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Factors of paddy grain and seed production at farm level in the Indo-Gangetic basin of West Bengal

M. S. SABLE, A. K. NANDI AND [1]R. BISWAS

Department of Agricultural Economics, [1]Department of Agricultural Statistics
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal

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ABSTRACT

Paddy contributes 90 percent food grains in the total food basket of West Bengal. Due to wide agro-ecological variations and traditional food habits, the farmers practiced paddy cultivation almost three seasons in high intensity cropping zones of lower Indo-Gangatic Basin. As it is a high volume low value food grain, the availability of quality seeds purely depends on either farm-saved or public institutions. The objective of this study is to identify the responsible factors for HYVs paddy seed production, apart from commercial grain production for increasing seed replacement rates, switching from farm-saved seeds to quality seeds in different locations, both in traditional (long history of rice-rice sequence) and non-traditional paddy dominating areas, as second or third crop per year. Two hundred samples have been selected from fourteen villages of eight CD blocks, two from each district based on probability proportional to net cropped area and at the ultimate stage with SRSWOR from four districts located each side of Lower Indo Gangetic Basin. Multivariate LSQ regression, considering the linear, linear logarithm, Cobb-Douglass production function and MahalanobisD^2 statistics has been used for the analysis of important predictors and the contribution of the significant predictors in discriminating the yield of commercial grain and seed production. Both winter and summer season are suitable for the seed production where balanced doses of fertilizers, human labour and plant protection chemicals are important factors, but the traditional belt is more advantageous than the non-traditional belts. On the other hand, for summer season, new alluvium Nadia district is suitable for seed productions. In both seasons the contribution of human labour and balanced doses of fertilizers can able to discriminate between high and low yielding groups. For the interest of cost effective higher productivity, the seed based entrepreneurs' may be developed within the state at present with existing resources to overcome the problems of quality seed in time.

Keywords: D^2 statistics and paddy seed production attributes

Acceleration of growth in agricultural production in developing countries for mitigating the increased demand for food grains in the coming years would depend more on enhancing productivity per unit of land. In 2017-18, world's total food grain production was estimated at 275 million tons (FAO). India is the largest food grain producer (25% of global production) as well as consumer (27 per cent of world consumption) in the world (FAO). The quality seed when combined with other complementary inputs such as fertilizer and irrigation does make substantial contribution to increased production and income to farmers. Paddy is a high volume low value crop and the availability of quality seeds purely depends on the supply from public institutions (Singh *et al.*, 2008). The private institutions emphasize the development of seed for the low volume high value crops like vegetables or other hydrides (FAO and ICRISAT, 2015). For paddy, seed replacement is essential in every four years interval to provide quality seed (Paroda, 2013). Some sporadic attempts were made to improve the seed quality and its distribution in the country in the pre-independence period and the activity received a fillip only in the post-independence era. The All India Coordinated Maize Project (1957), the establishment of National Seed Corporation (1963), implementation of the Seed Act (1966) since 1969, launching of the National Seed Programme (NSP, 1975) with World Bank assistance, the New Policy on Seed (1988) are some of the important milestones in the evolution of the seed industry in the country. Simultaneously, the private sector was also encouraged by government by way of providing breeder and foundation seed of public bred varieties. Seed production is profitable but risky business enterprise (Pouchepparadjou and Thimmappa, 2009) but to ensure the supply of quality seed timely to the farmers the area under seed production must be increased (Radha and Chowdry, 2005). Concessional finance with the foreign exchange was made available under NSP for investment in research, processing and storage facilities for seed (GOI, 1975; GOI, 1978; Paroda, 2013).

The West Bengal agriculture is mainly dominated by marginal & small farmers and they devoted a major part of their land in paddy cultivation. Seed multiplication by the agencies are highly sporadic in nature and the farmers are interested to pay higher price

[1]*Email: ria.biswas6@gmail.com*

for quality seeds but lack of availability in time they are compelled to use farm saved seeds which yielded lower production (Nandi *et al.,* 2013). Therefore, farm level input-output relation for the production of paddy seed grain and non- seed grain production needs to be analyzed with a view to identify the important factors that have brought about inter-farm variability in yield and finding out the individual factor contribution to such a yield variability, which in turn seems useful to the farmers both in commercial grain production and side by side the seed production in their own farm. The present paper is devoted to find out the major yield varying factors and their relative contributions towards farm to farm variation in yield of paddy seed and paddy grain in both seasons for high cropping intensity zones of traditional (long history of Rice-Rice crop sequences) and non- traditional areas in lower Indo-Gangatic basin. The first part is therefore, devoted in order to identify the factors which have impact upon the yield variation. The another part, in contrast to the first part, purports to classify the dependent variable (Productivity) according to its value and find out the power of individual predictor variables (factors) in classifying both the season and location of seed production.

MATERIALS AND METHODS

The present study has been covered four districts, two from West side (Bardhaman-Hooghly) and two from East side (Nadia-Murshidabad) of the Lower Indo Gangetic Basin. The data collection has been done in the year 2010-2011 from 200 selected farmers clustering from fourteen villages of eight CD Blocks (Kalana and Katawa from Bardhaman; Chakadah and Haringhata from Nadia; Arambagh and Pandua from Hooghly and remaining two blocks, Khargram and Kandi from Murshidabad district) of four districts with probability proportional to area following simple random sampling without replacement (SRSWOR).

Form the view point of production of the crop, the major input like seed, the major nutrients like Nitrogen (N), Phosphorus (P) and the total nutrients (N+P+K) used are reported to be the most important factors contributing to quantity as well as the quality of output. It is also reported that use of phosphorus (P) and potash (K) along with Nitrogen (N) in balanced amount contributes largely to increase the yield in both aspects: quantity and quality. In view of short duration nature of the crops, human labour used in the production period should be taken into account while examining the yield variability because of a series of operation done by the human labour like intercultural operations and applications of other inputs in proper way. Based on proposition, the location advantage has considered as one of the qualitative factor causing yield variability. Other factors like plant protection chemicals and irrigation for short duration crop in different seasons also relinquishes the yield variability. Based on the presumption that the extent of family labour per unit of crop area is an indicative of extent of care to crop cultivation and their by contributing to yield.The variable like family size and age for experience in management has been taken into account. Similarly, the proportion of crop area to total operated area has also considered in order to capture the relative importance of the crop to the family households. To examine whether there is any possibility of yield variation with respect to location and hence location of cultivation considered as qualitative factor. In view of this, physical yield instead of value of yield are been taken as the response variable in order to avoid the market imperfection of seed and grain prices during the crop season of 2010-11.

Based on foregoing discussion the yield and yield influencing variables are given below in usual notational form.

Quantitative independent variables

(i) SD = quantity of seed in kg, (ii) N = quantity of Nitrogen in kg, (iii) P = quantity of Phosphorus in kg, (iv) NPK = quantity of major nutrients (NPK) in kg, (v) HL = Number of human labour utilized for cultivation in man days, (vi) PPCL = Value of Plant protection chemicals in Rs, (vii) IRRGN = Value of irrigation required in Rs, (viii) AG = Age of farmer, (ix) FS = Family size in adult unit, (x) OHL = Operational holding in Hectare, (xi) RPOHL = Ratio of paddy area to operational holding.

Qualitative dummy variable

(xii) LA = location Advantage

Dependent variable

(xiii) y = output i.e. Productivity in qha^{-1}.

Analytical tool

Multivariate LSQ regression has been proposed as the analytical tool in identifying the important yield determining factors. Linear, Linear logarithm and Cobb-Douglass forms have been attempted to identify the yield determining factors.

1) Linear $Y = \alpha + \sum_{i=1}^{m} \beta_i x_i + \varepsilon_i$

Y = Return (Physical), α = intercept,

β_i = regression co-efficient of ith predictor variable

2) Linear-logarithm function

The form of the function is $Y = \beta_1 + \beta_2 \log(x_i) + \varepsilon_i$

3) Cobb-Douglass

To study resource productivity in farming systems, a modified Cobb-Douglas type of function was fitted. This was done with a view to determine the extent to which the important resources that have been quantified, explain the variability in the output (yield) of the farming systems and to determine whether the resources were optimally used in these farming systems. The Cobb-Douglas type of function has been the most popular of all possible algebraic forms in the farm analysis as it provides comparison, adequate fit, computational feasibility and sufficient degrees of freedom (Heady and Dillon, 1963). They further indicated that Cobb-Douglas type of function has the greatest use in diagnostic analysis, reflecting the marginal productivities at mean levels of returns.

The general form of the function is $y = axi^{bi}$

where, 'xi' is the variable resource measure, 'y' is the output, 'a' is a constant and 'bi' estimates the extent of relationship between xi and y and when xi is at different magnitudes. The 'b' coefficient also represents the elasticity of production in Cobb-Douglas production function analysis.

This type of function allows for either constant or increasing or decreasing returns to scale. It does not allow for total product curve embracing all the three simultaneously. Test was conducted to observe if the sum of regression coefficients were significantly different from unity. Functions of the following form are fitted for different Farming Systems.

$y = ax1^{b1} .x2^{b2} .x3^{b3} \ldots\ldots\ldots\ldots\ldots\ldots xn^{bn}$

On linearization it becomes

$\text{Log } y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + \ldots\ldots\ldots\ldots\ldots + b_n \log x_n + e$

Production function employed for identification of significant predictors in seed multiplication system as a whole is below.

$\text{Log}(y) = \log(a) + b_1\log(x_1) + b_2\log(x_2) + b_3\log(x_3) + b_4\log(x_4) + b_5\log(x_5) + b_6\log(x_6) + b_7\log(x_7) + b_8\log(x_8) + b_9\log(x_9) + b_{10}\log(x_{10}) + b_{11}\log(x_{11}) + e$

where,

y	=	Output in quintal.
a	=	Intercept
$x_1 - x_n$	=	Explanatory variables
b_i	=	Elasticities of production (i = 1 to n)
ε	=	Error term

Discriminant function analysis

The linear discriminant function analysis has been proposed to identify the variables that are important to discriminate between the two groups of farms. In multivariate analysis, linear discriminant function, which is better than any other linear function will discriminate between any two chosen classes (Dillion and Goldstein, 1994). The concept underlying the discriminant function analysis is that linear combinations of the independent variables are formed and they serve as the basis for classification. For application of linear discriminant function, two groups of roughly equal size are required.

The multiple linear discriminate functions

$Z = l_1x_1 + l_2x_2 + \ldots\ldots\ldots\ldots\ldots\ldots l_px_p$

$$i.e., \quad Z = \sum_{i=1}^{p} l_i x_i$$

where, l_i – Coefficient of discriminant function of the ith predictor variable representing power of discrimination of ith predictor variable.

X_i = ith predictor variable

p = number of predictor variables (factors)

i = 1, 2 ……..p.

Z = Total discriminant score for two groups of farmers.

The method seek to find out the values of coefficients (lps) such that squared difference between the mean Z-score for the one group and the mean Z-score for the other group is as large as possible in relation to the variation of Z-score within the group. The determination of the value of coefficients necessitates the solution of the following equations shown in matrix notation.

The determination of the value of coefficient (lps) necessitate the solution of the following equation shown in matrix notation.

SL=D

$$S = \begin{pmatrix} S_{11} & S_{12} & S_{1p} \\ S_{21} & S_{22} & S_{2p} \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ S_{P1} & S_{p2} & S_{pp} \end{pmatrix} \qquad L = \begin{pmatrix} l_1 \\ l_2 \\ \ldots \\ \ldots \\ l_p \end{pmatrix} \qquad D = \begin{pmatrix} d_1 \\ d_2 \\ \ldots \\ \ldots \\ d_p \end{pmatrix}$$

where, p = number of selected variables ($X_1 \ldots\ldots X_p$)

L_{pxl} = vector of co-efficient of the discriminant function

S_{pxp} = pooled dispersion matrix

D_{pxl} = vector of the element representing difference between the means of the two groups.

The discriminant function thus obtained is subjected to test of statistical significance in order to examine whether the yield determining factors considered together are effectively discriminating the fragments belonging to two yield groups as well as two farming systems. To determine the important variables that discriminate the groups i.e., high yielding groups and low yielding groups, paddy seed producer and paddy grain producer, the discriminant function analysis were used in the study. The Mahalanobis D^2statistic has been used to measure the distance between the two groups. In terms of D^2, the test statistic can be transformed into F-statistic of the following form in order to examine whether the two groups are different to each other.

$$F = \frac{N_1 N_2 (N_1 + N_2 - P - 1)}{P(N_1 + N_2)(N_1 + N_2 - 2)} * D$$

$$\text{Where, } D^2 = \sum_{i=1}^{p} \sum_{k=1}^{p} C_{ik} \text{ did } K = \sum_{i=\int}^{p} li_{di}$$

C_{ik} = (I, k) th element of the inverted matrix of S;

N_1 = number of conservatory belong to high yielding groups;

N_2 = number of conservatory belonging to low yielding groups;

The value of observe F is compared with that of tabulated F with (P) and ($N_1 + N_2$ - P - 1) df. at desired level of significant (Kendall *et al.,*1983).

RESULTS AND DISCUSSION

Three models namely, Multiple Linear Regression (MLR), Linear Logarithmic and Cobb-Douglass has been chosen as best fit. To get better estimates (or remedy for multicolinearity) and to avoid model specification bias, stepwise regression has been carried out. It has revealed in Table 1 where, R^2 and adjusted R^2 in stepwise regression for all groups, *viz*., winter paddy seed, winter paddy grain, summer paddy seed and summer paddy grain of model Multiple Linear Regression and Cobb-Douglass showing highest values except as compared to the values of R^2 and adjusted R^2 of Linear Logarithm model. Both stepwise MLR and Cobb-Douglass model for each group in the table - 1 showing the efficacy among variables on output after eliminating redundant variables.

In winter paddy seed group, both models representing impact of location advantage, utilization of NPK and human labour per unit area and cost of plant protection chemicals (PPC) to determine yield parameter. In winter paddy grain group, human labour per unit area and cost of PPCs are the most reliable yield determining factors in MLR and Cobb-Douglass model.

Utilization of NPK, human labour and cost of PPCs in case of summer paddy seed group are considered as important factors. While, location advantage, utilization of seed, NPK and human labour in summer paddy grain group having their influence in yield determination. For all the four groups of cultivation these two models as Multiple Linear Regression and Cobb-Douglass showing the most common factors or variables apart from other variables which are significant to their respective group and judging dependent variable yield.

The significant negative factors of multiple linear regression model are irrigation factor in case of winter paddy grain, level of nitrogen in summer paddy grain production and level of Phosphorous in summer paddy seed production and cost on irrigation which indicates over use of particular factor in the process of production. Therefore, it is important that balancing of fertilizer dose and pricing of irrigation water is also a problem of standardization. In case of linear logarithmic model the significant negative factors are seed and age for winter paddy seed production, ratio of paddy to operational holding for winter paddy grain and location advantage, irrigation factor for summer paddy grain production.

Winter and summer paddy seed

The results of discriminant function analysis avails in distinguishing within two groups of winter paddy seed cultivation viz., low yielding and high yielding as Mohalanobis D^2 Statistics has found to be statistically significant at one percent level (Table 2). It could be deduced that seed and plant protection chemicals are the major contributing factors to discriminate winter paddy seed production group.

For summer paddy seed production, the D^2 statistic is found to be statistically significant at one percent level of significance. The relative importance of the discriminators as calculated through their percent contribution to total distance (Nandi and Pal, 2001) reveal that Nitrogen (N) followed by total nutrients (NPK), phosphorus (P), seed and age contributed mostly to discriminate between low and high yielding group of summer paddy seed production.

Winter paddy and summer paddy grain

The results of discriminant function analysis for winter paddy grain and summer paddy grain are also shown in the table 2. Here, the D^2 value has found to be statistically significant at one percent level of significance. It could be inferred that human labour followed by seed, nitrogen, plant protection chemicals and location advantage are the major contributing factors

Table 1: Summary of stepwise models used for different seasons of output

Model	Crop	R^2	$\overline{R}^2$	Significant Coefficients
Multiple Linear Regression	Winter paddy seed	0.993	0.992	LA**, N*, NPK,* HL**, PPCL**
	Winter paddy grain	0.984	0.984	SD**, N**, P**, HL**, PPCL**, (-)IRRGN*
	Summer paddy seed	0.984	0.983	N**,(-) P**, NPK*, HL*, PPCL**, IRRGN**
	Summer paddy grain	0.987	0.986	(-)LA**, SD*, (-)N**, NPK**, HL**, PPCL**, OHL**, RPOHL*
Linear Logarithm	Winter paddy seed	0.806	0.795	LA**, (-)SD*, HL**, (-)AG*
	Winter paddy grain	0.855	0.850	N**, HL**, (-)RPOHL*
	Summer paddy seed	0.870	0.868	HL**
	Summer paddy grain	0.831	0.824	(-)LA**, SD*, HL**, (-)IRRGN*, OHL**
Cobb-Douglass	Winter paddy seed	0.989	0.988	LA**, NPK**, HL**, PPCL**
	Winter paddy grain	0.985	0.985	NPK**, HL**, PPCL*
	Summer paddy seed	0.983	0.982	SD**, NPK**, HL**, PPCL**
	Summer paddy grain	0.979	0.979	LA*, SD**, NPK**, HL**

*Note: Dependent variable: output (yield); *,** denote value significant at 5% and 1% level, respectively*
(-) denotes negatively significant factors

to discriminate between low and high yielding group of winter paddy grain production.

For summer paddy grain production the D^2 value has found to be statistically significant at one per cent level of significance. It could be proposed that irrigation followed by nitrogen, seed, operational holding, plant protection chemicals and total nutrients are the major contributing factors to discriminate between low yielding and high yielding groups.

Discriminating characteristics between winter paddy seed cultivar - winter paddy grain cultivar and summer paddy seed cultivar – summer paddy grain cultivar groups

The results of discriminant function analysis as studied between two distinct groups as paddy seed farmers and paddy grain of winter cultivation shown in the table 2. D^2 value has found to be statistically significant at one percent level of significance, indicating that variables considered in the function are useful in the distinguishing the two groups of farmers in Paddy cultivation.

The relative importance of the discriminators as calculated through their percent contribution to total distance reveals that human labour followed by total nutrients, irrigation and age contributed mostly to discriminate between the seed and grain groups of paddy. In winter cultivation, the facts observed mostly are utilization of human labour, total nutrients and irrigation in the production process. Winter cultivation though depends on rain water but due to misbehavior of climatic situation may create obstacles and hence, human labour and irrigation contributed towards the significant differences between seed and grain production. Thus, it could be inferred that human labour, total nutrients and irrigation are the three major contributing factors to discriminate between the two groups of farms.

For summer paddy seeds and summer paddy grain cultivar group the D^2 value has found to be statistically significant at one percent level of significance. It is conspicuous from the equation of allvariables as well as of useful variables the total yield variability is explained by total human labour used for cultivation is the most contributing factor towards yield variability. While, total yield variability is explained by this factor along with other factors namely level of total nutrients followed by location advantage, seed and ratio of paddy area to operational holding are also the major contributing factors and come one by one in order of importance and thus able to discriminate between seed and grain producer of summer paddy.

It is interesting from the result that seed production of paddy in winter season is favourable in the traditional belt of higher yielding zones like Bardhaman and Hooghly district but in summer season, Nadia district is favourable for seed production.

Comparisons between the Paddy seed and grain production with the help of three models, like MLR, linear logarithm and Cobb-Douglass production function have applied in a stepwise procedure through SAS packages. Human labour, plant protection chemicals and plant nutrients shows positive significant relation in the final steps for all the models.

In comparison with the winter paddy seed and non-seed production apart from plant protection, human labour and irrigation use are the main yield discriminating factors. Due to uncontrolled situation in winter it is difficult to stress out the efficacy of different parameters.

Table 2: Discriminating characteristics between paddy seed vs. grain production and paddy seed cultivar vs. grain cultivar groups for both seasons

Variables	Discrimination based on high yielding groups and Low yielding groups								Discrimination based on seed and grain cultivation			
	Paddy Seed				Paddy Grain				Winter paddy seed cultivar - Winter paddy grain cultivar		Summer paddy seed cultivar – Summer paddy grain cultivar	
	$(L_i)\times(D_i)$		% contribution to total distance		$(L_i)\times(D_i)$		% contribution to total distance		$(L_i)\times(D_i)$	% contribution to total distance	$(L_i)\times(D_i)$	% contribution to total distance
	Winter paddy	Summer paddy	Winter paddy	Summer paddy	Winter paddy	Summer paddy	Winter paddy	Summer paddy				
LA	0.00	-1.60	0.02	-10.09	0.88	-0.06	12.22	-1.14	-0.00	-0.01	1.03	13.07
Seed	7.21	2.75	64.09	17.31	2.00	1.52	27.67	28.18	-1.24	-17.86	0.22	2.87
N	3.63	12.18	32.30	76.57	1.27	2.04	17.49	37.92	-0.59	-8.56	-0.91	-11.49
P	2.17	3.34	19.28	20.99	-0.05	-1.81	-0.63	-33.65	-0.70	-10.05	-0.05	-0.69
NPK	-8.93	11.12	-79.45	69.91	-1.48	0.84	-20.47	15.65	2.96	42.48	1.26	15.89
HL	1.94	-1.07	17.23	-6.76	3.20	-2.32	44.14	-43.09	6.36	91.12	7.04	88.78
PPCL	5.00	-0.75	44.47	-4.71	1.02	0.87	14.07	16.15	-1.37	-19.72	0.07	0.96
IRRGN	-1.29	-0.42	-11.49	-2.63	-0.12	2.66	-1.63	49.26	1.71	24.49	-0.36	-4.57
Age	0.07	1.05	0.61	6.61	0.00	-0.05	0.01	-0.87	0.13	1.99	0.04	0.51
Family size	0.09	-0.03	0.83	-0.21	0.03	0.05	0.44	0.85	-0.00	-0.02	-0.01	-0.14
OHL	1.40	-7.53	12.44	-47.32	-0.03	1.29	-0.44	23.91	-0.27	-3.93	-0.56	-7.15
RPOHL	-0.04	-3.13	-0.37	-19.68	0.52	0.37	7.13	6.84	0.00	0.07	0.15	1.94
	For winter paddy: Mahalanobis distances: D^2= 11.24**; Fisher distances= 12.38; Z_1= -9.69; Z_2= -20.94 and Z= -15.31 For summer paddy: Mahalanobis distances: D^2= 15.91**; Fisher distances= 8.43; Z_1= 0.78; Z_2= -15.13 and Z= -7.17				For winter paddy: Mahalanobis distances: D^2= 7.24**; Fisher distances= 19.59; Z_1= -4.57; Z_2=11.81 and Z= -8.19 For summer paddy: Mahalanobis distances: D^2= 5.39**; Fisher distances= 14.18; Z_1= -2.91; Z_2= -8.31 and Z= -5.61				Mahalanobis distances: D^2=6.9897**; Fisher distances= 30.157; Z_1= 6.8116; Z_2= -0.178 and Z= 3.3168		Mahalanobis distances: D^2= 7.93981 **; Fisher distances= 25.808; Z_1= 5.23872; Z_2= -2.70109 and Z= 1.268814	

Note: where, L_i = Mean Difference and D_i = Discriminant Coefficient

But the production of summer paddy are more or less controlled situation and here the locational advantage, level of NPK application, human labour engagements are the important yield discrimination factors.

Policy suggestions

Firstly, the seed village concept as recommended by M. S. Swaminathan in 1965 for thequality seeds during green revolution at Jounti village in New Delhi state (Gopalkrishnan, 2002), have again accepted throughout the country with a subsidy by the Seed Division, Ministry of Agriculture, GOI, but its implementation has to be faster as a war footing exercises.

Secondly, the adaptive research on package of practices for seed production are the prime concern for the improvement of seed replacement rate and thereby the production also.

Lastly, the seed growers' fails to achieve the premium prices of field crops and this incidence hampered the seed production of open pollinated crops. Special emphasis has to be taken care for the development of seed entrepreneurs' in the regional level, linking with the other rural developmental schemes that running in rural areas in our labour surplus economy.

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