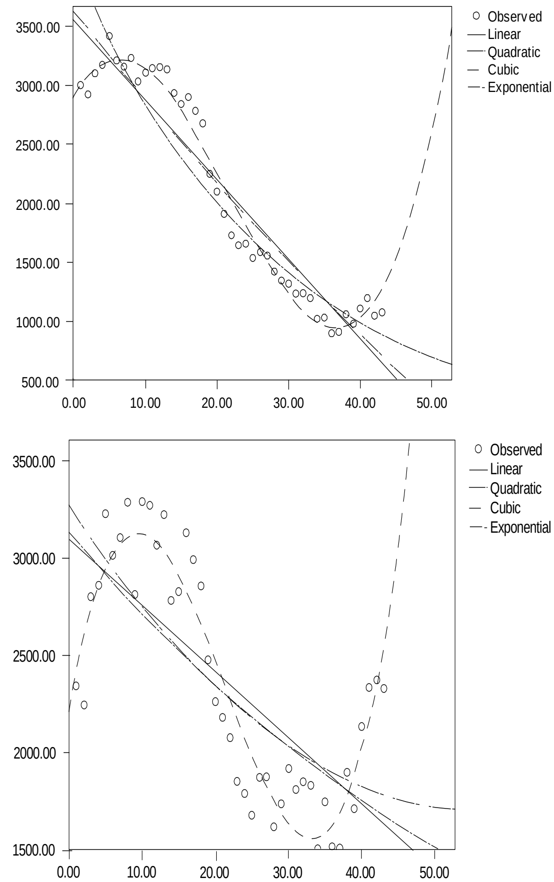

Fig. 1. Trend curve for yearly area and production of Aus rice in Bangladesh.

The normality of the original series has been tested by Jarque-Bera test for normality (Fig. 2). This test is based on the hypothesis that the underlined series is normal. P-value for Aus area and production is 0.072 and 0.147 respectively, indicates that both the series are normally distributed.

Test for stationarity

The assumption of Box-Jenkins ARIMA model is that the underlined time series should be stationary. To test the staionarity of the data, both informal and formal tests have been done.

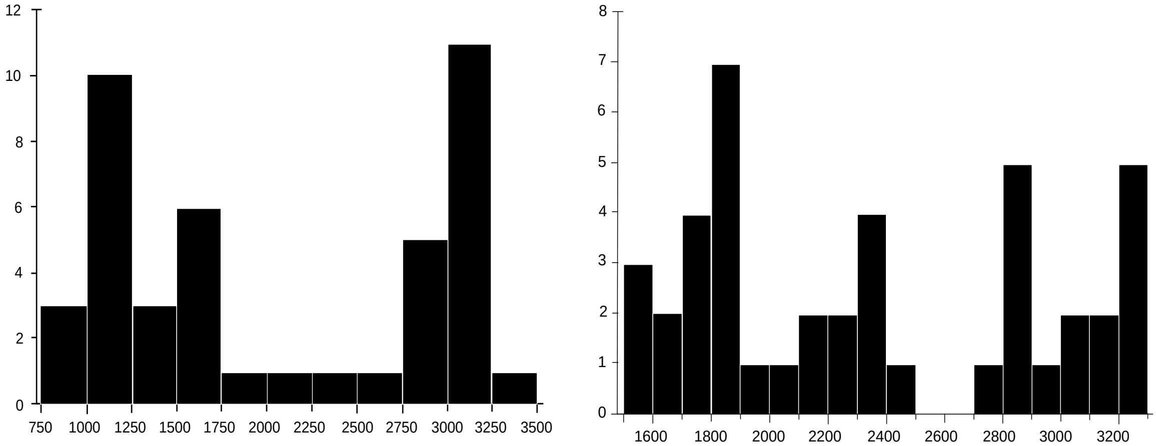

Fig. 2. Normality test of the original series for Aus area and production.

Informal approach (Correlogram). It is clear that from the constructed correlogram (Figs. 3-6) for the both series area and production of Aus rice that the autocorrelation function decaying gradually that indicates the series consists of higher order of moving average term and the fall off of the spike of partial autocorrelation function indicates that there may be one autoregressive coefficient exists in the series. So, it is revealed from the correlogram that the original series for both area and production of Aus rice are not stationary but stationary after taking the first difference. These results support with work of Hamjah (2014).

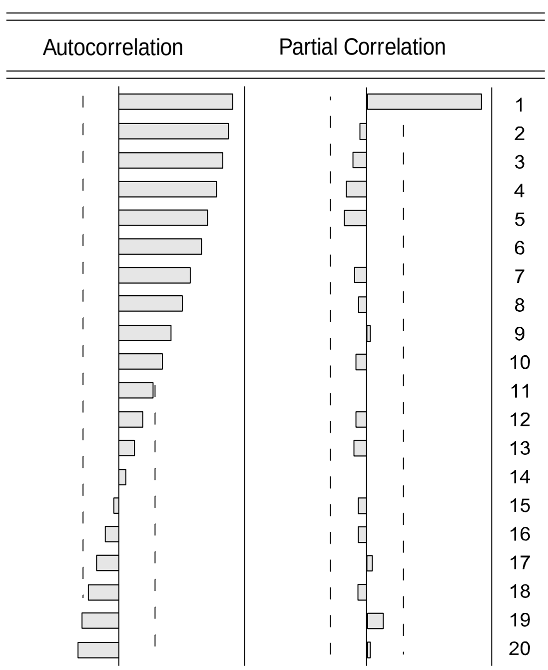

Fig. 3. Correlogram for Aus area (Original series).

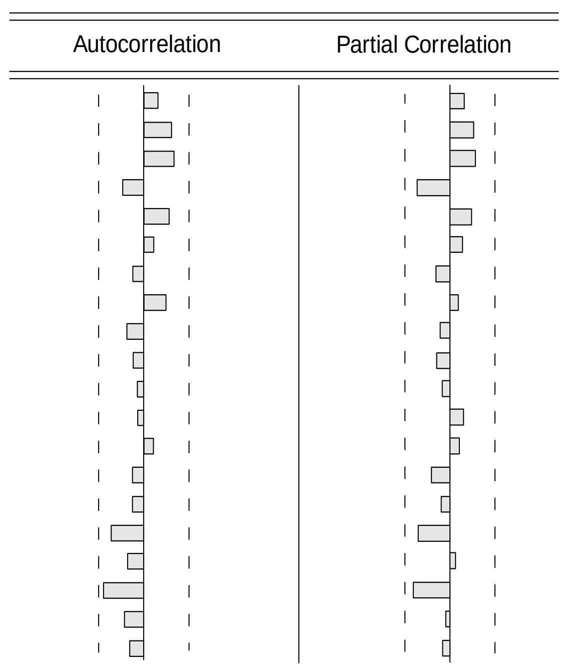

Fig. 4. Correlogram for Aus area (Differenced series).

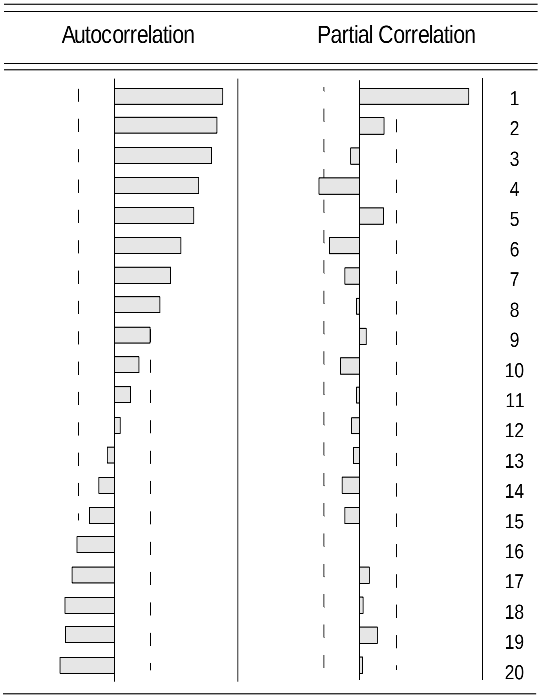

Fig. 5. Correlogram for Aus production (Original series).

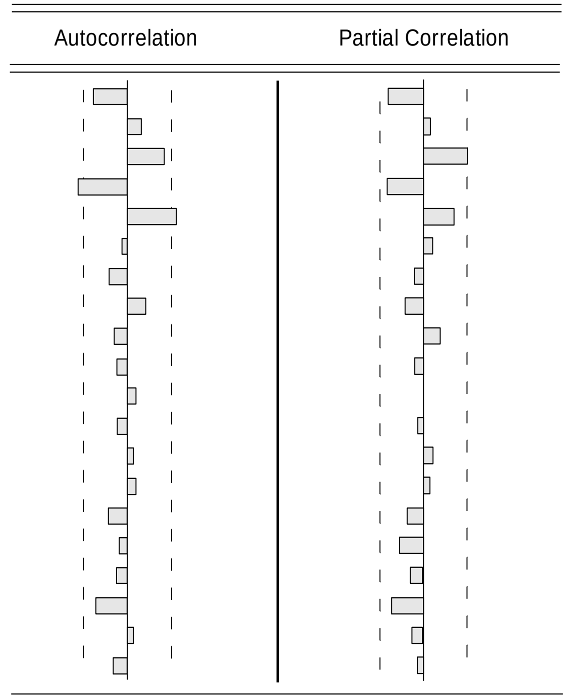

Fig. 6. Correlogram for Aus production (differenced series).

Formal approach (ADF test). The hypothesis of the Augmented Dekay Fuller test is:

H_0: the series has a unit root, i.e. **non-stationary**

H_1: the series has no unit root, i.e. **stationary**

Aus area	Original series	Differenced series
Augmented Dickey-Fuller test	-0.35	-5.71
(P-value)	(0.90)	(0.000)

The non-stationary (P-value=0.90) original series become stationary after taking the difference of order 1.

Aus production	Original series	Differenced series
Augmented Dickey-Fuller test	-1.32	-7.95
(P-value)	(0.61)	(0.000)

Under this hypothesis ADF depicted that at the level the series has a unit root (P-value=0.61) that means the series is not stationary. So, to make the series stationary we take the difference order one that makes the series stationary (P-value=0.000).

Model selection criteria

Some tentative ARIMA models for Aus area and production were considered and the best fitted model is accepted on the basis of minimum RMSE (Root Mean Square Error), MAE (Mean Absoulate Error), MAPE (Mean Absolute Percentage Error), AIC (Akaike's Information Criterion), SBC (Schwarz's Bayesian Criterion), HQ criterion and maximum R^2 and adjusted R^2 value (Tables 1, 2 and 3).

Table 1. Comparison of different ARIMA models with model fit statistics for area of Aus rice.

Model	RMSE	MAE	MAPE	AIC	SBC	HQ criterion	R^2	Adj. R^2
ARIMA (1,1,4)	94.97	70.38	4.04	12.23	12.49	12.33	0.42	0.34
ARIMA (1,1,5)	84.93	69.54	4.02	12.06	12.36	12.17	0.54	0.46
ARIMA (1,1,6)	86.31	72.30	4.24	12.14	12.48	12.27	0.52	0.42

Table 2. Estimated parameters of ARIMA (1,1,5).

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-60.20	32.51	-1.85	0.072
AR(1)	0.41	0.18	2.21	0.034
MA(1)	-0.20	0.11	-1.88	0.048
MA(3)	0.20	0.07	3.01	0.005
MA(5)	0.27	0.06	4.23	0.000
MA(6)	0.66	0.06	10.67	0.000
MA(7)	-0.62	0.10	-5.99	0.000
F-statistic	6.65	Durbin-Watson stat		1.87
Prob (F-statistic)	0.000102			

Table 3. Comparison of different ARIMA models with model fit statistics for production of Aus rice.

Model	RMSE	MAE	MAPE	AIC	SBC	HQ criterion	R^2	Adj. R^2
ARIMA (1,1,3)	175.04	149.72	6.67	13.46	13.71	13.55	0.49	0.42
ARIMA (1,1,4)	155.41	127.76	5.94	13.23	13.48	13.33	0.60	0.53
ARIMA (1,1,5)	156.69	128.10	5.98	13.27	13.56	13.38	0.60	0.53

For the series of production of Aus rice it is observed from the results that ARIMA (1,1,4) provides the best fitted model.

For the series of area of Aus rice it is observed from the results that ARIMA (1,1,5) provides the best fitted model.

From the above tables we have seen that entire coefficient of estimated model is significant at 5% level of significance. The R^2 of the estimated models are 0.54 and 0.53 that implies that about 54 and 53% variation the Aus area and production can be explained by the estimated coefficients and the rest are unexplained, may be due to other factors that are not encountered in this model. Test of autocorrelation was done by Durbin-Watson test and the value of D-W statistics suggested that the estimated coefficients are free from autocorrelation problem. The minimum value of RMSE, MAE, MAPE, AIC, SBC and H-Q criterion are also confirmed. The existing results are supported by Hamjah (2014) and Biswas and Bhattacharyya (2013).

Results of empirical models. Estimation of parameters for area (Table 2) and production (Table 4) suggests the models may be represented mathematically as:

Aus rice area	$\hat{Y}_t = -60.20 + 0.40Y_{t-1} + 0.20\varepsilon_{t-1} - 0.20\varepsilon_{t-3} - 0.27\varepsilon_{t-5} - 0.66\varepsilon_{t-6} + 0.622\varepsilon_{t-7}$
Aus rice production	$\hat{Y}_t = -30.89 - 0.587Y_{t-1} - 0.63\varepsilon_{t-1} - 0.52\varepsilon_{t-3} - 0.55\varepsilon_{t-5} - 0.89\varepsilon_{t-6}$

The time series models those are tested and found satisfactory in all stages of model fitting process being used for estimation of the time series coefficient. These models would be used for forecast purpose, which is the ultimate goal of univariate time series analysis. Moreover, the residual analysis of the estimated models confirmed the stability

Table 4. Estimated parameters of ARIMA (1,1,4).

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-30.89	59.52	-0.51	0.607
AR(1)	-0.581	0.13	-4.22	0.001
MA(1)	0.626	0.042	14.93	0.000
MA(3)	0.516	0.064	8.00	0.000
MA(5)	0.545	0.043	12.60	0.000
MA(6)	0.891	0.029	30.03	0.000
F-statistic	10.11	Durbin-Watson stat		1.82
Prob (F-statistic)	0.000175			

to forecast and others relevant diagnosis of the fitted models. The works of Awal and Siddique (2011), Biswas and Bhattacharyya (2013) and Hamjah (2014) were also observed as the satisfactory and adequate model for rice production forecasting.

Results of residual analysis. The residuals correlogram is a good measure to have the idea about the adequacy of the fitted model (Fig. 7). The constructed correlogram by using the residuals from the fitted models indicate that all the series are free from autocorrelation problem since all the spikes are laying by the limit of permissible lines and that has also been tested by the Q-stat.

Normality test of residuals. Normality of the residuals is a vital issue since it is expected that produced residuals from the model used for estimation process would be dispersed consistently. By assuming the hypothesis that the series under study are normally distributed after being tested and found that all the models produced normal residuals implying the adequacy of the models (Figs. 8 and 9).

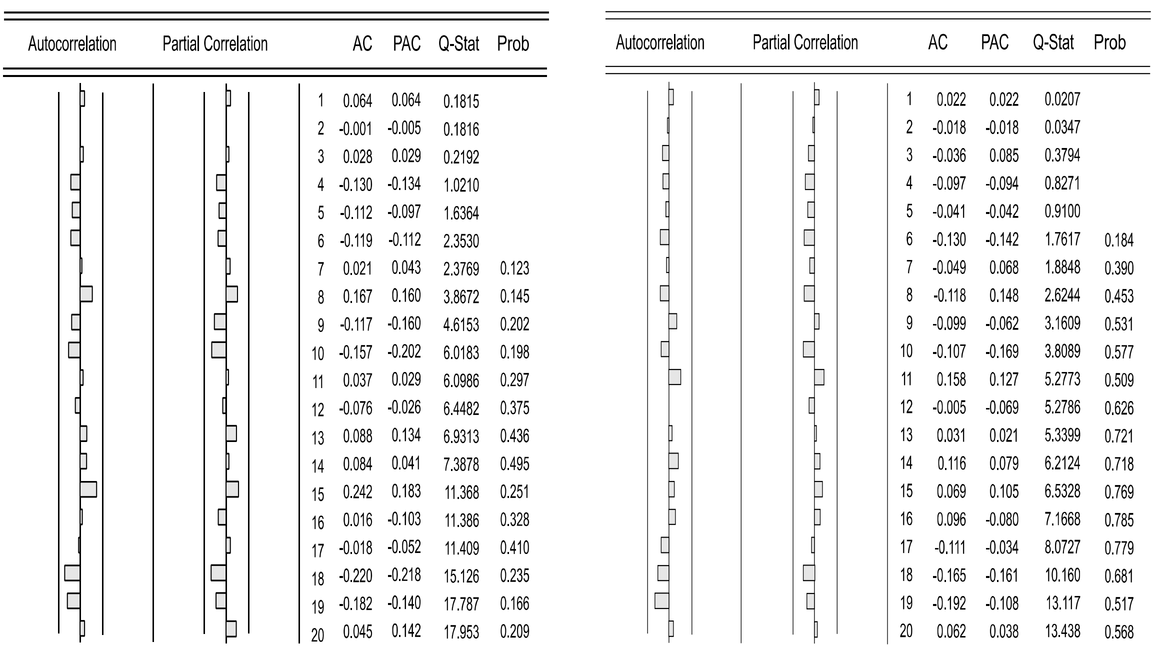

Fig. 7. Correlogram for the residuals of Aus area and production.

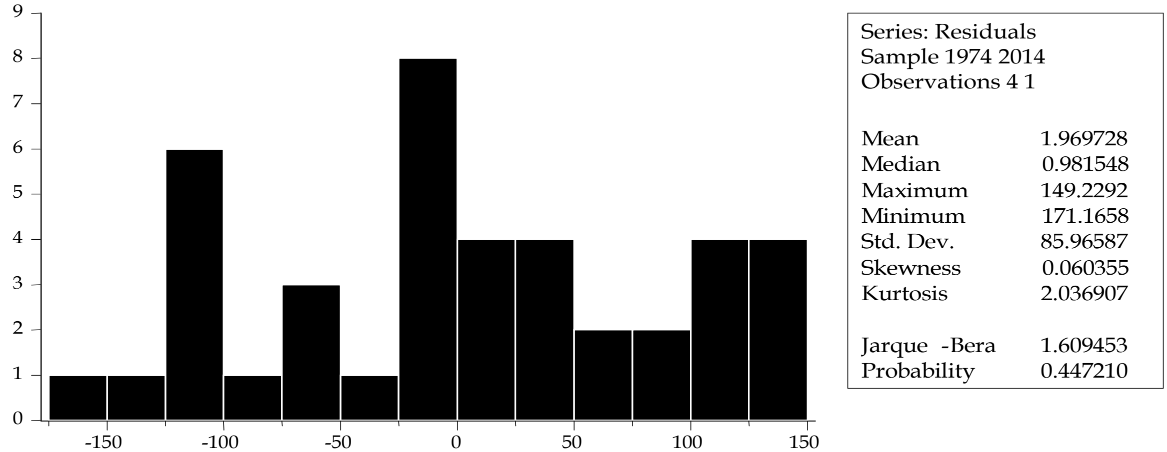

Fig. 8. Normality of residuals for Aus area.

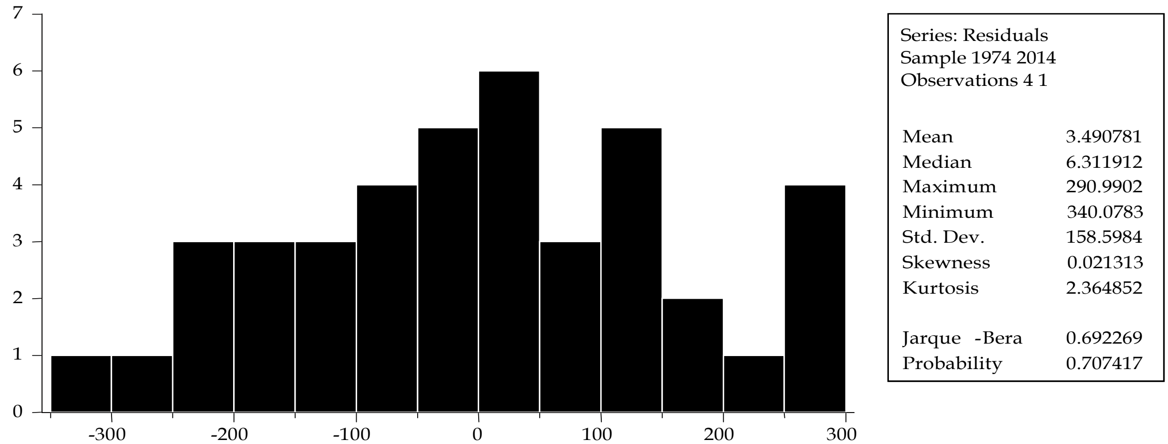

Fig. 9. Normality of residuals for Aus production.

Breusch-Godfrey serial correlation LM test. Breusch-Godfrey serial correlation LM test is based on the hypothesis that the residuals are not serially correlated. The estimated p-value for Aus area and production (p-value=0.65 and 0.94) confirms that the residuals are free from serial correlation.

Aus area	F-statistic	0.428913	Prob. F(2,32)	0.6549
Aus production		0.061797	Prob. F(2,33)	0.9402

Forecasting

Projections have been made for the Aus area and production on the basis of their actual performance during 1971-72 to 2013-14. Table 5 shows these projections. Since the time series model building is an iterative process, until and unless the forecast value found by maintain the proper statistical rigor it is iterated from the identification process. The same things followed here and used the models those strictly avail the criteria for having better forecast. Forecast of Aus rice area and production showed a decreasing trend. The same result for Aus rice production is found in Hamjah (2014) and Awal and Siddique (2011).

Table 5. Forecasted value of area (000′ ha) and production (000′ ton) of Aus rice.

Year	ARIMA (1,1,5)			ARIMA (1,1,4)		
	LPL	Forecast	UPL	LPL	Forecast	UPL
2015	855.12	1041.12	1227.12	1773.64	2059.64	2345.64
2016	794.92	980.92	1166.92	1742.74	2028.74	2314.74
2017	734.72	920.72	1106.72	1711.84	1997.84	2283.84
2018	674.52	860.52	1046.52	1680.94	1966.94	2252.94
2019	614.32	800.32	986.32	1650.04	1936.04	2222.04
2020	554.11	740.11	926.11	1619.14	1905.14	2191.14
2021	493.91	679.91	865.91	1588.24	1874.24	2160.24
2022	433.71	619.71	805.71	1557.34	1843.34	2129.34
2023	373.51	559.51	745.51	1526.45	1812.45	2098.45
2024	313.31	499.31	685.31	1495.55	1781.55	2067.55

LPL: Lower Predictive Value; UPL: Upper predictive value

CONCLUSION

The Box-Jenkins approach as an ARIMA model was used for the patterns of the past movement of a variable to forecast the future values. In this study, a short run forecasting of Aus rice area and production model were formulated. To select the best model for forecasting the latest available model selection criteria such as MSE, RMSE, MAE, MAPE, AIC, SBC, H-Q criterion, R square and Adjusted R square were used. The best selected ARIMA model for forecasting Aus area and production were observed ARIMA (1,1,5) and ARIMA (1,1,4) respectively. The Aus rice area and production of Bangladesh were observed 1041.12 thousand hectare and 2059.64 thousand metric tons in 2014-15 and it were forecasted 499.31 thousand hectare and 1781.55 thousand metric tons for 2023-2024. The forecasted Aus rice area and production showed a decreasing trend. These projections help the government to make policies with regard to relative price structure, production and consumption and also to establish relations with other countries of the world.

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Bangladesh Rice J. 20 (1) : 11-16, 2016

Estimating Area and Production of Rice under Different Crop-cut Methods in Bangladesh

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ABSTRACT

Crop-cut is a widely used and well accepted procedure for estimating rice yield. This yield is then multiplied by the area planted under rice cultivation to determine rice production of the country. In Bangladesh, crop-cut is used to estimate transplanted rice yield. Department of Agricultural Extension (DAE) and Bangladesh Bureau of Statistics (BBS) as the public agencies provide estimate on area and production of rice but they use different methods of crop-cut. The estimates of these two agencies on area and production of rice are different posing a question to the users on the reliability of the estimates. An attempt has been made with the objective to formulate a protocol that provides reliable and unique estimates on rice area and production. It is suggested to make at least three cuts in each plot to minimize the chance of over or under estimation of the whole plot yield and the radius of the circle should be 178.5cm so that the cut area becomes 10 m^2 in order to easy conversion of the crop-cut yield to t ha^{-1}.

Key words: Crop-cut, BBS, DAE, rice, area and production

INTRODUCTION

Rice is the staple food crop and occupies about 80% of the country's total cropped area. To assess the total rice production, it is essential to estimate the accurate yield and production of rice. Real estimation is needed for future projection of rice production in relation to population growth, which is important at national level. Crop cutting in the real sense is a statistical survey method to estimate yield of crop in a population through cutting a crop at small parts of fields. In Bangladesh, crop area figures are compiled on the basis of complete enumeration while the crop yield is estimated on the basis of sample survey approach and crop cut is the most important method of this approach. A series of studies were carried out by the statistician and a scientific technique was developed for conducting the crop cutting experiments to obtain the reliable yield rates (Mahalanobis, 1945; Sukhatme and Panse, 1951; Murthy, 1997). Also, Department of Agricultural Extension (DAE, 1990) and Bangladesh Bureau of Statistics (BBS, 1982) adopted two different methods of crop-cut for yield estimation. DAE estimates yield from a rectangular area of 10 square meters and BBS estimates from a circular area of radius $5'7\frac{1}{2}'' = 9.248\ \text{m}^2$. At least one of the methods may have some limitations as their estimates differ by a substantial degree. So, for the different methods of crop-cut, users and stakeholders often confused about these two organizations method and which one is better for rice yield estimates. Later, BBS (2013) tried to uniform BBS-DAE crop cutting method through Harmonization and Dissemination of Unified Agricultural Production Statistics (HDUAPS) project. Recently, BBS (2014) published a report on crop cutting experiments in Bangladesh. Yet still, in any farmers field the researcher/agriculture

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extension worker, stakeholders has to face the problem for assessing the rice yield through crop-cut method. Because, the researchers, extension personnel and stakeholders have been facing the problem about BBS unified crop cut method. To avoid these sorts of confusions among government agencies a consensus among ministry of Planning, Ministry of Agriculture and Ministry of Food, BRRI statisticians proposed a modified procedure to estimates the yield of rice through crop cut. The objective of this study is to estimate rice yield through crop-cuts at farmers' field and to formulate a protocol that provides suitable estimates of area and production of rice in Bangladesh.

MATERIALS AND METHOD

The technique of crop cut experiment (CCE) has various steps. There is certain equipment/material required for conducting the crop cutting experiments. These are:

- Measuring tape as per requirement (30 or 50 meter)
- Weighing balance as per requirement (Beam of spring balance)
- Set of weights (1, 2, 5, 10, 20, 50, 100, 200, 500; 1, 2 and 5 kg)
- String or rope (30 meter)
- Four pegs
- The Hessian Cloth: is a coarsely woven fabric usually made from vegetable fibers and jute
- Cloth bags for keeping the produce for crying
- Two strong water proof bags (one for keeping crop cutting equipment's and other for keeping schedules and papers etc.)

There are various steps involved in the conduct of crop cutting experiments. These steps are:

- Selection of field (including size and shape of the CCE plot) where crop cutting experiment is to be carried out,
- Locating and marking of the experimental plot of a given size in the selected field,
- Harvesting of the CCE plot,
- Threshing of crop harvested from the CCE plot,
- Winnowing and weighing of the produce obtained from the CCE plot,
- Drying of produce, if it contains moisture, and
- Weight of the dry produce.

The study was conducted at Kapasia upazila of Gazipur in Boro season 2007. The crop-cut was done in a farmer's field in Boro. Farmers were selected randomly. At maturity, crop was cut and yield was estimated following standard procedure. Weight was taken and moisture was adjusted. The present crop-cut methods include the followings:

Method A followed by DAE

For each variety, DAE takes three cuts each of size 5-×-2m, one from good crop, one from intermediate crop and the other from a bad crop in each block. The crop condition (good, intermediate and bad) is judged by visual inspection of crop stand, which is very much subjective and is likely to vary from person to person. Rice area in each season planted to different varieties is determined through farmer's interview by the Sub-Assistant Agriculture Officers (former Block Supervisors). At the block level, the moisture content of crop-cut paddy is used as per directives of the upazila agriculture office. The directives are based on some sample crop-cuts and measurement of moisture content using moisture meter. DAE also uses BBS method of crop-cut where BBS personnel join DAE in crop-cut.

Method B followed by BBS

BBS (BBS, 1982), on the other hand, uses a three-fold instrument (Fig. 1) where crop-cuts are done in three circular areas (Fig. 2). Crops are harvested separately from each shaded area starting from the middle one and weighed. All harvests are then mixed and a sample of one kg of paddy from the harvest is brought to the office and dried for 10 days under room condition and weighed. The sample is then weighed at every evening until the weight becomes stable. The dry weight of paddy for each shaded area is recorded by adjusting the loss in weight of the sample. The three adjusted weights are then added together that gives the dry weight of paddy for the circular area of radius $5^{'}7\frac{1}{2}^{"} \approx 9.248\ m^2$ and converted to t ha^{-1} that represents yield of the plot selected for crop-cut. However, in cases where DAE and BBS jointly do the crop-cut, the moisture content is measured using moisture meter where available.

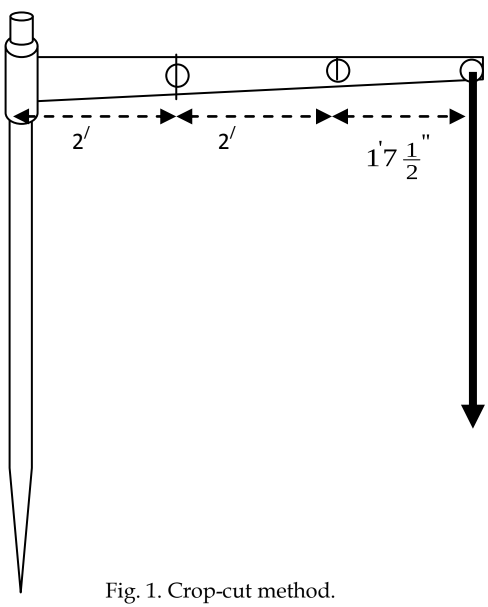

Fig. 1. Crop-cut method.

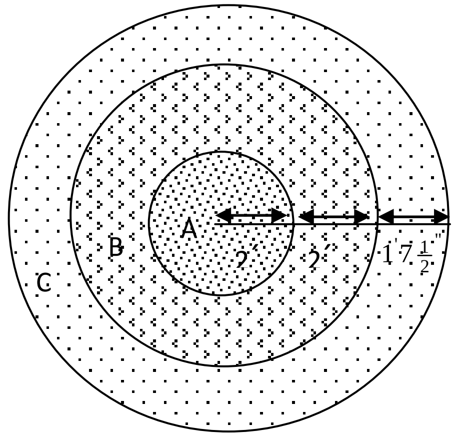

Fig. 2. Crop-cut method

Comparison of yield estimates using DAE and BBS procedures

Procedures followed by DAE (Method A) and BBS (Method B) were compared through actual crop-cut taken in farmer's field. Crop-cut was done in a farmer's field in Boro 2007 at Kapasia upazila of Gazipur district. The variety was BRRI dhan29. Before crop-cut, an area of 300 m^2 (20-×-15) m was demarcated in the field leaving one meter from each levy as boarder. The area was then divided into 12 small areas each with (5-×-5) m size (Fig. 3). Twelve crop-cuts, six following method A and six following method B were done within 300 m^2 area. The assignment of 12 cuts to 12 small areas was done at random. Figure 3 shows the position of each cut with their sequence number.

For method A, three cut areas were laid out with length of the cuts in the north-south direction and three with length of the cuts in the east-west direction and the position of each cut was at the middle of each small area. Crops were harvested separately from each cut area, threshed, cleaned, weighed and moisture content was measured using a moisture meter.

For method B, the centre of the circle was positioned at the middle of each small area. The harvests were then threshed, cleaned, weighed and moisture content was measured

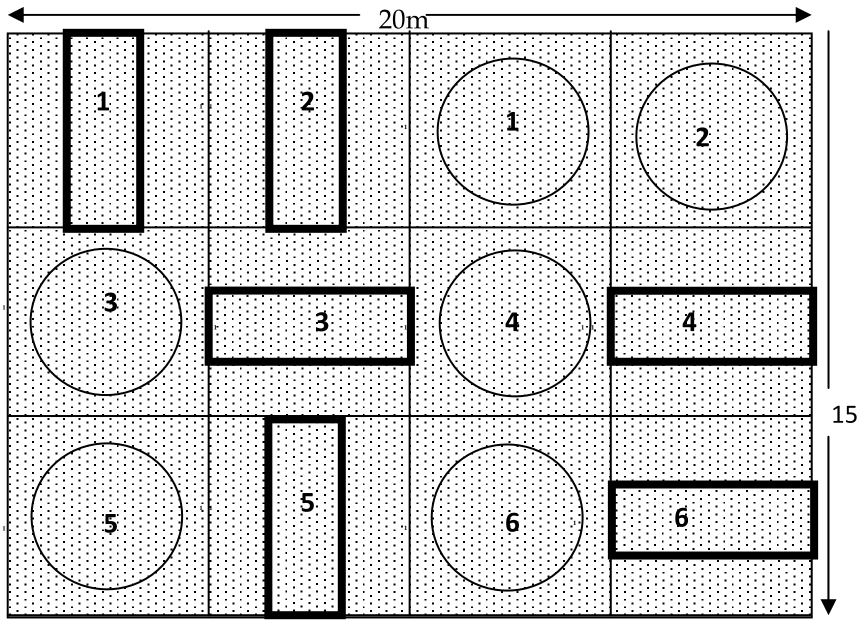

Fig. 3. Position of 12 different cuts with their sequence number (a rectangles represents a rectangular cut of size (5-×-2) m and a circle represents a circular cut of an area of 9.248 m^2)

separately for each portion of a crop-cut (three shaded area of Fig. 2). In case the pointer goes through a hill, the tillers falling within the circle were harvested. If the pointer passes through several hills, alternate hills were included in the crop-cut.

The yield estimates using different methods and that for the whole plot (300 m^2) were obtained as follows:

Method A. The average of three measures of moistures was considered to be the moisture content of the fresh harvest for each crop-cut and adjusted at 14% moisture content. The adjusted weight was then converted to t ha^{-1}. The formula for adjusting fresh weight at 14% moisture content is given by

$$Adjusted\ weight\ at\ 14\%\ moisture\ content = \frac{w(100 - MC)}{86}$$

where, w = fresh weight, MC = moisture content

Method B. The average of three measures of moisture content was considered to be the moisture content of the fresh harvest for each portion of a circular cut and adjusted at 14% moisture content. The adjusted weight was then added together and converted to t ha^{-1} that gives the weight of paddy for a circular area of radius $5'7\frac{1}{2}''$.

Method C (proposed). Yield was estimated using a modified procedure where all hills within the circular area of radius $5'7\frac{1}{2}''$ were considered to be harvested through a single cut instead of harvesting crops in three portions (Fig. 2) under method B. For the present exercise, the fresh weight of paddy obtained from three portions of a circular cut under method B were added and the average moisture content of nine measures of moisture content was used to estimate the rice yield. The fresh weight (total of three portions of a circular cut) was then adjusted to 14% moisture content and converted to t ha^{-1}.

Estimation of whole plot yield. The rest of the area (184.5 m^2) that remained after 12 crop-cuts was harvested separately, threshed, cleaned and weighed. The moisture content was the average of the moisture content measured from three samples from the lot. The fresh harvest of the remaining area was then adjusted to 14% moisture content and converted to t ha^{-1}. The weight of the whole plot was obtained as the total weight of remaining area and the weights of all cuts done using methods A and B.

Computation of precision and relative efficiency of the estimates

(a) The mean yield $(\bar{y})$ of six cuts under each crop-cut method is given by

$$\bar{y} = \frac{\sum_{i=1}^{6} y_i}{6}$$, where y_i is the estimate of yield for i^{th} cut

(b) The variance (V) of the estimates for each crop-cut method is obtained as

$$V(Yield) = \frac{\sum_{i=1}^{6} (y_i - \mu)^2}{6}$$, where y_i is the estimate of yield for i^{th} cut and μ is the true or the whole plot yield.

(c) The relative efficiency (RE) of a method over that of method A is measured as

$$\text{RE (Method B)} = \frac{V(Method\ \ A)}{V(Method\ \ B))} \times 100$$ and

$$\text{RE (Method C)} = \frac{V(Method\ \ \ A)}{V(Method\ \ \ C))} \times 100$$

RESULTS AND DISCUSSION

Table 1 presents the estimated yields following different crop-cut methods. Results show a large variation in the estimate of yield using method A compared to that using methods B and C. The high variability in the estimate for the method A is due to overall fertility gradient of the field from east to west. This is evident from the fact that the estimates for the cuts with length in the north-south direction are higher than those for the cuts with length in the east-west direction. In general, yield estimated using method A is found to be higher than the yield estimated by circular methods. In case of method A, the percent deviation of crop-cut yield from the whole plot yield ranges 2-14%, which is less than 2% in case of methods B and C. It is seen that average of crop-cut yields estimated using either of the circular methods (B and C) is about five times more precise than the average yield obtained using method A. It is to be noted that there is practically no difference between the estimates obtained using method B and method C as evident from difference of the estimates obtained from the same area. Moreover, method B is operationally more laborious and time consuming than method C. Results clearly reveal the superiority of circular methods (B and C) over the rectangular method (A) and a similar result was reported by Amin *et al.* (1994).

The results suggest that method C i.e., a single circular cut where the plants falling inside the circumference of the circle are harvested, may be followed for crop-cut in estimating transplanted rice yield. It is suggested to make at least two cuts in each plot to minimize the chance of over or under estimation of the whole plot yield and the radius of the circle should be 178.5 cm so that the cut area becomes $10m^2$ in order to easy conversion of the crop-cut yield to t ha^{-1}.

CONCLUSIONS

A detail block-wise account of area and the number of plots planted to rice crop in different seasons has to be made at every five-year interval.

In each year, a detail block-wise account of the number of plots planted to rice crop in different seasons has to be made.

Three crop-cuts have to be made in three rice fields for each variety under each land type.

Table 1. Yield (t ha^{-1}) of transplanted rice using different crop-cut methods in Boro season.

Cut no.	Yield (t ha^{-1})			
	Method A	Method B	Method C	Difference between methods B and C
1	6.97	6.20	6.21	-0.01
2	6.73	6.63	6.63	0.00
3	6.41	6.06	6.03	0.02
4	6.60	6.29	6.31	-0.02
5	7.16	6.08	6.09	-0.01
6	5.54	5.89	5.89	0.00
Mean	6.57	6.19	6.21	
Standard deviation	0.58	0.26	0.26	
Relative Precision (%)	100	522	510	
Plot yield (t ha^{-1}) = 6.30				

A single circular cut where the plants falling inside the circumference of the circle are to be harvested for crop-cut in estimating transplanted as well as direct seeded rice yield and the radius of the circle should be 178.5 cm so that the cut area becomes 10 m^2 in order to easy conversion of the crop-cut yield to real yield at 14% moisture.

At least two crop-cuts have to be made in each plot to minimize the chance of over or under estimation of the rice yield.

DAE collects the information at the block in collaboration with BBS at upazila level. Upazila agriculture office will lead the coordination of the activities of DAE and BBS personnel.

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Bangladesh Rice J. 20 (1) : 17-22, 2016

Water Productivity Improvement Using Water Saving Technologies in Boro Rice Cultivation

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ABSTRACT

An experiment was conducted at farmers' field aimed to evaluate the water saving technologies in Boro rice. The experiment involved three plots at 33 m, 65 m and 100 m distance from the water source. Each plot was divided into two parts to accommodate two management practices as research management (RM) and farmer's management (FM). RM comprised of plastic pipe water distribution system to reduce conveyance loss and alternate wetting and drying (AWD) method for field water management. FM comprised of earthen canal water distribution system and conventional irrigation method. BRRI dhan28 was cultivated with recommended agronomic practices. In RM, irrigation was applied when water level went 15 cm down below the ground surface where FM included conventional practice. Result showed that conveyance loss of water in earthen canal increased with increasing the distance from water source to field. Conveyance loss found 6.1 and 0.5 l s^{-1} per 100 m in earthen canal and plastic pipe distribution system, respectively. Plastic pipe distribution system successfully minimized 91.6% water loss that occurred in earthen canal. AWD practice alone saved 20.2% field water over conventional practice. Combination of AWD and plastic pipe had saved 42% water, Tk 2,270 ha^{-1} as electricity cost and Tk 2,947 ha^{-1} as irrigation cost over farmer's management. RM had higher yield than FM due to better performance of yield contributing parameters. Water productivity increased from 0.35 kg m^{-3} in FM to 0.65 kg m^{-3} in RM. Both the technologies in RM are environment friendly for reducing groundwater use in the irrigated ecosystem.

Key words: Alternate wetting and drying, conveyance loss, distribution system, water productivity

INTRODUCTION

Agriculture is the major water user, accounting for about 70% of the world's freshwater withdrawals and over 40% of OECD countries' total water withdrawals (OECD, 2010). Water shortage is very high in south-west and north-west regions of Bangladesh during the dry season due to low annual rainfall. The demand for both surface and groundwater for irrigation is on the rise in the dry winter season and amounts to 58.6 percent of the total demand for water (GoB, 2005). The principal crop during this season is Boro rice, which is 70 percent of the total crop production of Bangladesh (GoB, 2005). Moreover, it requires more water in the production process than either wheat or potato. Biswas and Mandal (1993) estimates that water requirements are 11,500 m^3 per hectare (ha) of Boro rice. A huge amount of water is misused by keeping continuous ponding condition in rice plots during Boro season in the irrigation projects as well in farmer's management in both major and minor irrigation systems of Bangladesh (Sattar *et al.*, 2009). Due to huge water loss, comparatively less area than potential is irrigated with this huge amount of water. Irrigation water is a critical factor for crop production in Bangladesh, which can make a crop either a success or a failure (Rashid *et al.*, 2005). The rainfall is not evenly distributed throughout the year. About 95 percent of the total rainfall occurs during April to October, leaving the remaining five months of the year essentially dry (Rashid *et al.*, 2005). During Rabi season, from November to March,

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rainfall is only 5% of the annual total. This amount is inadequate and results in low production (Huq *et al.*, 1992). A rice crop cannot be sustained during this period from rainfall alone and is fully dependent on irrigation (Rashid *et al.*, 2005). In Bangladesh, the heavy use of groundwater has led to shallow wells falling dry by the end of the dry season and to severe problems of arsenic pollution in rice-growing areas (Ahmed *et al.*, 2004). Geethalakshmi *et al.* (2011), reported that about 3,000-5,000 liter of water input is required in rice field to produce 1 kg of rice depending on different rice cultivation methods. Irrigated rice makes the highest demand of water in agriculture sector. Currently, on-farm availability of fresh water is reducing due to many reasons (Uphoff, 2006). Future predictions indicate that two million hectare of fully irrigated and 13 million hectare of partially irrigated lands in Asia during wet season would experience a 'physical water scarcity' and 22 million hectare of irrigated lands in the dry season would face 'economic water scarcity' by 2025 (Tuong and Bouman, 2003).

Water conveyance loss consists mainly of operation losses, evaporation and seepage into the soil from the sloping surfaces and bed of the canal. The most important one of them is seepage. The seepage loss in the irrigation canals accounts for the major portion of water conveyance loss (98.37%) while approximately 0.3 percent of the total stream is lost due to evaporation (Akkuzu *et al.*, 2006). Major or minor irrigation projects of

Bangladesh get water loss about 30 to 40 percent of total applied through the earthen channels at the time of distribution (Satter, 2004). Improper design, poor management of the canal, insufficient freeboard and socialconflicts are the factors affecting conveyance loss. The recent BRRI (2007) findings indicate that 95% of total conveyance loss in earthen canal can be minimized by adopting plastic pipe distribution system in STW. Beside this, it can reduce the irrigation time by about 50% resulted in reduced fuel, oil, irrigation cost, labour cost and also 45% command area can be increased by using plastic pipe distribution system (Sattar *et al.*, 2009).

Alternate wetting and drying (AWD) is a matured technology, which successfully saved irrigation water in rice filed. By applying AWD, farmers or pump-owners are able to save 15 to 30% of their irrigation water (Bouman *et al.*, 2007). AWD practice enables farmers to save irrigation water by 25-50% and also getting higher yields and more profits than conventional rice production (CRP) (Uphoff, 2006). Experts state that on a national level, the implementation of AWD could save costs for irrigation of up to 56.4 million Euros in electricity or 78.8 million Euros in fuel (30 liter diesel ha^{-1}) (GoB, 2005). The above discussion will necessitate and encourage research on alternative measures for reducing water use and increasing the efficiency of water use in order to ensure food security. With decreasing water availability for agriculture and increasing demand for rice, water use in rice production systems need to reduce and water productivity to increase. Individually i.e. distribution system and field water loss for Boro rice production may be studied by many researchers. But the combined effect of distribution system and field water management is lacking. Therefore, this study was undertaken to increase water productivity through improved water saving technologies in Boro rice cultivation.

MATERIALS AND METHODS

An experiment was conducted at farmers' field in Kushtia, Bangladesh during Boro 2013-14. Soil type of the experimental field was silt loam. Experimental area belongs to AEZ-11 (High Ganges river flood plain) with mean annual rainfall 1,478 mm (BRRI, 2014). The experiment involved three plots at 33 m, 65 m and 100 m distance from water source.

Each plot divided into two parts. One part was under research management (RM) and another part was under farmer's management (FM). The variety was BRRI dhan28 and 42-days old @ 2-3 seedlings were transplanted with 20 cm × 15 cm spacing. BRRI recommended fertilizer doses and cultural practices were applied during the season. The whole amount of P, K, S and Zn fertilizer was applied as basal dose during land preparation. Urea was top-dressed in three equal splits at 15 DAT, 30 DAT and 40 DAT. Herbicide was applied after five days of transplanting. Furthermore weeding and spraying were done to control weed and insect pests. Rice yield was assessed taking samples from 10 square meter area of each plot and collected yield parameters. Finally, the yield was adjusted to 14% moisture content to determine yield per hectare. Data were analyzed using Cropstat 7.2 version.

Management practices

RM plot included two management practices such as plastic pipe water distribution system followed by alternate wetting and drying (AWD) irrigation method. FM plot also had two management practices as earthen canal water distribution system followed by conventional irrigation method. Finally, water saving for RM was compared with FM. Besides water saving, cost of energy and irrigation were also calculated for both the management.

Conveyance loss management. Water was supplied to the RM plot through 12.7 cm diameter plastic pipe but in FM plot water was supplied through earthen canal. To measure conveyance loss for RM discharge was measured at the pump delivery point by using V-notch before installing plastic pipe and after installing plastic pipe discharge was measured at the outlet of plastic pipe using V-notch. But for FM discharge was measured by installing V-notch at inlet and outlet of the earthen canal. Thus the Conveyance loss was calculated using inflow-outflow method. Conveyance loss was calculated with the formula following:

$$S = \{(Q_1-Q_2) \div L\} \times 100 \text{................ (i)}$$

Where, S = rate of conveyance loss in the canal ($m^3 s^{-1}$ per 100 m distance), Q_1 = rate of flow at the inlet ($m^3 s^{-1}$), Q_2 = rate of flow at the outlet ($m^3 s^{-1}$), L = distance between two points (m)

Field water management. Alternate wetting and drying method was followed in RM after 15 days of transplanting. A 10 cm diameter and 25 cm long perforated (15 cm) PVC pipe was installed at the corner of the plot having 10 cm above the ground surface and perforated 15 cm part was below the ground surface. Irrigation provided at 5 cm depth when water level went down 15 cm below the ground surface. This practice stopped only during one week before to one week after flowering stage and 2-3 cm standing water was maintained in this period. In case of FM, irrigation had been applied following conventional method. Usually farmers' don't follow definite irrigation schedule. Sometimes they applied irrigation when water disappeared from the field and sometimes maintained continuous standing water. Amount of water applied in both methods was recorded.

Discharge measurement. Discharge of the STW was measured using a 90° V-notch weir, which is suitable to measure small flow accurately. The weir was placed across the canal at inlet and outlet of the canal. The following equation is used to calculate the rate of flow (Khurmi, 1997):

$$Q = 1.417 \times H^{5/2} \text{..................... (ii)}$$

Where, Q = discharge ($m^3 s^{-1}$), H= height of water above the apex of notch (m)

RESULTS AND DISCUSSOIN

Conveyance loss and its control measure using plastic pipe. Conveyance loss in earthen canal water distribution system (FM) found greater than plastic pipe distribution system (RM) (Table 1). Result shows that conveyance loss in FM varied with the length of distribution system. The conveyance loss in FM found 16.1%, 27.4% and 41.3% for the length of conveyance system 33 m, 65 m and 100 m respectively (Fig. 1). Water loss in this system occurs through seepage, percolation, over flow etc. Improper design of canal, poor management, insufficient freeboard etc are the main factors of the loss. This result is similar to Sayed (2010), who found 41%, 48% and 45% conveyance loss in earthen canal at Mithapukur, Manikganj sadar and Dhamrai respectively. Water loss in conveyance found 6.1 and 0.5 l s^{-1} per 100 m in FM and RM respectively. Experiment reveals that conveyance loss had controlled successfully by 91.6% using plastic pipe distribution system (Table 1). This result is identical to Satter *et al.* (2009), who found in an experiment that 95% of total conveyance loss can be minimized by adopting plastic pipe distribution system in STW.

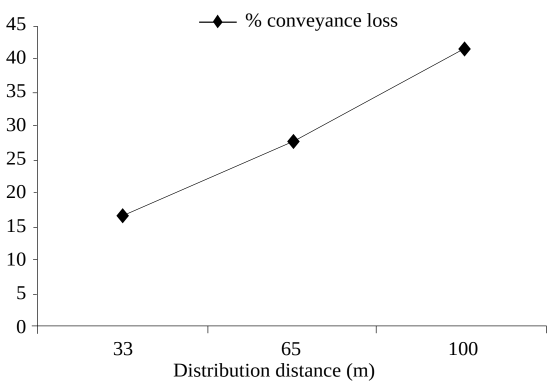

Fig. 1. Conveyance loss of water in earthen canal for different field distances from water source at Kushtia during Boro 2013-14.

Water saved by AWD method. Table 1 shows the number of irrigation and amount of water applied for both the treatments measured during the growing period. Result indicates that RM saved 4 numbers of irrigation over FM in case of BRRI dhan28. AWD method required 17 numbers of irrigation whereas conventional method received 21 numbers. About 104.6 cm irrigation water was applied in AWD method where 131.0 cm water in conventional method. RM saved 20.2% water over FM. This result is identical to Bouman *et al*. (2007) who reported that the AWD plots had the same yield as continuous flooding, but saved 16–24% in water costs and 20–25% in production costs.

Benefits of AWD and plastic pipe use. RM had great advantages over FM in terms of water, electricity and time saving. Combination of plastic pipe distribution and alternate wetting and drying method (RM) saved about 42% irrigation water than FM (Table 2). BRRI dhan28 produced 6.97 and 6.33 t ha^{-1} in RM and FM respectively. Yield increased in RM because of higher number of panicles as well as field grain and grain weight than FM. Water productivity of BRRI dhan28 under RM was 0.65 kg m^{-3} and under FM it was 0.35 kg m^{-3}. Electricity consumption was found 1,394 and 819.4 kWh in FM and RM respectively. RM also saved Tk 2,270 ha^{-1} as electricity cost and Tk 2,947 ha^{-1} as irrigation cost over FM (Table 3).

Table 1. Conveyance loss measurement and field water used by different methods during Boro 2013-14.

Conveyance loss management				Field water management			
Management practice	Conveyance loss l s^{-1} per 100 m	% water loss	Conveyance loss saved by RM (%)	Management practice	Irrigation (no.)	Amount of irrigation (cm)	Field water saved in RM (%)
FM	6.1	44	91.6	FM	21	131.0	20.2
RM	0.5	3.7		RM	17	104.6	
$LSD_{0.05}$	1.03	8.54		$LSD_{0.05}$		17.7	
CV (%)	9.10	10.30		CV (%)		4.3	

Table 2. Total water used and water productivity of BRRI dhan28 in RM and FM during Boro 2013-14.

Treatment	Water supplied cm)	Water saved in RM over FM (%)	Panicle m^{-2}	Filled grain $Panicle^{-1}$	Yield (t ha^{-1})	Water productivity kg m^{-3}
FM	184.9	42	423	96	6.33	0.35
RM	107.3		406	117	6.97	0.65
$LSD_{0.05}$	52.6		11.6	35.5	0.5	0.10
CV (%)	10.4		1.8	9.6	2.2	5.9

Table 3. Electricity and irrigation costs in two management practices at Kusthia during Boro 2013-14.

Treatment	Time of irrigation (hr ha^{-1})	Electricity consumed (kWh ha^{-1})	Electricity cost (Tk ha^{-1})	Electricity cost saved in RM (Tk ha^{-1})	Cost of irrigation (Tk ha^{-1})	Irrigation cost saved in RM (Tk ha^{-1})
FM	317.8	1394	5506.4	2270	22246	2947
RM	275.7	819.4	3236.4		19299	

Electricity cost = Tk 3.95 per unit, Irrigation cost = Tk 70 hr^{-1}.

CONCLUSIONS

Alternate wetting and drying method combined with plastic pipe water distribution system was found effective water saving technologies in Boro rice cultivation. Plastic pipe distribution system saved 91.6% water, which is lost as conveyance loss in earthen canal. AWD technique alone saved 20.2% water (four irrigations) over conventional method. In combination of plastic pipe and AWD method saved 42% water with Tk 2270 ha^{-1} as electricity cost and irrigation cost of Tk 2947 ha^{-1} than farmer's management. Water productivity increased from 0.35 kg m^{-3} to 0.65 kg m^{-3} in farmer's management to research management. Both the techniques are environment friendly for reducing groundwater use in the irrigated ecosystem. Considering water scarcity during dry months, cost of electricity and understanding all the benefits of AWD method and plastic pipe, farmers of the study area showed interest to adopt these technologies.

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Bangladesh Rice J. 20 (1) : 23-32, 2016

Postharvest Loss Assessment of Rice at Selected Areas of Gazipur District

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ABSTRACT

Mechanical intervention in rice (*Oryza sativa* L.) postharvest operation especially harvesting, threshing and carrying is increasing due to shifting labour from agriculture to non-agricultural sector. It was hypothesized that mechanical intervention in rice postharvest operation will increase the postharvest losses. A two-year study (2008-2010) was conducted during Aus, Aman and Boro seasons in six locations of sadar upazila at Gazipur district to test the hypothesis. The widely used varieties of BR11, BR23, BR26, BR27, BRRI dhan28, BRRI dhan29 were used to assess the losses during harvesting to drying. In the study areas, farmer's common practices (harvesting paddy by sickle; transportation by head, shoulder and power tiller operated trolley; threshing by open drum and close drum thresher; cleaning by traditional cleaning device *kula* and winnower and sun drying) were used to assess the postharvest losses. The average postharvest losses from harvesting to drying recorded 10% in three rice growing seasons. Losses due to mechanical threshing and traditional sun drying were 3.16% and 3.14% respectively. Power tiller operated trolley showed the lowest carrying loss compared to shoulder and head carrying methods. Both *kula* and winnower were observed as the most appropriate method of grain cleaning. Mechanical intervention in threshing increased the losses, whereas decreased in transportation and winnowing. These data might be used for policy makers to assess the national food grain loss and for researchers to design and development new technology to reduce the postharvest loss. The study should be continued to other regions for consistent results.

Key words: Mechanical intervention, harvesting, carrying, threshing, drying

INTRODUCTION

Bangladesh produced 34.4 million tons of clean rice in 10.61 million hectares land (BRRI, 2014). Two millions of population added in each year and expected to reach 215.4 million in 2050 when 44.6 million ton of cleaned rice will be required (Kabir *et al.,* 2016) whereas the estimated annual shrinkage of agricultural land is about 0.08 million hectares due to various non-agricultural activities such as the construction of houses, offices, roads, mills, factories etc (BRRI, 2009). Rice yield, therefore, needs to be increased from its present level of 2.74 to 3.74 t ha^{-1} (BRRI, 2013). Decreasing resources (e.g. land, labour, soil health and water) and increasing climate vulnerability (e.g. drought, salinity, flood, heat and cold) appeared as the great challenges to keep pace of food production in the background of increasing population. Sufficient rice production is the key to ensure food security in Bangladesh. In fact, 'rice security' is synonymous to 'food security' in Bangladesh as in many other rice growing countries (Brolley, 2015).

The government has given the top priority in increasing the availability of food in the country, while rice land is not expanding (MoA, 2013). One way to increase the production is to minimize yield gap between research and farmers level. Another important task is to minimize postharvest loss. Rice postharvest practices in the country vary between localities depending upon the existing physical, topographical and climatic conditions in the area.

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A portion of the rice (paddy) is lost in postharvest operations due to numerous factors and a portion of rice is wasted to feed poultry and livestock, and in transportation, marketing and consumption processing. The wastes indicate that postharvest food loss translates not just into human hunger and minimizing the revenue of farmers, but tremendous environmental waste as well (Afsar *et al.*, 2001). It was also varied with seasons, variety and mode of operations.

FAO/BRRI (1986) estimated postharvest losses (harvest to storage) in Bangladesh were 13.02-13.72% (drying loss: 1.63%-2.84%, parboiling loss: 1.93-2.75% and milling loss: 3.28% and 4.54%) in three rice growing seasons. Little variation of total losses was observed in different seasons (Aman-13.04, Boro-13.02 and Aus-13.75%). Mechanical intervention in post harvest operation was not included in that study. After 1998, the wide scale adoption of power tiller for tilling caused tremendous changes in the crop production sector. Land preparation, irrigation, weeding and threshing are already mechanized successfully in Bangladesh although some operations like transplanting, harvesting, winnowing, drying are still gaining space in farmers' level (Islam *et al.*, 2016). There is insufficient data on postharvest losses of rice in Bangladesh after introducing machinery in rice cultivation. It is urgently needed to estimate the losses occurred due to mechanical intervention in postharvest operation. Therefore, the aim of this study is to assess the postharvest losses (harvesting to drying) in rice for providing information to reduce postharvest losses.

MATERIALS AND METHODS

Experiment site, variety and rice growing seasons

Considering easy access from BRRI headquarters and to secure farmers' cooperation, six blocks of Gazipur sadar upazila in Gazipur district were selected to assess the post harvest losses of rice in 2008-2010 seasons. Table 1 presents detailed information of seasons and varieties in six locations.

Experimental design

The experiment was laid out in randomized complete block design. Six postharvest operations were considered (harvesting-sickle; transportation- head, shoulder and power tiller operated trolley; threshing- open drum and close drum thresher; cleaning-traditional cleaning device *kula* and winnower and drying-sun) in this study. The method(s) in each operation were replicated three times. Existing farmers' practices were taken in consideration to determine the postharvest losses including selection of crops maturity date; harvesting process, threshing methods and drying practices in each stage.

Experimental procedure

The method and procedures in this study were followed as mentioned by Jose *et al.*, (1985). Table 2 describes field techniques and laboratory procedure for determination of postharvest losses of rice.

Laboratory techniques

The grain samples and raw data were collected from the field and analyzed in the research laboratory, FMPHT division, BRRI. The collected samples were cleaned, weighed and recorded the moisture content. Filled and unfilled grains were counted manually and weights were adjusted to 14% moisture content (wet basis).

Procedures

According to Jose *et al.* (1985), the sample of 50 m^2 area was harvested by sickle; stacking on canvas; bundled by rope; transported by head/shoulder/trolley; threshed by ODT/ CDT to get the grain weight as yield. The loss was calculated on the basis of grain weight expressed as average and percentage. Pre-testing was done before the final test in order to minimize the error in each methods and seasons.

Table 1. Information on experimental location, season and variety.

Season	Aus		Aman		Boro	
Location	Laxmipur	Chandana	Mariali	Harinal	Purba Chandana	Jogitala
Year	2008	2009	2008	2009	2009	2010
Variety	BR26	BR27	BR23	BR11	BRRI dhan28	BRRI dhan29

Table 2. Field operation techniques and components at different stages of crop production.

Operation	Loss component	Tool	Collected datum
Reaping a. Pre-harvest	Shattering loss due to environmental condition(wind, rain)	-	Amount of paddy fallen
b. Harvest	harvesting	Sickle	Amount of paddy fallen
Field stacking/ bundling	Staking/bundling loss	-	Amount of paddy fallen
Field transport	During the process of transporting the harvested grain	Head/shoulder and trolley	Amount of paddy fallen
Threshing	Scattered and un-threshed	ODT and CDT	Amount of scattered, un-separated and un-threshed paddy
Cleaning/ winnowing	Scattered, chaff and straw loss	Winnower and *kula*	Amount of scattered and un-separated (chaff and straw) paddy
Drying	Quantity loss (birds, chicken, duck, spoilage, yard etc.)	Sun drying	Quantity loss (amount paddy loss by weight)

ODT= Open drum thresher; CDT=Close drum thresher

Postharvest operations

Determination of harvesting losses. The field was marked with nylon rope and bamboo pole for harvesting. One-twentieth portion (2.5 m^2: 0.5×5 m) of the total area (50 m^2) in one end was used for measuring the pre-harvesting (natural shattering loss by wind, varietal characteristics) and harvesting (cutting) loss of manual harvesting by sickle. The remaining 47.5 m^2 area was also harvested by sickle to determine the grain yield. Grain falls on the ground was collected manually for calculating pre and post harvesting losses.

Determination of in-field stacking/ bundling losses. Leave the harvested paddy on the canvas, as in the normal practice of the farmer and allowing the farmer to carry the harvested paddy by bundling for threshing. Grains falls on the canvas during bundling was collected in a poly bag for laboratory analysis.

Determination of transport losses. Power tiller operated trolley, head and shoulder carrying methods as common practiced in the study area for transport the harvested paddy to the threshing floor. Clothing bag were added for head and shoulder carrying and lay out the plastic sheet on the trolley to collect the fallen grain during transportation.

Determination of threshing losses. Two different types of threshing methods (ODT, CDT) as practiced by farmers were used to determine the threshing losses. Plastic sheet was laid down on the threshing floor for collecting scattered paddy from outside of the threshing range. Weighted all the threshed straw and taken $1/16^{th}$ of that straw (Jose *et al.,* 1985), which is called straw factor, used to determination of un-threshed paddy.

Determination of winnowing/cleaning losses. Two types of equipment (winnower and *kula*) were used for the purpose of cleaning losses. Initially, weight of threshed paddy (un-cleaned) were recorded and cleaned by winnower and *kula*. Finally, the weight of cleaned paddy was measured to estimate the cleaning loss. Scattered paddy was collected from outside the winnowing range and gathered chaff to collect paddy.

Determination of drying losses. Sun drying method was used for the purpose of drying loss calculation. Weighted the cleaned paddy and dried in the famers' yard and finally again weighted the dried paddy for drying loss calculation.

Procedure of loss calculation

The following formulas were used to calculate postharvest losses of rice.

Moisture conversion factor (MCF): $\frac{100-M_1}{86}$ (1)

Where,

M_1=Initial moisture

Area faction (AF): $\frac{50m^2}{2.5m^2}=20$ (2)

Straw factor (SF): $\frac{\text{Totalstraw}}{16}$ (3)

Rice yield (RY): $Y_2 = Y_1 \times MCF \times F_g$ (4)

Where,

Y_1= Weight of the grain of the sample area at field moisture content including filled and unfilled grain (kg)

F_g= Percentage (%) of the filled grains

Y_2=Adjusted weight of the grain of the sample area at 14% moisture content (kg)

Preharvest loss: $P_{r2} = P_{r1} \times MCF \times AF$ and

$$P_{r3} = \frac{P_{r2}}{Y_2} \times \frac{1}{10} \quad (5)$$

Where,

P_{r1}=Preharvest loss of rice (2.5 m^2) at field moisture content (g)

P_{r2}= Preharvest loss of rice (50 m^2) at 14% moisture content (kg)

P_{r3}=Preharvest loss in %

Postharvest loss: $P_{o2} = P_{o1} \times MCF \times AF$ and

$$P_{o3} = \frac{P_{o2}}{Y_2} \times \frac{1}{10} \quad (6)$$

Where,

P_{o1} =Postharvest loss of rice (2.5 m^2) at field moisture content (g)

P_{o2}= Postharvest loss of rice (50 m^2) at 14% moisture content (kg)

P_{o3}=Postharvest loss in %

Field bundling/stacking loss: $F_{b2} = F_{b1} \times MCF$ and $F_{b3} = \frac{F_{b2}}{Y_2} \times \frac{1}{10}$ (7)

Where,

F_{b1}=Stacking /bundling loss of rice (2.5 m^2) at field moisture content (g)

F_{b2}=Field stacking loss of rice (50 m^2) at 14% moisture content (kg)

F_{b3}=Field staking/ bundling loss in %

Transport loss: $T_2 = T_1 \times MCF$ and

$$T_3 = \frac{T_2}{Y_2} \times \frac{1}{10} \quad (8)$$

Where,

T_1=Transport loss of rice (2.5 m^2) at field moisture content (g)

T_2=Transport loss of rice (50 m^2) at 14% moisture content (kg) $_3$=Transport loss in %

Threshing loss

Scattering loss: $T_{sc2} = T_{sc1} \times MCF$ and

$$T_{sc3} = \frac{T_{sc2}}{Y_2} \times \frac{1}{10} \quad (9)$$

Where,

T_{hc1}=Scattering loss of rice (2.5 m^2) at field moisture content (g)

T_{hc2}=Scattering loss of rice (50 m^2) at 14% moisture content (kg)

T_{hc3}=Scattering loss in %

Separation loss: $T_{se2} = T_{se1} \times MCF \times SF \times F_g$ and

$$T_{se3} = \frac{T_{se2}}{Y_2} \times \frac{1}{10} \qquad (10)$$

Where,

T_{he1}=Separation loss of rice (2.5 m^2) at field moisture content (g)

T_{he2}=Separation loss of rice (50 m^2) at 14% moisture content (kg)

T_{he3} =Separation loss in %

Total threshing loss (%): $T_{sc3}+T_{se3}$ (11)

Clearing / winnowing loss

Scattering loss: $C_{sc2}= C_{sc1} \times MCF$ and

$$C_{sc3} = \frac{C_{sc2}}{Y_2} \times \frac{1}{10} \qquad (12)$$

Where,

C_{sc1}=Scattering loss of rice (2.5 m^2) at field moisture content (g)

C_{sc2} =Scattering loss of rice (50 m^2) at 14% moisture content (kg)

C_{sc3} =Scattering loss in %

Chaff and straw separation loss: C_{se2}= $C_{se1} \times MFC \times F_g$ and $C_{se3} = \frac{C_{se2}}{Y_2} \times \frac{1}{10}$ (13)

Where,

C_{se1}=Chaff and straw loss of rice (2.5 m^2) at field moisture content (g)

C_{se2} =Chaff and straw loss of rice (50 m^2) at 14% moisture content (kg)

C_{se3} =Chaff and straw loss in %

`**Total cleaning/winnowing loss (%):**
$C_{hc3}+ C_{se3}$ (14)

Drying loss: $D_{2i} = D_{1i} \times MCF \times F_g$ and $D_{2f}= D_{1f} \times MCF \times F_g$

$$\text{Drying Loss, (\%)} = \frac{(D_{2i} - D_{2f})}{D_{2i}} \times 100 \qquad (15)$$

Where,

D_{1i}=Initial weight at field moisture content (kg)

D_{2i}=Adjusted weight at 14% moisture content (kg) = Y_2

D_{1f}=Weight of the sample after drying (kg)

D_{2f}=Adjusted weight after drying at 14% moisture content (kg)

Statistical analysis

Data were analyzed according to Gomez and Gomez (1984) using statistical software Statistix 10 programme. Means were compared with least significant difference (LSD) test.

RESULTS AND DISCUSSION

Comparative loss assessment (operation basis) pre-harvest and harvest (cutting) losses. Table 3 shows that the pre-harvest and harvest losses were depended on variety and season. The cutting losses (%) also varied as same as pre-harvest losses. The harvest loss was the highest in Aus season in both the years due to heavy rainfall and lodging by wind. In contrast, the harvesting loss was observed as the lowest in BRRI dhan28 in Boro season. FAO/BRRI (1986) obtained harvest losses of 2.01, 2.5 and 1.14% in Aus, Aman and Boro seasons respectively, which is similar to the present findings.

Table 3. Effect of variety on pre-harvest and harvest (cutting) losses (%).

Item	Aus		Aman		Boro	
	BR26	BRRI dhan27	BR23	BR11	BRRI dhan28	BRRI dhan29
Pre-harvest loss	0.53	0.74	0.20	0.33	0.36	0.37
Harvest loss (Sickle)	2.10	2.15	1.88	2.00	1.83	1.94

Transportation losses. Table 4 shows the transportation losses of rice in three seasons. Transportation loss varied significantly with the different methods of carrying except rice variety BR26. Irrespective of seasons, carrying method of power tiller operated trolley reduced the carrying losses significantly whereas losses are at par between head and shoulder carrying methods. FAO/BRRI (1986) observed that transport loss varied 0.52 to 0.57% for head and shoulder carrying, which is similar to the present findings (Table 4). However, transportation loss obtained the lowest while carrying in power tiller operated trolley. Some grains are separated from the panicle due to vibration and farmers can easily collect those grains from the trolley. Therefore, mechanical intervention reduced the transportation losses.

Threshing losses. Scattered and un-threshed losses are expressed as threshing loss. Two-way interaction of threshing methods and type of threshing losses did not varied significantly whereas single effect of threshing methods and type of losses varied significantly in all seasons (Table 5). Irrespective of season, un-threshed losses showed the highest in CDT (2.48 to 2.69%) whereas scattered losses showed the lowest in ODT (0.56 to 1.0%). CDT showed significantly higher grain losses (1.20 to 2.27%) in all seasons than ODT (0.86 to 1.21%). In contrary, un-threshed losses (1.85-2.14%) were observed significantly higher in all seasons than scattered loss (0.88-1.39%).FAO/BRRI (1986) obtained threshing loss of 0.81, 0.77 and 0.98% in Aus, Aman and Boro seasons, respectively in traditional method of threshing. The threshing losses in the present study were higher because of existence of un-threshed grain in the panicle and some grains spillsfar with straw due to high speed throwing of straw.

Table 4. Effect of carrying methods on transportation losses (%).

Carrying method	Aus		Aman		Boro	
	BR26	BRRI dhan27	BR23	BR11	BRRI dhan28	BRRI dhan29
Trolley	0.20	0.195	0.16	0.23	0.15	0.24
Head carry	0.65	0.84	0.49	0.66	0.51	0.81
Shoulder carry	0.75	0.79	0.69	0.63	0.72	0.72
$LSD_{0.05}$	NS	0.41	0.26	0.30	0.37	0.04
CV (%)	18.82	15.82	13.48	14.1	18.96	1.38

NS=Not significant

Table 5. Effect of threshing method on threshing losses (%).

Operation	Aus					
	BR26			BRRI dhan 27		
	Scattered	Un-threshed	Mean	Scattered	Un-threshed	Mean
ODT	0.62	1.79	1.21	0.56	1.65	1.10
CDT	1.47	2.48	1.98	1.19	2.6	1.2
Mean	1.05	2.14	-	0.88	2.13	-
$LSD_{0.05}$	T=0.19 and M=0.21, T×M= NS			T=0.29 and M=0.18, T×M= NS		
CV (%)	8.5			9.3		
Operation	Aman					
	BR23			BR11		
	Scattered	Un-threshed	Mean	Scattered	Un-threshed	Mean
ODT	0.82	1.31	1.07	0.59	1.13	0.86
CDT	1.86	2.69	2.27	1.88	2.64	2.26
Mean	1.34	2.0	-	1.24	1.89	-
$LSD_{0.05}$	T=0.41 and M=0.52, T×M= NS			T=0.20 and M=0.20, T×M= NS		
CV (%)	17.56			9.09		
Operation	Boro					
	BRRI dhan28			BRRI dhan29		
	Scattered	Un-threshed	Mean	Scattered	Un-threshed	Mean
ODT	1.00	1.19	1.10	0.75	1.51	1.13
CDT	1.77	2.5	2.14	1.38	2.54	1.96
Mean	1.39	1.85	-	1.10	2.02	-
$LSD_{0.05}$	T=0.31 and M=0.50, T×M= NS			T=0.55 and M=0.55, T×M= NS		
CV (%)	9.09			25.28		

T=Threshing loss type (Scattered and Un-threshed), M=Method of operation (ODT and CDT), NS=Not significant

Cleaning losses. Scattered and chaff losses were considered cumulatively as cleaning losses. Two-way interaction of cleaning methods and type of cleaning losses did not varied significantly whereas single effect of cleaning methods were found significant only in BR26 during Aus season. In contrary, cleaning methods showed significant variation in BR27 and BRRI dhan28 during Aus and Boro season, respectively (Table 6). Cleaning losses in three seasons and two methods of operation (winnower and *kula*) showed similar in all the seasons. The cleaning loss in-terms of chaff and scattered values have no relation. It was changed regarding season and operation. Irrespective of season, cleaning losses varied from 0.16 to 0.29 % and 0.17 to 0.25% for winnower and *kula* and 0.15 to 0.23% and 0.19 to 0.29% for scattered and chaff respectively, which is similar to the finding of FAO/BRRI (1986).

Table 6. Effect of winnowing method on cleaning losses.

Operation	Aus					
	BR26			BRRI dhan 27		
	Scattered	Chaff	Mean	Scattered	Chaff	Mean
Kula	0.23	0.28	0.25	0.18	0.16	0.17
Winnower	0.19	0.30	0.25	0.24	0.29	0.26
Mean	0.21	0.29	-	0.21	0.23	
$LSD_{0.05}$	C=0.05			M=0.06		
CV(%)	15.04			20.64		
	Aman					
	BR23			BR11		
	Scattered	Chaff	Mean	Scattered	Chaff	Mean
Kula	0.18	0.25	0.22	0.17	0.25	0.21
Winnower	0.21	0.27	0.24	0.28	0.29	0.29
Mean	0.19	0.26	-	0.23	0.27	
CV (%)	23.07			36.85		
Operation	Boro					
	BRRI dhan28			BRRI dhan29		
	Scattered	Chaff	Mean	Scattered	Chaff	Mean
Kula	0.18	0.17	0.17	0.19	0.17	0.18
Winnower	0.23	0.33	0.28	0.11	0.20	0.16
Mean	0.20	0.24		0.15	0.19	
$LSD_{0.05}$	M=0.07			NS		
CV (%)	21.75			38.36		

M=Operation, C=Cleaning loss type (Scattered and chaff), NS=Not significant

Drying losses. Drying losses varied significantly with the seasons (Fig. 1). The average loss estimate in drying operations was ranged from 2.38 to 2.98% for the three seasons (Aus, Aman and Boro). Significantly higher drying losses were observed in Boro (3.14%) due to bulk volume of production compared to others seasons, whereas the lowest drying loss (2.68%) was observed in Aman season, because of dry weather. However, the drying losses were the second highest in Aus season due to rainy days. Greeley(1981) stated that total physical losses in the operation from harvesting to sun drying did not exceed 7%, whereas total drying losses ranged from 1.56 to 5% (Bala, *et al.*, 2010). Drying loss depends on diversity factor like farmers' initiatives, weather condition and yard condition etc. The possible causes of drying losses were observed that grains feeding by the chicken, birds, ducks, grain spoilage, scattered during drying etc. Drying yard (Mud ground, pacca floor, canvas, bamboo mat, plastic sheet, and road side) also influenced the drying losses.

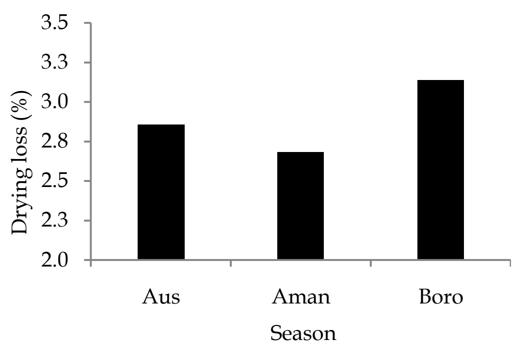

Fig. 1. Drying losses in three distinct seasons.

Comparative loss estimates on season basis

Farmers in Gazipur district cultivated different popular rice verities as well as other places of Bangladesh, which were used for postharvest loss assessment from pre-harvest to drying. Pre-harvest, cutting, field stacking, transportation, threshing, cleaning and drying losses were the parts of total losses. Among the different moods of losses, cutting loss only varied significantly with the seasons, whereas in Aus season, it was significantly higher cutting losses (2.13%). The total estimated losses were varied 10.42, 10.04 and 10.28% in Aus, Aman and Boro seasons, respectively (Table 7). Among the three seasons, losses in Aman season (10.04%) were comparatively lower due to dry weather condition. In contrary, the highest loss was 10.42 in Aus season due to rainy season. The highest losses were found in threshing method (3.09 to 3.23%) followed by drying (2.86 to 3.14%) and lowest in pre-harvest losses (0.27 to 0.64%). NAPHIRE (1997) stated that harvest loss in the traditional cutting method (sickle) at optimum maturity stage for different rice varieties ranged from 6% to 17%, which increased substantially with the delay of harvesting. Calverley (1994) also observed that average loss in harvest, threshing, drying, storage and milling was 13.56% under eleven FAO projects implemented in several countries of Central and South-Eastern Asia. In another study in China, it was also observed that total average losses of the six operations of threshing, drying and cleaning, storage, transport and milling amounted to 14.81% of total production (FAO, 2004).

CONCLUSION

The total postharvest losses from harvesting to drying were observed 10% in Gazipur district. Mechanical intervention increased the threshing losses whereas it decreased in transportation and winnowing losses. Quantitative relationship between machinery and traditional practice requires further investigation with more representative areas.

Table 7. Season wise rice postharvest losses as affected by different modes and methods of operation.

Season	PHL	CL	FSL	TL	Threshing			Cleaning			Drying	Total
					SL	USL	Total	SL	Chaff	Total		
Aus	0.64	2.13	0.69	0.57	0.97	2.14	3.09	0.21	0.26	0.47	2.86	10.42
Aman	0.27	1.94	0.97	0.48	1.29	1.95	3.23	0.22	0.27	0.48	2.68	10.04
Boro	0.37	1.89	0.83	0.53	1.23	1.94	3.16	0.18	0.22	0.39	3.14	10.28
$LSD_{0.05}$	NS	0.115	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	16.88	1.35	8.8	5.46	6.84	5	0.90	14.29	10.85	11.23	4.72	2.12

PHL=Pre-harvest loss, CL=Cutting/harvested loss, FSL=Field stacking loss, TL=Transportation loss, SL=Scattered loss, USL=Un-separated loss

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Bangladesh Rice J. 20 (1) : 33-43, 2016

Comparison of Tegra and Conventional Rice Cultivation in Bangladesh

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ABSTRACT

Tegra practice (healthy seedling, mechanical transplanting, herbicide application and advisory services), as a new concept in commercial rice cultivation, needs to be evaluated with farmer's practices in our country. This study was conducted in the farmers' field during Aman 2013 and Boro 2013-14 seasons in Bogra district. In each season, six farmers within one kilometer radius were selected to conduct this study. Randomized complete block design (RCBD) with two treatments namely farmer's practices (FP) and Tegra practices (TP) were used in the experiment. Self-propelled four rows walking-type rice transplanter was used to transplant seedling in TP. Seedlings were raised in plastic tray to use in mechanical transplanter. The mat seedlings were ready to transplant when attained 3-4 leaves and 10-12 cm height. Mechanical transplanting found faster than manual transplanting. Missing/floating hill observed insignificant in mechanically transplanted field. Fuel consumption of mechanical transplanter obtained 4.5 L/ha. Tender aged seedling was used in TP and seedling age was higher in FP than TP. Plant height followed the similar trend in both the practices. Tillering ability obtained the highest in TP than FP. TP produced significantly higher (14-23%) grain yield in both seasons. The total cost of production, gross return, gross margin and BCR obtained the highest in TP. BCR showed 5-13% higher in TP than FP in both the seasons due to higher grain and straw yield. The economic analysis clearly revealed the profitability of TP over FP in both the seasons.

Key words: Fuel, missing hill, spacing, hill density, input cost, yield, benefit-cost ratio

INTRODUCTION

In Bangladesh, rice is grown in the three distinct seasons namely Aus, Aman and Boro. Aus rice is grown in March to August. Transplanted Aman (T. Aman) is grown from July to December, while Boro rice is grown mainly under irrigated conditions and planted in December-January and harvested in April-May. There are many ways to transplant seedling-manual, mechanical, throwing. Transplanting of seedlings into heavy puddled soils is the common practice of rice cultivation in Bangladesh. Farmers typically prepare land by two passes of dry tillage followed by exposure to sun for a few days and then inundation of the field, ploughing and harrowing with standing water. Manual paddy transplanting appeared as tedious, laborious and time consuming operations requiring about 123-150 man-h ha^{-1} which is 19-22% of total labour requirement of rice production (Islam *et al.*, 2015). It was reported that a delay in transplanting by one month reduces the yield by 25% and a delay of two months reduced the yield by 70% (Rao and Pradhan, 1973). Further, due to rapid industrialization and migration to urban areas, the availability of labour became very scarce and with hike in the wages of labour, manual transplanting found costly leading to reduced profits to farmers. Under such circumstances a less expensive and labour saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi *et al.*, 2004). Mufti and Khan (1995) found 30% increase in yield and a reduction of about 70% in labour requirements in

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transplanting with machine compared to the manual transplanting. Manjunatha *et al.* (2009) reported the breakeven area of Chinese made 8-row self-propelled rice transplanter (Model: 2 ZT-238-8) was at least 28 hectares per year. Their results indicated that the cost of mechanical transplanting per hectare was about 51% lower than that of manual transplanting. The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Rice transplanters are considerably expensive for almost all Asian small-hold farmers. It is popular in industrialized countries where labour cost is high, for example in South Korea. According to above and necessity of time saving and crop yield, in recent years new models of rice transplanting machine have been introduced in the country and farmers were encouraged to adopt mechanized methods of rice transplanting.

Syngenta, a joint venture company of Syngenta AG Switzerland and BCIC, Bangladesh came forward to start business on mechanized transplanting in the name of Tegra, which is called rice solution in other words. It is a brand name developed by Syngenta. Tegra package consisting of planting high quality seeds coated with seed treatment, raised seedlings, mechanical rice transplanting, labour for logistics while transplanting, and application of herbicides at the time of transplanting, besides advisory on agronomic practices. Rice seedlings are established by the company in a special media comprising rice husk, soil, ash, press mud, nutrients and chemicals. Tegra starts in our country during Aman 2012. Mechanical transplanting is a crucial part to success of Tegra business. It is hypothesized that Tegra practice is cost effective in commercial rice cultivation and produce more grain yield than farmer's practice. Hence, the present study was undertaken to evaluate the Tegra package in the farmers' field.

MATERIALS AND METHODS

This study was conducted in the farmers' field under Bogra district in Kodma, Omorpur, Nandigram during Aman 2013 season and Amin Nagar, Nandigram during Boro 2013-14 season. The soil type was clay loam (Sand 0%, Silt 3% and Clay 97%), AEZ 25 level Barind tract. Figure 1 shows the weather condition during the experimental period. This experiment was carried out in randomized complete block design (RCBD) with two treatments, viz 'farmers' practices (FP) and Tegra practices (TP). In each season, six farmers within one kilometer radius were selected to conduct this study. The field was prepared using common tillage practice, which is first ploughing (primary tillage) once, followed by puddling (secondary tillage) twice and leveling using two-wheel tractor under the flooding conditions. After first rotatilling, the field was flooded with water and kept as such for seven days and then second rotatilling was done on 8th day and the field was leveled by a plank. The plastic trays were used to raise mat-type seedlings. Dry soil was filled in tray in such a

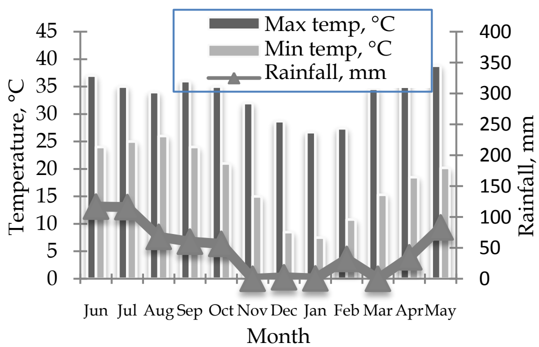


Fig. 1. Temperature and rainfall distribution during experimental period (2013-14).

way that the soil was free from any stone, stubble and grass. Syngenta developed recipe was used to fill tray for seedling establishment. Sprouted seeds were spread uniformly over the tray by using mechanical sowing line. To protect the seeds from the birds, the mats were covered with black net. Water was sprinkled normally twice a day by rose cane until there was complete emergence of seedlings. The mat seedlings were ready to transplant when they had 3-4 leaves and 10-12 cm height. Seedbed preparation often involves secondary tillage by using spade and puddling was done after inundating the field. Drainage canals were constructed for proper water removal. Puddled soil was leveled and raised to 5-10 cm height. Organic manure (decomposed) and a small amount of inorganic fertilizer was applied as basal dressing to increase seed vigour and allows easier uprooting for transplanting. Sprouted seeds were broadcast in the seedbed.

Tables 1 and 2 show the rice variety, seed rate, seedling characteristics in Aman and Boro seasons. Self-propelled four rows walking-type rice transplanter (Asia Transplanter) was used to transplant seedling. It has a fixed row spacing of 30 cm and has provisions for adjustments of planting depth, number of seedlings per hill and hill spacing. Before starting the transplanter, all the required adjustments as hill spacing, number of plant per hill and planting depth were done based on the machine operator's manual and other agronomical aspects. Tables 3 and 4 show comparative input in two practices in Aman and Boro seasons. Seedling age was higher in FP than TP. Rice variety, fertilizer rate, cultural practices, disease infestation depended on rice season. Proper care was taken and agronomic services were provided regularly in TP. Data on fuel consumption, planting depth, number of seedlings per hill, hill spacing, number of missing hill, floating hills, effective tiller and plant population were collected in both the seasons. Grain yield were recorded from pre-selected 10 m^2 land area and adjusted moisture content at the 14% moisture level. For computing yield contributing characters, four hills were collected from outside the selected area. Panicle number of each hill was counted to determine the panicle number m^{-2}. Plant samples were separated into straw and panicles. Panicles were hand-threshed and the filled spikelets were separated from unfilled spikelets. Spikelets per panicle, grain-filling percentage and harvest index were calculated.

Table 1. Seedling characteristics during Aman 2013 season.

Parameter	TP	FP
Variety	BRRI dhan49	BRRI dhan49
Date of seeding	6 Jul 2013	6 Jul 2013
Seed rate	150 gm dry seed $tray^{-1}$	37.5 kg ha^{-1}
Seedling raising technique	Plastic tray method	Traditional seedbed
Seedling raising media	Syngenta developed media	Farmers' nursery bed
Date of transplanting	26 Jul 2013	31 Jul 2013
Age of seedling	16 days	20 days

Table 2. Seedling characteristics during Boro 2013-14 season.

Parameter	TP	FP
Variety	BRRI dhan28	BRRI dhan28
Date of seeding	20 Dec 2013	20 Dec 2013
Seed rate	150 gm dry $seedtray^{-1}$	37.5 kg ha^{-1}
Seedling raising technique	Plastic tray method	Traditional seedbed
Seedling raising media	Syngenta developed media	Farmers' nursery bed
Date of transplanting	18 Jan 2014	1 Feb 2014
Age of seedling	28 days	42 days

Table 3. Comparative inputs during Aman 2013 season.

Parameter	TP	FP	Remarks
Basal Fertilizer	TSP- 105 kg ha^{-1} MOP-75 kg ha^{-1} Gypsum- 60 kg ha^{-1}	TSP- 105 kg ha^{-1} MOP-75 kg ha^{-1} Gypsum- 60 kg ha^{-1}	
Micro Nutrient	Grozin-7.5 kg ha^{-1} Bingo-2.5 kg ha^{-1} Megma-15 kg ha^{-1}	Grozin- 7.5 kgha^{-1}	
Weedicide	Rifit + Laser (1 litre + 130gm ha^{-1})	Rifit (1 Litre ha^{-1})	
Time of application	30 Jul 13	3 Aug 13	
Weeding	No manual weeding	No manual weeding	
Top dressing	Urea-187 kg ha^{-1} MOP-37kg ha^{-1}	Urea-150 kg ha^{-1} MOP- 56kg ha^{-1} DAP-56kg ha^{-1}	
1st top dress	Urea- 75 kg ha^{-1} at 15 DAT	Urea-75 kg ha^{-1}at 21 DAT	
2nd top dress	Urea-75 kgha^{-1}at 30 DAT		
3rd top dress	Urea-37 kg ha^{-1} MOP-37 kg ha^{-1}at 41 DAT	Urea-75 kg ha^{-1} MOP-56 kg ha^{-1} DAP-56 kg ha^{-1}at 55 DAT	Late application of more urea and DAP in FP, tiller and vegetative growth enhance at 60 to 80 DAT in FP.
Thiovit (sulfur)	Thiovit-1 kg at 15 DAT	Thiovit-1 kg at 21 DAT	
Insecticide	Virtako- 75gm ha^{-1} Plenum- 300gm ha^{-1}	Virtako- 75gm ha^{-1} Plenum- 300 gm ha^{-1}	BPH was 10% in Tegra and 20% was in FP than immediately take action.
Fungicide	Amister Top- 500 ml ha^{-1}, Filia- 1 litre ha^{-1} Score- 500 ml ha^{-1}	Amister Top- 400ml ha^{-1}, Filia- 1 L ha^{-1} Score- 400 ml ha^{-1}	False smut was 5% in Tegra and 15% was in FP.
Date of maturity	14 Nov 13	20 Nov 13	Tegra can be harvested 7 days earlier than FP

Table 4. Comparative inputs during Boro 2013-14 season.

Parameter	TP	FP	Remarks
Basal fertilizer	TSP@99 kg ha^{-1} MOP@70 kg ha^{-1} Gypsum@60 kg ha^{-1}	TSP@104 kg ha^{-1} MOP@110 kg ha^{-1} Gypsum@75 kg ha^{-1}	Farmer used more basal fertilizer than Tegra
Micro nutrient	Zn@7.5kg ha^{-1} B@2.5 kg ha^{-1} Mg@15 kg ha^{-1}	-	
Weedicide	Rifit+Laser@1L+185 g ha^{-1}	Rifit@750 ml ha^{-1}	
Time of application	23 Jan 2014	6 Feb 2014	
Weeding	One time harrowing only	3 times	
Top dressing	Urea 185 kg ha^{-1}	Urea 280 kg ha^{-1}, DAP 50 kg ha^{-1}	Farmers applied more fertilizer
1st top dress	Urea 74 kg ha^{-1}	Urea 120 kgha^{-1}	
2nd top dress	Urea 74 kg ha^{-1}	Urea 120 kg ha^{-1}	
3rd top dress	Urea 37 kg ha^{-1}	Urea 40 kg ha^{-1} DAP 50 kg ha^{-1}	
Cow dung	-	170 kg ha^{-1}	Used as top dressed
Thiovit (sulfur)	7.5 kg ha^{-1}	4.75 kgha^{-1}	
Insecticide	Virtako 2 times@ 75 g ha^{-1} Plenum 2 times@300g ha^{-1}	Virtako 1 times@75 g ha^{-1} Plenum 2 times@300 g ha^{-1}	
Fungicide	Score 1 time@500 ml ha^{-1} Amister Top 2 times@500ml ha^{-1}	Score 2 time@500ml ha^{-1} Amister Top 2 times@500ml ha^{-1}	
Date of maturity	25 Apr 2014	28 Apr 2014	

Border areas of all sides of the plot were excluded to avoid border competition effects. In order to estimate transplanting cost, the data on working speed, total time and labour inputs by the transplanter were recorded. Land value and interest on investment was considered to calculate the total input cost. Price of the produce was collected from the local markets to compute total production cost, gross return, gross margin and benefit-cost ratio. Statistical analysis was done by following Gomez and Gomez (1984). Data were analyzed using the ANOVA and the means comparison was determined using Duncan's multiple range tests (DMRT) with the help of the computer package MSTAT-C.

RESULTS AND DISCUSSION

Fuel consumption

Fuel consumption in walk behind type mechanical transplanter in both seasons ranged from 4.4-4.6 L ha^{-1} and varied depending on the soil condition. Fuel consumption depended on soil type and operational speed.

Plant spacing and hill density

In mechanical transplanter, line to line spacing was fixed at 30 cm whereas, plant to plant spacing can be varied and set at 15 and 17 cm. Figure 2 shows the distribution of plant to plant spacing in actual field condition. In mechanically transplanted plot, hill density ranged from 20.5-21.7 and 18.9-20.8 in Aman and Boro season respectively. Inconsistent hill density was observed in both the seasons. Exact plant spacing could not be maintained in mechanically transplanted plot due to slippage and skidding of the machine caused by water height, puddled depth and land leveling. In manually transplanted plot, hill density no. m^{-2} ranged from 14.8-18.3 and 17.46-21.2 in Aman and Boro season, respectively. It might be due to labourers transplanted seedling by eye estimation and unable to maintain proper plant spacing.

Missing hill

In mechanically transplanted plot, missing hill was observed 1-2%, which might be treated as acceptable range in crop production. Missing hill largely depended on the seed rate, seed germination, uniformity of seeding and seedling emergence in tray. Seeds having germination of more than 95% is recommended for seeding in tray to get the uniformity of seedling emergence (Islam and Rahman, 2015).

Number of seedlings dispensed per hill

Figure 3 presents the number of seedlings dispensed per hill in mechanically transplanted fields. Number of seedling dispensed per hill dependent on the seedling density in tray and seedling density setting. Seedling tray requirement in each plot largely depended on the seedling dispensed per stroke. More number of seedling dispensed per hill increased the tray requirement. In practical situation, number of seedlings in each hill varied in different plots. In most of the cases, 1-8 numbers of seedlings dispensed per hill. Single vigour seedling is enough to satisfy agronomic requirement. Calibration should be done on seedling density setting before operation in each plot to get optimum seedling density. To avoid missing hill, number of seedling dispensed should be more than one.

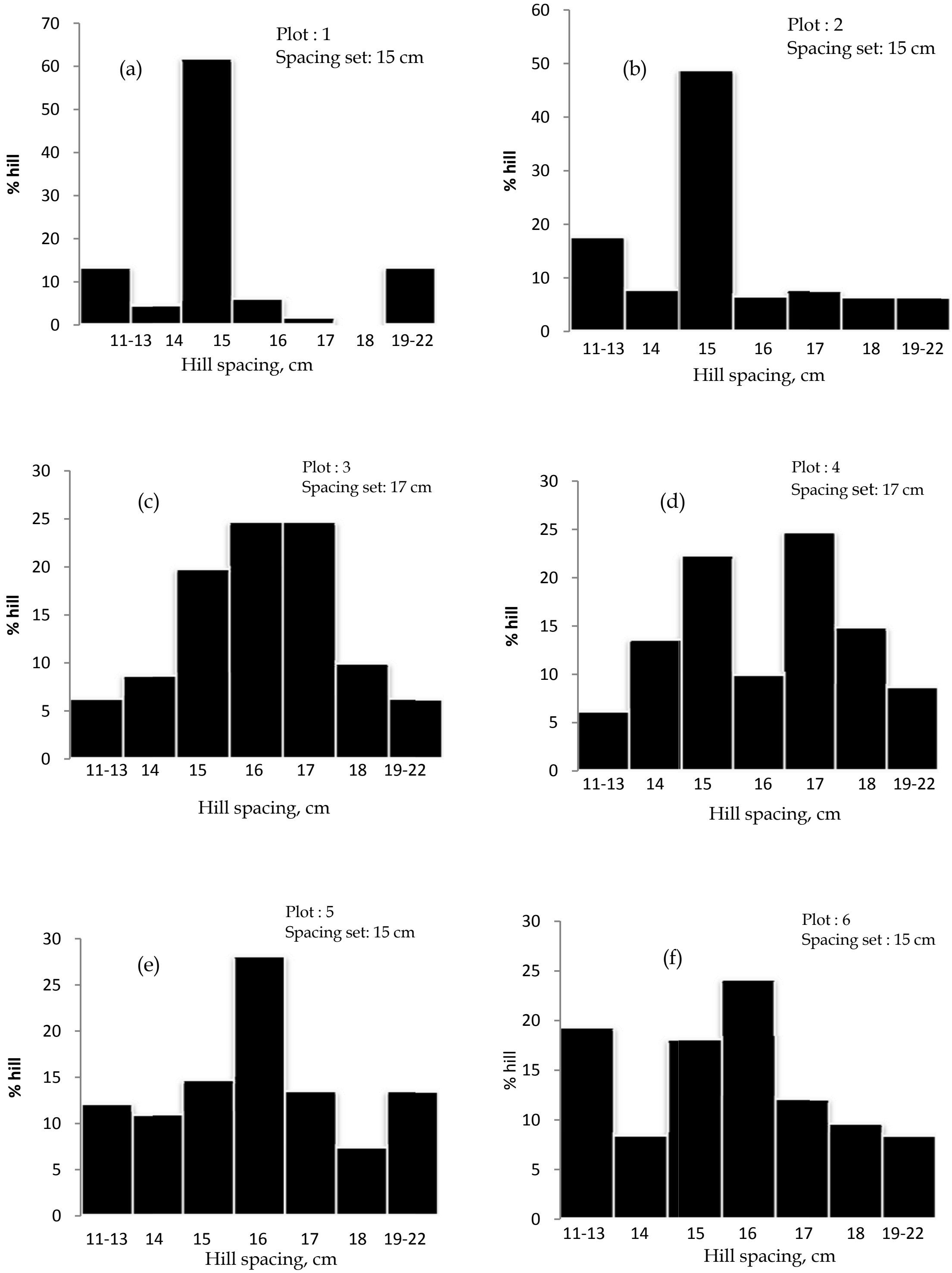


Fig. 2. Hill spacing under different space settings in mechanically transplanted plot.

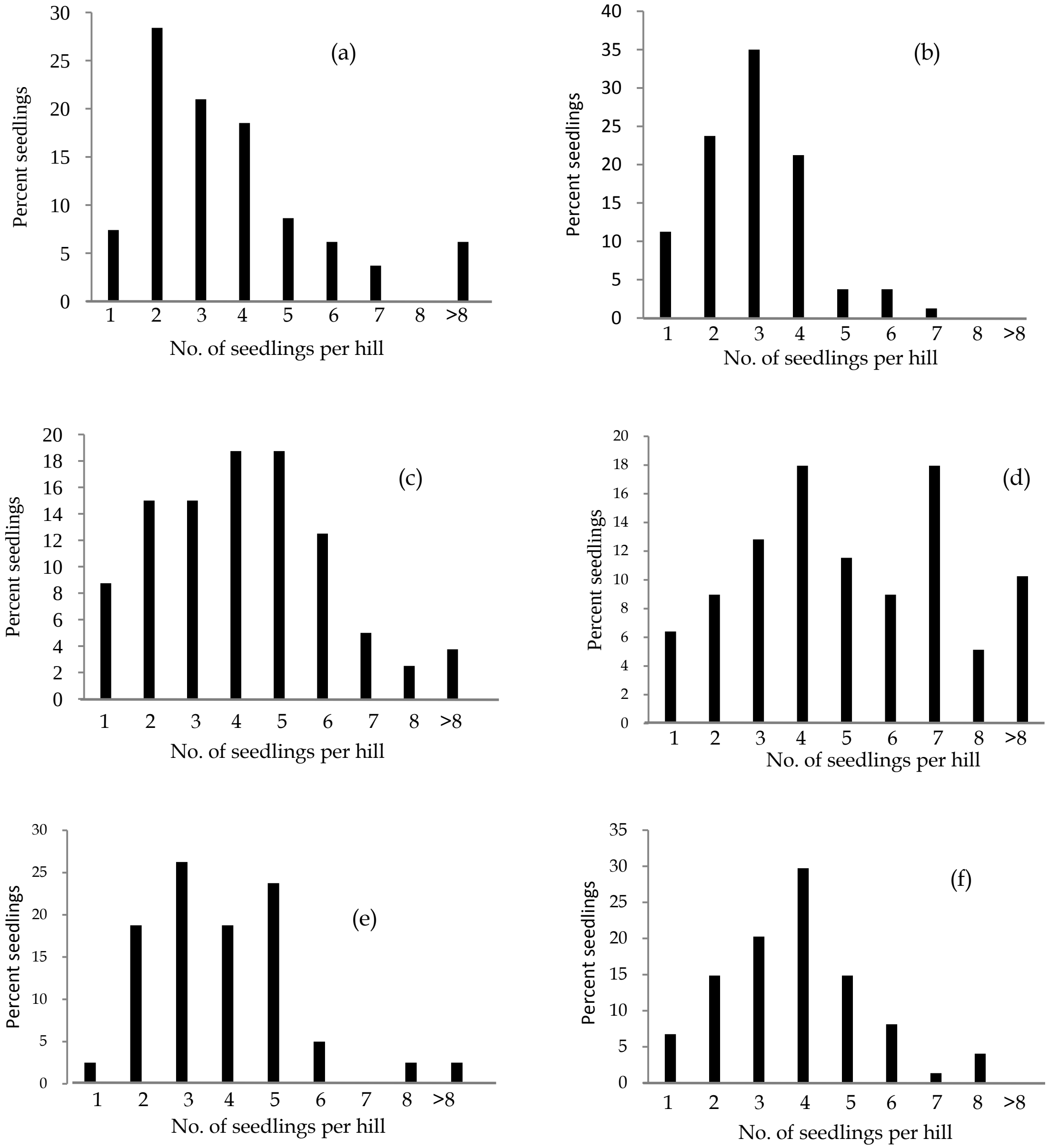


Fig. 3. Seedling density in mechanically transplanted field.

Plant height

The effects of management practices at different days after transplanting produced significant effect on plant height. Plant height observed similar in both the practices (Fig. 4). Plant height increased progressively overtime attaining the highest at 85 and 100 DAT in Aman and Boro season respectively and there after decreased at the maturity stage. It was due to leaf senescence. Plant height followed rapid growth from 20 to 55 DAT.

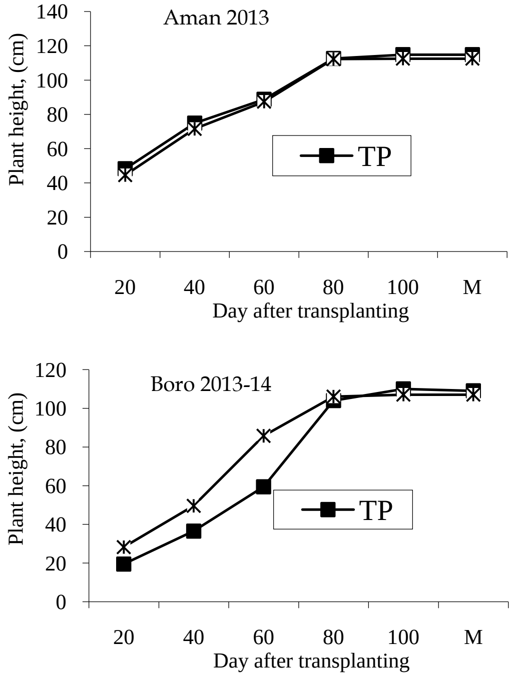


Fig. 4. Plant height in different management practices.

Tillering pattern

Figure 5 shows the effect of management practices on tillering pattern of Aman and Boro rice. Tillering pattern behaved similarly throughout the production period. Irrespective of management practice, tillering pattern followed increasing trend upto 40 DAT. In both the practices, the tiller production sharply increased from 20 DAT and the maximum tillering stage reached in 40 DAT in Aman and 60 DAT in Boro season and then decreased gradually due to tiller mortality. Tegra practices produced remarkably higher tillers than farmer practices upto maturity stage.

Stage-wise plant population

Figure 6 shows the stage-wise tiller production under different management practices. Tegra practices produced the highest tillers at all the studied stages and it was more pronounced at maximum tiller and panicle initiation stages. Figure 6 also shows that the highest tiller was produced in TP at the maximum tillering stage. Irrespective of management practices, tiller number was reduced at flowering and maturity stages.

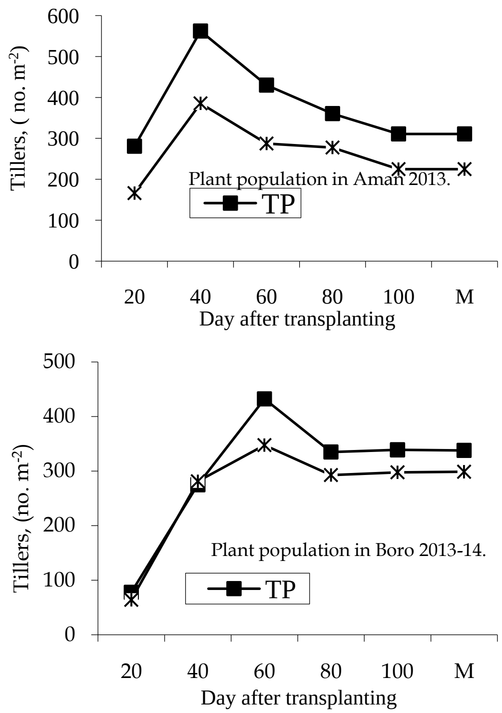


Fig. 5. Effect of management practices on tillering pattern of Aman and Boro rice.

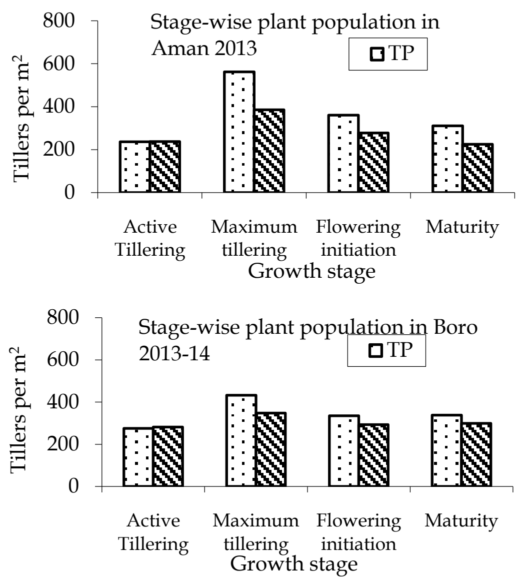
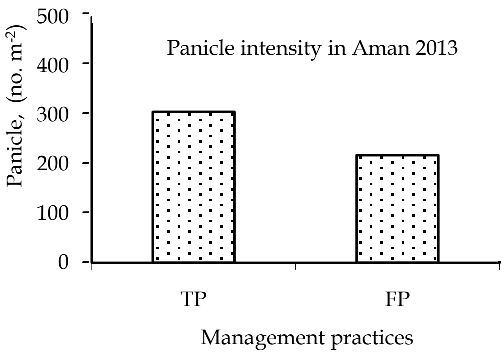


Fig. 6. Growth stage-wise tiller production in different management practices.

Panicle intensity

Figure 7 shows the panicle intensity as influenced by TP and FP. The data demonstrated that management practices showed statistically significant effect on panicle intensity in both the seasons.



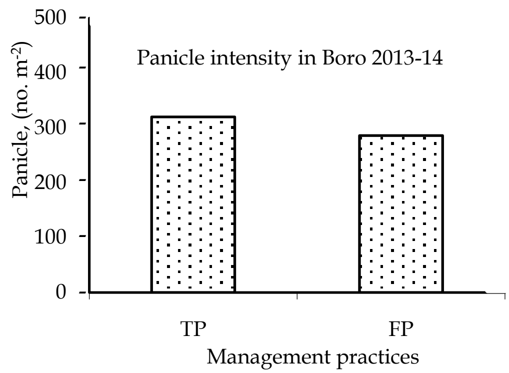


Fig. 7. Panicle intensity as influenced by TP and FP.

Yield and yield contributing character

Crop matured 3-6 days earlier in TP than FP. Management practices had significant effect on panicle length. TP produced the longest panicle than FP in both the seasons. TP produced the highest grain per panicle than FP. Sterile spikelet production was not significantly affected by management practices. TP produced the highest 1000-grain mass than FP (Tables 5 and 6). Grain yield is a function of interplay of various yield components such as number of productive tillers, spikelets per panicle and 1000-grain weight (Hassan *et. al*., 2003). TP produced significantly highest grain yield in both the seasons due to use of tender age seedling and good management practices. Grain yield obtained 14-23% higher in TP than FP in both the seasons.

Economic analysis

Table 7 shows the price of the product collected from the local market. Table 8 includes all inputs (fuel, labour, irrigation, pesticides, weeding and other expenses) from seedbed preparation to harvesting operations and benefit-cost ratio. Same amount of seed, labour, fertilizer and irrigation water was applied in all the plots of FP. This is not the real farmers' practices.

Farmers always influenced by the Tegra practices and applied more input with a hope to increase yield. The total production cost, gross return, gross margin and BCR were the highest in TP in two seasons. Production cost was 12% higher in TP than FP in Aman season due to applying higher input. Input cost was almost similar in Boro season as the farmers applied same input by following the Tegra practices. Gross return was higher in TP than FP due to higher grain and straw yield. Gross margin was higher in TP than FP in both the seasons. BCR was 8-19% higher in TP than FP in both the seasons due to the higher input cost as well as the higher gross margin compared to FP. TP was more remunerating than FP in both the seasons.

Table 5. Yield and yield contributing character during Aman 2013 season.

Practice	Panicle length(cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000-grain weight (gm)	Grain yield, (t ha^{-1})
TP	23.01	129.4	26.53	22.4	5.32
FP	22.16	108.8	27.11	21.9	4.66
CV, (%)	2.22	7.63	9.76	0.77	3.78
Level of significance	**	*	NS	*	*

Table 6. Yield and yield contributing character during Boro 2013-14 season.

Practice	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000-grain weight (gm)	Grain yield, (t ha^{-1})
TP	23.30	112.60	30.90	23.20	6.40
FP	24.50	122.70	37.00	22.30	5.20
CV (%)	1.97	18.24	42.78	1.34	7.24
Level of significance	*	NS	NS	*	*

Table 7. Product name with price.

Name of product	Quantity	Price (Tk)	Name of product	Quantity	Price (Tk)
TSP	50 kg	1220	Plenum	100 g	480
MOP	50 kg	730	Score	500 ml	1110
Urea	50 kg	820	Amister Top	500 ml	1335
Gypsum	10 kg	220	Rifit	500 ml	380
Zinc	1 kg	200	Laser	25 g	45
Megma	1 kg	105	Thiovit	1 kg	180
Bingo	1 kg	400	DAP	50 kg	900
Paddy price	1 t	20000			

Table 8. Production cost and benefit-cost ratio of TP and FP during Aman 2013 and Boro 2013-14 season.

Item, Tk ha^{-1}	Aman 2013		Boro 2013-14	
	TP	FP	TP	FP
Seed	2805	2319	2618	1309
Seedling raising	13464	3625	6508	3590
Land preparation	4488	4488	6732	6732
Basal fertilizer	8243	6859	8826	6016
Irrigation	2244	2244	7480	7480
Transplanting	1122	5984	2094	3740
Herbicide	1047	748	898	648
Gap filling + weeding			11220	14960
Urea top dressed	3740	4563		
Sulpher + Thiovit	1346	1346	4294	6024
Insecticide	4712	3815	3590	2525
Fungicide	6313	4795	3642	3643
Harvesting +Threshing	9724	9724	11220	11220
Sub total	59249	50510	69121	67887
Land value	20000	20000	20000	20000
Interest on investment (12%)	1982	1764	2229	2198
Total production cost	81231	72274	91351	90086
Gross return	123760	101779	148397	122615
Gross margin	42529	29505	57046	32529
Benefit-cost ratio	1.52	1.41	1.62	1.36

CONCLUSION

Plant spacing of mechanically transplanted plot varied depending on puddled condition, soil type and water height. Plant height followed the similar trend in both the practices. Tillering ability showed the highest in TP. TP showed significantly higher grain yield than FP due to use of tender age seedling and good management practices. Tegra practice was more profitable in Boro than Aman season. It could be promoted extensively in farmer's field to get better yield and economic performance.

RECOMMENDATION

The results should be validated in different Agro-ecological zone.

ACKNOWLEDGEMENT

The authors acknowledge the support of Syngenta Bangladesh Limited to conduct the validation trial in two seasons.

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Bangladesh Rice J. 20 (1) : 45-50, 2016

Characterization and Evaluation of Aerobic Rice Genotypes under Transplanted Condition

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ABSTRACT

Due to over sinking of underground water, scarcity of irrigation water is becoming a threat to the sustainability of irrigated rice production and the concept of aerobic culture appeared prominently. Aerobic rice has the ability to grow under minimum irrigation water and minimum yield reduction occurs when grown under aerobic culture with less water. This experiment aimed to evaluate two advanced aerobic rice lines under transplanted condition in net house. Two advanced lines, IR83140-B-36-B-B and IR83142-B-71-B-B and two check varieties BRRI dhan28 and BRRI dhan29 were grown in three moisture regimes. The moisture regimes included a) continuous standing water (CSW) b) saturated moisture condition (SMC) and c) moisture content at field capacity (FCM). The experimental units, drum containing 110 kg soil, were arranged in randomized complete block design (RCBD) with five replications. Three to four seedlings of forty days were transplanted at the soil surface of each drum. Seedlings were thinned to one plant per genotypes one week after transplanting. Genotype × water interaction showed significant variation in total dry matter production, panicle length, panicle exertion rate, sterility percentage and yield contributing characters. Irrespective of the genotypes, CSW conditions favored to produce maximum number of tiller and panicle. Although BRRI dhan29 gave the highest yield at both CSW and SMC, IR83142-B-71-B-B produced the highest yield at FCM. However, BRRI dhan28 gave similar yield to that of IR83142-B-71-B-B in FCM treated drums.

Key words: Aerobic rice, moisture regimes, transplanted condition, growth characters, yield contributing characters, yield

INTRODUCTION

Irrigated rice fields of Asian countries consume more than 40% of the world's freshwater that is used for agriculture (Bouman 2001). Tuong and Bouman (2003) estimated that by 2025, approximately two million hectares of irrigated dry-season rice and 13 million hectares of wet-season rice land will experience water scarcity. The declining availability of irrigation water and increasing costs of water threaten the traditional method of cultivating irrigated rice. Moreover, due to climate change insufficient rainfall would be a major production constraint in rain-fed areas where many marginal farmers live. As water is the most limited and essential natural resource in agriculture, the dwindling water resources reveal a grim situation for lowland puddled rice cultivation. Because of increasing water scarcity, there is a need to develop alternative systems that require less water (Bouman *et al.,* 2002).

Aerobic rice production is a revolutionary way of growing rice in non-puddled, non-flooded fields (Singh *et al.,* 2008; Rajakumar *et al.,* 2009) and rice is grown like an upland crop (unsaturated condition) with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman, 2001). This system uses input-responsive specialized rice cultivars and complementary management practices to achieve at least 4-6 t ha^{-1} using only 50-70% of the water required for irrigated rice production. Varieties suitable for this type of cultivation also possess ability to withstand intermittent drought spells with minimum yield loss with maximum yield

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potential of 6 tons per hectare. Aerobic rice could be cultivated with 600 to 700 mm of total water in summer and entirely on rainfall in wet season (Hittalmani, 2007). So aerobic rice recommended in areas where water is too scarce or expensive to allow traditional irrigated rice cultivation. Growing rice aerobically saves water by eliminating continuous seepage and percolation, reducing evaporation and eliminating wetland preparation. It is also reported that amount of methane emitted under aerobic situation is very low and contributes to lowering of greenhouse gas emission (Hittalmani, 2007).

Suitable rice genotypes for aerobic cultivation are limited. Recently International Rice Research Institutes developed fixed lines (IR83140-B-36-B-B and IR83142-B-71-B-B), which would be suitable to grow in aerobic soil condition. These lines have not been tested for its suitability in the climatic conditions of Bangladesh. Field testing of the aerobic rice lines encounters difficulties in moisture control. Therefore, their potentiality needs to be tested under control net house conditions with different moisture regimes. Physiological characteristics (eg. photosynthesis rate and dry matter production) along with yield and yield contributing characters of the aerobic lines need to be compared with regular varieties. Therefore, a net house experiment was conducted to compare physiological traits and yield of IR83140-B-36-B-B and IR83142-B-71-B-B against the Boro varieties under different moisture regimes.

MATERIALS AND METHODS

Two advanced lines IR83140-B-36-B-B and IR83142-B-71-B-B along with standard Boro varieties BRRI dhan28 and BRRI dhan29 were evaluated in drum (56 cm x 43 cm) containing 110 kg soil. The soil was fertilized with Urea-TSP-MP @ 50-25-25 g/drum. Forty day aged seedlings were transplanted at 21 January, 2015. Three to four seedlings were transplanted at the soil surface of each drum. Seedlings were thinned to one plant per genotypes one week after transplanting. The experiment was conducted under three water regimes as continuous standing water (CSW), saturated moisture condition (SMC) and moisture content at field capacity (FCM).Water treatment was started at tillering stage. Saturation and moisture content at field capacity were determined through the Gravimetric Method and the desired moisture contents were maintained by quantitatively adding water to the respective drums at two to three days interval. To avoid rainfall all the drums were shaded by polythene sheet. The drums were arranged in RCB design and replicated five times. Photosynthesis data was taken at maximum flowering stage considering flag leaf at the middle portion using LI-6400 portable photosynthesis system. Panicle exertion rate was measured following the formula (Length of the exerted panicle /Total length of panicle)*100. Data on other growth characters, yield and yield contributing characters were collected and analyzed by using CROPSTAT 7.2 statistical software of IRRI.

RESULTS AND DISCUSSION

Growth characters

Genotype × water regime demonstrated insignificant interaction in case of plant height, tiller number, rate of photosynthesis and days to heading (Table 1). The tested genotypes had significant variation in plant height. BRRI dhan28 produced the highest plant height followed by BRRI dhan29 and

Table 1. Plant height, tiller number, photosynthesis rate, days to heading and total dry matter of tested genotypes at different moisture levels.

Genotype	Treatment	Plant height (cm)	Tiller no. hill^{-1}	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Day to heading	Total dry matter (g hill^{-1})
IR83140-B-36-B-B	Control	93.2	22.2	22.0	115	54.2
	Saturation	84.3	15.4	19.6	114	40.1
	Field capacity	79.5	16.0	18.0	117	32.9
IR83142-B-71-B-B	Control	94.6	20.2	22.6	111	75.4
	Saturation	94.0	18.8	20.3	114	64.8
	Field capacity	93.0	16.2	20.5	113	50.8
BRRI dhan28	Control	110.0	20.8	20.3	107	74.2
	Saturation	102.2	15.0	20.5	108	54.8
	Field capacity	108.4	15.6	21.4	110	44.6
BRRI dhan29	Control	107.4	20.8	18.3	125	98.5
	Saturation	99.0	19.0	18.1	127	83.3
	Field capacity	92.2	18.4	14.3	127	34.1
$LSD_{0.05}$ for genotype (G)	-	5.4	2.6 ^{ns}	3.2	1.7	10.8
$LSD_{0.05}$ for moisture level (M)	-	4.7	2.2	2.8	1.5	9.4
$LSD_{0.05}$ for G×M	-	9.4^{ns}	4.5 ^{ns}	5.6 ^{ns}	3.0 ^{ns}	18.8

the advanced lines (IR83140-B-36-B-B and IR83142-B-71-B-B) had relatively shorter plants height. This is due to the varietal differences of the tested genotypes. Water treatment produced significant effect on the plant height and tiller number per plant as well. Irrespective of genotypes, maximum plant height and tiller number per plant was observed in continuous standing water condition and minimum in field capacity condition (Table 1). Bakul *et al.* (2009) observed reduced tiller production under moisture stress condition.

Rate of photosynthesis at flowering stage also showed insignificant interaction. But effect of genotypes and water regimes was significant for this trait. Assimilation rate was statistically similar for the genotype IR83142-B-71-B-B, BRRI dhan28 and BRRI dhan29 at CSW and SMC condition. But moisture content at field capacity BRRI dhan29 had the lowest assimilation rate whereas BRRI dhan28 and IR83142-B-71-B-B showed the highest assimilation (Table. 1). Patel *et al.* (2010) reported similar results where genotypes having high photosynthesis rate performed better at water deficit condition.

Genotype × water regime showed significant interaction for total dry matter production (Table 1). Maximum total dry matter was produced in BRRI dhan29 followed by IR83142-B-71-B-B at CSW condition and SMC condition. But moisture content at field capacity IR83142-B-71-B-B and BRRI dhan28 produced maximum amount of total dry matter. Genotype IR83140-B-36-B-B produced minimum amount of total dry matter at all moisture regimes (Table 1). These findings are in accordance with the results obtained by Patel *et al.* (2010) where dry matter accumulation is more in CSW condition than moisture content at field capacity. Because water deficit at the vegetative stage hampered crop growth and development and reduced the number of tillers and dry matter. Significant variation was not observed for heading date at different moisture regimes. Days to heading was recorded minimum in BRRI dhan28 and maximum in BRRI dhan29 than other two genotypes (Table 1). Variation in what are the growth characters as total dry matter and photosynthesis rate among the genotypes under aerobic condition are useful to determine the appropriate aerobic rice genotypes. In this regards, IR83142-B-36-B-B was found as the best genotype under water stress condition.

Yield contributing characters

Genotype × water regime interaction showed insignificant variation for number of panicle per hill. Irrespective of genotypes, panicle number varied significantly with moisture regimes. Maximum number of panicle was observed at CSW condition and minimum at field capacity condition (Table 2). Number of panicle in genotype IR83142-B-71-B-B and BRRI dhan29 was similar at saturated moisture condition. But at field capacity condition BRRI dhan28 produced maximum number of panicle and BRRI dhan29 produced the least number of panicle. Panicle length showed significant variation for the interaction of genotypes and water regime. Maximum panicle length was observed at continuous standing water and saturated moisture condition. Moisture content at field capacity BRRI dhan28 and BRRI dhan29 produced the highest and lowest length of panicle, respectively. Bakul *et al*. (2009) also observed poor emergence of panicle and reduced length of panicle under moisture stress condition.

Panicle exertion rate showed significant variation for genotype × water regime interaction (Table 2). The highest rate of panicle exertion was recorded with BRRI dhan28 at continuous standing water whereas other genotypes were statistically similar for panicle exertion. At saturated moisture condition panicle exertion rate was the highest in IR83140-B-71-B-B followed by BRRI dhan28. Moisture content at field capacity BRRI dhan29 had the least panicle exertion rate. Higher panicle exertion rate might be due to the genetic potentiality of the genotypes. However, panicle exertion rate was about 80 to 90%, 78 to 91% and 64 to 89% at CSW, SMC and FCM condition, respectively. Genotype × water regime interaction showed significant variation for spikelet sterility percentage. The highest spikelet sterility percentage was observed at moisture content of field capacity for the genotype BRRI dhan29 (Table 2). High spikelet sterility was due to the water deficiency at field capacity condition. Because water stress reduced the number of tiller as well as reduced total dry matter production which ultimately increased the spikelet sterility percentage at this condition than continuous standing water condition. Begum (1990) reported that water deficit increased the number of empty spikelet per panicle.

Table 2. Panicle number, panicle length, panicle exertion rate and sterility percentage of tested genotypes at different moisture levels.

Genotype	Treatment	Panicle no. $hill^{-1}$	Panicle length (cm)	Panicle exertion rate (%)	Sterility percentage
IR83140-B-36-B-B	Control	20.8	20.6	84.3	47.8
	Saturation	13.6	20.8	90.9	39.2
	Field capacity	13.6	18.3	86.9	48.9
IR83142-B-71-B-B	Control	18.2	20.5	84.7	42.7
	Saturation	16.0	19.6	80.9	47.7
	Field capacity	13.0	19.0	80.1	53.2
BRRI dhan28	Control	19.0	21.6	90.4	36.4
	Saturation	14.4	20.8	91.6	28.8
	Field capacity	14.0	21.0	89.8	49.2
BRRI dhan29	Control	18.6	18.9	80.5	26.6
	Saturation	18.2	19.4	78.9	27.3
	Field capacity	11.8	14.3	64.0	70.8
$LSD_{0.05}$ for genotype (G)	-	2.03^{ns}	1.2	4.5	9.6^{ns}
$LSD_{0.05}$ for moisture level (M)	-	1.7	1.1	3.9	8.3
$LSD_{0.05}$ for G×M	-	3.5^{ns}	2.2	7.8	16.7

Yield and yield component

Number of filled grain per panicle showed significant variation for genotype × moisture regime interaction. BRRI dhan28 and BRRI dhan29 produced maximum number of filled grain per panicle both at CSW and SMC condition than other two genotypes (Table 3). Bakul *et al*. (2009) also found the similar result that water deficit reduced the number of filled grain per panicle. However, maximum number of filled grain was observed in BRRI dhan28 followed by IR83142-B-71-B-B at field capacity of soil. This is due to the production of higher total dry matter production at field capacity condition. As total dry matter has positive relation with number of filled grains per panicle. There was significant difference in 1000 grain weight among the tested genotypes. Higher grain weight was observed for the genotype IR83142-B-71-B-B at all moisture regimes than other genotypes. This is due to the varietal effect of this genotype. Grain weight (1000 grain) also varied significantly with the different water regime. However, the highest reduction for thousand grain weight was obtained at field capacity condition for all the genotypes (Table 3). This result was also in agreed with Bakul *et al*. (2009).

Grain yield varied significantly for the genotype × moisture regime interaction. Under CSW maximum and minimum grain yield was observed in BRRI dhan29 and IR83140-B-36-B-B, respectively. At saturated moisture condition grain yield of all tested genotypes were statistically similar with continuous standing water except BRRI dhan28. The highest grain yield was obtained with IR83142-B-71-B-B and BRRI dhan28 whereas IR83140-B-36-B-B and BRRI dhan29 gave the lowest yield at the field capacity condition (Table 3). The findings are in accordance with of Patel *et al.* (2010). They stated that the grain yield of rice under aerobic condition was lower than flooded condition. Decrease in grain yield of aerobic rice compared to flooded rice was also reported by Bouman *et al.* (2005) and Peng *et al.* (2006). Maximum grain yield reduction was observed in BRRI dhan28 followed by IR83140-B-36-B-B at saturated condition. There was the lowest grain yield reduction (>50%) in IR83142-B-71-B-B both at saturated moisture and moisture content at field capacity (Table 3). The higher grain yield was obtained due to higher number of filled grain number per panicle as well as higher thousand grain weight.

Table 3. Yield and yield components of tested genotypes at different moisture levels.

Genotype	Treatment	Filled grain no. panicle^{-1}	1000-grain wt (g)	Grain yield (g hill^{-1})	% yield reduction
IR83140-B-36-B-B	Control	56	20.9	24.5	-
	Saturation	68	20.3	17.3	29.4
	Field capacity	38	20.1	10.8	55.6
IR83142-B-71-B-B	Control	75	23.5	32.5	-
	Saturation	79	23.0	28.8	11.2
	Field capacity	69	22.0	19.9	38.8
BRRI dhan28	Control	100	19.3	36.7	-
	Saturation	97	18.1	25.4	30.6
	Field capacity	72	18.8	18.2	50.2
BRRI dhan29	Control	132	18.5	46.7	-
	Saturation	126	18.7	43.0	7.7
	Field capacity	50	16.5	10.8	76.7
LSD $_{0.05}$ for genotype (G)	-	16	1.1	5.4	-
LSD $_{0.05}$ for moisture level (M)	-	14	0.9	4.7	-
LSD $_{0.05}$ for G×M	-	28	1.9^{ns}	9.4	-

CONCLUSION

The new aerobic rice line IR83142-B-71-B-B demonstrated the least reduction in total dry matter production and grain yield among the tested genotypes under field capacity conditions. The aerobic rice line IR83142-B-71-B-B may be recommended for field evaluation under water stress condition.

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Bangladesh Rice J. 20 (1) : 51-58, 2016

Integrated Nutrient Management for Potato-Maize-T. Aman Rice Cropping Pattern

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ABSTRACT

A field experiment on integrated nutrient management (INM) for Potato-Maize-T. Aman cropping pattern was conducted at BRRI RS farm, Rangpur (AEZ-3) during 2007-2010. The objectives were to examine the effect of Potato-Maize-T. Aman cropping on soil fertility and to develop appropriate fertilizer management practices for the above mentioned pattern. Inorganic and organic nutrient sources were tested in six different combinations in Rangpur region. Poultry manure (PM) @ 3.0 t ha^{-1} + IPNS based inorganic fertilizers for potato (N_{80}, P_0, K_{30}, S_0, Zn_0, Mg_4, B_1) and maize (N_{136}, P_0, K_{40}, S_2, $Zn_{1.8}$, Mg_2, B_1) crops, and STB dose for T. Aman crop (N_{65}, P_3, K_{27}, S_8) has been recommended for Potato-Maize-T. Aman cropping pattern in Rangpur region. In fertilized plots, there was an apparent negative balance for N and K. The balances for P and S were positive. Organic C, total N and available P in soil increased due to integration of chemical fertilizer with PM. Results indicate that it is necessary to apply organic manure in combination with chemical fertilizer for sustaining soil fertility. For maize and potato crops, fertilizer dose needs to be updated after every three years of successive crop cultivation under Potato-Maize-T. Aman cropping pattern. Net additional income was the highest in T_5 where PM and IPNS based fertilizer applied.

Key words: Poultry manure, nutrient sources, soil health, nutrient balance

INTRODUCTION

Maize is occupying third position among the cereals in Bangladesh and its acreage and production is increasing day by day from the base period. But three crops in a year Potato-Maize-Rice pattern uptakes a lot of nutrients from the soil. Gill and Singh (1978) found that fodder crop removed more K than either grain or cash crops. It was also found that combined application of organic and inorganic sources of nutrient to soils increased the use efficiencies of production inputs and also increased crop yields (Rahman, 2012; Rahman, 2013). Long-term basis poultry litter application and continuous cropping can increase soil carbon sequestration and labile carbon fractions, thereby offsetting atmospheric carbon dioxide emission and improving soil and environmental quality (Sainju *et al.*, 2008). Poultry manure has favourable effects on improving the soil moisture content and bulk densities of soil. According to Boateng *et al.* (2006) bulk density values were slightly lowered by the poultry manure. High moisture contents and lower bulk densities are better soil characteristics for good plant growth. In this context, this study was undertaken to find the effect of integrated nutrient management approach for Potato-Maize-T. Aman pattern in maintaining soil fertility and improving crop productivity as well to update fertilizer recommendation.

MATERIALS AND METHODS

Field experiment was conducted at the BRRI RS farm, Rangpur (AEZ-3) during the period of Kharif-1, 2007 to Rabi, 2009-10. Table 1

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Table 1. Initial soil characteristics of the experimental field.

Parameter	BRRI RS farm, Rangpur	
	0-15 cm	16-30 cm
pH (1:2.5)	5.03 ± 0.13	5.30 ± 0.06
Org. C (%)	0.73 ± 0.02	0.57 ± 0.05
Total N (%)	0.07 ± 0.00	0.04 ± 0.00
Available P (ppm)	15.43 ± 0.89	7.03 ± 1.47
Exchangeable K (meq/100 g soil)	0.13 ± 0.02	0.10 ± 0.01
Exchangeable Na (meq/100 g soil)	0.27 ± 0.00	0.16 ± 0.10
Available S (ppm)	2.90 ± 0.20	2.70 ± 0.10
Available Zn (ppm) (DTPA)	1.10 ± 0.17	-

presents the initial soil characteristics of the experimental field. The soil texture of BRRI RS farm, Rangpur is sandy loam having strongly acidic reaction. Six treatment combinations were tested: T_1=Native nutrient; T_2=AEZ basis (BARC fert. Recom. Guide, 2005); T_3=Soil testbased (STB) dose; T_4=20% more than STB dose; T_5=Poultry Manure (PM) @ 3 t ha^{-1} (oven dried) + IPNS basis inorganic fertilizer for maize and potato crop/T_5=same as T_3 for T. Aman crop and T_6=Farmers' practice (based on interview of 15/20 local farmers). Nutrient content of poultry litter is given as follows: moisture (33.6±4.77) %, OC (11.4±1.14) %, Total N (2.00±0.11) %, P (2.34±0.13) %, K (2.00±0.15) %, S (1.00±0.12) %, Zn (0.04±0.002) % and Mg (0.07±0.001) %. Table 2 presents detailed treatment description. The experiment was laid out in a randomized complete block design with three replications. The sources of N, P, K, S, Zn, B and Mg were urea, TSP, MoP, gypsum, zinc sulfate, borax and magnesium sulfate, respectively. Except urea, all other inorganic fertilizers were applied at final land preparation for all crops in the cropping pattern. Well decomposed PM was applied at final land preparation for maize and potato.

Urea was applied into three equal splits for maize and T. Aman crop: 1/3 N as basal, 1/3 N at 25-30 day after sowing (maize)/1/3 N at 15-20 DAT (T. Aman) and 1/3 N at 45-50 DAS (maize)/1/3 N at 27-30 DAT (T. Aman). For potato, urea was applied into two equal splits: ½ as basal and the rest ½ at 30-35 DAS. Necessary intercultural operations were done as and when ever required for each crop.

Potato

Potato (cv. Diamont/Granula) was tested. It was seeded on last week of November. One seed/pit (depth of 5.0-7.5 cm) was sown with line to line 50 cm spacing and seed to seed 20 cm apart.

Maize

Maize (BARI hybrid 3 (1^{st} yr), BARI hybrid 2 (2^{nd} yr) and BARI hybrid 5 (3^{rd} yr), Kharif I) was grown at 2^{nd} week of March of the conducted year. Two seeds/pit (at the depth of 2.5-5.0 cm) was sown with line to line 80 cm spacing and seed to seed 20 cm apart.

T. Aman rice

BRRI dhan33 was tested. Thirty- to thirty-five-day-old seedlings were transplanted using 2/3 seedlings/hill at 20 cm × 20 cm spacing on the 2^{nd} and 3rd week of July of the conducted year.

At maturity, the maize and potato were harvested from the whole plot (Plot size: 4 m × 4 m) and T. Aman crop was harvested from 5 m^2 area at the centre of each plot. The grain yield of maize and T. Aman rice was adjusted to 14% moisture. The crop residue was recorded at oven dry basis. Economic analysis was done.

Table 2. Treatment details for the Potato-Maize-T. Aman cropping pattern.

	Nutrient (kg/ha)						
Treatment	N	P	K	S	Zn	Mg	B
			Kharif-I (Maize)				
T_1	0	0	0	0	0	0	0
T_2	196	36	75	30	3	3	1
T_3	196	42	99	32	3	4	1
T_4	235	50	119	38	3.6	5	1
T_5	136	0	39	2	1.8	2	1
T_6	95	15	30	10	0	0	0
			Kharif-II (T. Aman)				
T_1	0	0	0	0	0	0	0
T_2	66	4	16	8	0	0	0
T_3	65	3	27	8	0	0	0
T_4	78	4	33	10	0	0	0
T_5*	65	3	27	8	0	0	0
T_6	46	0	10	0	0	0	0
			Rabi (Potato)				
T_1	0	0	0	0	0	0	0
T_2	96	16	64	10	1.5	6	1
T_3	139	11	91	10	1	6	1
T_4	167	13	109	12	1	7	1
T_5	79	0	31	0	0	4	1
T_6	139	21	154	19	2	7	4

T_1 = Native nutrient, T_2 = AEZ basis (BARC fert. recom. guide, 2005), T_3= Soil test based (STB) dose, T_4 = 20% more than STB dose, T_5= PM @ 3 t ha^{-1} (O D basis) + IPNS basis inorg. fertilizer, T_5* = Same as T_3 and T_6 = Farmers' practice.

Nutrient contents (N, P, K and S) from plant samples of the 1st and 2nd crop-cycle of the cropping pattern were determined by standard laboratory procedure (Yoshida *et al.*, 1972). After the completion of three crop-cycles, some physico-chemical properties of post harvest soil were studied following the standard procedure (Blake and Hartge, 1986; Black, C A, 1965; Jackson, M L, 1962; Page *et al.*, 1982). The recorded data were statistically analyzed using IRRISTAT version 4.1 (IRRI, 1998).

RESULTS AND DISCUSSION

Yield of potato

Table 3 presents the yield of potato in Potato- Maize-Rice pattern. Application of fertilizer significantly increased the tuber yield of potato and oven dried foliage yield. In 2007-80 the highest total fresh tuber yield (24.36 t ha^{-1}) was obtained with T_5 (Table 3). The significantly highest total biomass was obtained with T_6 (1.09 t ha^{-1}) followed by T_5 (1.08 t ha^{-1}). In 2008-09 treated plots T_2, T_3, T_4 and T_5 produced significantly identical total fresh tuber yield (17.41-19.57 t ha^{-1}) (Table 3). Significantly higher total biomass was obtained with T_4 (0.59 t ha^{-1}) followed by T_5 (0.55 t ha^{-1}).

In 2009-10 treatment T_4, T_5 andT_6 produced identical fresh tuber yield. The treatment T_3 reduced the fresh tuber yield than that of T_4. It indicates that T_3 (STB) is not quietly sound to produce tuber yield. After third year, it is needed to reformulate the STB dose after soil testing in case of potato. The treatment T_5 and T_6 produced identical bio-mass (Table 3).

Table 3. Effect of integrated nutrient management on the yield of potato in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2010.

Treatment	Potato yield (t ha^{-1})							
	2007-08 (cv. Diamont)		2008-09 (cv. Diamont)		2009-10 (Granula)		Mean	
	Tuber	Residue	Tuber	Residue	Tuber	Residue	Tuber	Residue
T_1 (Native nutrients)	8.53	0.31	8.71	0.13	5.52	0.17	7.59	0.20
T_2 (BARC Rec. Dose)	19.01	0.62	17.41	0.37	17.06	0.30	17.83	0.43
T_3 (STB)	19.36	0.63	17.43	0.42	17.08	0.39	17.96	0.48
T_4 (20% >STB)	18.17	0.70	19.57	0.59	18.33	0.30	18.69	0.53
T_5 (PM+IPNS)	24.36	1.08	19.40	0.55	18.90	0.66	20.89	0.76
T_6 (FP)	20.37	1.09	16.60	0.52	19.13	0.65	18.70	0.75
$LSD_{0.05}$	2.68	0.50	2.77	0.10	1.63	0.08	-	-
CV (%)	8.1	17.6	9.2	12.5	5.6	10.3	-	-

Maize yield

Table 4 presents the yield of maize (BARI hybrid 3, 2 and 5) in Potato-Maize-Rice cropping *pattern. Applied fertilizer significantly increased the grain and straw yield of maize. In 2007, the highest grain yield of 6.67 t ha^{-1} was obtained with T_4 followed by T_2, and these treatments were* statistically similar with other treated plots except T_1. All treated plots (T_2-T_6) produced statistically identical total biomass yield (9.59-12.71 t ha^{-1}).

In 2008, the highest grain yield of 6.29 t ha^{-1} was obtained with T_5 followed by T_4, and these treatments were statistically identical. Treatment T_2, T_3 and T_4 produced statistically identical grain yield (5.31-5.75 t ha^{-1}). T_1 yielded the lowest yield (1.53 t ha^{-1}). The significantly highest straw yield (10.65 t ha^{-1}) was obtained with T_5 followed by T_4 and these treatments were statistically identical.

In 2009, the highest grain yield of 7.25 t ha^{-1} was obtained with T_4 followed by T_3, and the treatments T_3, T_4 and T_5 were statistically identical. The highest straw yield of 10.71 t ha^{-1} was obtained with the T_5.

Yield of T. Aman rice

Table 5 presents the yield of T. Aman rice in Potato- Maize- Rice cropping pattern. Application of fertilizer significantly increased the grain and straw yield. In 2007, the significantly highest grain yield of 4.06 t ha^{-1} was obtained with treatment (T_4) followed by T_3 (3.59 t ha^{-1}) (Table 5). The significantly highest straw yield of 4.57 t ha^{-1} was obtained with T_3 followed by T_4 (4.12 t ha^{-1}).

In 2008, the significantly highest grain yield of 5.03 t ha^{-1} was obtained with T_5 followed by T_2 (4.49 t ha^{-1}) (Table 5). The significantly highest straw yield of 4.27 t ha^{-1} was obtained with T_5 followed by T_3 (3.79 t ha^{-1}).

Table 4. Effect of integrated nutrient management on the yield of maize in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2009.

Treatment	Maize yield (t ha^{-1})							
	2007 (BARI hybrid 3)		2008 (BARI hybrid 2)		2009 (BARI hybrid 5)		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 (Native nutrients)	2.22	5.13	1.53	3.89	1.83	3.49	1.86	4.17
T_2 (BARC Rec. Dose)	6.28	10.27	5.31	7.98	5.65	7.28	5.75	8.51
T_3 (STB)	5.94	10.93	5.55	8.27	6.39	9.01	5.96	9.40
T_4 (20% >STB)	6.67	12.71	5.75	10.52	7.25	8.76	6.56	10.66
T_5 (PM+IPNS)	5.92	11.84	6.29	10.65	6.28	10.71	6.16	11.07
T_6 (FP)	4.13	9.59	4.64	7.78	5.27	8.80	4.68	8.72
$LSD_{0.05}$	3.21	3.17	0.71	1.78	1.50	1.58	-	-
CV (%)	6.3	17.3	8.1	11.9	15.1	10.9	-	-

Table 5. Effect of integrated nutrient management on the yield of T. Aman rice (BRRI dhan33) in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-09.

Treatment	Rice yield (t ha^{-1})							
	2007		2008		2009		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 (Native nutrients)	2.44	2.35	2.82	2.37	2.06	1.58	2.44	2.10
T_2 (BARC Rec. Dose)	3.39	3.37	4.49	3.16	4.65	3.01	4.18	3.18
T_3 (STB)	3.59	4.57	4.42	3.79	4.69	3.05	4.23	3.80
T_4 (20% >STB)	4.06	4.12	4.27	3.25	4.59	3.00	4.31	3.46
T_5 (PM+IPNS)	3.54	3.98	5.03	4.27	5.33	3.13	4.63	3.79
T_6 (FP)	3.11	2.99	4.10	3.41	3.58	2.42	3.60	2.94
$LSD_{0.05}$	0.51	0.65	0.59	0.61	0.71	0.78	-	-
CV (%)	8.4	10.1	7.7	10.0	9.5	16.0	-	-

In 2009, the significantly highest grain yield of 5.33 t ha^{-1} was also obtained with the same treatment T_5 (PM+IPNS). It was similar to that of T_2 and T_3. But T_4 significantly reduced the grain yield than that of T_5. It indicates that T_5 (PM+IPNS) i.e. poultry manure adjusted with chemical fertilizer performed better. All treated plots (T_2-T_6) produced statistically identical straw yield (2.42-3.13 t ha^{-1}) (Table 5).

Economic analysis

Table 6 presents the estimated total variable cost (TVC), gross return, total value of extra production (added return), net additional income and marginal benefit cost ratio (MBCR). Economic analysis was done considering the following: fertilizer cost, fertilizer application cost and labour cost for the additional product including by products due to fertilizer application.

The application of fertilizer increased the gross and added return and net additional income in all the treatments (Table 6). The gross return from the control plot (mean of 3 crop-cycles) was Tk 1,76,070/- and the application of fertilizer increased the gross return, which ranged from Tk 3,79,720/ha/crop-cycle in T_6 to Tk 4,51,520/ha/crop-cycle in T_5. The highest added-return and net additional income (Tk ha^{-1}/crop-cycle) was obtained with T_5. The MBCR of all treated plots ranged from 5.43 (T_5) to 6.40 (T_6), which were higher than the permit able limit (2.00). Considering economic analysis and the soil health, it is appeared that the treatment T_5 (PM + IPNS) may be recommended.

Table 6. Economic analysis of fertilizer management packages for Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur (mean of 3 crop-cycles).

Treatment	Grossretun** (Tk ha^{-1}/crop-cycle)	Total value of extra production (Tk ha^{-1}/crop-cycle)	TVC* (Tk ha^{-1}/ crop-cycle)	MBCR	Net additional income (Tk ha^{-1}/crop- cycle)
T_1 (Native nutrients)	176070	-	0	-	0
T_2 (BARC Rec. Dose)	393675	217605	35058	6.21	182547
T_3 (STB)	401980	225910	38383	5.89	187527
T_4 (20%>STB)	421780	245710	44666	5.50	201044
T_5 (PM+IPNS)	451520	275450	50756	5.43	224694
T_6 (FP)	379720	203650	31802	6.40	171848

*Total variable cost (TVC) included fertilizer cost (chemical fertilizer and poultry manure), fertilizer application cost and labour cost for additional product. Price (Tk kg^{-1}): Urea=12; TSP=22; MP=15; Gypsum=5; $ZnSO_4$=100; $MgSO_4$=25; Borax=180 and PM=4. Labour wage rate = Tk.180/day. Two additional man-days/ha are required for applying fertilizer and four man-days/ha for per ton additional products including byproducts. **Price (Tk/kg): Rice grain=20; maize grain=12.50; potato=12; crop residue=2.

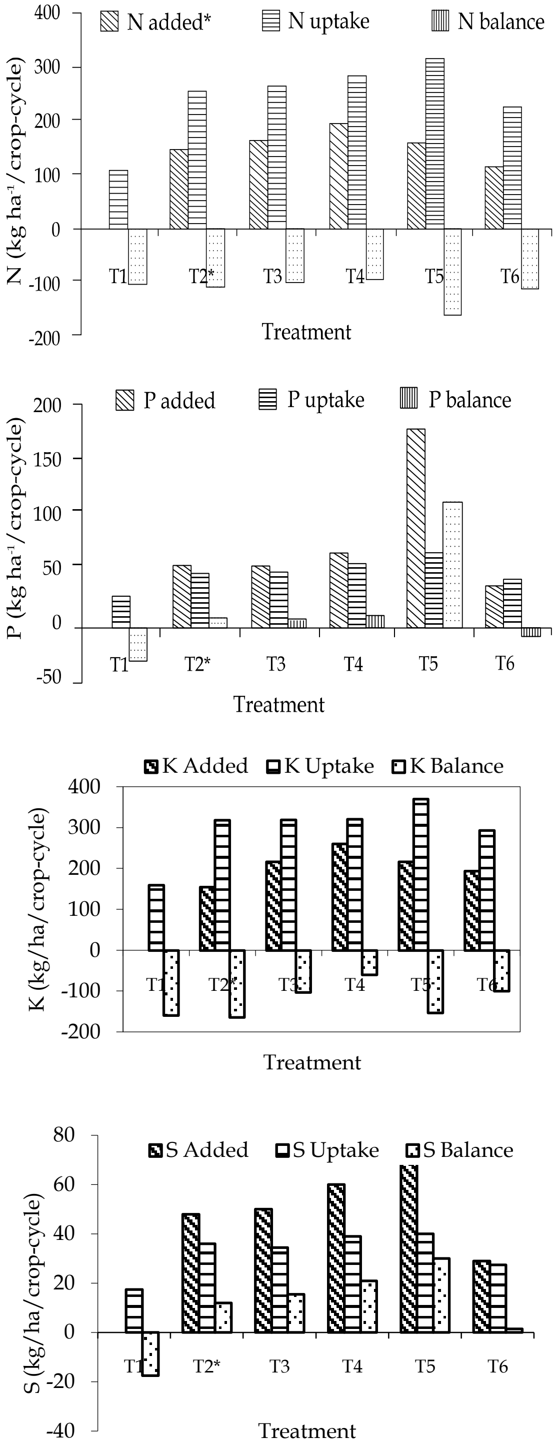

Fig. 1. An apparent nutrient balance sheet in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-2009 (Mean of 2 crop-cycles).

Apparent nutrient balance

An apparent nutrient balance was calculated as the difference between the amounts of nutrient added through fertilizers and manures and the amount of nutrients removed by crop annually (Maize + T. Aman + Potato). It was observed that the apparent nutrient balance in the control plot was always negative for all the nutrients since no fertilizer or manure was added to the plot. In the fertilized plots there was an apparent negative balance for N and K. The balances for P and S were positive as expected, a good amount of P and S were accumulated in the fertilized plot, which indeed, had residual effect on the following crops and also for applied poultry litter (Fig. 1).

Changes of chemical properties

After the completion of three crop-cycles, some physico-chemical properties of post harvest soil were studied. Table 7 shows that the mean bulk density ranged from 1.28 to 1.55 gm cm^{-3} among the treated plots at different soil depths. Organic C, total N, available P increased due to integration of chemical fertilizer with poultry manure (Table 8). Manure application has been reported to increase soil P concentrations of both total and soluble P, as well as concentrations of specific P forms, including stable organic P moieties (Waldrip-Dail *et al*. 2009). The available status of Seven in control plot was increased from initial value. This increase might be due to the industrial urbanization. Whereas, the exchangeable K decreased from the initial soil value because of luxurious consumption by the crops and nutrient mining.

Table 7. Effect of integrated nutrient management on the soil bulk density in Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2007-10.

Treatment	Soil depth, cm	BRRI, Rangpur Bulk density (g/cm3)		
		R-I	R-II	Mean
T_1 (Native nutrients)	0-15	1.40	1.50	1.45
	16-30	1.21	1.35	1.28
T_3 (STB)	0-15	1.57	1.53	1.55
	16-30	1.55	1.41	1.48
T_5 (PM+IPNS)	0-15	1.47	1.55	1.51
	16-30	1.43	1.37	1.40

Table 8. Effect of integrated nutrient management on the chemical properties of post harvest soilin Potato-Maize-Rice cropping pattern at BRRI RS farm, Rangpur, 2009-10.

Treatment	pH	Org. C (%)	Total N (%)	Available P (ppm)	Exch. K (meq/100 g soil)	Available S (ppm)
0-15 cm						
T_1	5.97	0.78	0.08	6.67	0.11	6.00
T_2	5.39	0.57	0.06	21.67	0.15	10.33
T_3	5.80	0.50	0.05	25.33	0.10	10.00
T_4	5.87	0.43	0.04	31.33	0.08	12.00
T_5	6.10	0.77	0.08	46.00	0.12	8.33
T_6	5.88	0.31	0.03	13.00	0.10	9.67
$LSD_{0.05}$	0.41	0.15	0.02	3.47	0.03	1.90
CV(%)	3.80	15.1	15.1	7.90	12.4	11.10
Initial soil	5.03	0.73	0.07	15.43	0.13	2.90
16-30 cm						
T_1	5.98	0.50	0.05	3.00	0.08	11.00
T_2	5.74	0.49	0.05	4.67	0.10	13.00
T_3	5.92	0.49	0.05	3.00	0.11	12.33
T_4	6.03	0.40	0.04	2.67	0.09	11.00
T_5	6.34	0.56	0.06	4.00	0.11	10.67
T_6	6.13	0.36	0.04	3.33	0.11	10.00
$LSD_{0.05}$	NS	0.11	0.01	NS	NS	NS
CV(%)	3.50	12.50	12.50	34.20	14.00	16.50
Initial soil	5.30	0.57	0.04	7.03	0.10	2.70

CONCLUSIONS

PM @ 3.0 t ha^{-1} + IPNS based inorganic fertilizers for potato and maize crops, and STB dose for T. Aman crop may be a good fertilizer management package for Potato-Maize-T. Aman cropping pattern. To sustain soil fertility, it is necessary to apply organic manure in combination with chemical fertilizer. For maize and potato crops, fertilizer recommendation should be updated alternate in every three years.

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Bangladesh Rice J. 20 (1) : 59-64, 2016

Effect of Fertilizer Management on NPKS Leaching Loss from Sandy Loam Soil under Alternate Wetting and Drying Condition

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ABSTRACT

Leaching loss of nutrients hampers plant growth and contributes to environmental pollution. An experiment was conducted at the net house of Soil Science Department, Bangladesh Agricultural University, Mymensingh during January to May 2009 to find out the leaching loss of N, P, K and S from sandy loam soil. Each pot received 6.67 kg dry soil with an opening at the bottom for collecting leachates. Six treatments were used: T_0 = control, T_1 = NPKS (120, 25, 60 and 20 kg ha^{-1}), T_2 = NPKS (180, 37, 90 and 30 kg ha^{-1}), T_3 = NPKS (90, 5, 28 and 17 kg ha^{-1}) + cowdung (2.5 t ha^{-1}), T_4 = NPKS (109, 25, 60 and 20 kg ha^{-1}, N as USG) and T_5 = as T_1 but N applied as foliar spray. Treatments were arranged in a completely randomized design with three replications. Leachates were collected at 15 days interval for determination of NPKS. The total leaching loss of N, P, K and S due to different treatments ranged from 16.00 to 90.21, 0.07 to 0.29, 9.60 to 11.20 and 3.75 to 17.81 kg ha^{-1}, respectively. Application of chemical fertilizer at higher rates resulted in greater loss of nutrients. Integrated fertilizer management with cowdung (T_3) minimized such losses. Use of USG also reduced leaching loss of N, P, K and S. The application of cowdung and USG with recommended balanced fertilizer might be useful for minimizing N, P, K and S loss from wetland rice field.

Key words: Leaching loss, Sandy loam soil, AWD, Boro rice

INTRODUCTION

Fertilizers are indispensable in modern agriculture and their uses are increasing over time. Chemical fertilizers are the key of successful crop production in Bangladesh (BARC, 1997). When we apply fertilizer for obtaining maximum crop production, a significant amount of nutrients are lost by leaching with water. This leaching loss depends on soil properties and rates of nutrients used. Nearly all nitrogen (N) fertilizers are completely water soluble and a significant portion is lost through leaching. Nitrate leaching occurs when soil NO_3^--N concentrations are high and water moves beyond the root zone. In well-drained sandy soils, much of the NO_3 can be lost by leaching (Camberato *et al.*, 2008). Standing water for a long time favours more leaching loss than saturation or alternate wetting and drying (AWD). Surface application of N-fertilizers in light textured soil causes more NO_3 loss. Application of N-fertilizers at higher doses cause higher leaching loss (Sahu and Samant, 2006). Sahu and Samant (2006) reported that soils having low organic matter status cause more N leaching loss than organic matter rich soil. It is estimated that upland lateritic sandy loam soils at Bhubaneswar caused 23-24% loss of applied N. Leaching losses in rice field studied in sandy loam mixed red and black soils of Hirakud command area were 45-46% under saturated condition and 80-84% under submerged condition. de Oliveira *et al.*, (2002) found the largest N losses in the first three weeks. Phosphorus (P) is less mobile in soil and leaching loss is lower as compared to

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other nutrients. Besides, phosphate binds strongly with aluminum, iron, manganese, calcium and other elements present in the soils at relatively higher levels (Hodges, 2010). A major portion of P fertilizer is fixed quickly when added to soil. Phosphorus losses vary depending upon amount, intensity, and duration of rainfall (Sharpley, 1997). The risk of K leaching loss is very high, especially when generous rates of K fertilizers are applied (Pieri *et al.*, 1986). The average leached N during the experimental period of 11 months was of 4.5 kg ha^{-1}. The mean losses of K^+, Ca^{2+} and Mg^{2+} were of 13, 320 and 80 kg ha^{-1}, respectively. The amount of sulphate lost by leaching tended to increase with the amount of drainage. However, such leaching studies are very little under different soil, water and agro-climatic conditions of Bangladesh. The present study was undertaken with the objectives of determining the leaching loss of N, P, K and S in sandy loam soil under AWD condition.

MATERIALS AND METHODS

An experiment was conducted at the net house of Soil Science Department, Bangladesh Agricultural University, Mymensingh from January to May, 2009 to study the leaching loss of NPKS under AWD condition. Soil was sandy loam (Old Brahmaputra Floodplain Soil, AEZ-9) in texture (46.8% sand, 48% silt and 5.2% clay) having pH, 6.6; total N, 0.08%; available P, 7.00 µg g^{-1}; exchangeable K, 0.07 cmol kg^{-1} and available S, 7.5 µg g^{-1}, respectively. Each pot received 6.67 kg soil (dry basis) with an opening at the bottom for collecting leachates. The upper surface area of the pot was 380 cm^2. BRRI dhan29 was used as the test variety. The treatments imposed were: T_0 = control, T_1 = NPKS (120, 25, 60 and 20 kg ha^{-1}), T_2 = NPKS (180, 37, 90 and 30 kg ha^{-1}), T_3 = NPKS (90, 5, 28 and 17 kg ha^{-1}) + cowdung (2.5 t ha^{-1}), T_4 = NPKS (109, 25, 60 and 20 kg ha^{-1}, N as USG) and T_5 = as T_1 but N applied as foliar spray. Treatments were arranged in a completely randomized design with three replications. Nitrogen, P, K and S content in cow dung was 1.2, 0.8, 1.3 and 0.13%, respectively. All the fertilizers except urea were applied as basal. Urea was applied in three equal splits at 10, 35 and 58 days after transplanting (DAT). In T_4, one piece of USG (0.90 g) was placed in each pot at 10 DAT. In T_5, one-third urea was applied at 10 DAT and the rest was sprayed as 3% urea solution in 6 equal splits at 10 days interval after first application.

Leachates from individual pots were collected at 15 days interval and analyzed for N content by rapid test method using soil testing kit, P by Olsen method (Olsen *et al.*, 1954), K by flame photometer (Black, 1965) and S by turbidimetric method (Page *et al.*, 1989). In case of initial soil analysis total N content was determined by micro-Kjeldhal method (Page *et al.*, 1989), texture by hydrometer method (Black, 1965) and pH by glass electrode pH meter (Black, 1965).

Analysis of variance, variation in means and standard error for the treatment effect were analyzed using IRRISTAT software version 4.1.

RESULTS AND DISCUSSION

Figures 1, 2, 3, 4 and 5 present the patterns of leaching loss (mg kg^{-1}) of NH_4^+-N, NO_3^--N, P, K and S under different treatments. All the treatments resulted in more leaching loss compared to control. The maximum leaching loss of nutrients was recorded due to application of fertilizers at higher rates (T_2). The loss of N was the highest when urea was applied at higher rates, which were followed by urea application at recommended dose either as splits or foliar sprays (Fig. 1 and 2). The loss of NH_4^+-N in T_1 was 30 mg kg^{-1} at 15 DAT, which was reduced by 10% at 30 DAT.

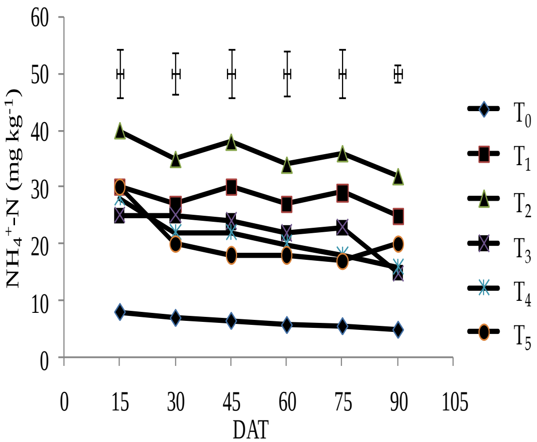

Fig. 1. Leaching loss of NH_4^+-N.

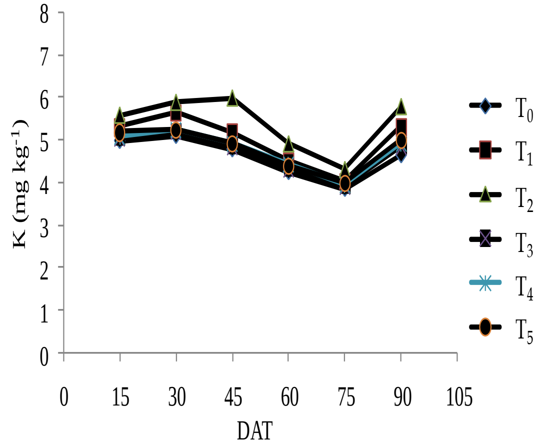

Fig. 4. Leaching loss of available K.

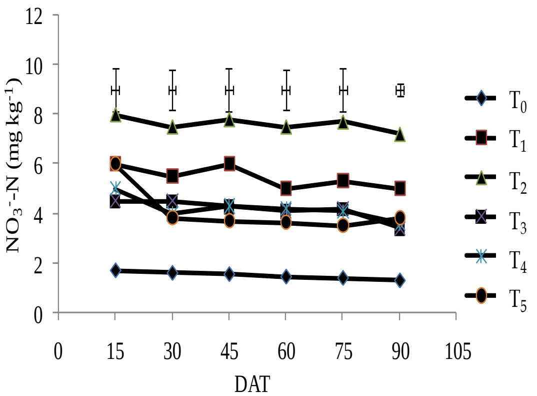

Fig. 2. Leaching loss of NO_3^--N.

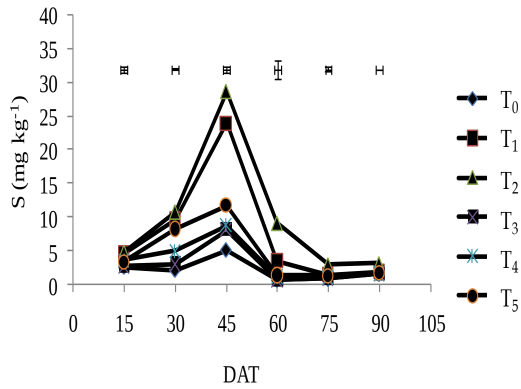

Fig. 5. Leaching loss of available S.

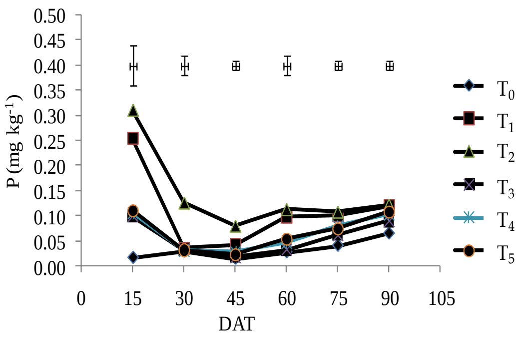

Fig. 3. Leaching loss of available P.

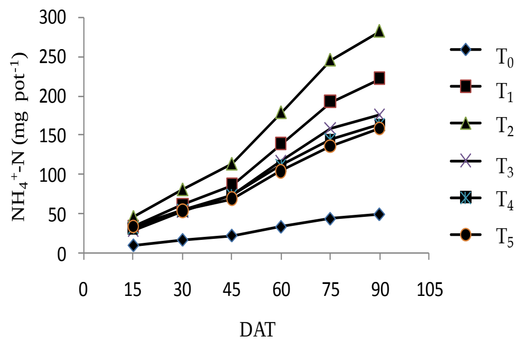

Fig. 6. Cumulative leaching loss of NH_4^+-N.

Vertical bars at the top of figure indicate standard error.

T_0 = control, T_1 = NPKS (120, 25, 60 and 20 kg ha^{-1}), T_2 = NPKS (180, 37, 90 and 30 kg ha^{-1}), T_3 = NPKS (90, 5, 28 and 17 kg ha^{-1}) + cowdung (2.5 t ha^{-1}), T_4 = NPKS (109, 25, 60 and 20 kg ha^{-1}, N as USG) and T_5 = as T_1 but N applied as foliar spray.

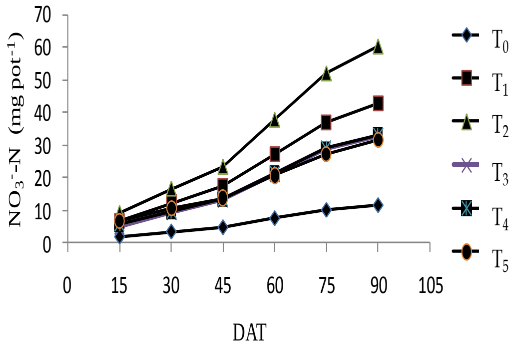

Fig. 7. Cumulative leaching loss of NO_3^--N.

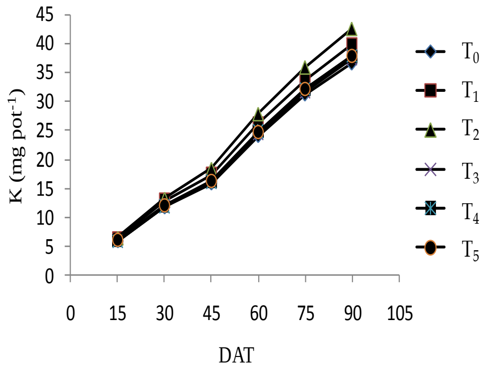

Fig. 9. Cumulative leaching loss of available K.

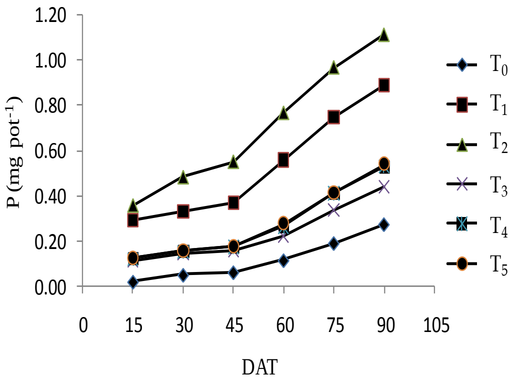

Fig. 8. Cumulative leaching loss of available P.

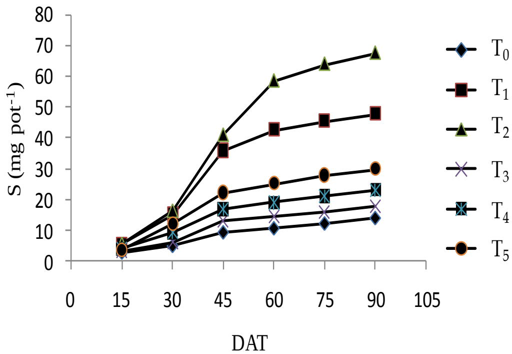

Fig. 10. Cumulative leaching loss of available S.

T_0 = control, T_1 = NPKS (120, 25, 60 and 20 kg ha^{-1}), T_2 = NPKS (180, 37, 90 and 30 kg ha^{-1}), T_3 = NPKS (90, 5, 28 and 17 kg ha^{-1}) + cowdung (2.5 t ha^{-1}), T_4 = NPKS (109, 25, 60 and 20 kg ha^{-1}, N as USG) and T_5 = as T_1 but N applied as foliar spray.

At 45 DAT, the amount of NH_4^+-N loss increased again and then almost static up to 75 DAT but sharply reduced by 16.67% at 90 DAT, a loss of 25 mg kg^{-1}. Similarly, loss of NO_3^--N at 15 DAT was 6 mg kg^{-1}, which reduced by 8.33% at 30 DAT. But amount of loss, increased at 45 DAT. Intensity of N losses increased after urea top dressing. Almost similar trend was found with other treatments except USG application. With USG, loss was very high at 15 DAT. Phosphorous loss was the highest at 15 DAT in comparison to 45, 60, 75 and 90 DAT (Fig. 3). The loss of P in T_1 was 0.254 mg kg^{-1} at 15 DAT, which reduced by 85.83% at 30 DAT (a loss of 0.036 mg kg^{-1}) and then almost static up to 90 DAT. It might be due to the decrease of P release or availability over time. Potassium loss was more up to 45 DAT and this loss was reduced at 60 and 75 DAT (Fig. 4). Less K loss at 60 and 75 DAT might be due to more requirement and K uptake for grain formation. Sulfur loss increased up to 45 DAT and then gradually decreased (Fig. 5). Above results supported the findings of Islam *et al*., (2013b) and Islam *et al*., (2014).

Figures 6, 7, 8, 9 and 10 present the cumulative leaching loss patterns (mg pot^{-1}) of NH_4^+-N, NO_3^--N, P, K and S. The highest cumulative leaching loss of applied N, P and S was observed in T_2 treatments followed by T_1. The highest loss might be due to higher rate of chemical fertilizer application. The lowest leaching loss of applied N, P and S was found in control treatment. The reason of the lowest loss in control plot might be due to no added fertilizer. It was also reported by Islam *et al.*, 2013 b. Treatments T_3, T_4 and T_5 showed similar leaching loss of NH_4^+-N, NO_3^--N and P at different DAT. Nitrogen and P leaching loss increased rapidly after 45 DAT and again slowly after 75 DAT in T_1 and T_2. Nitrogen loss increased after urea application, because urea fertilizer dissolved rapidly. On the other hand, TSP (P fertilizer) might be taken more time to become soluble. In case of USG application, N losses rate was stable over time. The cause behind that finding might be slow conversion of N at reduced zone (Lamb *et al.*, 2014). Sulfur leaching loss rapidly increased from 30-45 DAT and then remains stable in T_1 and T_2. The reason might be less amount of available S was present after specified time. Leaching loss of S was stable over the growing periods in T_0, T_3, T_4 and T_5 (Fig. 10). On the other hand, cumulative leaching loss of applied K was followed similar pattern among all treatments over time (Fig. 9).

About 44.35, 40.72, 42.57, 32.93 and 28.26% of applied N was lost through leaching in T_1, T_2, T_3, T_4 and T_5, respectively. Leaching loss of N in the form of NH_4^+-N was 37.53% while 6.74% applied N was lost as NO_3^--N in T_1. In other treatments, almost similar trends were found. Leaching loss of P in T_1, T_2, T_3, T_4 and T_5 was 0.65, 0.59, 0.18, 0.27 and 0.28%, respectively. Potassium lost through leaching was 1.74, 2.06, 0.43, 0.87 and 0.87% in T_1, T_2, T_3, T_4 and T_5, respectively. Leaching loss of S in T_1, T_2, T_3, T_4 and T_5 was 44.74, 47.37, 5.26, 11.84 and 21.05%, respectively. Although application of chemical fertilizer at higher rates resulted in greater amount of N and P loss, it was not greater than recommended dose. However, in case of K and S, higher rates of application resulted in higher rate of leaching loss.

Total leaching loss of NH_4^+-N, NO_3^--N P, K and S in sandy loam soil during Boro rice culture under different treatments ranged from 12.91to 74.34, 3.09 to 15.87, 0.07 to 0.29, 9.60 to 11.20 and 3.75 to 17.81 kg ha^{-1}, respectively. Total N loss during study period ranged from 16.00 to 90.21 kg ha^{-1} (Table 1). Slow release of nutrients from the organic manure might have resulted in lowering the loss of nutrients for T_3. Again, due to USG deep placement (T_4) the losses of N were lower. Losses of P, K and S were also minimum in USG treated pot. Minimum loss of P, K and S might be due to more vegetative

Table 1. Total leaching loss of NPKS in sandy loam soil under AWD condition (kg ha^{-1}), BAU, Mymensingh.

Treatment	N			P	K	S
	NH_4^+-N	NO_3^--N	Total			
T_0	12.91	3.09	16.00	0.07	9.60	3.75
T_1	58.34	11.25	69.59	0.23	10.46	12.58
T_2	74.34	15.87	90.21	0.29	11.20	17.81
T_3	46.45	8.67	55.12	0.12	9.79	4.73
T_4	42.97	8.75	51.72	0.14	9.92	6.09
T_5	41.84	8.34	50.18	0.14	9.97	7.87

T_0 = control, T_1 = NPKS (120, 25, 60 and 20 kg ha^{-1}), T_2 = NPKS (180, 37, 90 and 30 kg ha^{-1}), T_3 = NPKS (90, 5, 28 and 17 kg ha^{-1}) + cow dung (2.5 t ha^{-1}), T_4 = NPKS (109, 25, 60 and 20 kg ha^{-1}, N as USG) and T_5 = as T_1 but N applied as foliar spray.

growth of plant and more uptake of nutrient. The reason for lowering of leaching loss of N from the foliar spray treatment is quite obvious (Islam *et al*., 2014). Application of chemical fertilizer at higher rates resulted in greater amount of nutrient leaching loss. Similar observations were found by Islam *et al*., (2013a), Islam *et al*., (2013b) and Islam *et al*., (2014).

CONCLUSION

Leaching loss of N, P, K and S from sandy loam soil (Old Brahmaputra Floodplain, AEZ-9) under AWD condition for Boro rice cultivation was quite significant. Application of chemical fertilizer at higher rates resulted in greater loss of nutrients. Integrated fertilizer management using cowdung could minimize such losses to some extent. Application of N in the form of USG might be helpful in reducing loss of N appreciably.

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Bangladesh Rice J. 20 (1) : 65-75, 2016

Fertilizer and Weed Management Options for Direct Wet Seeded Rice in Dry Season

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ABSTRACT

Direct seeding of rice is an emerging technology. However, direct seeded rice culture in the main field is hindered by enormous weed infestation and it lacks judicious fertilizer management. So, experiments were conducted during dry seasons of 2010 and 2012 with three fertilizer packages and four weed control measures. Rice seed was sown in the field using drum seeder in wet soil. The results revealed that weed density and weed biomass were strongly influenced by weed control methods and fertilizer rates. Weed density was higher in unweeded plots with 140:36:43 kg NPK ha^{-1}. Among the species *Echinichloa crusgalli* (L.) P. Beauv. was the dominant species. Three hand weeding controlled maximum weeds. Uses of herbicide for controlling weeds were above 80 and 70% effective. Strong negative correlation was recorded between grain yield and weed density. Herbicide with one hand weeding and BRRI weeder in combination with 160:46:53 kg NPK ha^{-1} produced about 81- 104% higher grain yield than no weeding. Weed free plot produced 112% higher yield with 160:46:53 kg NPK ha^{-1}. Besides, herbicide with one hand weeding and BRRI weeder treated plot produced similar yield irrespective of fertilizer doses. The strong positive and linear relationship was found in case of yield and yield components. Herbicide with one hand weeding and 120:26:33 kg NPK ha^{-1} gave higher net return (1145 $/ha). The benefit cost ratio was also higher in herbicide based weed management with reduced rate of fertilizer. Direct seeded culture using herbicide with one hand weeding and 120:26:33 kg NPK ha^{-1} could be an option for reducing production cost in dry season along with satisfactory grain yield.

Key words: Direct seeding, Boro rice, weed, fertilizer, benefit cost ratio

INTRODUCTION

Traditionally, rice is grown through transplanting on puddle soil, which needs huge labour as well as water. To combat with this situation, growers in many Asian countries shifting their production system from traditional puddle transplanted rice to direct seeded culture. Direct seeded rice (DSR) is less labour intensive, consumes less water, crop matures 7 to 10 days earlier than traditional transplanted rice. But, DSR faces multiple problems during its growth and development processes from sowing to maturity. Inconsistent plant population, injudicious use of fertilizer, water stress or presence of weeds in the field often limit crop yield of DSR. Among the crop production constraints, judicial use of fertilizer and economic weed management are very important. The risk of yield loss from weeds in DSR is greater than transplanted culture (Rao *et al.*, 2007).

Grain yield reduction in DSR could be 35-91% depending on water and fertilizer management (Sunil *et al.*, 2010). However, different weed control options are available in rice production. Physical control are eco-friendly but labour-intensive (Roder and Keobulapha, 1997). Delayed weeding due to unavailability of labour is another constraint of physical control (Johnson, 1996). Biological

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control by using different bio-agents (Smith, 1992) and mycoherbicides (Thi *et al.*, 1999) may not be effective under aerobic soil conditions. Worldwide Chemical control measures are becoming popular day by day. Many researchers working on weed management in direct seeded rice opined that herbicide may be considered to be a viable alternative to hand weeding (Anwar *et al.*, 2012). However, single weed control approach may not be able to keep weeds below economic threshold level, and may resulting in weed flora, resistance development and environmental hazards. Therefore, diverse weed management strategies need to be practiced for effective weed management.

Like weed management, imbalanced fertilizer rates cause yield reduction. Improper doses of fertilizer often stimulate higher weed prevalence in rice field. Management of weeds along with balanced fertilizers increased net income by reducing losses due to weeds, increasing fertilizer use efficiency and finally increasing the grain yield (Rana *et al.*, 2000).

Limited information on weed and fertilizer management options with DSR system is available for Asian regions. As DSR is an emerging production system, information on integrated effect of fertilizer and weed management on DSR may be helpful to achieve higher yield and to reduce production cost. It is, therefore, a need to explore the efficacy of the methods of weed control and fertilizer rates for augmenting the crop yield. The present study was, therefore, conducted to determine a suitable weed control method and fertilizer management option for obtaining higher grain yield and cost effectiveness under direct wet seeded rice culture.

MATERIALS AND METHODS

Experimental site

Two field experiments were conducted at research field of Bangladesh Rice Research Institute, Gazipur (90°33´ E longitude and 23°77´ N latitude), Bangladesh during Boro season (January to May) in 2010 and 2012. The soil of the experimental field belongs to the Shallow Red Brown Terrace Soils. The soil was loamy having 47, 35 and 18% sand, silt and clay respectively. Initial soil pH, 6.13; organic matter, 1.4%; the total N, 0.133%; available P, 13.80 mg g^{-1}; exchangeable K, 0.126 meq 100 g^{-1}; available S, 20.27 mg g^{-1} and Zn were, 0.582 mg g^{-1}. The average air temperature (°C) was almost similar during two reported years. However the highest rainfall was recorded in mid April during 2012 (Fig. 1).

Execution of experiments

The treatments were assigned in a randomized complete block design with factorial arrangement and repeated thrice. Unit plot size was 4.6-×3-m. Rice varieties BRRI dhan29 and BRRI dhan28 were used as test crops during 2010 and 2012 respectively. The experiment comprised of three fertilizers and four weed management options (Table 1).

The pre-germinated seeds were sown on puddled and leveled soil by drum seeder. The whole P and K and one third of N were applied at final land preperation. The remaining N was applied in two splits at tillering and panicle initiation equally. Herbicide, Sirius 10WP (pyrazosulfuran ethyl) was applied at 2-3 leaf stage of weed at 150 g ha^{-1}. BRRI developed rice weeder was applied at 20 and 45 DAS.

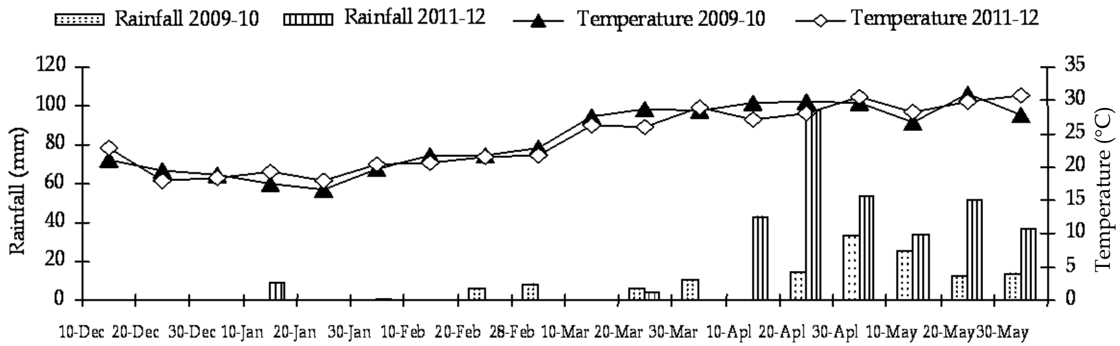


Fig. 1. Temperature and rainfall pattern during experimentation, BRRI, Gazipur.

Collection of weed data

Weed samples were collected at 50 DAS. Plot wise weed species were counted and dry weights were taken after drying in oven (Perkin-Elmer Corporation, USA) at 60°C for 72 hours. Weed control efficiency (WCE) was calculated according to Rao (1985).

The contribution of an individual weed species to the weed community were determined by its two factor summed dominance ratio (SDR) (Janiya and Moody, 1989). This was calculated using Relative Weed Density (RWD) and Importance value (IV), as following:

$$\text{RWD (\%)} = \frac{\text{Density of individual weed species in the community}}{\text{Total density of all weed species in the community}} \times 100$$

$$\text{IV (\%)} = \frac{\text{Dry weight of a given oven dried weed species}}{\text{Dry weight of all oven dried weed species}} \times 100$$

$$\text{SWD (\%)} = \frac{\text{RWD+IV}}{2}$$

$$\text{WCE (\%)} = \frac{\text{(Dry weight of weeds in weedy check plots} - \text{Dry weight of weeds in treated plots)}}{\text{Dry weight of weeds in weedy check plots}} \times 100$$

Statistical analysis

Data were analyzed following analysis of variance (ANOVA) and mean differences were depicted by multiple comparison test (Gomez and Gomez, 1984) using the statistical programme MSTAT-C (Russell 1986).

Gross return, net return and total variable cost were calculated and expressed as dollar ($) ha^{-1}. Net return was calculated by (Gross return - Total variable cost). Benefit cost ratio (BCR) was calculated as:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

Economic analysis

Table 1. Description of treatments.

Factor	Symbol used	Level of nutrients (kg ha^{-1})		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Fertilizer package	F_1=120:26:33 kg NPK ha^{-1}	120	26	33
	F_2=140:36:43 kg NPK ha^{-1}	140	36	43
	F_3=160:46:53 kg NPK ha^{-1}	160	46	53
		Description of weeding		
Weed control	W_1	Post emergence herbicide (Pyrazosulfuran ethyl)+one hand weeding at 45 days after sowing (DAS)		
	W_2	Three hand weeding at 20, 35 and 45 DAS		
	W_3	BRRI weeder at 30 and 45 DAS		
	W_4	No weeding (control)		

RESULTS AND DISCUSSION

Weed vegetation

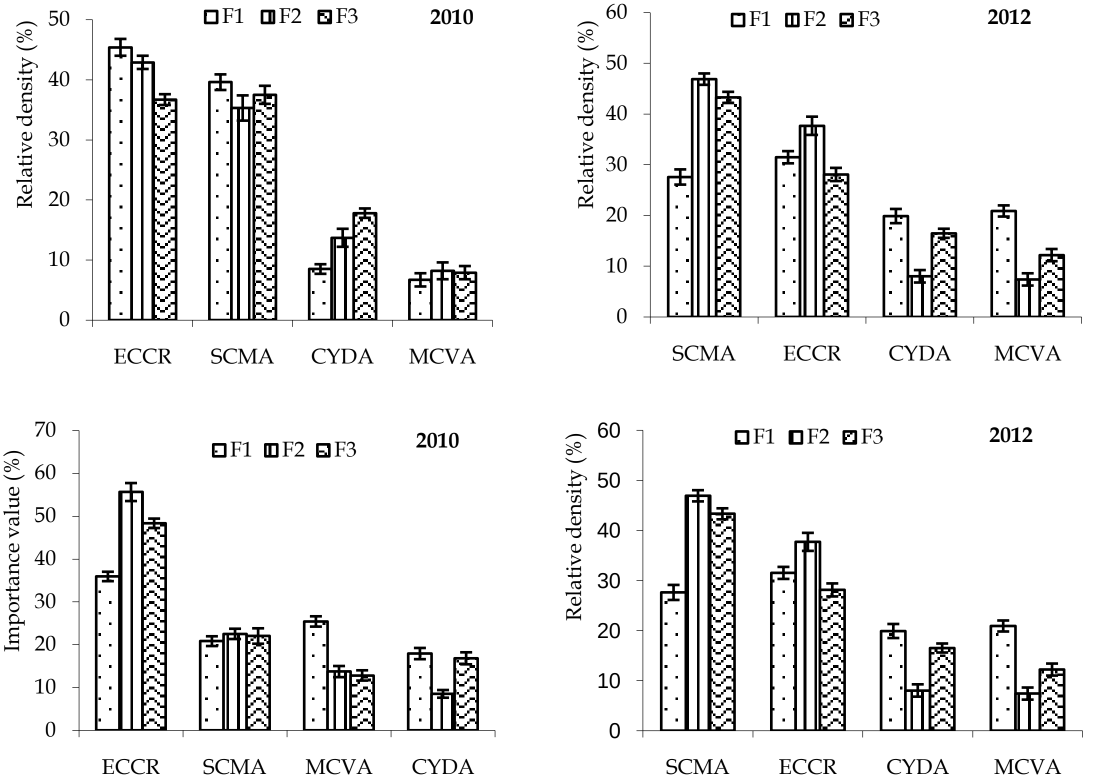
The dominant weed species were *Echinochloa crusgali* (L.), *Cynodon dactylon* (L.), *Scirpus maritimus* (L.) and *Monochoria vaginalis* belonging to family Poaceae, Cyperaceae and Pontederiaceae comprises three major classes Grass, Sedge and Broadleaf.

Weed density and biomass

In both the years, weed density and weed biomass were higher in no weeding treated plot with 140:36:43 kg NPK ha^{-1}. However, weed free plot with fertilizer doses 120:26:33 kg NPK ha^{-1} resulted 94.88% and 93.74% lower weed density and 97.57% and 97.99% lower weed biomass than 140:36:43 kg NPK ha^{-1} treated no weeding plot in 1st and 2nd year, respectively. The plot received herbicide with one hand weeding and fertilizer doses 120:26:33 kg NPK ha^{-1} produced 74.56% and 75.40% lower weed density and 83.66% and 86.29% lower weed biomass in year 1 and year 2 respectively (Fig. 2). BRRI weeder treated plot with fertilizer doses 120:26:33 kg NPK ha^{-1} gave 72.22% and 75.29% lower weed density and 79.15% and 82.92% lower weed biomass compared to 140:36:43 kg NPK ha^{-1} with no weeding treated plot in year 1 and year 2 respectively (Table 2). Weed density increases with the increased rate of fertilizer application. Weeds have a higher nutrient requirement than crops and compete strongly for nutrients when high fertilizer rates are applied (Burgos *et al.,* 2006; Chauhan and Johnson, 2010a and 2011a). Application of post emergence herbicide with single hand weeding plus minimum rate of fertilizer not only produces lower weed density but also lower weed biomass. This findings is supported by Chauhan and Ope˜na (2013). They observed that additional yield in herbicide treated plot could be achieved by following one hand weeding after post emergence herbicide application.

Table 2. Interaction effect of fertilizer and weed management on weed density and biomass in direct wet seeded Boro rice 2010 and 2012, BRRI Gazipur.

Treatment	Boro 2010		Boro 2012	
	Weed no./m^2	Weed wt (g/m^2)	Weed no./m^2	Weed wt (g/m^2)
120:26:33 NPK kg ha^{-1}				
Herbicide + 1 HW	58.00	14.81	56.67	12.47
Weed free	11.67	2.20	14.67	1.83
BRRI weeder	63.33	18.89	56.67	15.53
No weeding	191.997	82.01	189.00	82.50
140:36:43 NPK kg ha^{-1}				
Herbicide + 1 HW	70.67	19.00	66.67	16.17
Weed free	16.00	3.40	18.00	2.80
BRRI weeder	81.33	40.54	82.00	39.83
No weeding	228.00	90.63	229.33	90.93
160:46:53 NPK kg ha^{-1}				
Herbicide + 1 HW	66.00	42.38	67.67	42.70
Weed free	13.33	2.93	16.00	2.53
BRRI weeder	110.77	53.49	115.00	54.43
No weeding	190.00	65.04	152.00	65.30
CV (%)	10.19	12.18	19.90	12.48
LSD (0.05%)	16.04	7. 580	30.25	7.618



ECCR = *Echinochloa crus-galli*, SCMA = *Scripus maritimus*, MCVA = *Monochoria vaginalis*, CYDA = *Cynodon dactylon*, F_1=120:26:33 kg NPK ha^{-1}, F_2 = 140:36:43 kg NPK ha^{-1}, F_3= 160:46:53 kg NPK ha^{-1}. The vertical bars represent the standard error.

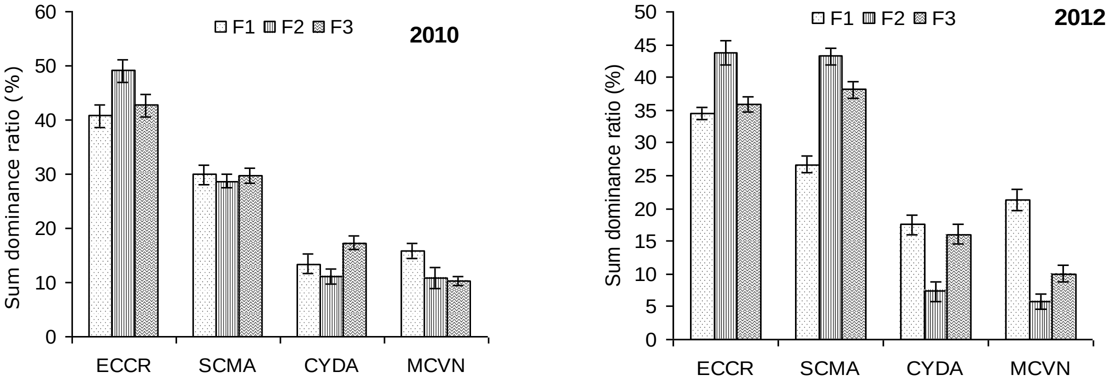
Fig. 2. Relative density and importance value of different weeds in direct wet seeded Boro rice 2010 and 2012, BRRI, Gazipur.

Relative density (RD) and importance value (IV) of weeds

Among the infesting weed species *E. crusgalli* showed maximum relative density with 120:26:33 kg NPK ha^{-1} (45.4%) in year 1, while in year 2, *S. maritimus* showed maximum relative density with 140:36:43 kg NPK ha^{-1} (46.9%). On the other hand *E. crusgalli* showed higher importance value with 140:36:43 kg NPK ha^{-1} both in year 1 (55.6%) and Year 2 (49.7%). Among the weed species *E. crusgalli,* recognized as the most devastating weeds for its higher density and importance value.

Weed ranking

In year 1, the most dominating weed species was *E. crusgalli* (40.76-49.05%). In year 2, *E. crusgalli* (43.7%) and *S. maritimus* (43.2%) were dominating weeds with fertilizer doses 140:36:43 kg NPK ha^{-1}. However, the grasses (11.08-49.0% in year 1 and 7.3-43.7% in year 2) were the most dominating weeds. The weed dominance ranking expressed *E. crusgalli* first in position. It proves that due to low land ecosystem our soil is very much conducive for germination and growth of *E. crusgalli*. Besides, new seed drops to soil surface every year and increases its seed bank. This findings is supported by Mortimer and Riches (2001), Shultana *et al.* (2011), Al-Mamun *et al.* (2010) (Fig. 3).



2ECCR = *Echinochloa crus-galli*, SCMA = *Scripus maritimus*, MCVA = *Monochoria vaginalis*, CYDA = *Cynodon dactylon*, F_1=120:26:33 kg NPK ha^{-1}, F_2 = 140:36:43 kg NPK ha^{-1}, F_3 = 160:46:53 kg NPK ha^{-1}. The vertical bars represent the standard error.

Fig. 3. Effect of fertilizer doses on weed dominance ranking in direct wet seeded Boro rice 2010 and 2012, BRRI, Gazipur.

Interaction effect of fertilizer and weeding method on WCE (%)

In both the years, the weed free plot had higher weed control efficiency than the other weeding methods. In year 1, the weed free plot with fertilizer doses 160:46:53 kg NPK ha^{-1} had 90.97% weed control efficiency. In year 2, the weed free plot gave 87.82% weed control efficiency with fertilizer doses 120:26:33 kg NPK ha^{-1}. The plot treated with herbicide with one hand weeding gave above 80% weed control efficiency irrespective of fertilizer dose in year 1 and above 70% weed control efficiency irrespective of fertilizer dose in year 2. In both the years, BRRI weeder treated plot showed above 60% weed control efficiency irrespective of fertilizer dose (Table 3).

Relationship of rice yield with weed density (plant m^{-2}) and biomass (g m^{-2})

In both the years grain yield showed strong negative relation with weed number and weed biomass. Singh *et al*. (2008) observed irrespective of the stage of crop growth and type of weed group, a significant negative correlation of weed density and weed dry weight with rice grain and straw yield, indicating the need for minimizing weed density and dry weight to attain optimal rice grain yield (Fig. 4).

Table 3. Interaction effect of different fertilizer rate and weeding options on weed control efficiency (%) in direct wet seeded Boro rice 2010 and 2012, BRRI, Gazipur.

Treatment	Boro 2010			Boro 2012		
	120:26:33 kg NPK ha^{-1}	140:36:43 kg NPK ha^{-1}	160:46:53 kg NPK ha^{-1}	120:26:33 kg NPK ha^{-1}	140:36:43 kg NPK ha^{-1}	160:46:53 kg NPK ha^{-1}
Herbicide+one hand weeding	81.72	80.26	80.41	80.40	77.88	71.25
Weed free	90.25	91.28	90.97	87.82	85.71	82.51
BRRI weeder	73.04	74.70	68.86	67.32	66.63	67.83
No weeding	-	-	-	-	-	-

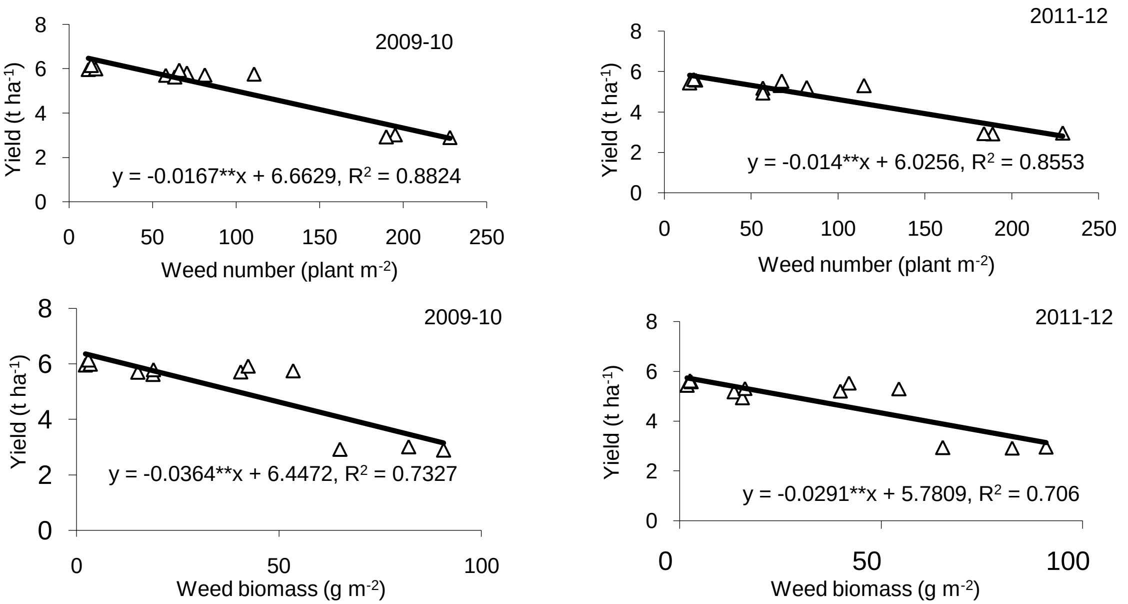


Fig. 4. Relationship of rice yield with weed density (plant m^{-2}) and biomass (g m^{-2}) in Boro season during 2010 and 2012.

Interaction effect of fertilizer and weeding options on yield contributing characters

In both the years, insignificant interaction effect was found in case of panicle m^{-2}. Although grains panicle^{-1} was significant in year 1, insignificant interaction effect was observed in year 2. Thousand-grain weight (TGW) varied significantly both in year 1 and year 2. In year 1, significantly higher grain panicle^{-1} were found in weed free treatment with 140:36:43 kg NPK ha^{-1} (85) and 160:46:53 kg NPK ha^{-1} (85), which was statistically similar to herbicide + 1 HW with 140:36:43 kg NPK ha^{-1} (83). The lowest grain panicle^{-1} was recorded in no weeding plot with 120:26:33 kg NPK ha^{-1} (43). However, in year 2, treatment effect was insignificant**.** The highest TGW in year 1 was recorded in weed free treatment with 120:26:33 kg NPK ha^{-1} (20.10g) which was statistically similar to weed free with 140:36:43 kg NPK ha^{-1} (20.02g), 160:46:53 kg NPK ha^{-1} (20.07) and herbicide plus one hand weeding with 120:26:33 kg NPK ha^{-1} (20.08g) treatment and the lowest was found in no weeding with fertilizer doses 160:46:53 kg NPK ha^{-1} (18.08g). In year 2, the highest TGW was found in herbicide + 1HW with fertilizer doses 160:46:53 kg NPK ha^{-1} (21.47). In year 1, weed free plot with 160:46:53 kg NPK ha^{-1} produced significantly higher yield, which was 112% higher than 140:36:43 kg NPK ha^{-1} with no weeding plot.

The plot received herbicide with one hand weeding and BRRI weeder were statistically similar irrespective of fertilizer rate. The plot treated with 160:46:53 kg NPK ha^{-1} and herbicide with one hand weeding and BRRI weeder with same fertilizer dose produced 104.45% and 98.62% higher than no weeding plot with 140:36:43 kg NPK ha^{-1}. In year 2, weed free with 160:46:53 kg NPK ha^{-1} produced significantly higher yield, which was statistically similar to weed free with 120:26:33 kg NPK ha^{-1} and 140:36:43 kg NPK ha^{-1} and shows 92.12% higher yield than 120:26:33 kg NPK ha^{-1} treated with no weeding plot. However, herbicide with one hand weeding and BRRI weeder treated plot gave higher yield with 160:46:53 kg NPK ha^{-1}. This is 89.38% and 81.51% higher than

120:26:33 kg NPK ha^{-1} with no weeding plot (Table 4). Significant interaction effect of fertilizer and weeding method on grain yield was observed in both the years. Among the treatment combination no weeding plot with higher rate of fertilizer produced significantly lower yield. It reveals that higher doses of fertilizer enhanced higher weed pressure. However, weed free plot, herbicide with one hand weeding and BRRI weeder treated plot produced statistically similar yield irrespective of fertilizer dose. Two times application of BRRI weeder resulted lower weed biomass. Due to lower rice weed competition, the maximum fertilizer effect was exhibited on herbicide based weed management and BRRI weeder treated plot. Weed prevalence was comparatively lower where the plot treated with post emergence herbicide at 1-2 leaf stages of weed with additional one hand weeding (43 DAS). Increased N dose for yield maximization was reported by Singh and Prasad (1999). These results were also supported by Kamara *et al*. (2011) and Oikeh *et al*. (2008). They reported that number of grains panicle^{-1} increased with increased in N rates and also found number of grains panicle^{-1} was positively correlated with grain yield and subsequently produced higher grain yields of NERICA 1 rice. Increase in grain yield for application of N was mainly due to improvement in yield components i.e. number of effective tillers and grains panicle^{1}.

Relationship between yield and yield components

Based on two years data, yield showed significantly strong positive correlation with yield components. (Fig. 5).

Table 4. Interaction effect of fertilizer and weeding options on yield and yield components in direct wet seeded Boro rice 2010 and 2012, BRRI, Gazipur.

Weeding option	Panicle m^{-2}			Grain panicle^{-1}			TWG (g)			Yield (t ha^{-1})		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
						Boro 2010						
W_1	370	367	374	77	83	84	20.08	19.83	19.61	5.71	5.8	5.93
W_2	375	377	372	83	85	85	20.10	20.02	20.07	5.97	6	6.15
W_3	360	366	367	72	80	82	18.92	19.10	19.11	5.63	5.72	5.76
W_4	314	319	315	43	53	68	18.63	18.72	18.08	3.02	2.9	2.93
LSD		NS			4.95			0.05			0.50	
CV%		10.18			3.87			0.38			9.05	
						Boro 2012						
W_1	365	371	368	72	75	81	21.01	21.43	21.47	5.18	5.31	5.53
W_2	368	370	377	80	78	77	21.04	21.10	21.13	5.44	5.58	5.61
W_3	363	364	363	67	75	71	20.73	20.67	21.01	4.94	5.21	5.3
W_4	338	335	328	47	59	50	19.84	19.89	20.09	2.92	2.96	2.94
LSD		NS			NS			0.42			0.40	
CV%		8.04			6.73			1.19			5.03	

F_1= 120:26:33 kg NPK ha^{-1}, F_2 = 140:36:43 kg NPK ha^{-1}, F_3=160:46:53 kg NPK ha^{-1}, W_1 = Herbicide+ 1HW, W_2 = Weed free, W_3 = BRRI weeder, W_4 = No weeding.

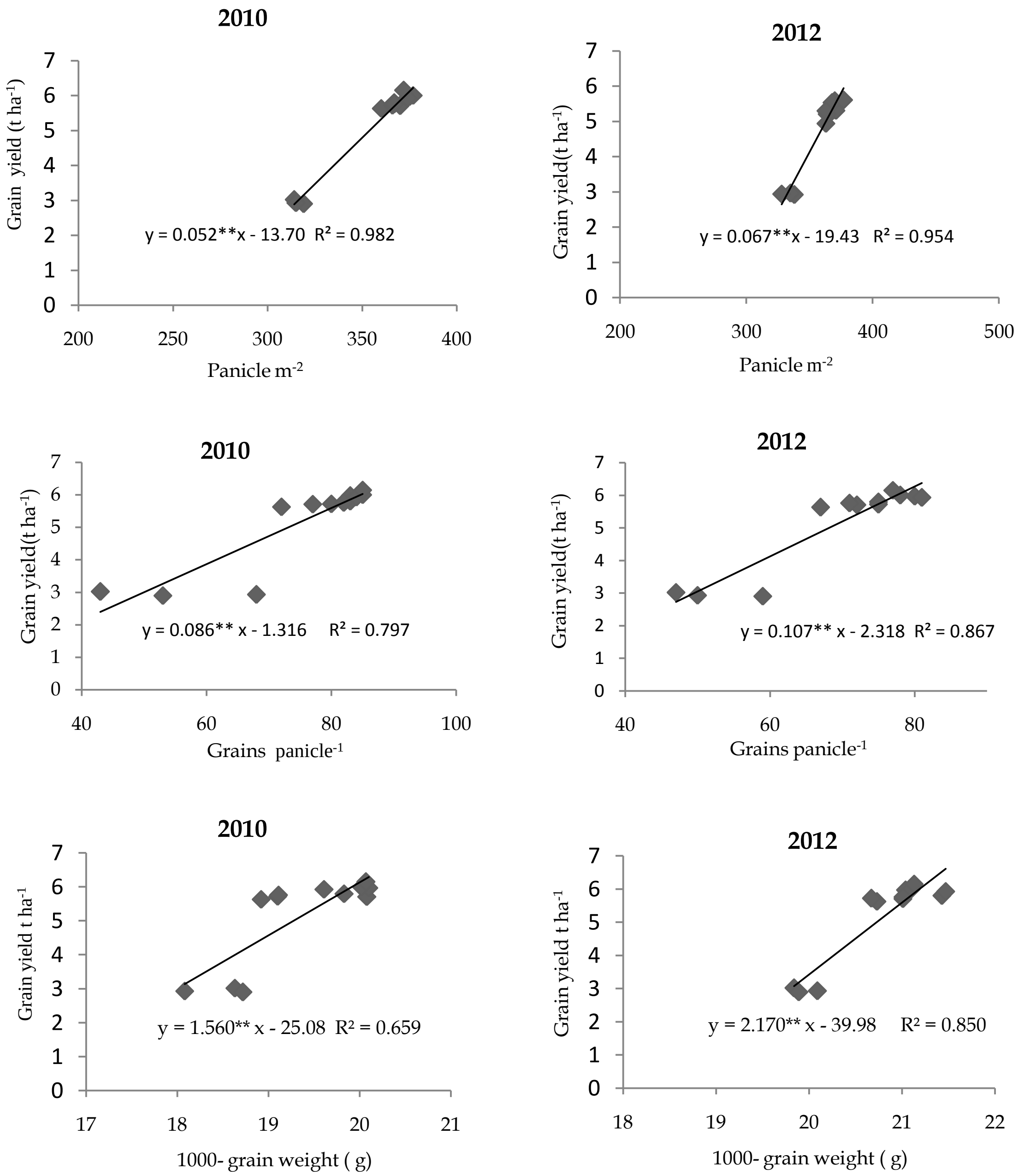


Fig. 5. Relationship of rice yield with panicle m^{-2}, grains $panicle^{-1}$ and 1000-grain weight in Boro season during 2010 and 2012.

Interaction effect of fertilizer and weeding options on economic performance

In year 1, higher gross return (1419.23 \$ ha^{-1}) was found in weed free plot with fertilizer doses 160:46:53 kg NPK ha^{-1} but the total variable cost was higher with this combination (362.21 \$ ha^{-1}). Although the gross return was higher, it requires higher labour. Due to higher labour price and fertilizer cost the total variable cost increases. Higher net return was found in herbicide with one hand weeding with 120:26:33 kg NPK ha^{-1} (1,145.004 $/ha). Higher BCR (6.63) was found in herbicide plus one hand weeding with 120:26:33 kg NPK ha^{-1}. In year 2, higher gross return (1,295 $/ha) was found in weed free with 160:46:53 kg NPK ha^{-1}. Total variable cost was higher in weed free with 160:46:53 kg NPK ha^{-1}(362 $/ha). However, higher BCR (6.63) was found in herbicide plus one hand weeding with 120:26:33 kg NPK ha^{-1} (5.92). Because herbicide based weed management requires less labour and less cost was involved due to reduced rate of fertilizer. The weed control by mechanical means (BRRI weeder two times) requires higher labour and it also failed to control weeds in between 2 hills. In consequence, the net return was low in BRRI weeder treatment, irrespective of fertilizer dose. (Table 5). These findings are supported by Khaliq *et al.* (2012) who stated that post emergence herbicide application appeared to be a viable strategy for weed control in direct seeded rice with higher economic returns.

CONCLUSION

The labour scarcity and fertilizer costs are increasing day by day. For profitable rice farming, reduction of production cost is very important. Direct were seeding of rice may reduce the production cost. Economically viable and satisfactory Boro rice yield under direct seeded culture could be obtained through herbicide use along with one hand weeding applying at 120:26:33 kg NPK ha^{-1}.

Table 5. Economic performance of fertilizer and weeding options in direct wet seeded boro rice, 2010 and 2012, BRRI, Gazipur.

Treatment	Gross return ($ ha^{-1})			Variable cost ($ ha^{-1})			Net return ($ ha^{-1})			BCR		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Boro 2010												
W_1	1318	1339	1369	173	201	229	1145	1138	1139	6.63	5.66	4.97
W_2	1378	1385	1419	306	334	362	1072	1051	1057	3.51	3.15	2.92
W_3	1299	1320	1329	229	257	285	1070	1063	1044	4.68	4.13	3.66
W_4	697	669	676	344	257	285	353	412	391	1.02	1.60	1.37
Boro 2012												
W_1	1195	1225	1276	173	201	229	1023	1024	1047	5.92	5.10	4.57
W_2	1255	1288	1295	306	334	362	950	954	932	3.11	2.86	2.57
W_3	1140	1202	1223	229	257	285	911	945	938	3.98	3.68	3.29
W_4	674	683	678	344	257	285	329	426	393	0.96	1.66	1.38

*Only fertilizer and weeding costs were considered, Labour and material costs were considered based on the price of the reported year. F_1= 120:26:33 kg NPK ha^{-1}, F_2 = 140:36:43 kg NPK ha^{-1}, F_3 = 160:46:53 kg NPK ha^{-1}, W_1 = Herbicide+ 1HW at 45 DAS, W_2 = Weed free at 20, 35 and 45 DAS, W_3 = BRRI weeder at 30 and 45 DAS, W_4 = No weeding, BCR= Benefit Cost Ratio.

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BRJ: Publication no.: 219; 500 copies
Published by the Director General, Bangladesh Rice Research Institute, Gazipur 1701, Bangladesh
Printed by Swasti Printers, 25/1, Nilkhet, Babupura, Dhaka 1205