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PRODUCTION, POST HARVEST HANDLING AND MARKETING OF CUT-FLOWERS IN BANGLADESH: AN AGRIBUSINESS STUDY

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ABSTRACT

The present field survey was an attempt to examine the production and marketing cost structure and profitability of some selected flowers such as tuberose, rose, gladiolus and marigold. Primary data were collected through stratified random sampling technique. The study covered primary market (Jessore), wholesale market (Dhaka city) and retail market (Dhaka city) for flower business. Data were collected from 20 farmers of two selected unions under Jhikargacha upazilla of Jessore district. Besides, 30 local traders, 10 wholesalers cum retailers and 20 retailers were interviewed from the selected markets. The highest net return was earned from rose (Tk. 3,53,927) followed by tuberose (Tk. 1,76,941), gladiolus (Tk. 1,33,069) and marigold (Tk. 84,643). Total marketing cost per hundred flower was highest for retailer (Tk 41.14) because of their diverse activities and lowest for wholesaler cum retailer (Tk 5.66) due to their limited functions. On an average, the net marketing margin was highest for retailers (Tk. 28.10) and lowest for wholesaler (Tk. 9.03). The flower-farmers and intermediaries faced various production and marketing problems in the study areas. Based on the findings, some recommendations were made to overcome the problems that include development of storage facility, provision for scientific knowledge and training facility, and establishment of permanent flower wholesale and local markets, etc.

Key words: Agribusiness; cut-flower; marketing; production.

INTRODUCTION

Cut flowers are parts of plants, characteristically including the blooms or inflorescences and some attached plant materials, but not roots and soil. The production of cut flowers specifically known as the cut flower industry is a branch of

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floriculture industry. In Bangladesh, small-scale flower production initially started in late seventies by some innovative farmers with the production of tuberose, but large scale commercial production was started in mid eighties in Jhikargacha Upazila of Jessore district (Sultana, 2003). The most common, commercially grown flower species in Bangladesh are tuberose (*Polianthes tuberosa*), rose (*Rosa indica*), marigold (*Tagetes erecta, T. patula*), gladiolus (*Gladiolus spp*) and orchids. Bangladesh is well suited for cut flower and foliage production due to its favourable climate and other conditions such as scope to expand cultivation in unutilized homestead lands, cheap labour, relatively low capital investment in contrast with high value addition and good prospect for exports. Cultivation of flower is reported to give 3-5 times and 1.5-2 times more returns than obtained from rice and vegetable cultivation, respectively (Dadlani, 2003). At present, 10,000 hectares of land covers flower cultivation taking the lead by Jessore district. More than 5,000 resilient farmers are growing flower and foliage in the country and about 150,000 people are directly or indirectly involved in floriculture business as their sole livelihood (Chowdhury, 2010). At present, the government has been emphasizing the need to accelerate diversified agricultural production. Floriculture with its ability to yield higher economic return per unit area is slowly gaining ground in the diversification plan in agriculture, which may help the typical crop farmers to improve their livelihood by shifting their business to flower production. After achieving certain level of food security, efforts in the crop diversification plans can accelerate the national and economic development of the country. However, floriculture has not received any direct attention or organized intervention for development. The achievements that have taken place silently in the floriculture sub-sector of agriculture, is almost entirely by the private sector initiative in an unorganised way and without support from the government. Therefore, if the flower industry is explored by farmers, traders, exporters and policy makers it can significantly contribute to the national economy by earning foreign exchange, generating employment and increasing GDP. Nevertheless, there is a lack of agribusiness studies on floriculture in Bangladesh. The present study thus attempts to cover the whole agri-business structure of cut-flowers as a commercial product. It may provide valuable information to the farmers, different intermediaries, policy makers of the Government and NGOs to formulate policy aimed at increasing production and marketing. The study was conducted with the specific objectives of analyzing the costs and returns structures of cut-flowers production, post harvest handling and marketing in Bangladesh.

METHODS

Data Collection

In Bangladesh flowers are cultivated commercially in few areas only. On the basis of high concentration, Jessore district is considered as one of the leading cut-flowers producing zone in Bangladesh. 'Godkhali flower market', is popularly known as the centre of floriculture of Bangladesh, under Jhikargacha upazilla of Jessore district where there is an annual sale of Taka 15 crore worth of flowers that covers 70 percent of the country's total flowers for both domestic use and exportation (Khan, 2008). Therefore, the Jhikargacha upazila of Jessore district was selected as the study area for primary market data. Furthermore, Shahbag area of Dhaka city was also selected as the study area to collect data for the wholesale market, because Shahbag flower market is the only wholesale flower market in capital Dhaka which was established in 1990 (Qamruzzaman, 2009). Primary data were gathered by field survey using a questionnaire. For the preparation of the questionnaire a pilot survey was conducted with 10 respondents which include flower farmers, local traders, wholesalers cum retailers and retailers. Attention was paid to incorporate any new information that had not been asked in the draft schedule. The draft questionnaire was then modified and improved. Based on the experience gathered from the pilot survey, respondents for the present study were selected through stratified random sampling.[1] For this sampling method a database of flower farmers, local traders, wholesaler and retailers were collected from *Upazila* Agriculture Offices, *Gadkhali*-Farmers and Traders Welfare Association[2] and Bangladesh Flower Small Business Association. Based on their information the respondents were classified into four groups: 1) Flower farmers 2) local traders 3) Wholesaler cum retailers and 4) Retailers. As each of these groups does unique jobs, they can be considered as appropriate strata of the population. A total of 90 samples which include 30 local traders, 10 wholesaler cum retailers, 20 retailers and 20 farmers were selected randomly and consequently interviewed at their work site. The survey was conducted during the period of January-February, 2006. The interviews focused on flower production costs and returns, marketing system, marketing costs and returns, constraints of flower business and the possible solutions of flower production for one year time period.

Data Analysis

Data from questionnaire interviews were checked, coded and entered into a database system using Microsoft Excel software. Economic analysis was carried out to determine production cost and return. The analysis was based on farm-gate prices of harvested flowers and current market prices of all other items, expressed in Bangladesh currency, Taka (Tk.).

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[1] A stratified sample is one obtained by separating the population elements into non-overlapping groups, called strata, and then selecting a sample from each stratum (Scheaffer et al. 1990). Arens and Loebbecke (1981) noted that the most common reason for stratification is to reduce the sample size needed to achieve a desired level of precision and reliability.

[2] The flowers from all around Jessore were being gathered at Gadkhali for its selling and price-bargaining.

Production cost

The production cost of flowers refers to the total expenditure incurred by the growers for producing flowers in a particular area of land, relate to the level of inputs and the price of inputs. For the present study data on costs and returns of flower production were collected to clarify production cost and to assess the profitability. Total production cost is the sum of variable costs and fixed costs.

Variable cost

Variable costs are directly related to the scale of farm operations in a given time period. Variable costs in flower production are cost of labor, manure, fertilizer, planting material, irrigation, pesticides, interest on operating capital, etc. Harvesting cost refers to labour cost as the main component of harvesting. Interest on operating capital was calculated by using the following formulas:

Interest on operating capital

$$= \frac{\text{Running capital x rate of interest x time considered (months)}}{100 \text{ x } 12}$$

Fixed cost

Fixed cost in flower farming is mainly the rental value of land which was Tk.18000/ha/year in the study area at the time of data collection.

Marketing cost

Marketing costs include the cost of all business activities necessary to ascertain the needs and wants of markets to facilitate the entire marketing process. Marketing cost items varies from flower farmers to different intermediaries involved in flower business. For farmers, marketing cost includes plucking and assembling, transportation, cleaning and sorting, grading, spoilage and damage, etc. Marketing cost of flower intermediaries includes the expenses incurred by different intermediaries for movement of the flowers through the marketing channel. Cost of different items such as assembling, loading and unloading, grading, packing, transporting, storage, market toll, spoilage, labour cost, salary, material, store rent and other costs were incurred by the intermediaries involved in flower marketing. The formula for calculating marketing cost is:

Marketing cost (Tk/ha) = Marketing cost (Tk/quintal) x yield (quintal/ha)

Total cost

Fixed costs and variable costs together make up total production cost. Thus, the total cost for farmers in producing flower enterprise encompasses total production cost plus marketing cost.

Gross return

The gross returns of the selected flowers were calculated by multiplying the yields of the selected flowers in hundred per hectare and prices per respective hundred flowers. The formula was:

Gross return (Tk/ha) = Yield (quintal/ha) x sale price (Tk/ quintal)

Net return/ profit

Net return is obtained by the difference between the gross return and total cost. To determine the per hectare profitability of flower production for the selected farmers the following equation were applied.

$$\Pi = \sum P_iY_i - (\sum P_iX_i + TFC + TMC)$$

Where,

Π= Net return from flower production

P_i= Per unit price (Tk./quintal)

Y_i= Yield (quintal/ha)

X_i=Total quantity of ith inputs used for flower production

TFC= Total fixed cost

TMC= Total marketing cost for farmers

Marketing margin

A marketing margin may be defined as (i) a difference between the price paid by consumers and that obtained by producer, or (ii) the price of a collection of marketing services which is the outcome of the demand for and the supply of such services (Tomek and Robinson, 1977, p. 109). In the present study the marketing margins and net margins of different intermediaries were estimated by the following formulas:

i. Gross marketing margin = Sale price – purchase price

ii. Net marketing margin = Gross marketing margin – marketing cost

The chain of intermediaries through which the transaction of goods takes place between producer and consumers constitutes a marketing channel ((Kohls and Uhl, 1980, p. 8). The flower-marketing channels in Bangladesh are vast and complex. For the limitation of time, money and resource personnel the study covered limited channels of flower marketing in the study areas (Figure 1).

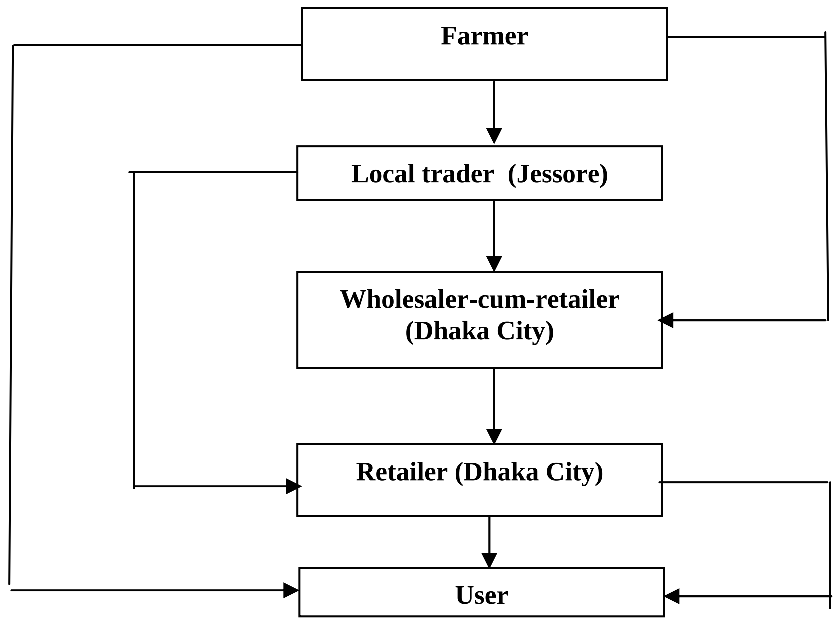

Figure 1. Marketing channels of selected flower in the study areas

The following channels can be identified on the basis of Figure 1.

Channel- I Farmer local trader wholesaler-cum-retailer Retailer user

Channel- II Farmer local trader retailer user

Channel- III Farmer local trader wholesaler-cum-retailer user

Channel- IV Farmer wholesaler-cum-retailer retailer user

Channel- V Farmer user

RESULTS AND DISCUSSIONS

Production cost of selected flowers

A comparison of the cost of production and its breakdown to components provides a better understanding of cost structure and relative production efficiency. This section compares flower production costs for different species. Farmers generally use labour, planting materials, manure, fertilizer, irrigation and pesticides in flower production.

Table 1. Per hectare inputs use by different flowers

Input	Tuberose	Rose	Gladiolus	Marigold
Labour (man-days)	390	422	190	205
Manure (kg)	3500	8000	3500	4000
Urea (kg)	750	1400	800	840
TSP (kg)	650	1200	500	680
MP (kg)	600	900	440	510
Bone meal (kg)	-	1000	-	-
Mustard. Oilcake (kg)	-	1100	-	-

Source: Field survey, 2006

The use of labour per hectare varied from 190 management-days for marigold to 422 management-days for rose production. Huge amount of manure was used in the production of flowers. The highest amount of manure per hectare was applied to rose fields (8000 kg) followed by marigold (4000kg), gladiolus (3500 kg) and tuberose (3500 kg). Urea, T.S.P. and M. P. were the common fertilizers used in the flower production. In addition bone meal and mustard oil cake were also applied in rose cultivation. The highest amount of fertilizer per hectare was used by rose (5600 kg) followed by tuberose (2000 kg), marigold (2030 kg) and gladiolus (1740 kg) (Table 1). Per hectare total production cost of rose was estimated at Tk.1, 90,969.6 followed by Tk. 1,08,488.3 for gladiolus, Tk. 96,609.38 for tuberose and Tk. 72,780.08 for marigold (Table 2).

Table 2. Per hectare cost of production for selected flowers (Tk/ha)

Input	Tuberose	Rose	Gladiolus	Marigold
Human labour	25000	25800	13000	14100
Planting material	12000	40000	50000	9000
Supporting material	-	10150	-	-
Fertilizer	26125	48525	21670	26330
Pesticide	5000	15000	3500	3000
Irrigation	5000	10000	3000	5000
Interest on operating capital	5484.375	17444.58	5318.25	3350.083
Total variable cost	78,609.38	1,66,969.6	96,488.25	60,780.08
Total cost of production	96,609.38	1,90,969.6	1,08,488.3	72,780.08

Source: Field Survey, 2006

Marketing cost of farmers for selected flowers

Marketing cost per hundred of the selected flowers for farmers are presented in Table 3. The spoilage and damage was the major cost item for all the selected species. The cost of spoilage and damage for tuberose was Tk.1.8 per hundred flowers followed by Tk. 4.45 for rose, Tk. 3.8 for gladiolus and Tk. 0.3 for marigold. The total marketing cost was found to be highest for rose (Tk. 9.1) followed by gladiolus (Tk. 8.12), tuberose (Tk. 5.29) and marigold (Tk. 1.27).

Table 3. Marketing cost of cut-flowers for farmers (Tk. per 100 flower)

Cost item	*Tuberose*	*Rose*	*Gladiolus*	*Marigold*
Plucking and assembling	0.9	1.4	1.25	0.3
Transportation	0.77	0.9	0.9	0.25
Cleaning and sorting	0.75	0.9	0.75	0.1
Grading	0.32	0.45	0.42	0.2
Loading and unloading	0.5	0.7	0.75	0.1
Spoilage and damage	1.8	4.45	3.8	0.3
Other	0.25	0.3	0.25	0.02
Total	5.29	9.1	8.12	1.27

Source: Field Survey, 2006.

Yield and return of selected flowers

Table 4 shows that the average yields per hectare of tuberose, rose, gladiolus and marigold were 5000, 4507, 2371 and 30,100 hundred respectively. Average prices for tuberose, rose, gladiolus and marigold were Tk. 60, Tk.130, Tk.110 and Tk.6.50 per hundred respectively.

Table 4. Per hectare yield and returns of selected flowers

Particulars	**Tuberose**	**Rose**	**Gladiolus**	**Marigold**
Yield (hundred/ha)	5,000	4,507	2,371	30,100
Price (Tk /100 flowers)	60	130	110	6.50
Total return (Tk/ha)	3,00,000	5,85,910	2,60,810	1,95,650

Source: Field Survey, 2006

It is clear from Table 4 that highest gross return per hectare was obtained from rose (Tk. 5,85,910) followed by tuberose (Tk. 3,00,000), gladiolus (Tk. 2,60,810) and marigold (Tk. 1,95,650).

Production and marketing cost of selected flowers

Per hectare production and marketing costs of the selected flowers for farmers are presented in Table 5. Thus, total cost of producing selected flowers for farmers has been calculated by adding up production cost and marketing cost (Table 5). The total cost was found highest for rose cultivation (Tk. 2,31,983) followed by gladiolus (Tk. 1,27,741), tuberose (Tk. 1,23,059) and marigold (Tk. 1,11,007).

Table 5. Per hectare production and marketing cost of selected flowers

Flowers	Production cost (Tk.)	Marketing cost (Tk.)	Total cost (Tk.)
Tuberose	96,609.38 (79)*	26,450 (21)	1,23,059 (100)
Rose	1,90,969.6 (82)	41,013.7 (18)	2,31,983 (100)
Gladiolus	1,08,488.3 (85)	19,252.52 (15)	1,27,741 (100)
Marigold	72,780.08 (66)	38,227 (34)	1,11,007 (100)

*Figures within parentheses indicate the percentages of the total. Source: Field Survey, 2006.

Table 5 also reveals that the share of marketing cost in total cost was highest for marigold (34 per cent) followed by tuberose (21 per cent), rose (18 per cent) and gladiolus (15 per cent), while production cost was 66, 79, 82 and 85 per cent for the respective flowers.

Net return from selected cut-flowers

It was observed that the flower production was a profitable business as the per hectare net return for tuberose, rose, gladiolus and marigold were Tk. 1,76,941, Tk. 3,53,927, Tk. 1,33,069 and Tk. 84,643 respectively, in which rose stood for the highest (Table 6).

Table 6. Per hectare return from selected flowers

Particulars	Flowers			
	Tuberose	Rose	Gladiolus	Marigold
Gross return Tk./ha/yr)	3,00,000	5,85,910	2,60,810	1,95,650
Total cost (Tk./ha/yr)	1,23,059	2,31,983	1,27,741	1,11,007
Net return (Tk./ha/yr)	1,76,941	3,53,927	1,33,069	84,643

Source: Field survey, 2006.

Marketing cost of intermediaries

Local traders (farm level) performed the functions of purchasing flowers from the farmers and transporting it to wholesaler-cum-retailers and retailers in Dhaka

City. Table 7 reveals that the average estimated marketing cost incurred by local trader was Tk. 12.60 per hundred flowers. Transportation was the highest cost item (46.63 per cent) for local traders. Wholesaler-cum-retailers performed the function of purchasing flower from the local traders (farm level) and sold those to retailers and sometimes to users. The average marketing cost of wholesaler-cum-retailer was worked out to be Tk. 5.66 per hundred flowers, in which spoilage shared the highest (47.37 per cent). The retailers were involved in the functions of purchasing flowers from wholesaler-cum-retailers and selling it to the users. The average marketing cost incurred by local trader was Tk. 41.14 per hundred flowers. Total marketing cost was estimated at Tk. 59.4 per hundred flowers, of which retailers' share was 69.25 per cent while local traders and wholesaler-cum-retailers incurred 21.21 per cent and 9.53 per cent respectively.

Table 7. Total marketing cost of selected flowers for different intermediaries

Cost items	Local trader	Wholesaler-cum-retailer	Retailer	Total (Tk per 100 flowers)	
				Cost	Percentage
Transportation	5.88	-	-	5.88	9.90
Assembling cost	0.36	-	-	0.36	0.61
Packing cost	4.91	-	-	4.91	8.27
Loading and unloading	-	0.76	-	0.76	1.28
Cleaning and sorting	0.48	0.59	-	1.07	1.28
Market toll	0.65	1.30	-	1.95	1.80
Spoilage		2.68	9.21	11.89	20.02
Basket	-	-	4.60	4.60	3.28
Refine + cellophane	-	-	1.79	1.79	7.74
Thread	-	-	0.88	0.88	3.01
Scotch tape	-	-	0.87	0.87	1.48
Salary of manager	-	-	4.19	4.19	1.46
Wages of labour	-	-	7.9	7.9	7.05
Electricity charge	-	-	2.08	2.08	13.30
Cost of water	-	-	0.64	0.64	3.50
Store rent	-	-	6.43	6.43	1.08
Cost of advertisement	-	-	0.77	0.77	10.82
Others	0.32	0.33	1.79	2.44	1.30
Total	12.60	5.66	41.14	59.40	4.11
Percentage	21.21	9.53	69.26	59.4	100

Source: Field survey, 2006

Marketing margin for different intermediaries

Marketing margins of different groups of intermediaries were calculated separately to examine their relative performance of marketing activities. The gross marketing margin of local traders was Tk. 21.63 and the net marketing margin was Tk. 9.03 per hundred flowers. The gross marketing margin of wholesaler-cum-retailers was worked out at Tk. 16.45 while the net marketing margin was Tk. 5.66. On the other hand, the gross marketing margin for retailers was estimated at Tk. 69.24 and consequently the net marketing margin was calculated at Tk. 28.10 (Table 8).

Table 8 also reveals that the net marketing margin was highest for retailers (Tk. 28.10), which indicates that the retailers are the most beneficiary intermediaries in marketing channel of cut-flower.

Table 8. Marketing margin for different intermediaries (Tk per 100 flower)

Paricular	Local trader	Wholesaler-cum-retailer	Retailer
Purchase price	76.63	96.73	113.06
Sale price	98.25	113.18	182.30
Gross marketing margin	21.63	16.45	69.24
Marketing cost	12.60	5.66	41.14
Net marketing margin	9.03	10.79	28.10

Production problems faced by flower farmers

For convenience, the problems and constraints faced by the selected flower farmers in the study area have been categorized under four general groups such as economic, technical, marketing and social and other, presented in Table 9.

Problems faced by intermediaries

The problems faced by different intermediaries of flower business are presented in table 10. This includes problem of capital, price instability, lack of storage and market information, etc**.**

Table 9. Problems faced by the farmers in producing flower

Reported problem	*No of respondents n=20*	*Percentage*
Economic problems		
Lack of capital or institutional credit	15	75
High price of fertilizer and insecticides	20	100
Technical problems		
Lack of scientific knowledge and training	10	50
Lack of quality seeds or plants	11	55
Insufficient irrigation	12	60
Attack by pest and disease	15	75
Lack of extension work	16	80
Marketing problems		
Inadequate and underdeveloped transportation and communication system	12	60
Low market price	14	70
Lack of adequate market facilities	13	65
Dominance of intermediaries	14	70
High market toll	12	60
Lack of market information	15	75
Social and other problems		
Loss of production due to thief	12	60
Flower damage by animals	11	55
Spoilage	15	75

Source: Field survey, 2006

Table 10. Problems faced by different intermediaries

Reported problem	**Flower traders**			
	Local trader	**Wholesaler-cum-retailer**	**Retailer**	**All**
Inadequate capital	9 (60)*	3(60)	11(55)	23 (57.5)
Price instability	12 (80)	4 (80)	18 (90)	34 (85)
Lack of adequate market information	13 (86.66)	3 (60)	15 (75)	31 (77.5)

Reported problem	**Flower traders**			
	Local trader	**Wholesaler-cum-retailer**	**Retailer**	**All**
Lack of storage facilities	14 (93.33)	4 (80)	16 (80)	34 (85)
Unsold flower	-	3 (60)	18 (90)	21 (55.5)
Inadequate space within the shop	-	-	11 (55)	11 (27.5)
Fluctuation of demand	13 (86.66)	4 (80)	16 (80)	33 (82.5)
Strike and hortal	11 (73.33)	3 (60)	14 (70)	28 (70)

*Figures within parentheses indicate the percentages of the total. *Source: Field survey, 2006.*

CONCLUSIONS

The findings of the present study indicate that production of flowers is a profitable business for farmers. The return over cost is almost double, which indicates high profitability. Also, trading of flower is a profitable venture for different intermediaries. It can be said that flower cultivation and marketing has wider scope in Bangladesh, so the farmers and intermediaries could certainly be benefited financially if performance of marketing system of flower becomes well developed. The growing demand of cut-flowers in the domestic as well as in the export market requires a concerted effort on the part of the government as well as the private entrepreneurs to develop floriculture industry on scientific lines. On the basis of the findings of the study, the following recommendations were made for the improvement of existing production and marketing system of flower.

i. Storage facilities should be established both in public and private sectors.

ii. Farmers need to be trained in the scientific production practices and technology related to this new enterprise.

iii. Traders need scientific knowledge and training on handling, grading, processing and displaying flower in attractive way for sale.

iv. Market information should be made available to the farmers and intermediaries regularly.

v. Government and local government may take necessary steps to establish permanent wholesale and local market.

vi. The floriculture sector should be patronized by the Government to harmonize the public-private partnership (PPP).

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PERFORMANCE OF BLACK BENGAL GOATS UNDER INTENSIVE AND SEMI-INTENSIVE FARMING SYSTEMS

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ABSTRACT

The study compares the productive and reproductive performances of Black Bengal goat under intensive and semi-intensive farming systems in Bangladesh. It was observed that in case of does of 5 years of age, the average body weight was 16.5±0.5 kg and 16.3±0.3 kg under intensive and semi-intensive systems respectively. Average birth weight of kids of litter size 1, was 1057.7±37.1 gm and 1016.7±441 gm while that of litter size 2, this was 778.0±14.8 gm and 761.1±28.6 gm under intensive and semi-intensive systems respectively. In case of litter size 3, such weight was 670.0±19.8 gm and 758.3±32.7 gm under intensive and semi-intensive systems respectively which was significantly different (P<0.01). A negative correlation existed between birth weight and litter size. In the intensive and semi-intensive systems, the average litter size was 2 and 1.95, which was 20.3% and 16.7% in case of singleton, 59.4% and 50% in twin but it was 20.3% and 33.3% in case of triplet. The average birth weight of kids was 813.4±20.4 gm and 802.8±29.6 gm, when the percentage of male kids was 53.1% and 59.0% under intensive and semi-intensive systems respectively. Mortality at 0 to 3 months of age was 27.3% and 20.5% and the average weaning weight at 3 months of age was 4.0±0.2 kg and 4.1±0.2 kg under intensive and semi-intensive systems respectively. Age of puberty was 202.5±5.5 and 237.5±5.5 days which was significantly different (P<0.01). The average gestation period was 146.7±2.1 and 145.5±1.1 days, kidding interval was 216.3±7.1 and 198±8.7 days and the interval to first post-partum oestrus was 68.3±6.4 and 52.1±3.3 days under intensive and semi-intensive systems respectively. The results indicated that the productive and reproductive performances were better in semi-intensive than in intensive systems.

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Key words: Black Bengal Goat; intensive and semi-intensive farming system; performance potential.

INTRODUCTION

Goats, an integral component of farming in Bangladesh, support a large section of landless and marginal farmers (Singh *et al.*, 2000). The total contribution of livestock sub-sector to Gross Domestic Product (GDP) in the country is approximately 6.5% (DLS, 1998). It generates 13% of foreign currency and provides 20% and 50% of full time and part-time employment respectively (Alam, 1993). There are 21.5 million goats (DLS, 2006) of which 90% are of Black Bengal type. Goats of this type are well-known for its high prolificacy, fertility, high quality meat (chevon), good quality skin and excellent adaptability. These are mainly reared by poor farmers and distressed women (FAO, 1991) which helps generating income and improving household nutrition (Husain1999). Recently, the government of Bangladesh and NGO have started a nation wide campaign to reduce poverty with goat rearing. Therefore, the study was undertaken to evaluate the productive and reproductive parameters of Black Bengal goats under different farming systems.

MATERIALS AND METHODS

Farms

The study was conducted during January 2008 to February2009 in two commercial goat farms namely Southern Agro Trades (kid multiplication farm under intensive system) and Akota Somobai Somiti (kid multiplication farm under semi-intensive system) at Kabirhat upazilla of Noakhali district, Bangladesh. The farms were run by the Regional Fisheries and Livestock Development Component (RFLDC), financed by Danish International Development Agency (DANIDA).

Animals and collection of data

The animals (goats) were purchased by observing phenotypic characteristics, body condition, litter size and ancestral history of productive and reproductive performance. For comparing between the two farms, data were taken from 69 intensive and 40 semi-intensive ear-tagged goats.

Management

In case of intensive system, the does (adult female goats) were stall-fed with 200gm concentrate, 40gm urea molasses straw (UMS) per day along with a small quantity of green grass or green leaves or roadside grasses. Newborn kids were provided with kid replacer containing 70% dried skimmed milk, 20% broken rice, wheat or maize, 7% soybean oil, 1% salt, 1.5% calcium-phosphorus preparation and 0.5% vitamin-mineral premix. One part of replacer mixed with nine parts of water (1:9) was boiled and cooled before feeding.

In semi-intensive system, the goats were grazed from 7 a.m. to 1 p.m. and 2 - 5 p.m. The does were given concentrate feed of 100gm/ day along with green leaves. No extra feed was given to the kids. Animals were dewormed with administration of leva-misole (Tricla bendazole) twice in a year (six month interval) with a dose of 20gm/kg body weight. intervewormed twice a year with levamisole Triclabendazole at the rate of 20mg per kg body weight. Most of the goats except some newly purchased ones were vaccinated against *Peste Des Petis Ruminants* (PPR) produced locally (Livestock Research Institute, Mohakhali, Dhaka).

Mating system

Five adult male goats (bucks) (three from Bangladesh Livestock Research Institute, two from local market) of 4 to 5 years of age mated 69 does in intensive system while three local bucks mated 40 does in semi-intensive system (Record book). Oestrus detection was a major problem in intensive system.

Productive and Reproductive data

Age determined by dentition, live weight (kg) of does, birth weight (gm) of kids and weaning weight (kg) were recorded while sex of kids, litter size and kid mortality were taken from the record book. Age of puberty was observed but gestation period, post-partum oestrus and kidding interval were obtained from the record book of the farms.

Statistical Analysis

Raw data were tabulated in Microsoft Excel and analysed by One–Way ANOVA of Compare means Procedure of SPSS 11.5. Least Significant Difference (LSD) test was performed to know the significance difference. To make the graph (histograms), Microsoft Excel and Sigma plot 9.0 were used.

RESULTS AND DISCUSSION

Productive Characteristics

Body weight

Body weights of Black Bengal does are illustrated in Figure 1. The average weight of these increased with age being higher with 16.5 ± 0.5 kg at above 5 years of age in intensive system while it was 16.3 ± 0.3 kg in semi-intensive one. The average weight of does at 1–3 years of age was 14.0 ± 0.3 kg and 13.4 ± 0.4 kg compared to 15.9 ± 0.4 kg and at 3–5 years of age 15.6 ± 0.6 kg at 3.5 years of age under intensive and semi-intensive systems respectively. In this regard, (Benerjee, 2004) observed that the average body weight of adult Black Bengal does was 14 to 20 kg. The observations of the present study of does of 5 years of age under both this systems are in agreement with the findings of Benerjee (2004) but differed by being

26.4 ± 1.1 kg at the same age as reported by Chowdhury and Faruque (2001). In the study reported here, the average body weight of does under intensive system was observed to be higher than that in semi-intensive system in all the age groups although the difference was not significant (P>0.05). It may be mentioned that live weight depends on birth weight, feeding, absence of disease and genetic background (Lamont, 1964; Skinner and Hofmeyr, 1964).

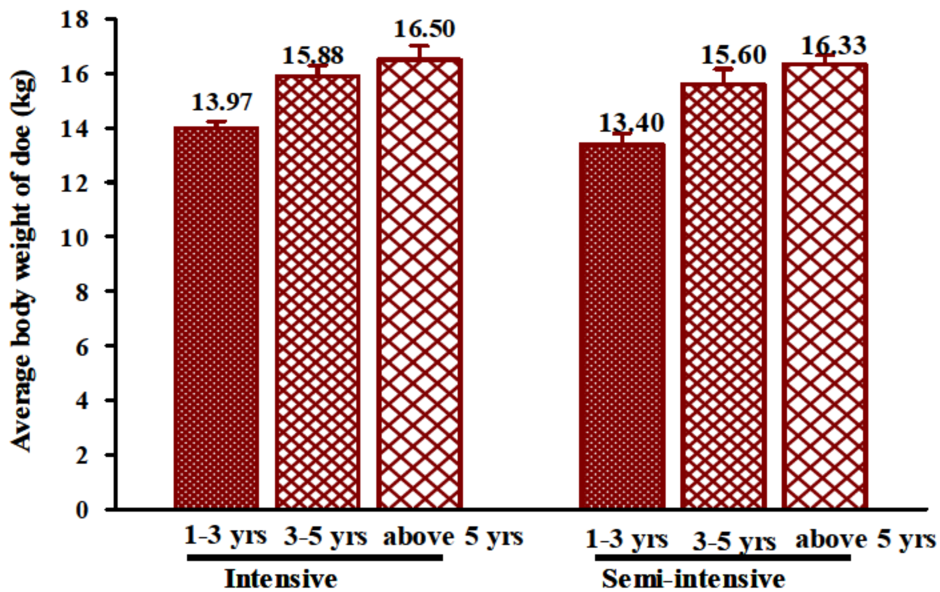

Figure 1: Age-wise body weight of Black Bengal doe under intensive and semi-intensive condition

Birth weight of kids

The average birth weights of Black Bengal kids in relation to litter size are presented in Table 1 and Figure 2. In both intensive and semi-intensive systems, birth weight (within 24 hrs. after parturition) of kids decreased with the increase of litter size. Such a phenomenon agreed with the studies of Epstein and Heritz (1964) and Amoah and Bryant (1983). The average birth weight of triplets was 670.0 ± 19.8 gm in intensive system and 758.3 ± 32.7 gm in semi-intensive system which was significantly different (P<0.01); and 778.0 ± 14.8 gm and 761.1 ± 28.6 gm for twins in intensive and semi-intensive systems respectively. The average birth weight of singleton kids was 1057.7 ± 37.1 gm in intensive system whereas in semi-intensive system it was 1016.7 ± 44.1 gm which was similar to Singh *et al*. (1979). Birth weight depends on feeding and management of pregnant does (Lamont, 1964; Skinner and Hofmeyr, 1969). Average birth weight of kids was 813.4 ± 20.4 gm and 802.8 ± 29.6 gm (Table 1) under intensive and semi-intensive systems respectively which was not significant (P>0.05).

Weaning weight

The weaning weight of Black Bengal kids at 3 months of age (Table 1) under intensive and semi-intensive systems was 4.0±0.2 kg and 4.1±0.2 kg respectively although such a difference was not significant. Such weaning weight of Black Bengal kids was reported as 6.56 kg (Chowdhury *et al.*, 2002) and 4.87 kg (Singh and Sengar, 1979) in case of intensive and semi-intensive systems respectively. The weights recorded in the present study were lower because of the fact that the does of both the systems were undernourished. It was earlier reported that weaning weight depended on adequate nutrition (Hussain *et al.*, 1999) and low weaning weight suggested malnutrition, poor management and health status of does.

Table 1. Average birth weight and weaning weight of kids under intensive and semi-intensive farming systems

Parameter	Intensive (Mean±SE) (gm)	Semi-intensive (Mean±SE) (gm)	F value	Level of significance
Litter size				
1	1057.7 ± 37.1	1016.7 ± 44.1	0.254	NS
2	775.0 ± 14.8	761.1 ± 28.6	0.167	NS
3	679.0 ± 19.8	758.3 ± 32.7	6.789	**
Average birth weight of kids	813.4 ± 20.4	802.8 ± 29.6	0.066	NS
Weaning weight of kids (kg)	4.0 ± 0.2	4.1 ± 0.2	0.643	NS

****** P<0.01; significance at 1% level.

Sex ratio

Frequencies of male and female kids under intensive and semi-intensive systems are exhibited in table 2. The goats produced more male kids like 53.1% in intensive system and 59.0% in semi-intensive respectively. The ratio of male and female in semi-intensive system was found to be 1:0.7 in the present study, while such a ratio of 1: 0.8 was found by Hossain *et al.* (*2004*).

Table 2. Frequency of male and female kids of Black Bengal goat under intensive and semi-intensive systems

Farming system	Total kids	Male kids	Percent (%)	Female kids	Percent (%)	Male : Female
Intensive	128	68	53.1	60	46.9	1: 0.9
Semi-intensive	39	23	59.0	16	41.0	1: 0.7

Litter size

Percentage of litter size and average litter size are presented in Table 3 and Figure 2. The most common litter size was 2 both in intensive and semi-intensive systems at 59.4% and 50%, and least common was litter size 1 at 20.3% and 16.7% respectively. Such an observation is in agreement with 21.4% as reported by Hassan *et al.* (2007). Hassan *et al.* (2007) also reported that twins were the most frequent at 56.3% and singletons and triplets were 21.1% and 20.1% respectively in scavenging system.

Table 3. Litter size of Black Bengal goats under intensive and semi-intensive systems

Litter size	Intensive system (%)	Semi-intensive system (%)
1 (single)	20.3	16.7
2 (Twins)	59.4	50.0
3 (Triplets)	20.3	33.3
Mean litter size	2.0 (64)	2.0 (20)

The average litter size was 2.0 in both the systems but was higher than that of 1.5 (Chowdhury *et al.*, 2002) and lower than 2.2 (Moulick *et al.*, 1966) in intensive and semi-intensive systems respectively. Good plane of nutrition and good body weight improved litter size in mature goats (Sachdeva *et al.*, 1973).

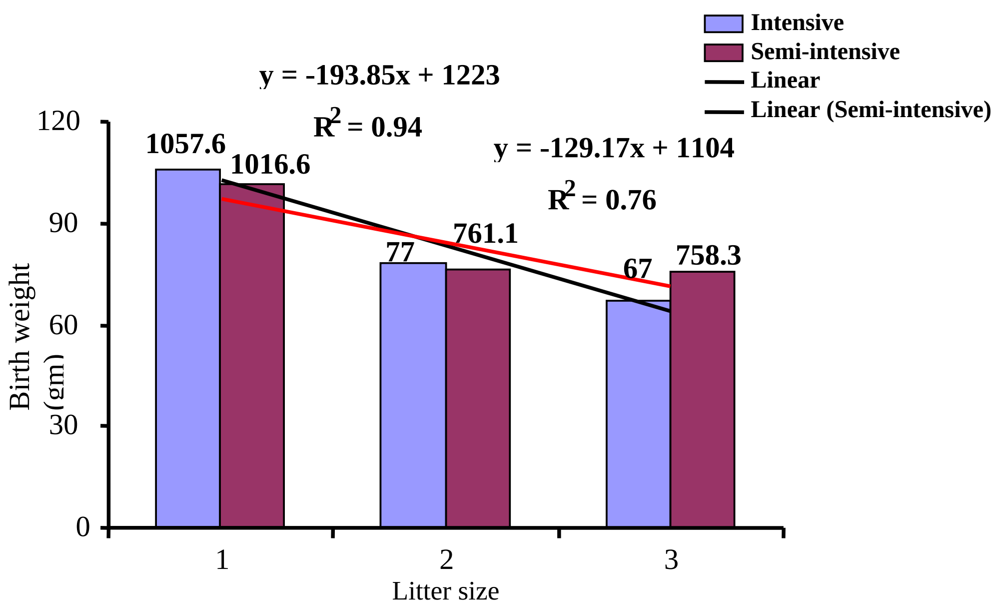

Figure 2: Effect of litter size on birth weight of kid under intensive and semi-intensive condition

Kid mortality

Kid mortality (Table 4) at 0 to 3 months of age was higher (27.3%) in intensive than semi-intensive system (20.5%). Kid mortality was 17% in rural scavenging system (Husain, 1999) which increased with litter size. In this study, kid mortality was high in both systems because of weakness of the does and low birth weight. Honhold (2001) found that kid mortality was 29.9% which was similar to the present findings under intensive systems. Kid mortality of Black Bengal goats was influenced by weight of doe, parity, birth weight, milk yield, season, feeding, housing and disease and could be as low as 7% if properly managed (Chowdhury *et al.*, 2002).

Table 4. Kid mortality (0 to 3 months of age) under intensive and semi-intensive systems

Farm system	Total no. of kids	No. dead kids	Percentage (%)
Intensive	128	35	27.3
Semi-intensive	39	8	20.5

Reproductive characteristics

Age of puberty

The average age of puberty (Table 5) of Black Bengal goat under intensive and semi-intensive systems was 202.5±7.1 days while in case of semi-intensive system this was 237.5±5.5 days being significantly different (P<0.01). Age of puberty depends on presence of buck (Gonzales, 1976; Devendra and Burns, 1983), plane of nutrition, availability of forage (Mishra and Biswas, 1966) and temperature (Rajkonwor and Borgohain, 1978). To this extent, Hossain *et al.* (2004) and Benerjee (2004) reported that the average age of puberty was 196.5±7.5 days and 200 days respectively which was similar to the findings recorded in intensive system of the present study. In semi-intensive system, the age of puberty was higher (237.5±5.5 days) as the goats were supplied with less concentrate feed along with less amount of green leaves /grass.

Table 5. Reproductive performance of Black Bengal does under intensive and semi-intensive farming systems

Parameters	Intensive (Mean±SE)	Semi-intensive (Mean±SE)	F value	Level of significance
Age of puberty (days)	202.5±7.1	237.5±5.5	11.93	·
Gestation period (days)	147.7±2.1	145.5±1.1	0.152	NS
Post-partum Heat Period (days)	68.3±6.4	52.1±3.3	2.11	NS
Kidding interval (days)	216.3±7.1	198.0±8.7	2.26	NS

****** P<0.01; significance at 1% level.

Gestation Period

The average gestation period of Black Bengal does under intensive and semi-intensive systems was 147.7 ± 2.1 days and 145.5 ± 1.1 days (Table 5 and Figure 3) respectively Gestation period of goat was reported to be fairly constant at around 146 days (Devendra and Burns; 1983), similar to the observation of the present study. Gestation period may be affected by season, year, sire, litter size, age and weight at mating, parity, birth weight and kidding interval (Chowdhury *et al.*, 2002). Gestation period is also affected by litter size and sex of kid (Amoah and Bryant, 1983).

Post-partum Heat Period (PPHP)

Post-partum heat period of Black Bengal does under intensive and semi-intensive conditions was 68.3±6.4 days and 52.1±3.3 days respectively (Table 5 and Figure 3). A similar period of 60 days was reported by Devendra and Burns (1983). This period in Black Bengal goats in rural scavenging system was 125 days after the first pregnancy and 70 days after the second (Amin *et al.*, 2001). The period was only 30 days under semi-intensive system (Chowdhury *et al.*, 2002) which was similar to the present observation. Post partum heat period in intensive system in the present study was a little higher due to poor nutrition. Parity, better management and nutrition were the most important factors responsible for lowering the post-partum heat period (Hossain *et al.*, 2004).

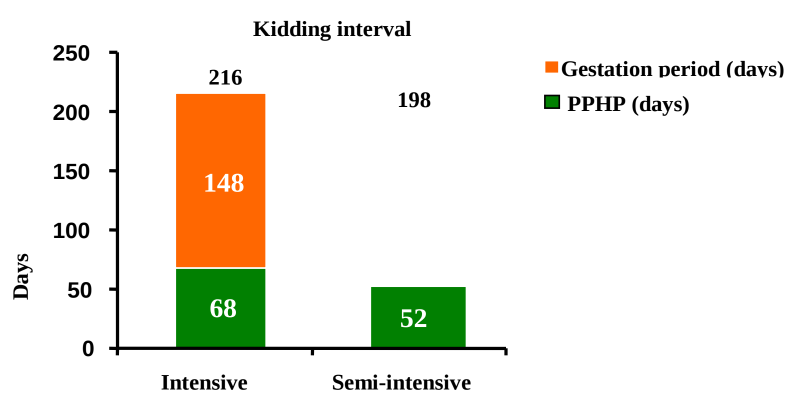

Figure 3: Kidding interval of Black Bengal goat in relation to Gestation period and PPHP

Kidding interval

The average kidding interval of Black Bengal goat under intensive and semi-intensive systems was 216.3±7.1 days and 198.0±8.7 days respectively (Table 5 and Figure 3). Kidding interval was 186.8 days at third parity and 193.1 days at second parity (Hossain *et al.*, 2004) which was in agreement with the findings in semi-intensive systems of the present study. Kidding interval of Black Bengal does in village conditions was 211 days (Amin *et al*., 2001) while under good semi-intensive conditions it was 180 days (Chowdhury *et al*., 2002) but in the present study it was higher due to longer interval of first oestrus. In village conditions, kidding interval ranged from 255 to 300 days (Hussain *et al*., 1999) which was in consistence with that of present study. Kidding interval was reduced from 192 days at low feeding level to 177 days of high feeding level (Chowdhury *et al*., 2002) with an average interval of 223.8 days (Benerjee, 2004).

CONCLUSIONS

Many of the productive and reproductive performances of Black Bengal goats were found to be better in semi-intensive system compared to intensive system and in considering of the socio-economic and climatic condition of Bangladesh, rearing in semi-intensive system would be more feasible than in intensive system.

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STATUS OF RICE BLAST (*Pyricularia grisea)*, CULTIVAR REACTION AND RACES OF ITS CAUSAL FUNGUS IN TEMPERATE AGRO-ECOSYSTEM OF KASHMIR, INDIA

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ABSTRACT

An intensive and stratified survey revealed that all the rice production zones of Kashmir, India were affected with leaf blast disease within the average severity range of 3.7 – 41.3%, whereas highest nodal blast was found in Kulgam (7.3%) followed by Khudwani (5.4%) and Larnoo (3.8%) zones of district Anantnag. The most destructive phase of neck blast severity was encountered in every district under survey, with average range of 0.3-4.9%. The local coarse grain cultivars, Safed China, Jhelum and Chenab were observed susceptible to leaf blast but plants were largely killed due to devastating occurrence of blast in Mushk Budgi, Khutch and Kamad cultivars. Six hundred twenty monoconidial isolates (MI) of rice blast pathogen (*Pyricularia grisea*) were developed from different agro-ecosystems/parts of Kashmir valley in India and tested for race spectrum first time in temperate conditions. They were ID-1, ID-2, IC-17, IC-25 and IB-4. A maximum of three races viz. ID-1, ID-2 and IC-17 appeared in the district of Anantnag, in Kashmir. Race groups ID-1 and IC-17 were recorded in valley with higher frequency occurrence of 28.54 and 34.19%, respectively followed by IC-25 with 18.39%. Race IB-4 and ID-2 were also found to be present with 12.42 and 6.45%, respectively.

Key wards: Rice blast disease; physiological races.

INTRODUCTION

Blast disease caused by *Magnaporthe grisea* (T.T. Hebert, Yaegashi & Udagawa) anamorph *Pyricularia grisea* (Cooke) Sacc. is an impossible deterrent impedance for rice production across the world where paddy is being cultivated. Rice

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crop occupies maximum area in hill and temperate zone of Kashmir in India and has become a staple food crop of people. It is cultivated under hundred percent irrigated and cool night ecology of Kharif wet season but its productivity has declined because resistance and high yielding varieties to blast pathogen collapsed (Anwar *et al*., 2003). Blast frequently occurs on coarse grain Kashmiri japonica/indica cultivars. Disease severity varies with location, weather, cultivar maturity and the inherent level of partial resistance expressed by various cultivars. Virtually avirulence of blast pathogen tends to shift in virulence nature rather than virulence to avirulence in rice crop. Therefore, such variability has made it difficult to point out strategies for selecting rice cultivar that show stable resistance to a blast pathogen in Kashmir. This fungus also infects other host grasses but specific host range is still contradictory. The discrepancy could be attributed to the variation in genetic background of the fungus (Padmanabhan *et al*., 1970).

Diverse pathogenicity in *P. grisea* on rice was firstly noted by Sasaki (1923) in Japan while its physiological races are known since long. Studies on the prevalence of races and their variable virulence throughout the world are still in progress. Agriculturally important isolates were (MI) developed from different locations in all the districts of Kashmir, India that differed from one another such as those virulent or avirulent on the eight international blast differential hosts (IBD). Various primitive rice cultivars are being cultivated in Kashmir from which blast isolates originate are important. In general, differences among *P. grisea* populations from different agro-ecological system in Kashmir probably reflect discernation in differential hosts by their reaction. Existence of pathogenic races has been discerned from many rice areas of the different countries (Atkins, 1965; Ou, 1968) but its variability of population in Kashmir is yet to be analyzed. Therefore, the present investigation was undertaken to ascertain the status of disease, cultivar reaction and physiological races among the isolates of *P. grisea* across the Kashmir valley of India.

MATERIALS AND METHODS

Status of rice blast in Kashmir

The distribution of rice blast disease was determined in 2002 to 2004 by field examination and laboratory confirmation on leaves, neck and nodes of the plant grown in complete irrigated ecology of all the temperate districts of Kashmir valley viz. Anantnag, Pulwama, Budgam, Srinagar, Baramulla and Sopore. An intensive survey of farmer’s fields was carried out during the months of May and September at complete tillering and doughing stages of crop following the stratified multistage random sampling. Each district of Kashmir region was divided into certain zones of approximately the same area by grouping adjacent blocks. These zones constituted the same strata. In each zone, six paddy growing villages were selected at random, four paddy fields of each village were taken by dividing fields into three concentric areas- central, middle and peripheral, four sampling units of 3x3 m^2 were located randomly. Five plants in each sampling units were selected to analyze the severity of disease and cultivars reaction grading on a 0-9 scale (Anonymous, 1988). Samples of leaves, neck and nodes with typical lesions were selected, then dried and kept in a desiccators for isolation of pathogen.

Isolation and culture maintenance

Single typical lesions were taken from each sample and then placed on sterilized glass slides in petri-dishes with macerated blotter paper and incubated at 28 ± 1^0C until adequate sporulation. The sporulating lesions were examined under stereoscopic microscope and clusters of conidia aseptically transferred with a pointed capillary tube on a thin layer of water agar medium (Tuite, 1969). Single conidium was identified under stereomicroscope and aseptically transferred to and cultured on potato dextrose agar medium (PDA).

A total of 100, 250 and 270 mass conidial cultures from single lesions of node, neck and leaves were developed in years 2002 to 2004, respectively. Thus single conidia isolates (MI) from single lesions were obtained to discern the physiological races of *P. grisea*. All cultures were maintained initially on PDA. For long term storage, barley grains were steeped, boiled and autoclaved for two consecutive days. The grains with fungus were incubated at 28 ± 1^0C until boiled grains were colonized and then used as stock cultures for all retested isolates.

Plant material

Seeds of international blast differentials (IBD) viz. Raminad Str. 3, Zenith, Usen, NP-125, Kanto-51, Dular, Tsa-tiao-sio and Caloro were obtained from Department of Plant Protection, Directorate of Rice Research, Hyderabad, A.P. India. Seedlings of these differentials were raised in galvanized iron trays 175 x 50 x 15 cm filled with 20 kg field soil bearing 7.0 pH previously mixed with 5.0 g ammonium sulphate. There were 15 plants per line of each differential host. Another dose of 2.5 g ammonium sulphate was applied when plants were 3 weeks old.

Inoculations and disease evaluation

Developed isolates (MI) of *P. grisea* from different places in Kashmir valley were multiplied on oatmeal agar (Tuite, 1969) medium, which incited maximum sporulation in petri plates. The inoculated plates were incubated at 28 ± 1^0C until the entire agar surface was covered with mycelium growth. The growth was scraped with a sterilized rubber spatula and plates were exposed to fluorescent light for 4 days to induce heavy sporulation. The culture was flooded with distilled water mixed with 0.02% Tween-20 and conidia were dislodged by scraping. The suspension was filtered through cheese cloth and the concentration of conidia was estimated with a heamaecytometer, then standardized to 5×10^4 per milliliter of water.

Plants of differential hosts (IBD) were inoculated with each isolate (MI) 20 days after sprout sowing, using atomizer to apply 30 ml of the conidial suspension per tray of seedlings. The trays were rotated slowly during inoculation to ensure uniform distribution of inoculum. Inoculated seedlings were incubated in a dew chamber of poly-cages at 24-26^{0}C for 24 hrs, then transferred into a poly-house.

Infection was scored at 8-9 days after inoculation. Each seedling of differentials was examined and rated using a classification proposed by Ou (1965), where, 0 = no evidence of infection; 1 = brown specks smaller than 0.5 mm in diameter, no sporulation; 2 = brown specks about 0.5-1 mm in diameter, no sporulation; 3 = roundish to elliptical lesions about 1-3 mm in diameter with gray centre surrounded by brown margins, lesions capable of sporulation; 4 = typical spindle-shaped blast lesions capable of sporulation, 3 mm or large with gray centers and water soaked or reddish brown margin, little or no coalescence of lesions and 5 = lesions as in 4 but the upper portion of one or two leaves killed by coalescence of lesions. Scores of 4 and 5 were considered susceptible reaction and rest were resistant reactions. The race numbers were given according to the system of Ling and Ou (1969).

RESULTS AND DISCUSSION

Status of blast disease in Kashmir

An intensive stratified survey of paddy growing areas carried out during the years of 2002, 2003 and 2004 for all the six districts revealed maximum average disease severity on leaves which was in variable range of 3.7-41.3 %. Highest severity occurrence of nodal blast was found in Kulgam followed by Khudwani and Larnoo zones of Anantnag district which is rice bowl of Kashmir. The most destructive phase of blast lesion i.e. neck blast incidence was found in every surveyed district in the range of 0.9-10.0 % owing to cultivation of primitive local coarse grain rice cultivars, which are to be variable in susceptibility to disease. However, in surveyed zones of district Kupwara, the average severity of neck blast was higher during all the wet season years. The incidence of neck blast at the end of the season usually appeared to be related to the amount of leaf blast occurring during the season although in some fields where little leaf blast was observed, this was a significant amount of neck blast. It was also evident that Anantnag district had consistently suffered with maximum blast incidence found on leaves, nodes and neck of the crop during consecutive three years (2002-2004) due to highest inoculum load or disease pressure than other districts. On the other hand, least severity of leaf and node blast was recorded in Baramulla but neck blast was determined in Kupwara district, which clearly indicated the pathogenic variability of disease or due to airborne inoculum from neighbouring fields when infected fields were at most susceptible stage of maturity for neck blast to occur (Table 1). The rice blast called “rye” was introduced since past in Kashmir. Although rice blast disease is prevalent and affected entire valley of Kashmir, and since 2000, it is in epidemic form (Ali Anwar, 2000).

Table 1. Severity status of blast disease (*Pyricularia grisea*) in temperate agro-ecosystem of Kashmir, India

District	Zone	Disease severity (%)									Average disease severity* (%)		
		Leaf			Node			Neck			Leaf	Node	Neck
		2002	2003	2004	2002	2003	2004	2002	2003	2004			
Anantnag	Shangas	37.5	42.2	44.2	3.8	3.5	5.3	5.0	6.0	3.7	41.3	4.2	4.9
	Kulgam	26.5	27.1	15.4	7.5	6.8	7.6	4.8	4.5	6.0	23.0	7.3	5.1
	Qaimoh	14.0	13.9	16.5	3.4	2.8	3.4	3.0	4.0	3.5	14.8	3.2	3.5
	Qazigund	17.3	16.8	13.9	2.9	3.4	3.3	2.5	3.0	3.4	16.0	3.3	2.9
	Khudwani	15.9	17.3	16.9	4.0	5.0	7.0	2.8	3.2	3.3	16.7	5.4	3.1
	Bijbehara	13.4	12.8	10.4	2.0	3.1	2.7	2.5	3.0	3.2	12.2	2.6	2.9
	Pahalgam	7.6	9.0	8.9	2.4	1.5	1.8	1.5	1.5	2.4	8.5	1.9	1.8
	Larnoo	14.2	11.7	13.7	4.0	3.7	3.7	4.0	4.5	2.6	13.2	3.8	3.7
	Acchabal	12.8	14.2	13.5	3.5	3.0	4.6	3.5	3.0	6.1	13.5	3.7	4.2
	Average	17.69	18.33	17.04	3.74	3.64	4.38	3.29	3.63	3.80	17.69	3.93	3.57
Baramullah	Pattan	9.7	10.2	7.7	0.5	0.0	0.4	1.0	1.5	1.4	9.2	0.3	1.3
	Rafiabad	9.0	11.0	6.4	1.4	1.5	0.7	2.4	1.5	1.5	8.8	1.2	1.8
	Sopore	4.0	3.6	3.5	0.7	0.5	0.0	2.0	2.5	0.9	3.7	0.4	1.8
	Bandipora	3.8	6.2	5.0	0.3	0.2	0.1	1.5	1.0	1.2	5.0	0.2	0.9
	Baramullah	11.3	8.7	9.0	1.2	1.7	0.7	2.5	3.0	1.4	9.8	1.2	2.3
	Average	7.56	7.94	6.32	0.82	0.78	0.38	1.88	1.9	1.28	7.3	0.66	1.62
Budgam	Khag	8.7	12.3	7.2	1.4	1.9	1.5	3.5	5.0	5.3	9.4	1.6	4.6
	Chadoora	7.5	8.2	9.5	1.5	2.0	2.2	3.0	2.1	3.0	8.4	1.9	2.7
	Budgam	9.0	7.5	6.9	1.2	1.0	2.6	1.5	1.6	2.0	7.8	1.6	1.7
	Beerwah	5.8	6.2	6.6	0.8	1.3	1.8	0.7	1.0	1.0	6.2	1.3	0.9

Table 1. Contd.

District	Zone	Disease severity (%)									Average disease severity* (%)		
		Leaf			Node			Neck			Leaf	Node	Neck
		2002	2003	2004	2002	2003	2004	2002	2003	2004			
	B.K. Pora	8.7	9.7	10.1	0.5	1.0	0.9	1.5	2.0	2.8	9.5	0.8	2.1
	Average	7.94	8.78	8.06	1.8	1.44	1.80	2.04	2.34	2.84	8.26	1.44	2.4
Pulwama	Keller	11.5	10.6	9.4	0.5	0.7	1.5	0.5	0.7	0.6	10.5	0.9	0.6
	Tral	9.6	13.0	14.9	1.7	1.0	0.9	0.6	0.8	0.4	12.5	1.2	0.6
	Kakpora	10.0	13.2	11.6	2.0	1.5	2.5	1.0	0.5	2.4	11.6	2.0	1.3
	Pampore	10.0	8.7	8.3	1.5	2.0	1.0	1.5	2.0	0.4	9.0	1.5	1.3
	Shopian	8.5	12.0	9.8	2.0	1.5	1.3	2.0	1.0	1.9	10.1	1.6	1.3
	Average	9.92	11.5	10.8	1.54	1.34	1.44	1.12	1.0	0.94	10.74	1.44	1.02
Srinagar	Gandarbal	14.0	8.0	17.3	1.7	2.5	2.7	2.6	3.3	5.8	13.1	2.3	3.9
	Srinagar	10.5	12.1	10.4	2.6	1.8	2.2	2.5	3.4	3.4	11.2	2.2	3.1
	Shalimar	12.3	11.7	10.5	1.9	3.0	3.8	2.0	3.0	2.5	11.5	2.9	2.5
	Nishat	6.8	8.2	6.3	1.0	1.5	0.5	1.8	2.0	4.0	7.1	1.0	2.6
	Average	10.9	10.15	11.13	1.8	2.2	2.3	2.23	2.93	3.93	10.73	2.1	3.03
Kupwara	Handwara	13.0	9.5	13.5	4.0	3.0	3.5	1.5	1.0	1.1	12.0	3.5	1.2
	Yaripora	10.0	10.0	10.0	2.5	2.0	4.5	2.0	1.0	1.8	10.0	3.0	1.6
	Kupwara	9.0	11.2	9.8	3.5	3.0	3.1	0.5	0.0	1.6	10.0	3.2	0.7
	Helmatpora	3.5	4.1	4.4	2.0	3.0	2.5	0.0	0.5	0.4	4.0	2.5	0.3
	Karansector	8.0	6.5	6.5	3.0	4.5	4.5	1.0	0.5	0.0	7.0	4.0	0.5
	Average	8.70	8.26	8.84	3.00	3.10	3.62	1.00	0.60	0.96	8.60	3.24	0.86

*Pooled mean of disease severity of three years (2002-2004)

Cultivar reaction

It is clear that currently grown Kashmiri rice cultivars are susceptible to rice blast despite of Shalimar Rice-1. In fact farmers of the valley mostly grow Safed China, Mushk Budgi, Jhelum, Chenab, China-1039. China-972, Kamad and Khutch. Blast appeared to be more severe in all the cultivars prevalent in Anantnag district, which has highest rice production area than others. Large areas of plants killed by blast were seen in the field of Mushk Budgi, Khutch, Safed China and Kamad with highest grading reaction (HS) in all the districts than other cultivars, less often in field of China-1039, China-972, Jhelum , Chenab and rarely in the field of Shalimar Rice -1 (Table-2). Similarly Ali Anwar *et al*. (2003) studied under artificial inoculated and conducive conditions and recorded that China-1039, China-972 exhibited susceptible reaction to blast whereas Shalimar Rice-1 was resistant.

Table 2. Status of Kashmiri cultivars reaction to blast disease pathogen at different districts

Cultivars	Average disease reaction grading/ districts							Disease reaction
	Anantnag	Budgam	Pulwama	Srinagar	Baramulla	Kupwara	Mean*	
Safed China	7.45	8.20	7.60	7.00	8.20	6.80	7.54	HS
Jhelum	5.00	6.20	4.30	4.50	6.00	4.00	5.00	S
Chenab	6.20	6.50	7.00	5.80	5.20	6.00	6.12	S
China-1039	5.20	6.00	5.00	4.00	4.30	5.00	5.02	S
China-972	6.20	4.20	5.70	6.00	7.30	5.40	5.80	HS
Mushk Budgi	8.60	9.00	9.00	8.70	8.30	8.60	8.70	HS
Khutch	9.00	8.70	8.50	9.00	8.50	8.60	8.72	HS
Kamad	7.50	8.20	7.00	7.60	7.30	7.80	7.57	HS
Shalimar Rice-1	3.00	2.50	2.70	3.20	2.80	2.50	2.78	MR

*Cultivar reaction in average grading of year 2002-2004 during wet season under a 0-9 scale (Anonymus, 1988) : 0 = Immune, 1 = Highly Resistant (HR),2 = Resistant (R), 3 & 4 = Moderately Resistant (MR), 5&6 = Susceptible (S) and 7, 8 & 9 = Highly Susceptible (HS)

Physiological races

Six hundred twenty monoconidial isolates (MI) from various zones of all the districts of Kashmir valley during Kharif 2002 to 2004 were tested on international differentials (IBD), which segregated their reaction and represent 5 pathogenic race groups viz. ID-1, ID-2, IB-4, IC-17 and IC-25 in Kashmir region of India (Table-3). Physiologic race group IC-17 of *P. grisea* was observed to be most predominant with a higher frequency of 34.19% followed by ID-1 and IC-25 while race ID-2 with 6.54% frequency was only encountered in Anantnag district but two races viz.IC-25 and IB-4 were observed in Srinagar, Budgam and Pulwama districts (Table-4). Meager presence of other race groups viz. IB-4 and ID-2 was ascertained in different isolates (MI) (Table-3).

All the isolates from monoconidial single lesions at different locations were found avirulent (R) to Raminad Str-3 but virulent to Kanto-51 (s) whereas a differential host Zenith showed resistant reaction to all the isolates (MI) except to isolates from Pampore, Khag and Srinagar locations, whereas rest five international differentials appeared with virulent or avirulent nature to isolates (MI) (Table-3) because of new physiologic races (Ou and Ayad, 1968).

Padhi and Chakabarti (1988) reported 5 race groups IC-1, IC-17, IC-22, IE-1 and IE-5 during their four year study at CRRI, Cuttak, Orissa, India of which similarly IC-17 was also found with highest frequency in Kashmir valley. Huerta (1976), in a study from international blast nursery over a period of 1964-71 found that the physiologic race IB-I was the most common race in Peru. However, some race group ‘IB’ was also discerned during the course of investigation in temperate rice of Kashmir.

Table 3. Reaction of international differential hosts (IBD) to local specific monoconidial isolates (MI) of *Pyricularia grisea* from single lesions in Kashmir, India

District	Locations	No. of isolates (MI)	Reaction to *Pyricularia grisea* isolates (MI)								Race group
			Raminad Str.-3	Zenith	NP-125	Usen	Dular	Kanto-51	Tsa-tiao-sio	Caloro	
Anantnag	Shangas	15	R	R	R	S	S	S	S	S	ID-1
	Kulgam	22	R	R	R	S	S	S	S	R	ID-2
	Qaimoh	28	R	R	R	S	S	S	S	S	ID-1
	Quazigund	19	R	R	S	R	S	S	S	S	IC-17
	Khudwani	38	R	R	S	R	S	S	S	S	IC-17
	Bijbehara	16	R	R	S	R	S	S	S	S	IC-17
	Yaripora	12	R	R	R	S	S	S	S	S	ID-1
	Larnoo	18	R	R	R	S	S	S	S	S	ID-1
	Achhabal	18	R	R	R	S	S	S	S	R	ID-2
Pulwama	Keller	18	R	R	S	R	R	S	S	S	IC-25
	Tral	22	R	R	S	R	R	S	S	S	IC-25
	Kakpora	16	R	R	S	R	R	S	S	S	IC-25
	Pampore	28	R	S	S	R	R	S	R	R	IB-4
Budgam	Khag	24	R	S	S	R	R	S	R	R	IB-4
	Chadoora	38	R	R	S	R	R	S	S	S	IC-25
	Budgam	26	R	R	S	R	S	S	S	S	IC-17
	Beerwah	17	R	R	S	R	S	S	S	S	IC-17
	B.K. Pora	19	R	R	S	R	S	S	S	S	IC-17
Srinagar	Gandarbal	20	R	R	S	R	R	S	S	S	IC-25
	Shalimar	25	R	S	S	R	R	S	R	R	IB-4

Table 3. Contd.

District	Locations	No. of isolates (MI)	Reaction to *Pyricularia grisea* isolates (MI)								Race group
			Raminad Str.-3	Zenith	NP-125	Usen	Dular	Kanto-51	Tsa-tiao-sio	Caloro	
	Brein	14	R	R	R	S	S	S	S	S	ID-1
Baramullah	Chhatarhama	12	R	R	R	S	S	S	S	S	ID-1
	Pattan	28	R	R	R	S	S	S	S	S	ID-1
	Rafiabad	18	R	R	S	R	S	S	S	S	IC-17
	Sopore	16	R	R	S	R	S	S	S	S	IC-17
	Bandipora	25	R	R	S	R	S	S	S	S	IC-17
	Baramulla	18	R	R	S	R	S	S	S	S	IC-17
Kupwara	Handwara	15	R	R	R	S	S	S	S	S	ID-1
	Yaripora	20	R	R	R	S	S	S	S	S	ID-1
	Kupwara	15	R	R	R	S	S	S	S	S	ID-1

Table 4. Frequency occurrence of international race groups of *P. grisea* in Kashmir region of India

International Race Group	Districts	No. Isolates (MI)	Frequency (%)
ID-1	Anantnag, Srinagar, Baramulla,Kupwara	177	28.54
ID-2	Anantnag	40	6.45
IC-17	Anantnag, Budgam, Baramulla	212	34.19
IC-25	Srinagar, Budgam, Pulwama	114	18.39
IB-4	Srinagar, Budgam, Pulwama	77	12.42

It is evident from the study that appearance of new pathogenic races of *P. grosea* might be due to the effect of changes in climatic factors as stated by Ezuka (1973). The prevalence of ambient weather factors such as relative humidity and temperature in surveyed localities might be responsible for occurrence of races (Tseng *et al*., 1965). Present study had confirmed the results reported by Veeraghavan and Premlatha Dath (1975) which revealed that the race groups IC-1 and IC-17 changed its pathogenicity after storage and confirmed about the ability of the pathogen. Similarly IC-17 appeared in all the districts of the Kashmir region in India except Srinagar where race ID-1 was dominated which might be due to the diversified agro-ecosystem. Singha and Maibangsa (2003) recorded dominant race groups viz ID-1 and IC-17 in Assam which were also prominent in Kashmir.

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SELECTION CRITERIA FOR HIGH YIELDING GENOTYPES IN EARLY GENERATIONS OF RICE

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ABSTRACT

The study was to find out the selection criteria for selecting high yielding genotypes in two different early segregating F_2 and F_3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F_3 and F_4 generations of two crosses in rice. The heritability estimates were high for spikelets/main panicle and 100-grain weight, whereas it was medium to low for grain yield and low for panicles/plant. Grain yield/plant had significant and positive associations with spikelets/main panicle but non significant and positive association with 100-grain weight. Path coefficients analysis also confirmed that spikelets/main panicle was important yield determinants followed by 100-grain weight as evident from their magnitude of direct contribution to grain yield. On the other hand, estimates of correlation coefficients between grain yield and panicles/plant were inconsistent in respect of both magnitude and significance as also observed in path coefficients analysis. Based on consistently high magnitude of heritability and correlation coefficients, it may be inferred that spikelets/main panicles and 100-grain weight must be used as selection criteria in early generations in rice.

Key words: Correlation coefficients; early generation; heritability; path analysis; Rice.

INTRODUCTION

Most agronomical important traits including grain yield have complex genetic inheritance and require the use of relatively large populations for efficient plant breeding programme. In self pollinating segregating population, the frequency of individuals with all favorable alleles is reduced with generations (Ramalho *et al*., 1993). In early stage of breeding programme, the direct estimates of yield are quite

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difficult. Plant breeders are commonly selecting for yield components which indirectly increase yield. Thus, yield components breeding to increase grain yield would be most effective if components involved were highly heritable and genetically independent or positively correlated in early generations. In rice, visual selection would be effective for yield and its component traits due to high heritability in F_2 as observed by Sun (1979) and Vivekanandan *et al*., (1992), and in F_3 and F_4 by Subrahmanyam *et al*., (1986) and Surek and Beser (2005). Similarly, Sip and Skorpik (1985) showed that productive characters like plant height, 1000-grain weight and grains/spike in the early generations would be more effective in spring wheat when the characters had high heritability. Further, the relationship between yield and its main economic components in segregating population has been extensively studied. The grain yield was significantly correlated with the spikelets or grain per panicle, panicles/plant and test weight (Shrivastava and Sharma, 1971; Dhanraj *et al*., 1987), spikelets/panicle and panicles/plant (Jangale *et al*., 1987; Rao and Jagdish, 1987; Sawant *et al*., 1994) and spikelets/panicle and test weight (Reddy and Ramachandraiah, 1990; Surek and Beser, 2005). Besides these, the information on relative direct and indirect contribution of each component character toward yield will help the breeders to formulate the effective criteria in selecting desirable genotypes in early segregating (F_2-F_3) populations. In view of this, the present study was planned to determine the magnitude of heritability, genetic correlation and path analysis for yield and important yield components by using F_3 and F_4 generations of two crosses in rice.

MATERIALS AND METHODS

The experimental materials comprised of F_2 and F_3 seeds of each of two single crosses viz; Jhona 349 X IET-12944 (Cross I) and Narendra 80 X Lalmati (Cross II) were developed under All India Coordinated Rice Improvement Programme (AICRIP) at Crop Research Station, Masodha, Faizabad. Each F_2 and F_3 population representing 600-700 plants was space planted at Crop Production Center during *kharif,* 2003. The 90 plants (15% selection intensity) on the basis of visual score for various economic characters were selected in each F_2 and F_3 populations. All the 90F_2 and 90F_3 plants were harvested individually to get 90 F_3 ($F_{2:3}$ derived lines) and 90F_4 ($F_{3:4}$ derived lines) families in both the crosses. The one row of each of 90 F_3 and F_4 families and parents were transplanted in Randomized Complete Block Design (RCBD) with three replications during *Kharif,* 2004 in a bed of 5 m length with 20 x 20 cm spacing between hills. Recommended agronomic practices under irrigated condition were followed. The observations on spikelets/main panicle, panicles/plant, 100-grain weight (g) and grain yield/plant (g) were recorded on 20 plants from each of the 90 F_3 and F_4 families in each of the three replications. The collected data in each F_3 and F_4 generations were subjected to estimation of heritability as per procedure suggested by Johnson *et al*., (1955), whereas correlation and path coefficient values were calculated as explained by Singh and Chaudhary (1985) where grain yield/plant was kept as resultant variable and other yield component characters as causal variables.

RESULTS AND DISCUSSION

The heritability of the important characters was estimated in F_3 and F_4 generations (Table 1). The heritability estimates were high for spikelets/main panicle and 100-grain weight, it was medium to low for grain yield. The low heritability was observed for panicles/plant. These results confirm the earlier findings (Maurya, 1976; Surek and Beser, 2005) in rice. The consistent and high heritability (>85%) of 100-grain weight and spikelets/main panicle in both F_3 and F_4 generation indicating that these characters had got established even in early generations (Singh and Sharma,1982). The selection of highly heritable traits in early generations was also emphasized by some workers (Sun, 1979; Vivekanandan *et al*., 1992; Subramanyan *et al*., 1986). On the other hand, heritability estimates for panicles/plant and grain yield decreased from F_3 to F_4 generations suggesting that selection of these two traits may be postponed till advanced generations when genotypes are nearly homozygous. The results obtained from the correlations (Table 2) indicated that genotypic correlations were at higher magnitude than their respective phenotypic correlations in both the generations as well as crosses. The lower values of phenotypic correlation may be attributed to lower modifying effect of environment on the association of characters at the gene level (Mamun-Hossain and Joarder, 1987). Moreover, the magnitude of correlation coefficients was, in general, higher in F_4 than F_3 generation due to fixation of recombination and segregation in earlier generations through selfing (Salimath and Patil, 1990). Grain yield/plant had significant and positive association with spikelets/main panicle but non-significant and positive association with 100-grain weight. These results are in agreement with earlier reports (Jangale *et al*., 1987; Sawant *et al*., 1994; Surek and Beser, 2005). On the other hand, estimates of correlation coefficients between grain yield/plant and panicles/plant were found to have fluctuated from cross to cross in respect of both magnitude and significance; being lower and non-significant in cross I but higher and significant in cross II, which suggests that the selection on the basis of panicles/plant may not give consistent results for grain yield owing to manifestation of particular genetic material and genotype x environment interaction. Path coefficient analysis (Table 3) based on grain yield /plant as dependent variable again showed that spikelets/main panicle had consistent and higher magnitude of direct effect on grain yield followed by 100-grain weight. Mehetre *et al*., (1994) and Samonte *et al*., (1998) also observed direct positive influence of these characters on the dependent variables. Similarly, direct influence of panicles/plant on grain yield also varied from cross to cross in both generations as observed in case of correlation coefficients.

Table 1. Heritability estimates of yield and its components in F_3 and F_4 populations of two crosses of rice

Character	Populations	Cross I	Cross II
Spikelets/main panicle	F_3	0.85	0.86
	F_4	0.86	0.88
Panicles/plant	F_3	0.43	0.68
	F_4	0.34	0.62
100-grain weight	F_3	0.90	0.96
	F_4	0.88	0.95
Grain yield/plant	F_3	0.77	0.81
	F_4	0.59	0.69

Cross I= Jhona 349 x IET-12944, Cross II= Narendra 80 x Lalmati

Table 2. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients between different pairs of characters in F_3 and F_4 populations of two crosses of rice

Character	F_3 Population				F_4 Population			
	SMP	PP	100-GW (g)	GYP (g)	SMP	PP	100-GW (g)	GYP (g)
Cross I: Jhona 349 X IET-12944								
SMP	---	0.240	-0.112	0.502**	---	0.002	0.002	0.533**
PP	0.329	---	0.076	0.032	-0.086	---	0.032	0.096
100-GW (g)	-0.126	0.170	---	0.100	0.010	0.018	---	0.270
GYP (g)	0.750	-0.337	0.186	---	0.640	-0.303	0.437	---
Cross II: Narendra 80 X Lalmati								
SMP	---	0.131	-0.033	0.485**	---	0.133	0.174	0542**
PP	0.178	---	-0.005	0.386*	0.216	---	0.114	0.381*
100-GW (g)	-0.030	0.014	---	0.238	0.195	0.157	---	0.346
GYP (g)	0.634	0.539	0.316	---	0.740	0.485	0.533	---

***&** *Significant at 5 and 1% level respectively.*

SMP= Spikelets/main panicle, PP=Panicles/plant, 100-GW=100-grain weight,

GYP= Grain yield/plant

Table 3. Direct (in bold) and indirect effects of component traits on grain yield at phenotypic (P) and genotypic (G) level in F_3 and F_4 populations of two crosses of rice

Character		F_3 Population				F_4 Population			
		SMP	PP	100-GW (g)	Correlation with yield	SMP	PP	100-GW (g)	Correlation with yield
Cross I: Jhona 349 X IET-12944									
SMP	P	**0.548**	-0.027	-0.019	0.502**	**0.532**	0.000	0.001	0.533**
	G	**1.056**	-0.250	-0.056	0.750	**0.614**	0.022	0.004	0.640
PP	P	0.131	**-0.112**	0.013	0.032	0.001	**0.087**	0.008	0.096
	G	0.347	**-0.760**	0.076	-0.337	-0.053	**-0.258**	0.008	-0.303
100-GW (g)	P	-0.061	-0.008	**0.169**	0.100	0.001	0.003	**0.266**	0.270
	G	-0.133	-0.129	**0.448**	0.186	0.006	-0.005	**-0.436**	0.437
Cross II: Narendra 80 X Lalmati									
SMP	P	**0.450**	0.043	-0.008	0.485**	**0.463**	0.039	0.040	0.542**
	G	**0.547**	0.097	-0.010	0.634	**0.604**	0.064	0.072	0.740
PP	P	0.059	**0.328**	-0.001	0.386*	0.062	**0.293**	0.026	0.381*
	G	0.097	**0.437**	0.005	0.539	0.130	**0.297**	0.058	0.485
100-GW (g)	P	-0.015	-0.002	**0.255**	0.238	0.080	0.033	**0.232**	0.346
	G	-0.016	0.006	**0.329**	0.316	0.118	0.046	**0.369**	0.533

& Significant at 5 and 1% levels respectively.*

SMP= Spikelets/main panicle, PP=Panicles/plant, 100-GW=100-grain weight,

GYP= Grain yield/plant

The selection strategy for less complex traits with consistently higher magnitude of heritability and good correlation with grain yield may facilitate the selection in early generations. The spikelets/main panicle displayed consistently high estimates of heritability and high degree of association with grain yield. This correlation is also supported by high and positive direct contribution to grain yield. Further, 100-grain weight and panicles/plant also seemed to be important yield determining characters but due to low heritability and expression of high genotype x environment effect on panicles/plant, the 100-grain weight seemed to be more reliable than panicles/plant for selection. In addition to this, 100-grain weight also had high heritability and consistently positive direct effect on grain yield. Thus it was suggested that spikelets/main panicle and 100-grain weight must be important selection criteria for high yielding genotypes while handling early generations (F_2-F_3) in rice.

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SELECTION OF PARENT FOR IMPROVEMENT OF RESTORER LINE IN RICE (*Oryza sativa* L.)

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ABSTRACT

Genetically diverged 44 restorers of rice hybrids were collected through IRHON (International Rice Hybrids Observation Nursery) program from IRRI (Philippines), China, and India in which 4 restorers were from hybrid rice breeding nursery of BRRI (Bangladesh). Genetic divergence was estimated using Mahalanobis's statistic (D^2) and principal component analysis. Cluster analysis revealed 44 restorers were grouped into 5 clusters. The lines chosen from the same ecogeographic region were found scattered in different clusters which indicated that genetic diversity and geographic distribution were not necessarily related. The inter-cluster distances were higher than the intra-cluster distance reflecting wider genetic diversity among the genotypes of different groups. The highest inter-cluster distance was observed between cluster II & V followed by I and IV where the highest intra-cluster distance was found in the cluster I indicated that the highly divergent types existed in these clusters. Plant height was found to be the maximum contributors towards the total divergence. The genetically diverged lines viz: IR72102-3-107-1-1-2R, IR68445-62-1-3-1R, Gui99R, MH77R, IR44675R, BR736R and IR64680-81-2-2-1-3R with highest mean value for the characters: grain yield, number of effective tillers/m^2, plant height, days to maturity, number of spikelets/panicle, spikelet fertility, panicle length, panicle weight and 1000-grain weight were selected as genetically diverse restorers to develop heterotic hybrid combinations with a promising CMS line.

Key words: Cluster; genetic diversity; heterotic hybrid; restorer.

INTRODUCTION

Genetic diversity is a powerful tool for determination for genetic discrimination among the genotypes which is used to select appropriate plant

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genotype(s) for hybridization to develop high yielding potential variety (Bhatt, 1970). With the development of advanced biometrical methods such as Multivariate analysis (Rao, 1952) based on Mahalonobis's D^2 statistics and principal component analysis (PCA), it has become possible to quantify the magnitude of genetic diversity among the germplasm for their evaluation in respect of breeding programme. For the development of any genotype with desirable traits, it is necessary to include diverged parents in crossing programme. Arunachalam (1981) reported that more diverse the parents, greater the chances of obtaining heterotic F_1. Divergence analysis is a useful tool in quantifying the degree of divergence between biological population at genotypic level and to assess relative contribution of different components to the total divergence both at intra and inter-cluster levels (Murty and Arunachalam, 1966; Ram and Panwar, 1970). It also permits to select the genetically diverged parents which can produce new recombinants with desirable traits when they are crossed together. Joshi and Dhawan (1966) reported that genetic diversity was very much important factor for any hybridization program aiming at genetic improvement of yield especially in self pollinated crops. They also inferred that Mahalanobis's D^2 statistics was a powerful tool for choosing parents for hybridization aiming at hybrid improvement. Hence, the present study was, undertaken to analyze the genetic divergence of 44 restorer lines of rice hybrid to identify diverged genotypes, which could be used as parents in developing heterotic rice hybrids.

MATERIALS AND METHODS

A total of 44 restorers of rice hybrids were included in the study consisting of 36 lines from IRRI, Philippines, four from BRRI, Bangladesh; and another four from China. All the genotypes were grown at BRRI, Gazipur in Boro (irrigated) season during November 2007 to May 2008. Thirty-days old seedlings of each entry were transplanted in $3m^2$ plots in RCB design with three replications using one seedling per hill with a spacing of 20cm x 20cm. Cultural practices were followed to raise the crop as per recommendation for transplanting irrigated rice. Observations from five randomly selected plants from individual plot were recorded for plant height (cm), days to maturity, effective tillers/m^2, number of spikelets/panicle, flag leaf length(cm), panicle length (cm), spikelet fertility (%), panicle weight(g), 1000-grain weight(g) and grain yield (t/ha). Means of these data over the replications were subjected to both univariate and multivariate analysis. Multivariate analysis viz. Principal component analysis (PCA), Principal co-ordinate analysis (PCO), Cluster analysis (CLU) and canonical vector analysis (CVA) were done by using a computer software GENSTAT 5.13 program of IBM computer.

Genetic divergence was studied following Mahalanobis's (1936) generalized distance (D^2) extended by Rao (1952). Canonical variate analysis was followed for determining the group constellation and principal component analysis (Rao, 1964) was carried out for graphical representation of the genotypes.

RESULTS AND DISCUSSION

The analysis of variance showed significant variations among the genotypes for all the traits studied. The principal component analysis produced Eigen values of principal component axes for coordination of genotypes in which the two axes accounted for 63.91 % of the total variation (Table 1). On the basis of principal component axes I (PCA score I) and II (PCA score II), a two dimension (Z1-Z2) scattered diagram of the 44 restorers was constructed where the genotypes were apparently distributed into five clusters (Figure 1).

Table 1. Latent roots (Eigen values) and their variations in ten yield and component characters of hybrid rice in 5 clusters

Principal component axes	Latent Roots	Percent variation	Cumulative %of variation
I	2.21	43.46	43.46
II	1.04	20.45	63.91
III	0.60	11.73	75.64
IV	0.41	8.01	83.65
V	0.28	5.52	89.17
VI	0.21	4.22	93.39
VII	0.14	2.83	96.22
VIII	0.11	2.19	98.41
IX	0.06	1.12	99.53
X	0.02	0.47	100.00

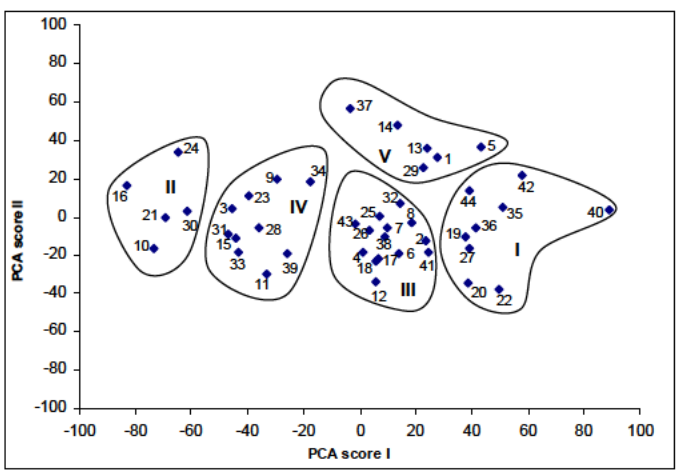

Figure 1. Scatter diagram of 44 restorers based on their principal component scores superimposed with clusters

The clustering pattern was determined by the principal component analysis (PCA) which represents composition of different clusters with the genotypes (Table 2). Cluster I was composed with nine genotypes in which three were of BRRI and six that of IRRI restorer lines. Cluster II contained five genotypes of IRRI lines. Cluster III composed of 14 restorers with 11 of IRRI and three of China. Ten restorers belong to the cluster IV and all these were collected from IRRI. Only six genotypes were in cluster V which was originated in Bangladesh, China and Philippines. Singh *et al.* (1987) and Rao *et al.* (1981) reported ten cluster. Anandakumer and Subramanian (1989), and Biswas and Sasmal (1990) reported six cluster and Ratho (1984) reported five in rice genotypes. Clustering pattern of 44 restorers in five distinct groups indicated that there was no influence of their geographical origin except the cluster II and cluster III contained five and 10 genotypes, respectively (Table 2). The irreverence of genetic and geographical divergence was also reported by Hussaini *et al.*(1977), in finger millet, Dani and Murthy (1985) in chickpes, Prassad *et al* (1988) in maize, Kumar *et al.*(1989) in triticale and Selvakumar *et al.*(1989) in rice.

Table 2. Distribution of 44 restorers of rice in 5 clusters

Cluster	No. of Genotype	Designation	Origin
I	9	IR72886-3-2-2-2R, IR70114-5-3-3-3R, IRBB60-1R, IR69701-9-3-1R, BR827R, BR168R, IR73004-107-3-3-2R, IR55838-B2-2-3-3R, BRRI10R	Philippines, Bangladesh
II	5	IR73387-1-8-2-1R, IR68445-62-1-3-1R, IR71694-39-2-52R, IR73885-1-4-3-2-1-6R, IR72102-3-107-1-1-2R	Philippines,
III	14	IR60199-B-B-2-1R, IR69807-13-2-1R, MH77R, IR44675R, Wan3R, IR69702-108-2-3R, IR69714-28-1-2R, IR69716-37-1-1-5-1R, IR71604-4-1-4-4-4-4-2-2-2R, IR71137-328-2-3-3-2R, IR73885-1-4-1-4-3-6R, IR7320-44-2-3-1R, Gui99R, IR46R	Philippines, China
IV	10	IR72875-94-3-3-2R, PSBRC 82R, IR64R, IR72102-3-135-1-1-1R, IR68011-15-1-1-2-3R, IR73885-1-4-3-2-1-6R, IR68448-10-1-1-2R, IR71604-4-1-4-2-3-2-3-2R, IR21567R, IR73944-3-2-3-2-2R	Philippines,
V	6	MH63R, IR69808-78-2-2-3R, IR69713-3-2-1-3-2R, IR64680-81-2-2-1-3R, IR63868-147-1-3-2R, BR736R	China, Philippines, Bangladesh

Using co-variate matrix with the application of non-hierarchical clustering, the 44 restorers were grouped into five clusters. The clustering pattern was determined by the principal component analyses (Table 2) which represented the composition of different clusters with the genotypes. Cluster I having the restorers IR70114-5-3-3-3R, BR827R and IRBB60-1R produced highest fertile grain per panicle, heavier panicle and the longest flag leaf, respectively. Cluster II consisting the genotypes IR72102-3-107-1-1-2R with shorter plant height and IR68445-62-1-3-1R with highest number of effective tiller per panicle. On the other hand, cluster III comprised the restorers Gui99R, MH77R and IR44675R produced highest yield, heavier grain and matured earlier (Table 3). Cluster V represents the genotype IR64680-81-2-2-1-3R which produced the highest number spikelets per panicle and another genotype BR736R exhibited longest panicle (Table 3). None of the ten genotypes in the cluster IV, was found to produce superior results for the characters studied. However, the clustering pattern failed to indicate any relationship between genetic divergence and geographic distribution, because all the lines from the same origin were found scattered in all the five clusters. The results are in agreement with the findings of Hossain *et al.* (2004).

The mean performance of ten characters in five clusters is presented in table 3. Most of the characters showed distinct differences among the clusters. The cluster I contained the highest value of flag leaf length (26.33). Similarly, the cluster II produced the highest value for effective tillers/m^2 (387.20) and yield (7.21) and the lowest value for plant height (92.30). The highest 1000-grain weight (25.03 gm) was found in the cluster III. The cluster V represented the highest mean value for five characters viz. number of spikelets/panicle (195.17), panicle length (26.00), spikelet fertility (89.17 %) and panicle weight (3.79 gm).

Table 3. Cluster means of 10 characters in 44 restorers of rice hybrid

Character	Cluster				
	I	II	III	IV	V
Plant height(cm)	101.92	**92.30**	100.61	96.45	104.90
Days to maturity	157.89	150.80	152.00	153.60	**150.50**
Effective tiller/m^2	270.22	**387.20**	305.00	351.40	311.67
No. of spikelet/panicle	161.56	135.20	143.43	135.80	**195.17**
Flag leaf length (cm)	**26.33**	21.20	22.07	21.70	21.83
Panicle length (cm)	24.33	23.00	24.64	23.60	**26.00**
Spikelet fertility (%)	87.33	88.40	86.93	88.80	**89.17**
Panicle weight (g)	3.37	2.39	2.89	2.88	**3.79**
1000-grain weight (g)	23.44	23.06	**25.03**	24.10	22.97
Yield (t/ha)	6.89	**7.21**	6.88	6.88	7.05

Somayajulu *et al.* (1970) reported that clustering revealed instability due to relatively lesser divergence, whereas widely divergent cluster remained distinct in different environment. These relationships were also reflected in the scatter diagram (Fig.1). Crossing of lines of the distinct clusters is suggested as it might result for improvement of restorer line by RxR crossing programme. Iftekharuddaula *et al.* (2002) reported that the crosses involving the parents belonging to distinct clusters would offer prime scope in the development of high yielding irrigated rice.

The analysis of cluster distance revealed that the inter-cluster distances were higher than the intra-cluster distance indicating wider genetic diversity among the genotypes of different groups. Intra-cluster distances were estimated using the inter-genotypic distance followed by Singh and Chaudhuary (1977). The highest intra-cluster distance was observed in cluster I (0.49) where the lowest distance was found in cluster II (0.30) (Table 4). This indicated that the lines in the cluster I were more diverged than that of cluster II. In case of inter-cluster distance, the highest value was found between cluster II and cluster V (9.99) followed by between cluster I and cluster IV (8.28) and cluster II and cluster III (8.20) (Table 4). On the other hand, the lowest inter-cluster distance was observed between cluster I and cluster II. The above result indicated that the genotypes included in the cluster II and cluster V were more diverse than the genotypes of cluster I and II. Therefore, parents selection for hybridization from the cluster II and V may give the desirable heterosis for heterotic rice hybrids.

Table 4. Average intra (bold) and inter-cluster distance ($D^{2)}$ in 44 restorers' of rice hybrid

Cluster	I	II	III	IV	V
I	0.49	1.20	3.83	8.28	4.75
II		0.30	8.20	3.81	9.99
II			0.33	4.44	4.19
IV				0.40	7.02
V					0.33

The canonical variance analysis of 44 restorers (Table 5) revealed that the vectors (vector 1 and vector 2) for number of spikelets/panicle, panicle length and spikelet fertility were found positive indicating maximum contribution of these characters to the total divergence of the genotypes. For the other characters viz. plant height, days to maturity and panicle weight were found positive in vector I, similarly, for effective tillers/m^2 and yield were found positive in vector II which revealed that those characters contributed less toward the total genetic divergence of the genotypes.

Table 5. The canonical vector values for the classification of 44 restorers in rice hybrid

Characters	Vector I	Vector II
Plant height (cm)	+0.023	-0.025
Days to maturity-	+0.041	-0.058
Effective tillers/m^2	-0.093	+0.018
No. of spikelets/panicle	+0.033	+0.067
Flag leaf length (cm)	-0.087	-0.070
Panicle length (cm)	+0.056	+0.252
Spikelet fertility (%)	+0.075	+0.047
Panicle weight (g)	+0.089	-0.239
Thousand seed weight (g)	-0.027	-0.011
Yield (t/ha)	-0.255	+0.482

CONCLUSION

Through the multivariate analysis IR72102-3-107-1-1-2R, IR68445-62-1-3-1R, Gui99R, MH77R, IR44675R, BR736R and IR64680-81-2-2-1-3R were selected due to their greater divergence for the mentioned characters that would offer a good scope to develop an elite restorer line by RxR improvement program for the exploitation of better heterosis with promising CMS line. Joshi and Dhawan (1966) reported that genetic diversity was very much important factor for any hybridization program aiming at genetic improvement of yield especially in self pollinated crops. Bhatt (1970) inferred that Mahalanobis's D^2 statistics was a powerful tool in choosing parents for hybridization aiming at hybrid improvement.

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ECOLOGICAL AND ENVIRONMENTAL SUSTATINABILITY OF JUTE PRODUCTION SYSTEMS IN BANGLADESH: LIFE CYCLE ASSESSMENT

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ABSTRACT

Two important studies on jute production systems were conducted through field experimentations for the two consecutive jute growing seasons in 2006 and 2007 to enumerate the ecological sustainability and the environmental consistency indicators of the system. Life Cycle Assessment (LCA) is one of the methods to assess the environmental consistency and ecological health indicators affected by the production systems. LCA of jute production system presents the emissions and extractions of nutrients to and from the soil and water as well as some important biogases to the air considering inputs and outputs to and from the production system boundary to the environment. Two distinct retting methodologies (conventional whole plant and improved ribbon retting) and jute production system as a whole were assessed for the environmental and ecological health consequences. The weighted emissions values of Global Warming Potential (GWP), Chemical Oxygen Demand (COD), Nutrification and Human toxicity: air according to the environmental themes indicated that the improved retting practice showed better performance and more environment-friendly characteristics than the conventional one. At the same time jute productions as a whole showed better performance considering environment than the other allied fibre productions systems. This revealed that the jute production system in Bangladesh as a whole is an environment-friendly production system.

Key words: Ecological health; environment friendly; global warming potential; jute; life cycle assessment.

INTRODUCTION

Being a non-food industrial crop, demand of jute fibre exclusively depends on industrial use in domestic as well as in international market. During the decades of

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1960s and 1970s jute fibre was extensively used for manufacturing gunny-bags to store and transport staples such as rice, wheat, corn, sugar, flour etc. and was appreciated as “the carries of the world trade”. Due to high demand the price of jute fibre was then also high. As a result the crop was then cultivated intensively in the best soils of Bangladesh. But reality pushed aside this crop to least fertile almost fallow lands after the introduction of artificial fibres in the world market. The Kyoto protocol of global climate change has resulted in an acceleration of the transition towards a sustainable and more environment-friendly economy. This transition is mainly realized by a shift in the use of agricultural crops from food to energy and a shift in the use of petrochemicals to renewable resources, such as non-food crops. As a major renewable resource lignocellulosic fibres derived from the structural plant tissues are expected to play an important role in this transition. A comparative study on the environmental implications of polypropylene (PP), high-density polyethylene (HDPE) and polyurethane (PU) relative to natural fibre based products, was conducted and discussed in order to identify follow-up actions. Recent awareness of environmental degradation due to non-biodegradable property of artificial fibre, jute is being automatically welcomed by the international community. Most popular car manufacturer in the world TOYOTA and MITSUBISHI MOTORS of JAPAN and GM MOTORS of USA have signed memorandum of understanding with Bangladeshi counterpart to use the natural fibre jute in the internal decoration of their car’s body instead of artificial one (The Daily Nayadiganta, 2005; Haque, 2006 and Islam, 2007). So, this is the high time for researchers to explore (quantification) the sustainability indicators as well as environment-friendly properties of jute fibre to help the experts and planners to be prepared for the days coming for jute (Rahman and Bala, 2007).

It is an important need of time to proceed with the assessment of environmental impacts in the life cycle of jute production activities because it should highlight for an effective environmental protection. Life Cycle Assessment (LCA) is a method developed in the early 1980s, which results in a systematic classification and quantification of the environmental impact and the ecological implications of the entire life of a product. LCA makes it possible to account for all the material and energy flows into the production systems while keeping track of outputs (products, energy, waste materials) all along the production cycle. LCA is also an effective method to assess quantitatively the material flows and environmental impacts throughout the life cycle of jute production systems (Hayo, 2004). LCA will explore the opportunity to support decision-making on an efficient allocation of efforts and wealth to protect environmental qualities. To meet the challenges of fulfilling the laps and gaps between the ecological balances and measurable outcome involving environmental accounting, multiple criteria assessment, environmental auditing, energy and material analysis and waste minimization, the International Standards

Organization (ISO) developed the ISO 14000 (particularly, ISO 14040-14043 for ecological efficiency) series of environmental management standard (Mohee and Beeharry, 1999; Brentrup *et al*., 2004; Rebitzer *et al*., 2004). The most up to date structure of LCA is proposed by the ISO 14040 can be synthesized in four main phases:

Phase 1: Goal definition and scoping (ISO 14040, 1997);

Phase 2: Life cycle inventory (ISO 14041, 1998);

Phase 3: Life cycle assessment (ISO 14042, 2000) and

Phase 4: Life cycle interpretation or improvement (ISO 14043, 2000).

One time's economic fortune and golden fibre of Bangladesh is no more an economic fibre after the introduction of synthetic fibres, although it is biodegradable. No study has been reported on environmental implications and ecological health indicators of jute production system in Bangladesh. The purpose of this study is to explore and evaluate the environmental and ecological health indicators using inputs and outputs (with harvested yield) to assess the environmental and ecological efficiency of the production process based on LCA (ISO 14000).

MATERIALS AND METHODS

Jute production systems for LCA study are addressed through four distinctive steps of (i) Sowing, (ii) Growing, (iii) Harvesting and (iv) Retting. Two different retting processes (a) Conventional (whole plant retting) and (b) Improved (separated green bark, i.e., ribbon retting), are quantified and compared in the LCA to identify the environmentally more sound one and at the same time to show that the jute production system as a whole is an environment-friendly one in comparison to the Jute and Allied Fibre (JAF) production systems in neighboring countries. Retting is the only stage where there are two different options considered in the LCA study. Equal attention was given for both the ribbon retting and whole plant retting processes in the field experimentation for quantifying the emissions to soil, air and water which affect the environment according to the globally recognized LCA methodology ISO 14000 (Figure 1).

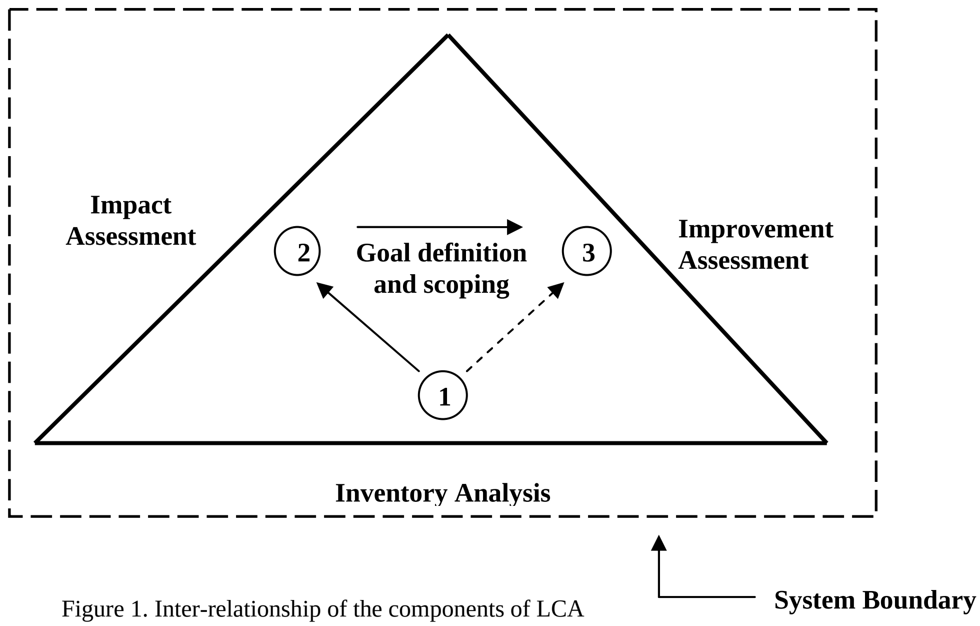

Figure 1. Inter-relationship of the components of LCA

Figure 1 shows the sequential activities of LCA. At first goal and scope of the study is to be defined. Once the system boundary is identified the inventory analysis of the system is done. From inventory analysis impact assessment is to be identified. And then improvement assessment is to be ascertained from the identified impact assessment. Sometimes improvement assessment is drawn directly from the inventory analysis.

The field experiments were conducted for the study at the Central Research Station (CRS) of Bangladesh Jute Research Institute (BJRI) in the two jute growing seasons in years 2006 and 2007. CRS is located at *sadar thana* of Manikgonj district, which is 56 km away, north-west direction from Dhaka Metropolitan City within $23^{o}42'$ to $23^{o}56'$ latitude and $89^{o}57'$ to $90^{o}08'$ longitude with an average altitude of 4.00 meter above mean sea level. Split plot experimental design was followed with treatment: A. Variety: 2 (a. CVL-1, b. O-9897) and B. Date of harvest: 10 with Replications: 3. For 10 harvests (plant sample collection) of different plant ages, 20 plots for 2 cultivars in each block and a total of 60 plots within 3 blocks were made for the study. Starting at the crop age of 20 days from the date of emergence, 10 harvesting dates were considered up to 110 days (at an interval of 10 days) of crop ages. Finally crop was harvested at the age of 120 days for other studies as LCA and Emergy Analysis.

Sowing of jute seed was done after the land preparation and leveling with recommended doses of manure and fertilizers (BARC, 2005) for good crop stand.

Between the two methods of seed sowing (broadcasting and line sowing) both are practiced at the farmer's level (Rahman *et al*., 2003). Line-sowing technique was followed in the present study. Optimum growing period for jute crop was 120 days (BJRI, 1996-1997) during which thinning, weeding, fertilization and plant protection measures were done as necessary. Around 70% seedlings were thinned for well growth of the jute crop (IJSG, 2003). This stage of jute crop growth needed large number of labour and most of the inputs sanctioned for the production system. Harvested crop was left in the field for 3 days for natural defoliation. Before placing the crop in the water for retting, one half of the crop was taken for manual green ribbon separation process.

Retting was the only stage where two different options were considered in the present study. Equal attention was given for both the ribbon (improved) retting and whole plant (conventional) retting processes for quantifying the emissions to soil, air and water which affect the ecology and environment.

Some assumptions made by the Institute for Applied Environmental Economics (TME, 2003) for greenhouse gas emissions of JAF production systems were considered for the jute production system in Bangladesh as:

- Fibre will be incinerated leading to CO_2 emissions (if composted emissions will be lower);
- Sticks are used for fuel leading to CO_2 emissions (if not incinerated, carbon remain fixed in the wood);
- Organic residues will only partly lead to CO_2 emissions. It is assumed that 25% of carbon in the residues will be converted to CO_2 (during composting about 75% of dry substance remains in the end product).

Environmental theme for COD is calculated on the basis of per kg fibre production from the COD concentration difference at the starting and at the end of the retting. Emissions of COD and N are converted to P equivalent in environmental theme for nutrification per kg fibre calculation. Similarly, emission of H_2S for the production of 1 kg fibre is considered in the calculation of environmental theme for Human toxicity: air (CLM, 1996).

Nutrients emissions to soil

In the jute production system in Bangladesh "mass balance" technique has been applied for the estimation of emission cases of nutrients and biogas taking help from the study conducted by IJIRA (2000). Nutrient emissions have been assessed as follows (Tables 1 and 2):

(i) estimation of N, P and K input through fertilizer and manure;

(ii) estimation of N, P and K output in product (fibre) and by-products (stick, biomass and waste water);

(iii) the difference is addressed as emissions to the soil (ignoring emission to air).

Table 1. Estimated amounts of N, P, and K in fibre, sticks and leaves as % of total dry weight of products

Type of product nutrients	Dry fibre (%)	Dry sticks (%)	Dry leaves (%)
N	0.43	0.21	3.00
P_2O_5	0.19	0.09	0.37
K_2O	1.65	0.75	2.20

Source: IJSG, 2003 and Dempsey, 1975.

Table 2. Estimation of input and output nutrients and their emissions to soil

Input and output item (kg/ha)			N (kg/ha)		P_2O_5 (kg/ha)		K_2O (kg/ha)	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Input:								
Cowdung	1250.00	1250.00	9.75	9.75	8.13	8.13	13.00	13.00
Urea	55.60	55.60	25.57	25.57				
TSP	18.36	18.36			3.67	3.67		
MP	20.73	20.73					10.37	10.37
Total input			**35.32**	**35.32**	**11.80**	**11.80**	**23.37**	**23.37**
Output:								
Fibre (dried)	1996.50	1906.00	8.58	8.20	3.79	3.62	32.94	31.45
Stick (dried)	5533.00	5714.00	11.61	12.00	4.98	5.14	41.50	42.86
Leaves	797.50	797.50	23.93	23.93	2.95	2.95	17.55	17.55
Ribbon waste	3264.10	3446.07	14.05	14.82	6.21	6.55	53.92	56.86
Stick waste	1260.50	1101.00	2.65	2.31	1.13	0.99	9.45	8.26
Total Suspended Solids (TSS)	21.50	7.74	0.69	0.26	0.30	0.11	2.61	0.99
Total output			**61.52**	**61.52**	**19.36**	**19.36**	**157.97**	**157.97**
Total emissions			**-26.20**	**-26.20**	**-7.56**	**-7.56**	**-134.60**	**-134.60**

Source: Field Experimentation, 2006 & 2007 (**A** represents Conventional and **B** Improved retting).

Biogas emissions to air and retting water quality degradation:

Concentrations of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) in retting water were assessed in the environmental engineering laboratory of Bangladesh University of Engineering and Technology (BUET) for the water samples prior to retting, during retting and after the completion of retting and the data were used for calculating the emissions to water by jute retting process (Table 3). According to Jantzen *et al*. (2003) the composition of biogas is CH_4 (50%), CO_2 (49%) and H_2S (1%).

Table 3. Retting water characteristics from chemical analysis

Sl. no.	Parameters	Pre-retting (mg/liter)	During retting (mg/liter)		Post-retting (mg/liter)	
			A	B	A	B
1	TSS	58	172	102	172	173
2	BOD	50	120	120	130	80
3	COD ($K_2Cr_2O_7$ value)	80	460	408	270	339

‘A’ for Conventional (whole plant) and ‘B’ Improved (green ribbon) retting practice

Total emissions to retting water were then calculated as follows: {(Concentration during retting)–(concentration after retting)}*(amount of water used in retting the product for 1 ha)*(amount of dry substance in unit amount of COD)=110 mg/l*188.496 m^3*0.88 DS/COD=31.52 kg/ha for conventional system of retting. Similarly, 11.37 kg/ha was calculated for improved system of retting. Per hectare CO_2 fixation and greenhouse gas emissions (kg) in the life cycle of jute were compared between the two different retting practices (Table 4).

Table 4. CO_2 fixation and greenhouse gas emissions (kg/ha) in the life cycle of Jute cultivation and net effect on greenhouse gas emissions for Conventional and Improved Retting Systems

Production Steps	Jute Retting Systems		
	Conventional	Improved	Average
CO_2 fixation during jute cultivation	19583.50	19583.50	19583.50
CO_2 emissions of processes (excluding retting)	0	0	0
CO_2 emissions of retting	50.71	18.14	34.43
CH_4 emissions of retting (CO_2 equivalent)	596.25	203.72	399.99
Total CO_2 fixation after agricultural process	18963.54	19361.64	19162.59
CO_2 emission from fibre	3001.68	2865.61	2933.65
CO_2 emission from stick	8318.70	8590.83	8454.77
CO_2 emission from residues	2001.91	2008.85	2005.38
Total CO_2 fixation in the life cycle of jute cultivation	5641.26	5896.35	5768.81

CO_2 fixation and greenhouse gas emissions (kg/ha) for the jute production in Bangladesh are compared with the similar results of jute production in India, kenaf of China and roselle of Thailand (Table 5).

Table 5. Per hectare CO_2 fixation and greenhouse gas emissions (kg) in the life cycle of JAF cultivation and net effect on greenhouse gas emissions in Bangladesh, India, China and Thailand

Production Steps	Jute		Kenaf	Roselle
	Bangladesh[2]	India[1]	China[1]	Thailand[1]
CO_2 fixation during JAF cultivation	19583.50	22755	36006	11001
CO_2 emissions of processes (excluding retting)	0	0	701	120
CO_2 emissions of retting	34.43	54	184	227
CH_4 emissions of retting (CO_2 equivalent)	399.99	604	2063	2545
Total CO_2 fixation after agricultural process	19162.59	22098	33058	8109
CO_2 emission from fibre	2933.65	4510	5262	1723
CO_2 emission from stick	8454.77	8937	15486	2279
CO_2 emission from residues	2005.38	2241	2876	3162
Total CO_2 fixation in the life cycle of JAF	5768.81	6409	9435	945

[1] Source: Institute of Environmental Economics (TME), 2003, [2] Average of Conventional and Improved Retting Systems.

Using the experimental data and assumptions described so far, the LCA inventory sheet for the jute production systems for conventional whole plant and improved ribbon retting was prepared (Table 6).

Table 6. Inventory sheet for jute production systems

Basis (1 hectare / season)	Units	Production system	
		A. Conventional	B. Improved
I. Jute sowing			
Inputs:			
Land preparation	ha	1	1
Manure	ton/ha	1.25	1.25
Fertilizer			
Urea (N)	kg/ha	18.53*	18.53*
TSP (P)	kg/ha	18.36	18.36
MP (K)	kg/ha	20.73	20.73
Seed	kg/ha	10.00	10.00
Manpower	man-day/ha	42	42
Diesel	liter/ha	16	16
Outputs:			
Sown land	ha	1	1
II. Jute Growing			
Inputs:			
Sowed land	ha	1	1
Fertilizer			
Urea (N)	kg/ha	37.07	37.07
Manpower	man-day/ha	100	100
Pesticide	kg/ha	2.90	2.90
Outputs:			
Growing plants	ha	1	1
III. Jute Harvesting			
Inputs:			
Growing plants	ha	1	1
Manpower	man-day/ha	30	30
Outputs:			
Product	kg/ha	44032.5	44032.5
Leaves	kg/ha	3676.5	3676.5
Roots	kg/ha	10660.5	10660.5

Table 6. Contd.

IV. Jute Retting			
Inputs:			
Product	kg/ha	44032.5	20484.5**
Water	liter/ha	188496	67320
Manpower	man-day/ha	55	65***
Time for retting	day/ha	20	12
Outputs:			
Jute fibre (dry)	kg/ha	1996.5	1906
Jute sticks (dry)	kg/ha	5533	5714****
Emission to water			
BOD	mg/liter	70.962	71.108
COD	mg/liter	167.202	168.895
Biomass solids (TSS)	kg/ha	21.50	7.74
Emission of biogas to air			
Methane	kg/ha	51.75	18.52
Carbon dioxide	kg/ha	50.71	18.14
Hydrogen Sulphate	kg/ha	1.04	0.37

*One third of the total Urea applied at the time of sowing. **Weight of green ribbon only. ***Including additional labor for green ribbon separation. ****Not retted with the ribbon.

RESULTS AND DISCUSSION

In jute fibre retting process microorganisms, such as bacteria or fungi are affecting the plant tissues surrounding the fibre cells, thus liberating the fibres from non-fibre hard-core parts. The water retting process of jute (10-20 days) takes place in ditches, or ponds and uses huge amounts of water approximated at a ratio of one to ten, thus causing pollution of large amount of surface water in the case of whole plant retting process (conventional retting) because of its large volume with the jute sticks beneath the ribbon in comparison to the ribbon only in the case of improved retting system. Organic degradation of decomposing plant tissues and accumulation of microbial biomass are not considered toxic, but the process causes oxygen depletion (BOD and COD) and foul smell (emission of biogas). Improved retting method developed by Bangladesh Jute Research Institute (BJRI) needs lesser amount of water and time due to controlled green ribbon retting (improved process in LCA study), and ultimately resulted in less pollution. Comparisons of these two retting processes were done considering the material and energy consumed, pollutant released and biogas emission to the soil and environment (Table 7).

Table 7. Performance comparison of Jute Production Systems in Bangladesh

Eco-efficiency Indicators	Unit	A. Conventional	B. Improved	Average
Overall Performance				
Retting Input	kg/ha	44032.50 (+122%)	19871.50	31952.00
Fibre (dry)	kg/ha	1996.50 (+4.75%)	1906.00	1951.25
Quality of Fibre	-	Top to Middle*	Bottom to Middle*	-
Stick (dry)	kg/ha	5533	5714 (+3.3%)	5623.50
Resource Consumption				
Retting Water	l/ha	188496 (+180%)	67320	127908
Labour Requirement	man-day/ha	227	237 (+4.4%)	232
Time of Retting	day	20 (+66.7%)	12	16
Ecological Health				
Emission to Air				
Biogas (CH_4)	kg/ha	51.75 (+180%)	18.52	35.14
Biogas (CO_2)	kg/ha	50.71 (+180%)	18.14	34.43
Biogas (H_2S)	kg/ha	1.04 (+181%)	0.37	0.705
Emission to Water				
BOD	kg/ha	13.38 (+64%)	4.79	9.085
COD	kg/ha	31.52 (+179%)	11.37	21.45
TSS	kg/ha	21.50 (+178%)	7.74	14.62
Emission to Soil				
N	kg/ha	-25.50	-25.94 (+1.7%)	-25.72
P_2O_5	kg/ha	-7.26	-7.45 (+2.6%)	-7.355
K_2O	kg/ha	-131.99	-133.61 (+1.2%)	-132.8

* According to Fibre Quality Improvement Division, BJRI, Dhaka-1207.

Improved ribbon retting practice needed 67,320 litres of retting water for the production/ha (green jute ribbon, 19871.50 kg) which was almost one third of 1,88,496 (+180% more) litres needed for conventional whole plant (19871.50 kg) retting practice. Total labour requirement for conventional whole plant retting was 227 nos. /ha, which was less than the requirement of improved retting practice (237 nos./ha, +4.40% more) for the additional ribbon separation process. On the other hand, the retting time needed for improved green ribbon retting was only 12 days which for conventional whole plant retting was 20 (+66.70% more) days. Dry fibre produced in conventional retting practice was more (1996.50 kg/ha, +4.75%) than the improved practice (1906 kg/ha), but the quality from the latter (improved) was superior due to the controlled ribbon retting process. Dry jute sticks produced by the systems were 5533 kg/ha for the conventional and 5714 kg/ha (+3.30% more) for the improved practice respectively. The sticks obtained in the improved ribbon retting process were of better quality (BJRI, 1995-1996) than the sticks obtained in the whole plant retting process because the sticks were retted for 20 days with ribbon.

Estimation of nutrients inputs and outputs and their emissions to the soil were estimated based on the experimental data using “mass balance” technique (IJIRA, 2000). For both the retting practices the nutrients emissions, N (-25.50 & -25.94 kg/ha), P_2O_5 (-7.26 & -7.45 kg/ha) and K_2O (-131.99 & -133.61 kg/ha) showed negative values which indicated the extraction of nutrients from the soil. In the case of conventional system the values were a little bit less than the improved ribbon retting system indicating less extraction. These negative values apparently indicated that the jute cultivation degraded nutrients N, P_2O_5 and K_2O in the soil and in the long run there may be exhaustion of the soil nutrients more by improved ribbon retting system (+1.70%, +2.55% and +1.21% more respectively) than the conventional whole plant retting. These nutrients emission values will be positive if the contribution of roots and leaves are included in the input section, which is more realistic because (i) roots remain under the soil and (ii) 99% of the leaves (1% of the leaves are consumed by the farmers in the form of vegetables) are left on the field and converted to organic manure (Rahman *et al.*, 2003).

The amount of retting inputs for conventional practice was more (product: 44032.50 kg/ha, +122% and water: 188496.00 l/ha, +180% more) than that of improved one (product: 19871.50 kg/ha, water: 67320.00 l/ha) thus the total emissions to water (BOD: 13.38, COD: 31.52, and TSS: 21.50 kg/ha) were also almost 3 times higher for the conventional retting process than that for the improved ribbon retting practice (BOD: 4.79, COD: 11.37, and TSS: 7.74 kg/ha) because the emission rates are almost similar. Emission to the air from conventional practice was also high, CH_4: 51.75 kg/ha (+180%), CO_2: 50.71 kg/ha (+180%) and H_2S: 1.04 kg/ha (+181% more) in comparison to the improved retting practice CH_4: 18.52 kg/ha CO_2: 18.14 kg/ha and H_2S: 0.37 kg/ha (Table 7).

It was observed that the resource consumption and emissions to air as well as in water for the jute production systems both in India (TME, 2003) and Bangladesh were more or less similar. But resource consumption and emissions in production of kenaf in China and roselle in Thailand (TME, 2003) were high compared to jute. It was also observed that the consumption of resources for 1 hectare of land was more or less similar except, retting water requirement for kenaf production in China and roselle production in Thailand were extremely high (+154% more) for kenaf and (+178% more) for roselle in comparison to the jute production in Bangladesh (127.91 m^3/ha) (Table 7). Accordingly emissions to air and as well as to water were also high for these two production systems (kenaf in China and roselle in Thailand). Emissions of CH_4, CO_2 and H_2S gases to air were high (+434%, +434% and +432% more for kenaf in China) and (+559%, +559% and +552% more for roselle in Thailand) respectively in comparison to the jute production system (average value for Conventional and Improved systems) in Bangladesh (CH_4: 35.14 kg/ha, CO_2: 34.43 kg/ha and H_2S: 0.705 kg/ha respectively). These values were also high for the jute production system in India CH_4: 54.90 kg/ha (+56% more), CO_2: 53.80 kg/ha (+56% more) and H_2S: 1.10 kg/ha (+56% more) in comparison to that of Bangladesh. Similarly emissions to water for kenaf and roselle production systems were also high; COD (+634% and +781% more), TSS (+12007% and 6227% more) in comparison to the jute production in Bangladesh (COD: 167.66 mg/l and TSS: 0.01462 ton/ha) respectively. Also for jute production in India COD: 744.50 mg/l (+344% more) and TSS: 0.023 ton/ha (+57% more) showed values which were higher to those in Bangladesh. Nutrients (N and P_2O_5) emissions to the soil are positive (N: +269.26 kg/ha for kenaf and +13.140 kg/ha for roselle, P_2O_5: +99.724 kg/ha for kenaf in China and +14.884 kg/ha for roselle in Thailand) but these values were negative for the jute production in Bangladesh and India, which meant extraction from soil rather than the emissions unlike the cases of China and Thailand (because they included the roots and leaves biomass added to the soil in the computation) and were almost similar for the mentioned two cases of jute productions in Bangladesh and India.

Total CO_2 fixation and greenhouse gas emissions in the life cycle of jute, kenaf and roselle production in Bangladesh, India, China and Thailand were compared and the result revealed that the JAF production systems fixed 945 to 9435 kg/ha per year from the environment (Table 5). Jute production systems in both Bangladesh and India showed almost similar values (5768.7 and 6409 kg/ha respectively per year) which are almost averages of the above two extreme values.

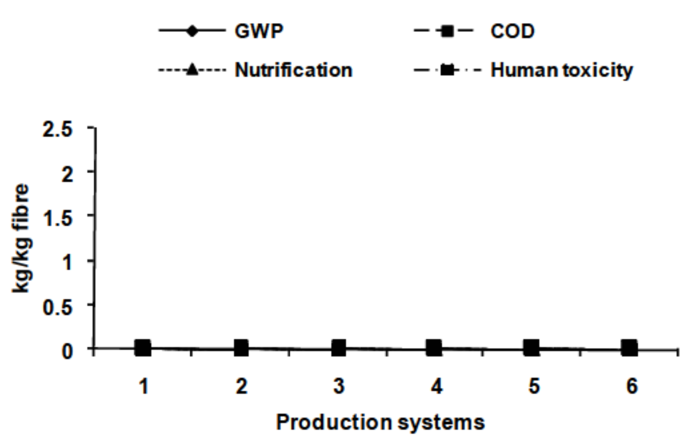

Figure 2. Weighted emissions according to environmental themes as CLM – factors, where Production systems 1: Conventional retting, 2: Improved retting, 3: Average of 1 & 2, 4: Jute production in India, 5: Roselle production in Thailand and 6: Kenaf production in China.

In case of weighted emissions (kg/kg fibre) (i) Global Warming Potential (GWP), (ii) Chemical Oxygen Demand (COD), (iii) Nutrification and (iv) Human toxicity: air according to environmental theme as CLM-factors (Figure 2) for both conventional (1) and improved (2) systems of jute production in Bangladesh (3) showed the more potentiality than the jute production system in India (4), roselle production system in Thailand (5) and the kenaf production in China (6). At the same time improved jute production system (2) showed more potentiality than the conventional one (1).

CONCLUSIONS

Life cycle assessment of jute production systems revealed that the conventional (whole plant) retting practice emits (nutrients, biogas and residues) little bit more to the air and water, hence exerts more burdens to the environment in comparison to the improved ribbon retting system. But jute production system as a whole exerts fewer burdens to the environment in comparisons to the kenaf production in China and roselle production system in Thailand and even jute production in India. Jute assimilates about 5.8 ton CO_2 from the atmosphere in its life time. It can be concluded that the jute production system is an environment-friendly production system as a whole in comparison to the JAF production systems in neighboring countries. At the same time jute cultivation system in Bangladesh served not as the source but sink for CO_2 emissions.

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ECOLOGICAL AND ENVIRONMENTAL SUSTATINABILITY OF JUTE PRODUCTION SYSTEMS IN BANGLADESH: EMERGY ANALYSIS

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ABSTRACT

Two important studies on jute production systems were conducted through field experimentations for the two consecutive jute growing season in 2006 and 2007 to assess the ecological sustainability and evaluate the environmental consistency indicators of the system. Emergy Analysis is one of the studies to assess the ecological sustainability and economic performances of the produces using Odum's well known emergy methodology. Two types of emergy indicators: sustainability and return on investment of jute production for (1997 to 2006) 10 years were also carefully investigated. Emergy sustainability indices for 10 years (1997-2006) indicated a very good figure between 1 and 2. But return on investment is very low (0.10-0.114) indicating the price paid for emergy expenditure for the produce is extremely underestimated in the greater exchange market. It is concluded that the jute production system in Bangladesh is ecologically sustainable, but economically the system is highly underestimated.

Key words: Ecological sustainability; emergy; jute; return on investment; transformity.

INTRODUCTION

Bangladesh is a country of rural agro-based economy. Total cultivated land is 7.97 million ha (BBS, 2006). Crop production systems especially jute in Bangladesh is mostly traditional and is mainly based on biomass, animal and human energy, chemical fertilizers (limited use of diesel and electricity) and manure (Bala, 1998). An important challenge facing the country and as well as the whole world now is how to feed and facilitate an increasing population with decreasing energy supplies and finite environmental resources. To meet this challenge the sustainability of agricultural systems need to be evaluated to determine those with greater yields

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relative to their resource use and environmental degradation. Processes using larger percentages of renewable energy need to be identified, because they are likely to be more sustainable than those using a larger percentage of non-renewable energy (Lefroy and Rydberg, 2003; Martin, 2002). Therefore, to increase agricultural sustainability, the trend of increasing production with greater non-renewable inputs which characterize the Green Revolution (Ko *et. al*., 1998), should end as they accelerate soil erosion and declining water tables, to ensure that future production is not jeopardized due to these adverse environmental consequences (Pimentel *et al*., 1997).

Emergy analysis which evaluates system components on a common unit basis is a promising tool to evaluate resource use and production of agricultural systems. Emergy analysis is a form of energy analysis that quantifies values of natural and economic resources and quantify the value of large-scale environmental support to the human economy (Odum, 1988). Solar emergy is used to determine the value of environmental and human activities within a system on a common basis: the equivalent solar energy required to produce each unit of service or product. The solar emergies of products and services are calculated by multiplying units of energy (i.e. joules of oil) by emergy per energy ratios (transformity), units of mass (i.e. grams of fibre) by emergy per mass ratios (specific emergy), and currency (US $) by emergy per unit money. Using this technique, natural (ecological) and economic contributions required to produce agricultural yields can be quantified and compared on a common basis of solar emergy – joules (emJoules).

Sustainability is another new fundamental issue of the 1990's. To be sustainable: (i) every production system must be environmentally sound (ecological compatibility); and (ii) the system must provide a suitable yield to the society (economic compatibility). Exploitation rate, efficient use, production of wastes and pollutants, are all different components of these two aspects of sustainability and are considered in the case of jute production system in Bangladesh. A general definition of sustainable agriculture is "the ability to maintain production over long time frames despite major ecological and socio-economic perturbations and stress" (Conway, 1985; Altieri, 1987). Economic sustainability is commonly assessed by calculating profitability, cash flow and returns on investment. Resources and resource degradation are also occasionally valued directly in economic terms although placing a dollar value on ecosystem services and their disruption remains problematic (Pearce, 1983; Pearce and Turner, 1990; Costanza *et al*. 1997; Pimentel *et al*. 1997; Edwards–Jones *et al*. 2000). A potential advantage of this method over conventional economic and energy analysis is the capacity to evaluate renewable and non-renewable natural resource inputs and environmental service outputs normally considered 'free'.

Several studies have been reported to assess the environmental aspects and overall sustainability. These studies were conducted on emergy evaluation of three cropping systems in South Western Australia, Chinese agriculture, three agricultural systems in USA and Mexico, integrated production systems of grains, pig and fish in small farms in the South Brazil, grazing cattle in Argentina and coffee production, processing and export in Nicaragua (Lefroy and Rydberg 2003, Chen *et al*. 2006, Martin *et al*. 2006, Cavalett *et al*. 2006, and Caudra & Rydberg, 2006). But no such study was reported yet on the jute production in Bangladesh. This study was undertaken to assess the ecological sustainability and greater market performances of the produces derived from the jute production system in Bangladesh.

MATERIALS AND METHODS

The field experiments were conducted at the Central Research Station (CRS) of Bangladesh Jute Research Institute (BJRI) in the two jute growing seasons in years 2006 and 2007. CRS is located at *sadar thana* of Manikgonj district, which is 56 km away, north-west direction from Dhaka Metropolitan City within 23°42' to 23°56' latitude and 89°57' to 90°08' longitude with an average altitude of 4.00 meter above mean sea level. Split plot experimental design was followed with treatment: A. Variety: 2 (a. CVL-1, b. O-9897) and B. Date of harvest: 10 with Replications: 3. For 10 harvests (plant sample collection) of different plant ages, 20 plots for 2 cultivars in each block and a total of 60 plots within 3 blocks were made for the study. Starting at the crop age of 20 days from the date of emergence, 10 harvesting dates were considered up to 110 days (at an interval of 10 days) of crop ages. Finally crop was harvested at the age of 120 days for Emergy Analysis.

The emergy accounting methodology has been developed over the last three decades as a tool for environmental policy and to evaluate the quality of resources based on the dynamics of complex environmental and economic systems (Ulgiati and Brown, 1998; Odum, 1996 and 1983). In short, emergy in jute production system is defined as the sum of all inputs of energy directly or indirectly required by the production process to provide fibre, stick and residues when the inputs (renewable and non-renewable; materials and labor) are expressed in the same form (or type) of energy, for instance solar energy. Transformity is the ratio of emergy input to available energy (exergy) output (Odum, 1988, 1995). For jute fibre production process, the solar transformity of fibre is computed 2.63E+06 solar emJoules of environmental inputs required to generate a joule of jute fibre. Emergy per unit money is the emergy supporting the generation of one unit of economic product, kg of jute fibre here (expressed as emergy per unit currency, sej / US$). Empower is the flow of emergy per unit of time (in this study emergy per season or year). Emergy flows are usually expressed in units of solar empower (i.e. sej/year). To compare the empower of different areas this quantity can be divided by the area to calculate empower per unit area (i.e. sej/m^2/year).

Emergy indicators

By means of a systemic analysis of the relationships among components of jute production systems web, the flows of energy and other resources converging to produce the output (fibre, stick, and residues) are evaluated on a common basis, i.e. the content of solar equivalent energy (Odum, 1996). Associated with the agro-ecosystem, the basic indices of ecological interest for crop production process are Percent Renewable (%R), Emergy Yield Ratio (EYR), Environmental Loading Ratio (ELR), Emergy Sustainability Index (ESI), Emergy Investment Ratio (EIR), Emergy Exchange Ratio (EER) and Return on Investment based on emergy flows (Odum and Odum, 1983; Ulgiati *et. al*., 1995; Odum, 1996; Brown and Ulgiati, 1997; Ulgiati and Brown, 1998).

(a) **%R = R * 100 / (R + N + F).** Here R, N and F= (M+S) stand for renewable (sunlight, manure etc.), nonrenewable (soil) and purchased flows from outside (M for material and S for service) the system boundary respectively. It is the percent of the emergy of all the environmental renewable inputs to the emergy of all products. This index indicates the environmental contribution to a productive system. The system with higher percent depends more on free environment and has more potential to raise productivity in case of more economic investment as emergy feedback from the main economy.

(b) **EYR = Y / (M + S).** Here M is non-renewable purchased inputs (such as purchased fossil fuels and chemical fertilizers), S is non-renewable purchased services (such as labor resources purchased from outside the boundary of the system under study) and Y is the yield (total sej / year). This index is taken as the emergy output divided by the emergy input as feedback from the outside economy. The higher the value of this index, the greater is the return obtained per unit of emergy invested.

(c) **ELR = (N + F) / R.** The environmental loading ratio expresses the use of environmental services by a system, indicating a load on the environment. It is the ratio of the total emergy of the non-renewable inputs to the emergy of the total renewable inputs. The lower the ratio, the lower is the stress to the environment exerted by the system.

(d) **ESI = EYR / ELR.** It is the ratio of the emergy yield ratio EYR to the environmental loading ratio ELR, indicating whether a process provides a suitable contribution to the user with a low environmental pressure. The ESI takes both ecological and economic compatibility into account. The larger the ESI, the higher is the sustainability of a system concerned.

(e) **EIR = (M + S) / (R + N).** Here R is free renewable local resources (such as sunlight, rain and wind). N is free non-renewable local resources (such as soil erosion, for instance). It is the ratio of the emergy inputs received from the economy to the emergy investment from the free environment. The less the ratio, the less is the economic costs. So the process with lower ratio tends to compete, prosper in the market. The higher the ratio, the higher is the economic development level of a system.

(f) **EER.** This is the ratio of emergy exchange in a trade or purchase. Trade could be carried out with two commodities or with sales of commodities. When a good is sold and money is received in exchange, both flows are converted to emergy units. In most of the cases the emergy value of the purchased product paid was much less to the emergy consumed by the product to be produced.

(g) **Return on investment**. The return on invested emergy is the ratio of the amount of emergy that can be purchased with the income received for the products to the emergy content of purchased goods and services in the economy. This reflects the terms of trade between the farming system and the broader economy in emergy units.

The first step of an emergy analysis is a system diagram showing energy and material flows for the production process (Figure 1). This is necessary to organize the relationships between the main components and process of a system of interest, and also to depict the ecosystem environmental basis and its connection to the larger economy. The jute production system comprises the components of renewable (sunlight, wind, rain and manure), non-renewable materials and services imported or purchased (fertilizer, biocide, energy and labor) and output or yield (fibre, stick and crop residues) etc.

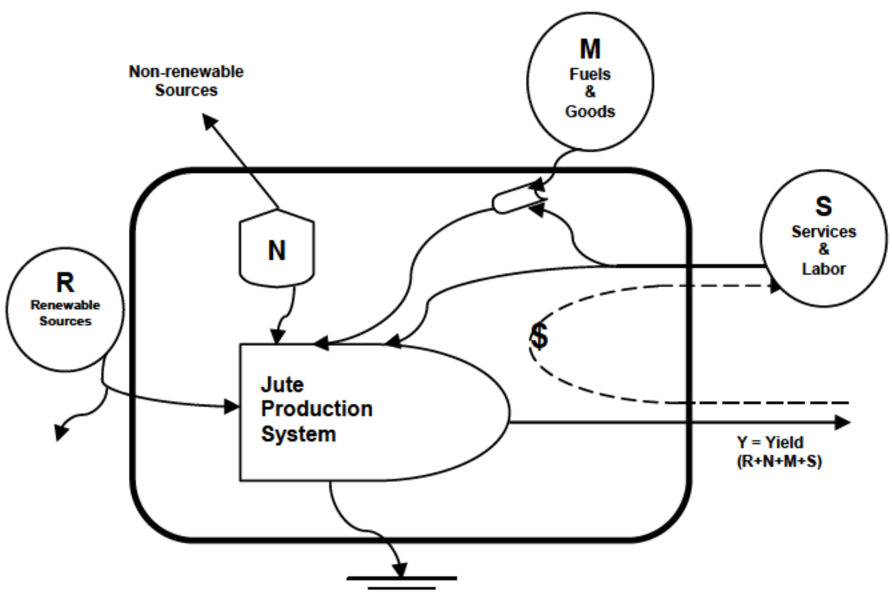

Figure 1. Systems diagram illustrating the flow of energy and materials to and from a jute production system expressed as flows of solar emergy per unit time

The second step for the emergy assessment is to organize the different inputs in emergy evaluation table. The preparation of the emergy evaluation table (Table 1) for the jute production system is based on the emergy diagram (Figure 1) and these allow the computation of emergy indicators.

Table 1. Emergy evaluation of jute cultivation for the year 2006 (all flows per square meter per season)

Item number	Item description	Units	Seasonal flow (raw units)	Source of Data	Transformity (sej/unit)	Solar EMERGY (sej/m²/ season)
I	***Renewable resources: R***					
1	Sunlight	J	1.26E+09	Calculated (T & SSH)[0]	1.00E+00	1.26E+09
2	Wind	J	1 54E+04	Meteorological Dept.[1]	2.45E+03	3.78E+07
3	Rain (Chemical energy)	J	4.63E+06	Meteorological Dept.[1]	3.10E+04	1.43E+11
4	Rain (Geopotential energy)	J	9.26E+04	Meteorological Dept.[1]	1.05E+04	9.72E+08
5	Manure	g	1.25E+02	AR, BJRI (1996)[2]	1.23E+09	1.54E+11
	Total Renewable					**3.00E+11**
II	***Non-renewable resources: N***					
6	Soil loss		Negligible	IJSG (2003)[3]		
III	***Materials: M***					
7	Jute seed	J	1.26E+04	Field Expt. (2006)[4]	8.30E+04	1.04E+09
8	Phosphate	g	8.26E-01	AR, BJRI (1996)	3.70E+10	3.06E+10
9	Potash	g	1.24E+00	AR, BJRI (1996)	2.92E+09	3.63E+09
10	Nitrogen	g	2.56E+00	AR, BJRI (1996)	4.05E+10	1.04E+11
11	Pesticide	g	2.90E-01	AR, BJRI (1996)	5.61E+04	1.63E+04
12	Fossil fuels	J	2.22E+06	CRS, Manikganj[5]	1.10E+05	2.44E+11
13	Electricity	J	1.80E+04	CRS, Manikgonj	2.69E+05	4.84E+09
	Total Materials Purchased					**3.87E+11**
IV	***Services: S***					
14	Labour	J	2.43E+05	Field Expt. (2006)	7.56E+06	1.84E+12
	Total Services Purchased					**1.84E+12**
V	***Output: Y***					
15	Fibre (j)	J	4.18E+06	Field Expt. (2006)	2.63E+06	1.10E+13
16	Stick (j)	J	1.18E+07	Field Expt. (2006)	1.31E+05	1.55E+12
17	Crop residues*****	J	1.10E+07	Field Expt. (2006)	1.34E+06	1.47E+13
	Total Output					**2.72E+13**

Table 1. Contd.

Item number	Item description	Units	Seasonal flow (raw units)	Source of Data	Transformity (sej/unit)	Solar EMERGY (sej/m2/ season)
VI	***Economic value of output***					
18	Fibre	(US$)	7.36E-02	Field Survey (2006)	2.40E+12	1.77E+11
19	Stick	(US$)	2.57E-02	Field Survey (2006)	2.40E+12	6.17E+10
20	Crop residues	(US$)	6.25E-03	Field Survey (2006)	2.40E+12	1.50E+10
	Total value					**2.53E+11**

[0] Calculated on the basis of temperature (T: min., max. & mean value ^{o}C) and sunshine hours (SSR) data recorded in CRS, BJRI, Manikganj.

[1] Meteorological Department of Bangladesh, Central Research Station, Bangladesh Jute Research Institute, Manikganj.

[2] Annual Report, Bangladesh Jute Research Institute, Dhaka.

[3] International Jute Study Group, Dhaka (negligible due to small land holding).

[4] Field Experiment at CRS, BJRI, Manikganj.

[5] Central Research Station (CRS), Bangladesh Jute Research Institute, Jagir, Manikganj.

[*] Included root, leaves (adding 10% during life time), solid and chemical biomass during retting.

In the third step emergy indices (%R, EYR, ELR, ESI, EIR, EER and Return on investment) are calculated for a time frame (Table 2). For jute production system, the indices of last 10 years were calculated and explained the trends of change of indices and environmental consequences (Figure 2 to 6), which was an important component of agro-ecosystem of Bangladesh.

Jute production system needs 4 to 5 months of time frame to produce dry jute fibre. For the overall agro-ecosystem of a country, 1 year reasonably might be taken as the time cycle for the system analysis (Chen *et al*., 2006). Most of the agricultural productions in Bangladesh are harvested seasonally (3 to 5 months) and they usually follow a particular multicropping systems round the year with 200 to 300 per cent cropping intensity (Rahman *et al*., 2003). Jute as a seasonal crop, is grown with the rotation of other crops with a location specific cropping pattern, one season (4-5 months) time frame was considered one year for the jute fibre production. All flows of energy, material and services were considered for one square meter of land area for one year (season) with a system boundary shown in Figure 1.

Table 2. Calculated Emergy Indicators of jute production for the year 2006

Item no.	Emergy Indicators	Expression	Values
A	**SUSTAINABILITY INDICATORS**		
1	Renewable percent $(\%R)$	$100\times R/(R+N+F)$	$1.19E+01$
2	Emergy yield ratio (EYR)	Y/F	$1.22E+01$
3	Environmental loading ratio (ELR)	$(N+F)/R$	$7.43E+00$
4	Emergy sustainability index (ESI)	EYR/ELR	$1.65E+00$
B	**RETURN ON INVESTED EMERGY**		
5	Emergy investment ratio (EIR)	$(M+S)/(R+N)$	$7.43E+00$
6	Emergy exchange ratio (EER)	$Y/(Output\_price\_emergy)$	$1.07E+02$
7	Return on investment emergy	$(Output\_price\_emergy)/(M+S)$	$1.14E-01$

RESULTS AND DISCUSSION

The renewability percent of the jute production system for the year 2006 is 11.9. In other words, 88.1% of the emergy used was derived from non-renewable resources (N+F). Production systems with a higher percentage of renewable emergy are likely to be more sustainable and prevail in the long run (they are more able to survive in the economical stress) than those with a high portion of non-renewable emergy (Brown and Ulgiati, 2004; Lefroy and Rydberg, 2003). Cavalett *et al*. (2006) found the renewability percent for grain (soybean, wheat and corn) production systems is 23. Caudra and Rydberg (2006) reported that renewability percents for cherries, green coffee, roasted coffee and instant coffee are 11.6, 10.5, 5.9 and 5.4 respectively. Martin *et al*. (2006) found that %R for corn production system in Mexico is lower (6) in comparison to blackberry system (31). Ulgiati and Brown (1998) reported a decreasing tendency of corn production system in USA and concluded that it was an indication of technological innovation with higher yield. In this study the percent of renewable resource was almost constant (10.8 to 13.3) with an exception in 2003 (7.77) which might be due to the very low rainfall in 2003 (only 226 mm) in the jute growing season (Fig. 2). This indicates that jute production system is dependent on renewable resources for 10.8 to 13.3% of its inputs for this period. This means that jute production system has a degree of sustainability of 10.8 to 13.3% for this period.

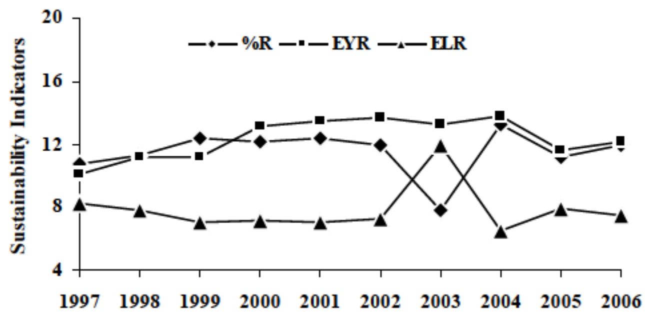

Figure 2. Sustainability indicators (%R, EYR and ELR)

The EYR value of the jute production system for the year 2006 is 1.22E+01 which is a satisfactory one (Table 2). The EYR value of Chinese agriculture for the year 2000 (Chen *et al,* 2006) is 2.08 which compares well with the EYR values for the agriculture of Italy (1989) and Switzerland (1996) which are 1.12 and 1.26 respectively. Martin *et al*. (2006) found EYR values for corn, blackberry and indigenous agricultural production system were 1.07, 1.45 and 12.17 respectively and concluded that those systems contributed less emergy to the economy. Comparing the EYR values of agriculture for these countries with the jute production system in Bangladesh, it is seen that jute production system provides a significant net emergy to the economy. The EYR values of jute production for the last 10 years (1997 to 2006) were greater than 10 (Fig. 2) which indicated that more than 10 times of solar emJoules of renewable energy were utilized for each solar emJoule of purchased resources invested in the system.

The ELR value for the jute production system for the year 2006 is 7.43 (Figure 2), which belongs to the group of creating moderate environmental impacts (3 to 10), while ELRs ranging from 10 to extremely high values indicate much higher environmental impacts due to large flows of concentrated non-renewable emery in a relatively small local environment (Brown and Ulgiati, 2004). ELR values for agricultural system of China (2000), Italy (1989) and Switzerland (1996) are 2.72, 10.43 and 4.50 respectively (Chen *et al*. 2006). Also the ELR values of lupin/wheat rotation, tagasaste plantation and alley cropping in southern Australia are 5.50, 0.70 and 2.30 respectively (Lefroy and Rydberg, 2003). But the ELR value of corn production system in Mexico is 18.83 (Martin *et al*. 2006). ELR values of jute production system for the last 10 years are shown in Fig. 2 and it shows that there is a decreasing tendency of ELR with an exception in 2003 (11.9) and provides moderate environmental loads.

ESI for jute production system in Bangladesh was 1.65 for the year 2006 (Figure 3). The overall trend of the sustainability index from 1997 to 2002 was increasing with fluctuations from 2002 to 2006 (Figure 3). But the value of the sustainability was always greater than 1.0. This indicates that jute production system is still an indigenous system and the overall trend of jute production system in Bangladesh is not moving towards the larger flows of non-renewables and import of purchased materials and services. Chen *et al*. (2006) reported that ESI for Chinese agriculture decreased gradually from 1.32 in 1980 to 0.67 in 1997 that indicate the modernization of Chinese agriculture with the larger flows of non-renewables and import of purchased materials and services. However, both the economies are developing category since the index between 1 and 10 is indicative of developing economy (Liu and Chen, 2005). The higher the sustainability index, the larger is the economic and ecological compatibility of the system.

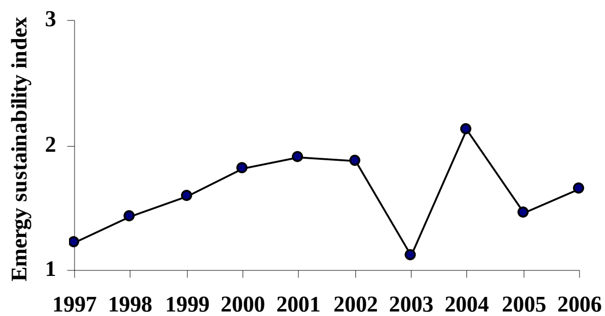

Figure 3. Jute production system ESI for last ten years

The EIR of jute production system for the year 2006 is 7.43 (Fig. 4). This means that the emergy purchased from the outside was 7.43 times greater than the renewable and non-renewable emergy acquired from the local environmental inputs. A lower EIR value represents more effective system with better use of renewable internal emergy sources, where the renewable energy can be replenished to continually feed the system. The present global trends indicate that less energy at low costs will be not available in the future (Campbell and Laherrere, 1998). Thus, production systems based on non-renewable natural resources may not be able to compete with systems characterized by lower economic investment (F) and bigger natural contribution (R + N), and the systems might be unsustainable in the coming future. The EIR for jute production system for last 10 years (1997 to 2006) maintained an almost constant value with an exception in 2003 (Figure 4). Chen *et al*. (2006) reported EIR values of 1.11 for Chinese, 8.52 for Italian and 4.10 for Switzerland agriculture. Cavalett *et al*. (2006) reported EIR values of grain, pig and fish farming lies between 2.28 and 4.61. EIR for jute production system in Bangladesh indicated that the purchased emergy used was on an average 7.5 times higher than that of environmental emergy used.

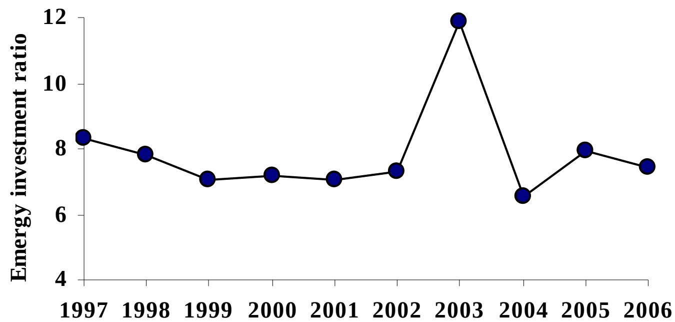

Figure 4. Jute production system EIR for last ten years

The EER value for the jute production system was 1.07E+02 in 2006, which is extraordinarily higher and this indicates that the solar emergy value of the currency paid for jute (solar emergy of jute) was much less than the emergy used for producing jute. The result demonstrates that the price received by jute producers is low and the buyers underestimate environmental values for production of jute. Price of jute should be higher than the present value determined by market rules. EER values of jute production system for the last 10 years (1997 to 2006) are shown in figure 5 and there is a decreasing tendency of EER from 282 in 1998 to 103 in 2005 and then it becomes almost constant. This indicates that the jute market is improving since 1998 but it is stagnant for the period 2005 to 2006. Caudra and Rydberg (2006) reported EER values for coffee cherries, green coffee and roasted coffee in Nicaragua were 1.99, 1.01, and 0.90 respectively and concluded that the coffee should get more price than its present values paid by the buyers.

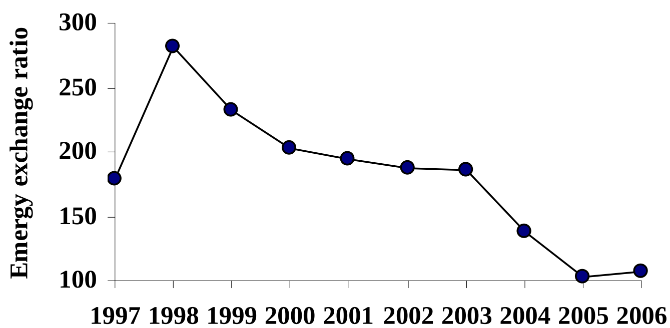

Figure 5. Jute production system EER for last ten years

The return on invested emergy was 0.114 of jute production system in 2006 (Figure 6). This reflects the terms of trade between the farming system and the broader economy in emergy units. A ratio below 1 indicates a loss in the trade. In that case, the farmers receive less emergy in the form of payments for the product in comparison to the emergy feedback from economy needed to produce the product. Very low value of return on investment emergy for jute production is indicative of no profitability of jute production on emergy basis. Lefroy and Rydberg (2003) found return on invested emergy values of 0.7 for lupin/wheat rotation, 1.0 for tagasaste plantation and 0.7 for alley cropping in southern Australia. Return on investment emergy of jute production for last 10 years (Figure 6) showed an increasing tendency up to 2000 (1997 to 2000), then gradual decreasing tendency up to 2006. This reveals a real picture of the present jute market and justifies the farmer's complaint that they do not get the production cost of jute fibre.

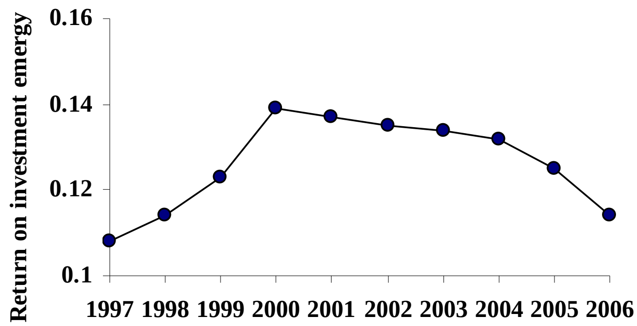

Figure 6. Return on investment emergy for last ten years

CONCLUSIONS

Emergy analysis presents an ecological analysis of jute production in Bangladesh for the period from 1997 to 2006, on the basis of Odum's well known concept of emergy in ecological economy, as an alternative to conventional market-based economic analysis. Emergy analysis methods are explained, illustrated and used to diagram the agro-ecosystem to evaluate environmental and economic inputs and harvested yield and to assess the sustainability of the jute production system as a whole.

The emergy of jute fibre in renewable (3.00E+11 sej/m^2/year), non-renewable purchased materials (3.87E+11 sej/m^2/year), non-renewable purchased services (1.84E+12 sej/m^2/year) and output (yield: 2.72E+13 sej/m^2/year) solar equivalent joule per unit area and time were quantified to open the environmental account of jute fibre production process with economic value of output (2.53E+11 sej/m^2/year) for the year 2006. It also quantified two types of environmental indicators namely, sustainability and return on invested emergy for last 10 years (1997 to 2006). Among the sustainability indices of jute fibre production system for the year 2006; (i) renewability fraction (R%) 11.9%, (ii) emergy yield ratio (EYR) 12.2, (iii) environmental loading ratio (ELR) 7.43 and (iv) sustainability index (ESI) 1.65 cut a good figure for the system in long run sustainability.

Percent of renewability indicated that 88.1% of the emergy derived from non-renewable sources, only from purchased materials and services which are little bit higher for jute production system. But appreciably it can be concluded that the use of this purchased non-renewable sources utilized efficiently (emergy yield ratio 12.2) for developing economy in Bangladesh. Medium load on environment (7.43) was given by jute fibre production system but achieved a good sustainability (ESI: 1.65) and can be explained well for developing economy. Emergy sustainability index for last 10 years (19897 to 2006) indicated a very good figure. In the case of return on invested emergy indices for the year 2006; emergy investment ratio (EIR) and emergy exchange ratio (EER) are 7.43 and 107 respectively, both are very positive for jute fibre production system. But in case of return on investment, which is extraordinarily low (0.114) indicating that the price emergy paid for the produce is extremely poor. This gives a real picture of the present local as well as international market price of jute fibre. Jute fibre needs 88.6% more emergy price to equalize the emergy expenditure of jute fibre production process. Similar picture is observed for the last 10 years (1997 to 2006) indices.

It is revealed from the study that the jute fibre production process did not impose any excessive load to the environment but much efficiently the process utilized the supplied emergies and at the same time the production process is sustainable for long run in developing the economy of Bangladesh. Jute fibre should get more price emergy to compensate the emergy expenditure for the produce.

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FRUIT CONSTITUENTS OF OKRA CULTIVARS AND THE INCIDENCE OF *Earias vitella* (FAB.) AS INFLUENCED BY THE INTEGRATED NUTRIENT MANAGEMENT SYSTEM

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ABSTRACT

As an alternate to chemical, the effects of Integrated Nutrient Management System (INMS) on the constituents in fruits of four okra cultivars vis-à-vis their effects in reducing *Earias vitella* incidence were evaluated during summer and rainy seasons 2005. The experiment comprising four okra varieties and eight INM practices was laid out in factorial Randomized Block Design with three replications at BCKV, India. Seed treatment with 50% recommended doses of fertilizers + Neem cake @ 1.25 t/ha + Bio-fertilizer and that with 50% RDF + Vermicompost @ 2.5 t/ha + Bio-fertilizer were superior in respect of fruit yield and enhancement of crude protein and ascorbic acid level. Moreover, INM practices minimized crude fiber in okra fruits irrespective of cultivars. Fruits of Pusa A4 and Indam 821 contained high crude protein (17.49 - 18.36%) and ascorbic acid (18.70 - 21.05 mg/100g) with low fiber (11.33 - 12.41%) irrespective of INM practices and seasons. Fruit borer incidence was inversely related to crude protein content and ascorbic acid, while it was directly related with the fiber content under INMS. Therefore, application of organic manures and bio-fertilizers could inhibit *E. vitella* activity in open pollinated okra varieties.

Key words: Ascorbic acid; crude fiber; crude protein; *Earias vitella* (Fab.); integrated nutrient management system; okra.

INTRODUCTION

Okra or bhendi [*Abelmoschus esculentus* (L) Moench] is cultivated predominantly in the Tropics and Sub-Tropics of the World. It is an important protein

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source in most developing countries. The fruit borers *Earias vitella* (Fabr.) causing damage to tender fruits are considered as a major constraint to commercial cultivation of this crop. The inorganic chemical fertilizers cause environmental risks including heavy incidence of pests and diseases. Therefore, it is felt imperative to reduce the use of inorganic fertilizers by adopting suitable integrated nutrient management system (INMS) comprising farm yard manure (FYM), composts, vermicompost, oilcakes etc. It is noteworthy that application of organic manures not only produced the highest and sustainable crop yield, but also improved the soil fertility and productivity (Sanwal *et al*., 2007). Although the organic manures contain plant nutrients in small quantities as compared to the fertilizers, its growth promoting constituents like enzymes and hormones, besides plant nutrients make them useful for improvement of soil fertility and productivity. Hence, the present investigation was undertaken to study the effect of INMS on the quality fruit production in open pollinated varieties of okra along with their reactions to the fruit borer, *E. vitella*.

MATERIALS AND METHODS

Field experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India during summer and rainy seasons of 2005 to study the impact of INMS on the quality of okra hybrids including their effects on the incidence of okra fruit borer, *E. vitella*. The initial characteristics of experimental soil was sandy loam in texture, pH 7.36, organic carbon 0.38 % and available N, P_2O_5 and K_2O were 114.69, 6.55 and 157.79 kgha^{-1}, respectively. Four open pollinated varieties of okra (i.e.; V_1=Pusa A4, V_2= Indam 821, V_3= Utkal Gourav and V_4= Arka Anamika) were grown following eight INM practices (P) including two checks *viz*., P_1: Farmer's Practice (70:90:25 NPK kg/ha), P_2=100% Recommended dose of inorganic fertilizer (RDF) @ 150:100:80 NPK kg/ha, P_3: 50% RDF + Cow Dung Manure (CDM) @ 25 t/ha + Bio-fertilizer (BF), P_4: 50% RDF + Neem Cake (NC) @2.5 t/ha + BF, P_5:50% RDF + Vermicompost (VC) @ 5 t/ha + BF, P_6: 50% RDF + CDM @ 12.5 t/ha + BF, P_7: 50% RDF + NC @ 1.25 t/ha + BF and P_8: 50% RDF + VC @ 2.5 t/ha + BF. The experiment was laid out in a factorial Randomized Block Design (FRBD) with three replications. Mixed culture of bio-fertilizers comprising *Azospirillum lipoferum* for nitrogen fixation, *Bacillus polymyxa* for phosphorus solubilization (PSB) and *Faturia aurintia* for potassium mobilization (PMM) were used as seed treatment @ 100g /1kg seeds one day before sowing. The seeds were sown at 50 cm X 30 cm spacing in 4.5 m X 3.0 m plot area as per the treatment schedule on 28.02.2005 and 20.06.2005 for summer and rainy season, respectively. All the recommended packages of practices excepting the nutritional aspects to raise the crop in both the seasons were adopted. The fruits harvested at each picking in the individual plot were counted for bored and healthy fruits and their weights were recorded separately and per cent fruit infestation by *E. vitella* was then worked out.

Fruits harvested six days after setting were collected from 5th, 10th and 15th picking and were utilized for fruit quality analysis applying methods recommended for ascorbic acid (Rangana, 1979), crude fiber (Anonymous, 1975) and crude protein (Dubiz and Well, 1968). Green fruit yield was calculated from the cumulative of all pickings for each treatment. The data were analyzed statistically following the procedures of Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

The crude protein, crude fiber and ascorbic acid content in open pollinated okra fruits distinctly varied with cultivars irrespective of INMS followed and seasons tested. The above constituents ranged from 15.02 to17.24%, 11.50 to 14.96 % and 13.70 to 20.79 mg/100g during summer and from 17.18 to 19.49 %, 11.17 to 12.90 % and 14.80 to 22.21 mg/100g during rainy season, respectively (Table 1). The data averaged over seasons showed that the above constituents had varied significantly from 16.10 to 18.36 %, 11.33 to 13.93% and 14.25 to 21.50mg / 100g in cultivars Pusa A4, Indam 821, Utkal Gaurav and Arka Anamika. In general it was noticed that irrespective of INM practices and cultivars, the overall concentration of crude protein and ascorbic acid was higher during rainy season than summer season, while that of crude fiber remained slightly higher in fruits of summer crop. The nutritional composition in okra is reported to be affected by the seasons and the age of the fruits (Sen and Mukherji, 2002). However, from the quality point of view the cultivars Pusa A4 and Indam 821 were considered superior to all other cultivars tested as the fruits of these cultivars contained high crude protein (17.49 - 18.36%), ascorbic acid (18.70 - 21.50 mg/100g) and a minimum of 12.41 - 11.33% crude fiber, irrespective of seasons under the INMS. The pods harvested beyond 7 days after pod set were reported as of poorer quality mainly due to an increase in crude fiber and a reduction in the moisture, crude protein and ash contents of older pods (Iremiren *et al*., 1991). Therefore, Agbo *et al*. (2008) opined that in order to get the highest concentration of nutrients, okra fruits should be harvested at 7-days old.

Similarly, when different INM practices were considered irrespective of cultivars the trends of high accumulation of crude protein and ascorbic acid were also noticed in fruits of rainy season crop (Table 2). Although, organic manures coupled with bio-fertilizers in most INM practices showed higher ascorbic acid content in fruits during summer season(16.79 -18.68 mg/100g), rainy season(19.81 - 21.33 mg/100g) and across seasons (18.54 - 19.21 mg /100g), application of 50%RDF + Neem cake @ 1.25 t/ha +Bio-fertilizer as seed treatment (P_7) and 50% RDF + Vermicompost @ 2.5 t/ha + Bio-fertilizer as seed treatment (P_8) had resulted in appreciable accumulation of crude protein (18.91-18.93%) and ascorbic acid (19.00 - 19.06 mg/100g) with minimum level of crude fiber (11.02 - 11.08%), irrespective of seasons. On the contrary, sole chemical fertilizers at recommended dose (P_2) showed low levels of crude protein (15.88%) and ascorbic acid (16.34 mg/100g) and high crude fiber (14.52%) under similar situations. The fruit yield in case of the above INM practices (P_7 and P_8) was statistically higher in summer (75.83 - 76.04 q/ha) and rainy seasons (93.58 -94.99 q / ha) than the average range of 84.71 - 85.51 q/ha across the seasons. However, the fruit yield irrespective of INM practices followed was significantly less in Arka Anamika (71.75 q/ha) as compared with the cultivars Pusa A4 (84.46 q/ha) and Indam 821 (81.72 q/ha). The fruit yield was lowest in plots receiving sole chemical fertilizers (P_2) during summer (46.74 q /ha), rainy (58.65 q / ha) as well as across seasons (57.68 q / ha). According to Shaheen *et al.* (2007) the use of bio-N fertilizer was highly effective for increasing vegetative growth, pods yield and nutritive values and application of bio-fertilizer as bacterial microorganisms with chemical nitrogen fertilizer for okra crop resulted in better nutritional values in pods tissue if compared with those of plants, which received its all nitrogen fertilizer requirements as chemical.

The extent of fruit damage by *E. vitella* in response to the INM ranged significantly from 3.74 to 8.09% and 7.32 to 10.87% during summer and rainy seasons, respectively. The average damage to fruits across the seasons also ranged distinctly from 5.53 to 9.48 % (Table 2). The fruit damage by *E. vitella* across seasons was significantly less in the cultivar Arka Anamika (5.93 %) which was followed by the cultivars, Pusa A4 (7.08%) and Indam 821(6.72%). Significantly minimum damage by *E. vitella* was noticed in case of INMS like 50%RDF + Neem cake @ 1.25 t/ha +Bio-fertilizer as seed treatment (5.53 %) and 50% RDF + Vermicompost @ 2.5 t/ha + Bio-fertilizer as seed treatment (6.10 %) were followed. The sole application of RDF had resulted in conspicuously high fruit damage of 9.48 % across seasons studied. Similarly, the farmers practice of sole fertilizer application of NPK @ 70:90:25 kg/ha also resulted in maximum fruit damage (8.09 - 10.87 %).

The correlation analysis between fruit damage and the constituents in okra fruits (crude protein, crude fiber and ascorbic acid) revealed that the status of the above constituents in cultivars tested could not exhibit statistically any definite relationship with the fruit damage, though crude protein and ascorbic acid content had influenced the fruit damage inversely, while the fiber content in fruits had a direct bearing on *E. vitella* incidence (Table 3). On the contrary, the INMS comprising organic manures and bio-fertilizers along with 50% RDF irrespective of varieties showed significant relationship between the constituents and fruit borer incidence in the seasons studied. Fruit damage was inversely related with the crude protein ($r = -0.836^{**}$ in summer; $r = -0.962^{**}$ in rainy season) and ascorbic acid ($r = -0.818^{*}$ in summer; $r = -0.915^{**}$ in rainy season) while, the fruit damage was directly and significantly influenced by the crude fiber content in fruits. Moreover, the crude fiber had high contribution towards *E. vitella* incidence as evident from high coefficient of determination values during summer (R^2 = 91.5%) and across seasons (R^2 = 94.8%). Appreciable contribution of crude protein(R^2 = 92.6%) was also noticed during wet season in regulating the pest. The organic manures seem to improve the plants tolerance to pest attack. Both vermicompost and FYM were also reported to prevent the build up of the okra pests more efficiently when compared to NPK as straight fertilizers (Surekha and Rao, 2000). Therefore, it was concluded that high crude protein and ascorbic acid with low fiber content in okra fruits could minimize the incidence of *E. vitella* irrespective of seasons. Organic manures gave better quality fruits with less fiber content. FYM would have caused accumulation of nutrients in comparison to synthetic fertilization (Sanwal *et al*., 2007) which resulted in better quality fruits with less fiber. Application of FYM @ 20 t ha^{-1} alone recorded fruits with 10.31% crude fiber content (Premsekhar and Rajashree, 2009). The use of organic manures and bio-fertilizers along with reduced levels of chemical fertilizers merit attention in respect of higher quality fruit yield and low borer incidence as against sole application of chemical fertilizers and farmers practice encountering high borer damage coupled with low fruit yield.

Table 1. Quality, fruit damage and fruit yield as influenced by okra cultivars irrespective of INM practices

Cultivar	Constituents in okra fruits during seasons									Fruit damage (%)			Fruit Yield (q/ha)		
	Crude Protein (%)			Crude fiber (%)			Ascorbic acid(mg/100g)								
	Summer	Rainy	Pooled mean	Summer	Rainy	Pooled mean	Summer	Rainy	Pooled mean	Summer season	Rainy season	Pooled mean	Summer season	Rainy season	Pooled mean
Pusa A4	17.24	19.49	18.36	11.50	11.17	11.33	20.79	22.21	21.50	4.54 (12.00)	9.61 (17.98)	7.08 (14.99)	76.32	92.60	84.46
Indam 821	16.50	18.48	17.49	12.85	11.96	12.41	16.79	20.62	18.70	4.39 (11.88)	9.04 (17.40)	6.72 (14.64)	72.90	90.53	81.72
Utkal Gaurav	15.02	17.18	16.10	14.96	12.90	13.93	13.70	14.80	14.25	6.81 (14.95)	10.14 (18.44)	8.47 (16.70)	59.68	75.04	67.36
Arka Anamika	16.12	18.30	17.21	13.40	12.27	12.83	14.36	18.18	16.27	5.26 (13.17)	6.60 (14.81)	5.93 (13.99)	63.36	80.15	71.75
Varieties (V):															
SE(m) ±	0.04	0.05	0.03	0.10	0.18	0.10	0.51	0.49	0.35	0.28	0.35	0.22	0.98	1.07	0.73
CD (P=0.05)	0.12	0.14	0.09	0.29	0.51	0.29	1.42	1.36	0.97	0.78	0.96	0.62	2.72	2.96	2.02
Seasons (S):															
SE(m) ±	-	-	0.02	-	-	0.07	-	-	0.25	-	-	0.16	-	-	0.52
CD (P=0.05)	-	-	0.06	-	-	0.20	-	-	0.69	-	-	0.44	-	-	1.43
Interaction (VxS):															
SE(m) ±	-	-	0.05	-	-	0.15	-	-	0.50	-	-	0.32	-	-	1.03
CD (P=0.05)	-	-	0.13	-	-	0.41	-	-	1.38	-	-	0.88	-	-	ns

Figures in the parentheses indicate the corresponding angular values; ns = not significant

Table 2. Quality, fruit damage and fruit yield as influenced by INM practices irrespective of okra cultivars

INM Practice	Constituents in okra fruits during seasons									Fruit damage (%)			Fruit Yield (q/ha)		
	Crude Protein (%)			Crude fiber (%)			Ascorbic acid (mg/100g)								
	Summer	Rainy	Pooled mean	Summer	Rainy	Pooled mean	Summer	Rainy	Pooled mean	Summer season	Rainy season	Pooled mean	Summer season	Rainy season	Pooled mean
P_1	12.70	14.22	13.46	17.38	14.50	15.94	13.38	13.61	13.50	8.09 (16.42)	10.87 (19.05)	9.48 (17.73)	46.74	58.65	52.70
P_2	15.31	16.44	15.88	15.63	13.42	14.52	14.71	17.97	16.34	6.09 (14.23)	9.88 (18.20)	7.99 (16.21)	50.52	64.84	57.68
P_3	16.23	17.97	17.10	13.92	13.29	13.60	16.79	17.61	17.20	6.51 (14.75)	8.79 (17.18)	7.65 (15.96)	71.86	89.89	80.87
P_4	16.91	19.78	18.34	11.13	11.04	11.08	18.68	19.81	19.24	3.80 (11.12)	8.46 (16.84)	6.13 (13.98)	75.28	90.78	83.03
P_5	16.51	18.25	17.38	11.21	11.00	11.10	17.04	20.08	18.56	4.07 (11.57)	8.81 (17.14)	6.44 (14.36)	73.92	92.21	83.06
P_6	17.43	19.19	18.31	13.17	12.13	12.65	16.79	20.29	18.54	5.64 (13.58)	8.55 (16.88)	7.09 (15.23)	74.33	91.72	83.02
P_7	17.38	20.44	18.91	11.50	10.67	11.08	16.79	21.33	19.06	3.74 (10.96)	7.32 (15.55)	5.53 (13.25)	76.04	94.99	85.51
P_8	17.26	20.59	18.93	11.50	10.54	11.02	17.08	20.92	19.00	4.08 (11.36)	8.11 (16.43)	6.10 (13.89)	75.83	93.58	84.71
INM Practices (P):															
SE(m) ±	0.06	0.07	0.05	0.15	0.26	0.15	0.72	0.69	0.50	0.40	0.49	0.32	1.39	1.51	1.03
CD (P=0.05)	0.17	0.20	0.13	0.41	0.71	0.41	2.00	1.62	1.38	1.10	1.36	0.88	3.84	4.18	2.86
Seasons (S):															
SE(m) ±	-	-	0.02	-	-	0.07	-	-	0.25			0.16			0.52
CD (P=0.05)	-	-	0.06	-	-	0.20	-	-	0.69			0.44			1.43
Interaction (PxS):															
SE(m) ±	-	-	0.07	-	-	0.21	-	-	0.70			0.45			1.46
CD (P=0.05)	-	-	0.18	-	-	0.58	-	-	1.94			1.25			ns

Figures in the parentheses indicate the corresponding angular values; ns = not significant

INM practices: P_1 = Farmer's Practice (70:90:25 kg NPK/ha)(Check-1); P_2 = 100% of RDF (90:60:40 kg NPK/ha)(Check-2); P_3 = 50% RDF + Cow dung manure @ 25 t/ha + Bio-fertilizer (seed treatment); P_4 = 50% RDF +Neem cake @ 2.5 t/ha + Bio-fertilizer (seed treatment); P_5 = 50% RDF + Vermicompost @ 5 t/ha + Bio-fertilizer (seed treatment); P_6 = 50% RDF + Cow dung manure @ 12.5 t/ha + Bio-fertilizer (seed treatment); P_7 = 50% RDF +Neem cake @ 1.25 t/ha + Bio-fertilizer (seed treatment); P_8 = 50% RDF + Vermicompost @2.5 t/ha + Bio-fertilizer (seed treatment).

Table 3. Correlation between fruit damage by *E. vitella* and constituents in okra fruits (crude protein, crude fiber and ascorbic acid) in different seasons

Variables compared	Correlation coefficient (r) during seasons					
	Summer		Rainy		Across seasons	
	Cultivars (n=4)	INM Practices (n=8)	Cultivars (n=4)	INM Practices (n=8)	Cultivars (n=4)	INM Practices (n=8)
Fruit damage *Vs*. Crude protein	- 0.937^{ns} (87.9)	- 0.836** (69.9)	- 0.100^{ns} (1.00)	- 0.962** (92.6)	- 0.530^{ns} (28.1)	- 0.941** (88.5)
Fruit damage *Vs*. Crude fiber	0.914^{ns} (83.5)	0.957** (91.5)	- 0.004^{ns} (0.001)	0.864** (74.7)	0.474^{ns} (22.4)	0.974** (94.8)
Fruit damage *Vs*. Crude Ascorbic acid	- 0.743^{ns} (55.2)	- 0.818* (67.0)	- 0.054^{ns} (0.30)	- 0.915** (83.8)	- 0.353^{ns} (12.5)	- 0.963** (92.7)

Figures in parentheses are the values of coefficient of determination (R^2) in percentage;

*Significant at P= 0.05; **Significant at P = 0.01; ns: not significant.

Thus, from the above studies, it was concluded that as an environmentally safe method INMS should be adopted for improving okra production in terms of quality, quantity and fruit borer tolerance contributing towards sustainable agriculture. INMS with organic sources not only restores soil health, but also can avert the risk of sole use of chemical fertilizers.

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MUSHROOM PRODUCTION IN BANGLADESH: PRESENT SCENARIO AND POTENTIALITIES

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ABSTRACT

On the basis of structured questionnaire, a detailed survey was conducted to assess the present status of mushroom-scenario in six meteorological regions of Bangladesh. Evidence showed that among the mushroom species *Pleurotus* spp., popularly known as Oyster mushrooms is cultivated and consumed by 97%, of which *Pleurotus ostreatus* alone accounts for 61%. The remaining 3% which belongs to *Agaricus* sp.; *Calocybe* sp.; *Volvareilla* spp. and *Auricularia* spp. are generally called Button, Milky, Paddy straw and Jew's ear or Ear mushrooms, respectively. It was also evident that available carbon source of the substrates for the cultivation of *Pleurotus* spp. was 76 % of sawdust where frequencies of flashes were recorded more than five times in 84% cases. The commercial yield was obtained namely from Oyster mushrooms. On an average, 240 gm from each of the spawn-packets which contained 400-500 gm of substrate and subsequently on an average 264963 spawn-packets were produced per month, which accounts for 620 - 675 tons of edible mushrooms production in Bangladesh per annum. It was also estimated that 67% of mushrooms were consumed as fresh, 22% in dried form, 10% in powdered form and 1% in other forms (pickling, frying etc) as processed or preserved ones. From the results of the survey, it was also evident that among the cultivators, 34% cultivated mushrooms on account of its nutritional and medicinal values, 27% to reduce unemployment, 14% for growing mushrooms as more profitable vegetable, 14% to pass leisure time, 10% due to hobby and 1% for other reasons.

Key Words: Mushroom production; present scenario; potentiality.

INTRODUCTION

Bangladesh is an agricultural country with a total area of 147570 km^2. The total population of the country is about 140.6 millions of which about 66% are dependent

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on agriculture (Anon, 2007). The total fruit and vegetables produced by the country can fulfill only 65-70% of national demand. A significant portion of fruits and vegetables are lost after harvest, as a result the available fruit and vegetables fulfill only 50% of our requirement (Muzammel and Shahjahan, 2005). The nutritional and medicinal values of mushrooms have long been recognized (Lucas *et al*., 1957 and Suzuki & Oshima, 1976). Edible mushrooms are good source of protein, vitamins and minerals (Khan *et al.*, 1981). As a group, mushrooms also contain some unsaturated fatty acids; provide several of the B vitamins, and vitamin D. Some even contain significant amount of vitamin C, as well as the minerals potassium, phosphorus, calcium, and magnesium (Park, 2001). Lintzedl (1941) indicated that100 to 200g (dry wt.) of mushroom were required to maintain nutritional balance in a normal human weighing 70 kg. Now, mushrooms are being cultivated in more than 100 countries of world, with an estimated total production of over 12 million tons (Suman and Sharma, 2007). This increase in production is due, in part, to increased production efficiency and to increasing consumer demand. During the past few decades, the demand has been increased due to easier-to-prepare fresh vegetables to a healthy diet. In recent times, however, mushrooms have assumed greater importance in the diets of both rural and urban dwellers (Bruhn, 1995). In Bangladesh, interest in mushroom began in the late 1960's in the then East Pakistan (Majid *et al*., 1968). Applications and market for mushrooms are growing rapidly in Bangladesh. Some of the tribes of our country are consuming mushrooms from the very beginning according to their custom. Today the situation has changed due to its nice aroma, excellent subtle flavour after all special taste and above all its nutritional and medicinal values. Many exotic food preparations like soup, vegetables, pickles etc. are made from mushrooms. They are also used for garnishing, to prepare many varieties of gravy and for stuffing several food preparations. Mushrooms can also be included as an export item and have an immense potential for production and consumption in local and also in abroad for export as global market is expanding very fast. However, no report on cultivable /edible mushrooms, their processing and preservation point of view, on Bangladesh perspective was published. So far as it was known, no scientific nation-wide mushrooms survey had been undertaken in the country till date in Bangladesh. Considering the suitability of climatic conditions, availability of variety of mushroom substrate, potentialities and prospects, an attempt was made to get an overall concept about the present status of mushroom-scenario of Bangladesh.

MATERIALS AND METHODS

A representative sample was used and concerned fundamental parameters were taken into consideration from different angles or dimension to assess the present mushroom-scenario of Bangladesh. Various influencing factors such as, temperature, humidity, specific species/strain, containment of substrates as compost or spawn, biological efficiency, total flash with seasonal variation, and parameters such as preparation of mother culture and losses due to contamination were also taken into account.

Sample Design

Since the objective of the study was to investigate the present status of mushroom-scenario in Bangladesh, total producers or growers of Bangladesh was the universe under this survey. From yield and production points of view, a mushroom producer/grower was regarded as a suitable sampling unit for the survey. To ensure rural and urban representation in the sample, the survey region was divided into six parts; which were treated as six distinct and independent sub-universes. As it has been well established among the abiotic factors, temperature (T) and relative humidity (RH) are the most vital parameters for mycelium running and frutification of true fungi (Mushrooms). That's why six meteorological regions of Bangladesh were preferred. Moreover, previous ten year's (1997-2006) temperature and relative humidity of those regions (Anon, 2007) were collected. All Municipal areas (City Corporation, Pauroshava, etc) were included in the urban region and the rest of the country was treated as rural region. Then sampling was done from these six strata on proportional and available area based with respect to mushroom producer.

Sample Size Consideration

Sample size is usually estimated by considering regional and socio-economic variations and budgetary provision. A total of 156 producers/growers covering each region were surveyed. Considering the nature of survey and budgetary provisions, the number of sampling spots could not be increased.

Selection Procedure for Mushroom Producers

In selection of the desired number of mushroom producers, a village in rural region and a ward in urban region were chosen as primary sampling units. List of number of mushroom producer for all villages/wards of the survey region were taken from concerned agricultural offices, local association of mushroom producer/growers. A village/ward was assumed to be relatively more homogeneous than any other administrative units. A village / ward was selected using systematic sampling plan. Then required number of mushroom producer was selected from selected villages / wards using randomly selected sampling method. Each of the selected villages / wards was segmented into equal parts of 10 (more of less) households and a segment were at random. Clustering was done from practical considerations (Khursheed and Mosharaff , 1998).

Data Collection Instruments

Considering the importance of the study in the national context, expected seven points structured questionnaires were prepared carefully for data collections. There were 33 questions were in the questionnaires with a slogan, "Providing the information regarding mushrooms to be authentic and would be used in research purpose." The questionnaires were pretested, modified and standardized prior to conduct actual field work.

Field Survey and Data Collection

Qualified students and temporary research assistants were recruited and trained by IFST, BCSIR, Dhaka, some of whom had prior experience in mushroom culture. They were employed to assist collection of specific information on the basis of such structured questionnaire. The questionnaires were pre-tested in consultation with sampled mushroom growers and experts.

Analysis of Data

Data obtained from structured questionnaires were converted to numerical figures. Statistical and mathematical formula were used in this study. For the estimation of mushroom yield/production, a formulae was developed.

RESULTS AND DISCUSSION

There are no published time series dependable data about how much people are involved in cultivate and consumption of mushroom. Attempts have been made in this aspect by several workers. The results showed that type of mushrooms as cultivatable genera were namely- *Pleurotus* spp., *Agaricus* spp., *Calocybe* spp. and others (*Volvariella* spp.; *Auricularia* spp. etc.) 97, 1, 1 and 1%, respectively and generally these are called Oyster, Button and Milky mushrooms. It was also indicated that among the *Pleurotus* spp., 61% were *Pleurotus ostreatus,* followed by 19% *P. sajor caju,* 12% *P. florida and* 8% of *P. high king*-51 (Figure 1).

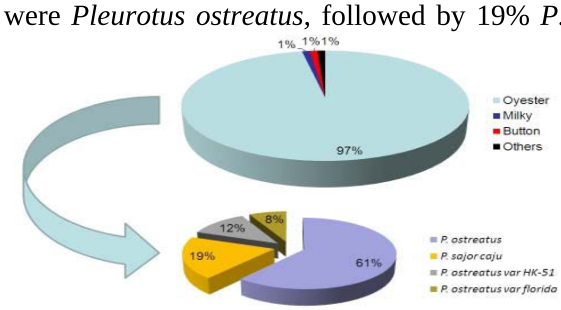

Figure 1. Cultivated Genera and Species of Mushroom in Bangladesh

It has been demonstrated that cultivated members of the genus *Pleurotus*, the Oyster mushroom, is rapidly increasing, and its edibility is especially appreciated in Europe and Asia. The past few decades have also seen great increases in production of *Lentinula* and *Pleurotus*, and to a lesser extent of *Volvariella* and *Flamrnulina* (Chang and P.G. Miles, 2004).

In this study, three categories of spawn producers were found. Those were as follows:

Category-1: In this category, 15% of the total producers produced mother-culture, mother-spawn including cultivating spawns.

Category-2: There were 13% producers in this category who were found to buy mother-spawn from them (Category-1) and they produced cultivating spawns for their own and as well as spawn for sales using mother-spawn purchased from Category-1.

Category-3: Of the total 72 % producers were in this category that purchased only cultivating spawns for their own mushroom cultivation. They were not able to make mother-culture or mother-spawn. It is clear from these three categories that almost 85% (72 +13) mushrooms producer were fully or partially dependent up on 15% of mushrooms producer for mother culture to some extent for cultivating spawns. In this regard spawn producers should be promoted as cottage industries like Category-1, who would not be producing mushrooms, but only generate spawns exclusively. While conducting this survey, it seemed that it was urgent need of time.

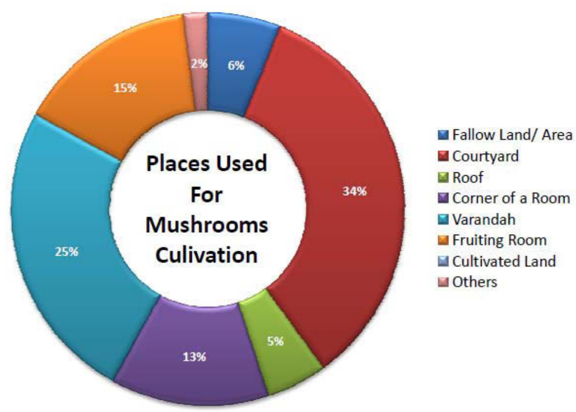

Figure 2. Different places are shown for cultivating mushrooms

As it was found that mushroom cultivation occupied 6% of Fallow land, 34% Courtyard, 5% on Roof, 13% Corner of a room, in 25% cases, Verandah, 15% in Fruiting-Room and it was 0% in case of cultivated land and in other cases 2% (Figure 2). These results indicated that mushroom cultivation did not require any fertile land and could be cultivated anywhere. No use of cultivated land and cultivation in 15% in Fruiting-Room further interpreted that cultivation of mushroom in Bangladesh are still in rudimentary stage. It was observed that total 72% (52%+20%) of the producers were not responsive to the seasonal variation, though 20% knew the interaction in between mushroom cultivation and seasonal variation. Remaining 8% were adopted with cultivatable mushrooms under prevailing temperature (Figure 3). Results revealed that 92% of the growers were not even familiar with cultivatable seasonal mushrooms. On the other hand, 8% of cultivators, having no idea about mushroom genus, had knowledge of the technical relation between seasonal temperature variation, species or strains in terms of their biological status.

However, there is little evidence to show fundamental differences in physiology of various mushrooms species (Kurtzman and Zadrazil, 1982). It is well established that temperature has a direct impact on physiological activities. Such scientific phenomenon was not well known to all producers. So, it is needless to say that without knowing this vital issue it would not be possible to grow more mushrooms. A study has also been made in Bangladesh in this respect (Siddique, 2002). He demonstrated that considering humidity requirement and availability of substrates there are seven kind of mushrooms available for cultivation in Bangladesh. These are: Oyster mushroom (*Pleurotus* spp.), Milky mushroom (*Calocybe indica*), Wood ear mushroom (*Auricularia polytricha*), Button mushroom (*Agaricus bisporus*), heat tolerant Button mushroom (*A. bitorquis*), Shittake mushroom (*Lentinula edodes*) and Paddy straw mushroom (*Volvariella volvacea*) including an indicated year round production schedule calendar. These findings could be preliminary solution to select cultivable mushrooms but it will not be possible to select the specific mushroom species or strains; which is very much important to supplement the schedule as it can be cultivated round the year in the six regions or all over Bangladesh depending on temperature and humidity as provided by the meteorological department of Bangladesh (Table 1).

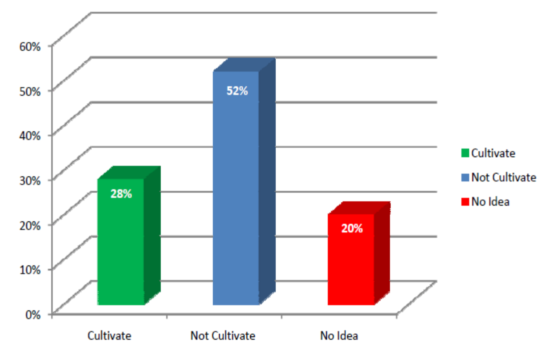

Figure 3: Mushroom Cultivation Scenario

As an example the mycelia of *Pleurotus* spp. was found to grow over the wide range of 7 to 37°C, the optimal temperature range for mycelial growth was 26-28°C ;whereas for fruiting body formation only from 12°C to 15°C (Low temp. strains), 16-22 °C (Med. temp. strains) and 25-30°C (High temp. strains) were required. These are representative values obtained from the literatures (Chang and Miles, 2004). Considering these categorized temperature ranges along with the meteorological data of temperature and humidity it could be suggested that the commercial varieties of mushrooms would be worth cultivation during the summer, are *P. flabellatus*, *P. sapidus*, *P. citrinopileatus*, *P. sajor-caju;* and suitable species for winter are *P. ostreatus*, *P. florida*, *P. eryngii*, *P. fossulatus* and *P. cornucopiae*. The findings obtained in this study are similar to those obtained by Sumon and Sharma (2005). Moreover, they also found that summer varieties can fructify at low temperature but the winter varieties can not fructify at

Table 1. Annual Average Temperature and Humidity of Six Regions (1997-2006)

Year	Dhaka			Chittagong			Rajshahi			Khulna			Barisal			Sylhet		
	Temp. ^{o}C		RH %	Temp. ^{o}C		RH %	Temp. ^{o}C		RH %	Temp. ^{o}C		RH %	Temp. ^{o}C		RH %	Temp. ^{o}C		RH %
	Max	Min		Max	Min		Max	Min		Max	Min		Max	Min		Max	Min	
1997	30.6	21.0	76	30.3	21.5	79	30.5	20.2	78	31.0	20.9	78	30.6	2.5	84	30.1	20.1	80
1998	30.8	21.9	77	31.0	22.4	80	30.9	21.1	80	31.1	22.0	80	30.7	21.1	84	30.0	20.9	80
1999	31.5	22.0	74	31.1	22.3	78	31.6	21.1	78	31.7	21.9	79	31.1	21.2	83	31.1	21.2	78
2000	30.1	21.8	73	30.5	21.6	78	30.7	20.6	79	31.5	21.2	80	30.6	20.9	83	29.4	30.5	79
2001	30.4	21.4	73	31.1	21.9	77	31.2	20.5	78	31.4	21.8	80	30.8	20.9	84	30.4	20.9	79
2002	30.3	21.5	73	31.0	21.8	77	31.0	20.6	79	31.6	21.8	80	30.7	21.2	83	30.2	20.7	80
2003	30.2	21.7	73	30.9	21.8	79	30.8	20.7	79	31.3	22.0	81	30.4	21.6	83	30.3	20.8	78
2004	30.5	21.9	72	30.7	21.9	79	31.1	20.7	77	31.0	22.1	80	30.4	21.6	83	30.1	20.9	76
2005	30.8	22.3	72	31.3	22.4	79	31.3	20.9	77	31.3	22.4	81	31.0	21.9	85	30.4	21.0	77
2006	31.2	22.4	71	31.6	22.3	79	31.7	20.9	77	31.7	22.3	78	31.2	21.9	83	31.1	21.4	75
Mean	**30.6**	**21.7**	**73**	**30.9**	**21.9**	**78**	**31.0**	**20.7**	**78**	**31.3**	**21.8**	**79**	**30.7**	**19.4**	**83**	**30.3**	**21.8**	**78**

Source: Meteorological department of Bangladesh

higher temperature and need a low temperature shock for inducing fructification. The growing temperature not only affects the yield but also the quality of produce. The pileus or cap colour of *P. florida* is light brown when cultivated at low temperature (10-15°C) but changes to white pale to yellowish at 20-25°C. Similarly fruit body colour of *P. sajor-caju* when cultivated at 15-19°C is white to dull white with high dry matter content while at 25-30°C it is whitish brown to dark brown with less dry matter. In a study by Amin (2002) reported that Oyster mushroom (*Pleurotus ostreatus)* gave the best performance in Bangladesh regarding mycelium running rate and yield. In this connection, a detailed study on the range of temperature and optimum temperatures is required for the production of some common cultivated mushrooms are demonstrated by the National Research Council for Mushroom (NRCM), Solan, India (Tripathi,2005). Extensive researches have been carried out on the range of temperature and optimum temperatures required for the production of mushrooms by various researchers Kaufert (1935, 1936); Block *et al.* (1958); Miller (1969); Jong and Peng (1975); Cailleux and Diop (1976); Oso (1977); Han *et al.* (1977); Zarazil (1976, 1978);

Quimio (1978); Huang (1979); Bano *et al*. (1979). Similarly, most fungi require adequate humidity for vegetative growth, and the requirements for fruiting are even more stringent. All the *Pleurotus* spp. require high relative humidity 70-80% during fruiting (Singh and Singh, 2005). The failure of fungi to fruit is frequently attributed to the accumulation of excessive moisture from respiration or surrounded humidity resulting in increased possibility of contamination. Many investigations have dealt with relative humidity for optimum mushroom yield. It has been obtained from literatures that some of the relative humidities desirable for the various species are: *Pleurotus* spp., 60-80% (Zadrazil, 1978), 80% (Hilber, 1977) *P. abolonus*, 90-95% (Han *et al.*, 1977) *P. eryngii*, 85-95% (Cailleux and Diop, 1976) *P. Jlabellatus*, 70-80% (Bano *et al*., 1979) P. florida, 85% (Block *et al.*, 1958), 75-90% (Kalberer, 1976), 80-95% (Zadrazil, 1973) *P. sajor-caju*, above 85% (Jandaik and Kapoor, 1976). It is suggested by various authors that considering all the possibilities, there may be considerable agreement between the humidities. However, if the range of humidity was much greater, it would expect rapid drying of the substrate below 60% RH and localized fog or rain in the mushroom house at *95%* RH (Chang and Quimio, 1984). In a recent review, it is optimized that 60% of the humidity is sufficient for mycelium running of *Pleurotus ostreatus* in Bangladesh context (Sarker *et al*., 2007). Thus, a generalization can be made that for mycelium running and fruiting bodies of higher fungi typically form best under conditions of optimum temperature and humidity available in Bangladesh (Table 1). Any environmental factor may affect mycelial growth as well as fruiting. It was evident that the optimal and critical temperatures and humidity are determined for mycelial growth and fruiting with a view toward possible commercial cultivation of these species. This specification type of cultivation is not only for round the year production but also necessary for higher yields and better quality of mushrooms; which is common expectation and considered to be the need of time.

In this survey using the standard median calculation method it was found that the average production of spawn per year 3179555 (Appx.) and average production of mushroom per spawn packet was 240 gm. It came out that on an average spawn production per month was below 1000 25%, 1001-2000 were 29%, 2001-3000 were 13% and the range in between 3000-4000 was observed 33% of cultivating spawn, simultaneously monthly production of spawns sold were (on an average), 7% of 1-500 spawn-packets, 51 % of 501-1000, 29% of 1001-3000 and 13% in case of 3000-5000 spawn-packets. The results revealed that the majority (80%) spawn producers produced 500-3000 spawn-packets on the other hand 60% demand were observed within 1-1000 spawn-packets for cultivating mushrooms to the beginner cultivator or mushroom producers. As per percentage of cultivating spawn production, it was calculated and estimated that approximately 26497 spawn-packets were produced per month. It was found that after harvest with integrated flashes from each spawn-packet usually contained 500 gm of substrate produced mushrooms as below 150 gm 28%, 25 gm 44%, 350 gm 16% and more than 350 gm were 12% (Figure 4). Again it was estimated that on an average 240 gm fresh mushrooms (Oyster) were produced from each spawn-packets.

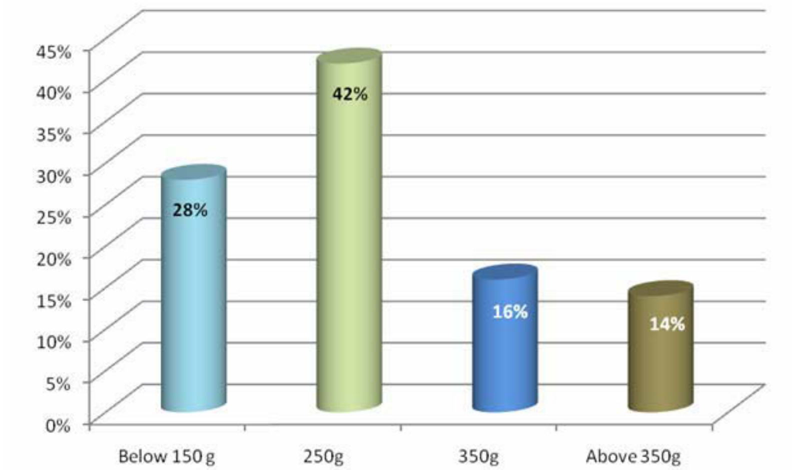

Figure 4. Yield of mushrooms from spawn packets each containing 400-500 gm of substrate

Now it was possible to find out the amount of mushrooms production per month as because if we denote, P = Total number of production of spawn-packets per month; W = Weight of commercial yield (integrated weight of total flashes) each of spawn-packet; P_1 = Spent spawn-packets for making mother culture; P_2 = Loss due to contamination; P_3 = Loss due to transportation; P_4 = So on …..(if there is any system loss to be occurred; this or these are variables). Despite these, if both of the biotic and abiotic factors of that particular environment (F) and the species/strains (S) are to be constant then the proposed formulae would be,

if 'M' stands for monthly production then the formulae:

$M = P – (P_1+P_2+P_3+P_4 …..) \times W$ [Where F and S is constant].

Here, P =264963, P_1 = 5% of P = 1325; P2 = 10% of P = 2650 and W = 240 gm. So, M = 264963 – (13248+26496) × 240gm = 54.05 MT per month; consequently 54 × 12 = 648 MT per annum. On account of seasonal glut it is supposed to be extended maximum 50 MT, so, 650 MT per annum. When production range was concerned then it was also estimated 620 - 675 MT of mushrooms produced per annum. Amin (2008) pointed out that in the year 2007, 5000 of spawns and 8-10 MT of fresh mushrooms were produced per day in Bangladesh and in 2008; about 60000 -70000 spawn packets, which resulted 15-20 MT of fresh mushrooms being produced per day throughout the country.

As has been observed that main constituents generally are sawdust, straw and others (waste paper, sugarcane baggase, etc) used as carbon sources for making spawn packets 76%, 14% and 10% respectively (Figure 5).

During harvesting, 26% of producers resorted to running on the mistaken notion that picking up of the larger ones is the right procedure, though in reality that decreased the yield and caused delay in appearance of the next flash. Hence the remaining 74% respondents, who resorted to harvesting without such discrimination, actually adopted the right course, though of course being aware of the fact.

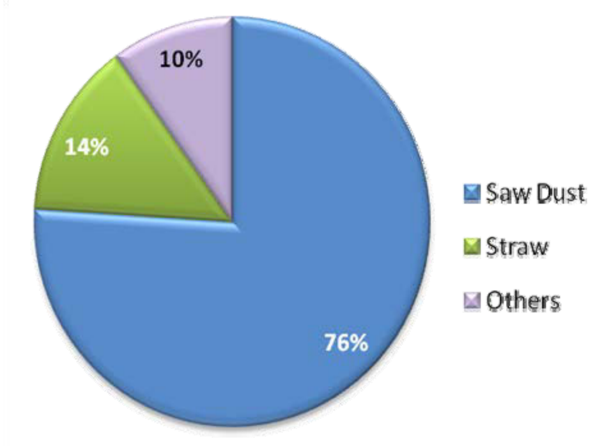

Figure 5. Pattern of carbon sources use as principle substrate

The picked-up mushrooms were found to be graded in 39% cases considering shape and size, which was not so in rest of the 61% cases during post harvest regime. It was also noted that 84% mushroom producers were habituated to pick-up mushrooms at least by five flashes; remainder16% mentioned that they pick-up 3-4 flashes from each spawn-packet.

It was recorded that mushrooms were consumed fresh by 67% and used as processed or preserved (dried) form by 22%, powdered by 10% and 1% in other form (pickling, frying etc.). Present findings showed that adopted processing methods (Figure 7) were 63% of sun drying, stove (Chula) 15%, using electric bulb 15%, solar dryer 4% and others 3% (fan, combined) for drying mushrooms. After drying, mushrooms were used to sale 55% in poly pack, 16% steeped in water and cook if necessary and powder was done by 29%. In order to get powder, adopted processing techniques were 30% by blender 50% by flower- mill, 2.5% by husking Pedal and17.5% cases applied other techniques (grinding- stone, mortar and pastel, etc. (Figure 6). Almost all (99.8%) producers enjoyed the unique taste of mushrooms and various type of mushroom based food products especially as snacks, with tea, fried items and soup. They had also shown keen interest in processed mushrooms as such liquid, dry or powder form and finally wanted to get mushroom based food diversification (Curry, Snacks, Drinks, Bakery Food etc) as value-added products.

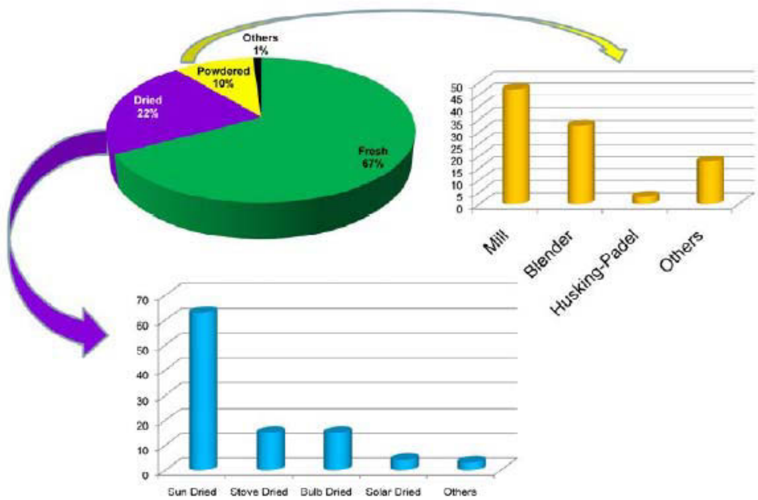

Figure 6. Consumption pattern of mushrooms and processing system

To find out the main hindering factors for cultivating mushrooms, the mushrooms producer were presented with six probable factors, their opinion about which have been graded as 58% believed that people were not motivated to eat, 20% thought that mushrooms were not available, 5% pointed out at problem related to marketing, 7% informed rise of price of poly packs, other 9% raised the question of legality to buy and carry of poly packs in view of the existing statutory limits over polyethylene use. Further, 1% mentioned that it was due to lack of availability of substrates (Figure 7).

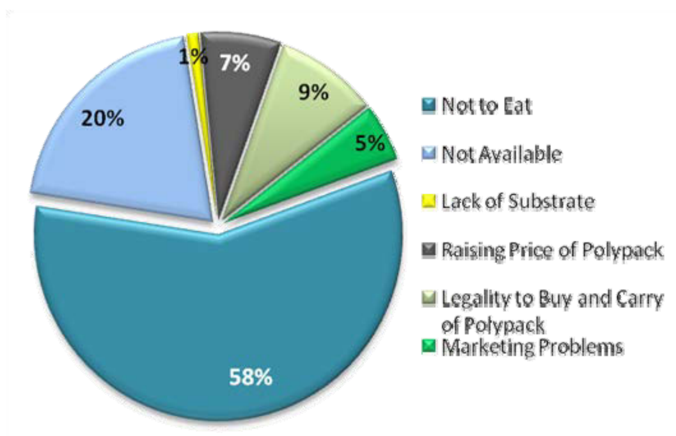

Figure 7. Major hindering factors for mushrooms cultivation

It was also found that stood on the way of mushroom production activities, 41% people attributed lack of knowledge about mushrooms and as how to consume it. The remainder 41% mentioned superstition, 16% stated high price and 2% pointed to other causes (Figure 8). It was also evident that 92% cultivator had taken training on mushroom cultivation and residual 8% had inculcated ideas and techniques from the neighboring trained persons. The training period was of different duration: 1-3 days, 4-7 days, about 1 month and more than 1 month for 31, 52, 9 and 8%, respectively. The mushrooms producer also obtained their professionalism by engaging in cultivation of mushrooms in varying periods: 72% were related with cultivation for less than 1 year, 16% for 2-3 years, 1% for 4-5 years and 11% were for more than 5 years. It was found that 34% of growers cultivated mushrooms on account of its nutritional and medicinal values, 27% for resolving their unemployment, 14% as more profitable vegetable, 14% just to pass leisure time, 10% due to hobby and 1% for other reasons (Figure 9). Considering afore-described facts and features it is clear that Bangladesh has an unlocking potentiality for cultivating mushrooms as because we have abundant wild or native isolates of various edible mushrooms, favorable climate, abundant agro-wastes, cheap labour, cultivatable by any one irrespective of time and location and also environment-friendly cultivation system. Hence, due to easy cultivation technique *Pleurotus* spp. should be the first choice for the beginners. Mushrooms cultivation requires minimal input, demands no fertile land or fertilizer or irrigation like other costly inputs, but only waste products which are cheap and available in plenty in villages keeping the production cost to the minimum. Thus farmers can take up mushroom cultivation as cottage industry by which they can earn additional money.

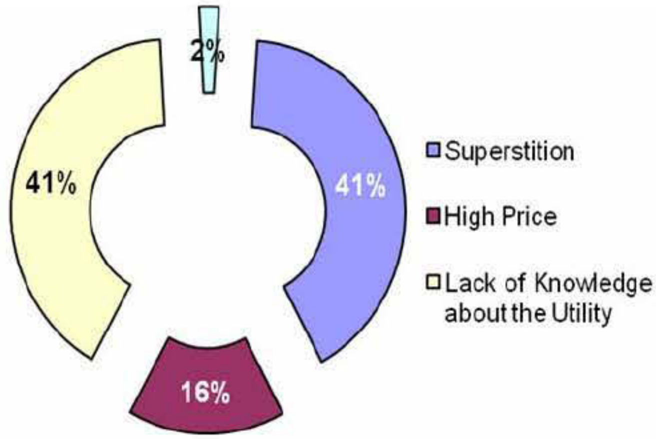

Figure 8. Major obstacles for extending mushroom cultivation in Bangladesh

It will create more jobs in processing, preservation and marketing of mushrooms. Moreover, its life cycle is very short, so, there is no chance to lose from natural disaster. It is easy to preserve and usable with other food, including value-added food products. Mushrooms are health tonic to all. It provides opportunity of minimum investment and scope for export, reducing import and ensuring early return. Suman and Sharma (2005) have concluded that mushrooms are a potential

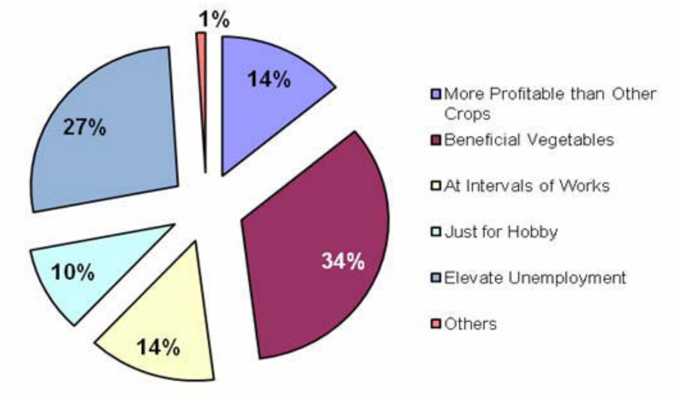

Figure 9. Rationale behind cultivating mushrooms in Bangladesh

foreign exchange earner and thus open up new avenues of employment potential for educated unemployment, landless peoples and to empowerment of women. Mushrooms cultivation can provide more food, more jobs, better family income, improved living standard, safe to human health and environmental pollution, curb global warming and CO_2 level, clear up crop residues. Spent mushroom substrates (SMS) can be used as feed and soil conditioner (Pope, 2000).

From the present study, it was also apparent that frequent feed back information need to be gathered from short term, mid term and long term trainees as well as from master trainers to bridge the gaps and knowledge of mushroom growers in respect of production, utilization, processing and preservation. The Mushroom Research and Develpement Center (MRDC), Savar; IFST, BCSIR, Dhaka and relevent research labaratories in the universities have a lot of scope to carry on such activities.

CONCLUSION

We should grow more mushrooms and if we consume it in scientific way, such effort will also make us more productive, reduce medical expenditure and able to contribute in poverty alleviation. Further studies are needed to find out endogenous more species and to optimize their culture, cultivation as well as processing and preservation keeping in view of value-added products as well as nutriceuticals.

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COMBINING ABILITY ANALYSIS IN HYACINTH BEAN [*Lablab purpureus* (L.) Sweet]

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ABSTRACT

The nature and magnitude of generations of five genotypes of hyacinth bean [*Lablab purpureus* (L.) Sweet] were studied in a full diallel to estimate combining ability effects during winter season of 2005/2006 at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. Combining ability studies of full diallel crosses revealed that the variances due to GCA and SCA were highly significant for all the characters which indicated the importance of both additive and non additive gene actions. However, GCA variances were higher than the SCA variances for most of the characters signifying a predominant role of additive gene action. In addition, all the characters showed reciprocal effects indicating the role of maternal cytoplasm on the differences of the hybrid performance. The parents P_1 and P_2 were the good general combiner for earliness; P_3 for number of pods per plant, individual pod weight, pod length and number of seeds per pod while P_4 for pod breadth and 100-green seed weight. The combinations P_1 X P_2 and P_1 X P_5 showed negative SCA effects for days to first flower indicating earliness. Combination P_1 X P_2 exhibited higher significant SCA effects for, number of pods per plant, pod yield per plant, 100-green seed weight indicating promising cross for higher production.

Key Words: Combining ability; GCA; hyacinth bean; SCA.

INTRODUCTION

Hyacinth bean [*Lablab purpureus* (L.) Sweet] is an important and nutritious vegetable crop grown during winter season in Bangladesh. Recently much interest has been developed in producing and growing F_1 hybrids of many vegetable crops in many countries. Considerable amount of heterosis for yield has also been demonstrated in various vegetable crops (Singh *et al*., 1995; Bhatt *et al*., 1999; Vidyasagar *et al*., 1997). Substantial amount of heterosis for some economic traits in hyacinth bean have been reported by several authors (Rajashekaraiah, 1979; Rao,

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1979). Hence an attempt was made to exploit heterosis for better yield and quality of hyacinth bean by selecting superior parents on the basis of their relative ability to transfer economic traits in hybrid combination. Combining ability is one of the powerful parameters used to identify the best combiner that may be used in crosses either to exploit heterosis or to accumulate fixable genes. It helps understanding the genetic architecture of various traits that enable the breeder to design effective breeding plan for genetic enhancement of the existing materials in the future and also to select diverse parents and hybrid combinations. However, research reported in this respect is scanty in Bangladesh (Kabir, 2004). Considering the prospects of the crop and scarcity of published work on the subject, the present study was planned with a view to determine GCA and SCA of the selected parents of hyacinth bean.

MATERIALS AND METHODS

The study was carried out at the experimental farm of BSMRAU, Gazipur during July 2005 to February 2007. Five genotypes of hyacinth bean were selected for this study based on their morphological diversity. The local name, source of collection of the selected parents are given in Table1. Two seeds of each genotype were sown in a poly bag on July 21, 2005 and ten days old seedlings were transplanted in the field on the raised beds at a spacing of 1.5m X 2.0m. Ten plants of each genotype used for crossing programme. The plants were fertilized with 10 t/ha of cattle manure, Urea 50 kg, Triple Super Phosphate (TSP) 150 kg and Muriate of Potash (MP) 150 kg per hectare of each (Rashid, 1999). One week before transplanting 10t/ha of cattle manure, TSP and half dose MP were applied as basal dressing during pit preparation. The remaining MP and urea were applied, as top dressings at 15, 30 and 45 days after transplanting. The parents were crossed as per techniques described by Chowdhury *et al*, (1989) in full diallel combinations during winter 2005/2006 making 20 cross combinations. On maturity pods (38-40 days after cross pollination) were collected and kept for seven days in the laboratory for seed to mature full and the seeds were then collected and kept in a desiccator for next season evaluation.

Growing of F_1's and their parents

Seeds Twenty F_1's and five parental genotypes were sown in polybags on June 15, 2006 and transplanted in the main field on June 25, 2006 using RCBD with three replicates with five plants in each replicate. The crop was fertilized as mentioned above. Staking of the plants and other cultural operations were done as per Rashid (1999). Observations were made on days to first flower, pods per raceme, pod length, pod breadth, individual pod weight, number of pods per plant, pod yield per plant, number of seeds per pod, 100-green seed weight. The collected data were subjected to combining ability analysis following Model I and Method I (Full diallel fashion) of Griffing (1956).

Table 1. Local name and source of collection of selected parents

Accession number	Local name	Origin/place of collection	Characteristics	Symbol
HB003	IPSA seem-1	BSMRAU	Pronounced twinning tendency, flower colour violet, pod colour green with purple edge.	P_1
HB004	IPSA seem-2	BSMRAU	Pronounced twinning tendency, flower white, pod colour light green.	P_2
HB018	Promising Line	Barisal	Pronounced twinning tendency, flower white, pods are cylindrical with green colour.	P_3
HB027	Promising line	Rajbari	Flower white, pods are flat with green colour.	P_4
HB041	Indian dwarf	India	Determinate growth of plants, flower white, pods are green, small and fibrous,	P_5

RESULTS AND DISCUSSION

A. ANOVA and GCA -SCA ratio

Highly significant difference observed in the analysis of variance (ANOVA) for all the characters studied shows the existence of wider genetic variability among the genotypes (Table 2). The mean sum of squares for general, specific and reciprocal combining ability were highly significant for all the characters indicating both additive and non additive gene action which played a significant role in the expression of these characters. Significant reciprocal effect shows the maternal effect. Similarly, Valu *et al*. (1999) reported significant GCA and SCA variances for yield and yield contributing characters in Indian bean.

The higher GCA:SCA ratio (more than 1) suggests all the characters except number of seeds per pod are predominantly under additive genetic control.. Similar results were also reported by Barelli *et al*. (2000) and Kurek *et al.* (2001) for common bean. El Hosary *et al*. (1997) also reported GCA/SCA ratio above unity for flowering date, branches per plant and 100-seed weight of faba bean (*Vicia faba*). Kabir (2004) also reported that the ratio of GCA: SCA was more than one for all the characters studied in lablab bean. In contrast, number of seeds per pod recorded higher SCA than GCA indicating pre dominant role of non additive gene action in the expression of this trait in hyacinth bean.

Table 2. Analysis of variance for combining ability of hyacinth bean

Sources of variation	DF	Days to flower	No. of pods/raceme	No. of pods/plant	Individual pod wt (g)	Pod length (cm)	Pod breadth (cm)	Pod yield/plant (kg)	100-green seed wt (g)	No. of seeds/pod
Block	2	2.85	0.07	165.72	0.356	0.2529	0.0045	0.0241	9.0761	0.0145
Genotype	24	3220.59**	5.80**	7368.74**	9.62**	18.429**	0.3805**	1.927**	373.84**	0.4447**
Error	48	70.14	0.28	184.9	0.115	0.2419	0.0237	0.06	7.8442	0.1295
GCA	4	5183.70**	5.52**	3199.40**	14.37**	25.056**	0.3851**	2.221**	396.54**	0.1409*
SCA	10	437.01**	0.65*	1584.89**	0.181**	0.3522**	0.0134**	0.129**	48.40**	0.1559**
Reciprocal	10	65.98**	1.78**	3030.33**	1.766**	4.3686**	0.1369**	0.524**	92.41**	0.1434**
Error	48	23.38	0.09	61.63	0.038	0.0806	0.0079	0.02	2.6147	0.0431
SCA/GCA		0.0843	0.177	0.49	0.0163	0.014	0.0347	0.058	0.121	1.106

*, **= Indicates significant at 5% and 1% level of probability, ns= not significant

B. General combining ability effect

A parent showing higher positive or negative significant GCA effect may be considered as a better parent for creating high yielding specific combination. The estimates of GCA (gi) effects are given in table 3.

The parent P_2 showed the highest but negative significant GCA effect (-20.38**) with the parental mean 51.3 days to first flower followed by P_1 (-17.81** with mean 50.6 days). So the parents P_1 and P_2 were the best general combiners for early flowering in hyacinth bean. The significant and positive GCA values for number of pods per raceme (0.9013**) and number of pods per plant (27.30**) recorded by parent P_3 qualifies it as a good general combiner for higher number of pods per plant.

Significant and positive GCA effect for pod weight was observed for P_3 (0.920** and mean 8.0g) followed by P_1 (0.780** and mean 7.6g). Thus, P_3 was identified as the best general combiner for pod weight followed by P_1. The highest significant and positive GCA effect for pod length was found in P_3 (2.04** and mean 12.3 cm) followed by P_1 and P_4. For pod breadth the parents, P_4 and P_1 were found to be desirable since they produced significant and positive GCA effects, 0.196** and 0.186**, respectively. With regard to pod yield per plant the parent P_3 was the best general combiner as it showed a significant and positive GCA effect (0.0506**). Among the five parents, P_4 was identified as good general combiner for 100-green seed weight on the basis of GCA. The significant and positive GCA effects for number of seeds per pod of P_3 (0.094** and mean 4) indicated that it was the best general combiner for number of seeds per pod in hyacinth bean.

C. Specific combining ability effect

Specific combining ability effects are presented in table 4. Earliness in lablab bean is a desirable trait. The cross combination of P_3 X P_4 (-19.15**) provided the highest significant SCA followed by P_1 X P_2 (-10.32**) and P_1 X P_5 (-10.25**). Thus these crosses provide good heterotic combinations for earliness. With respect to number of pods per raceme, P_3 X P_4 was the best specific combination to improve the crop for higher number of pods per raceme. The solitary cross P_1 X P_2 produced the highest positive and significant SCA effect (50.26*) for number of pods per plant. The cross combination P_1 X P_2 had positive and significant SCA effect (0.473**) followed by P_2 X P_5 (0.231**) for individual pod weight. The cross P_1 X P_3 was the best specific combination for pod length while the cross combination P_3 X P_4 was the best (0.088**) specific cross combination for pod breadth in hyacinth bean.

The cross combination P_1 X P_2 was selected as the best specific cross combination as it recorded positive and highly significant SCA (0.520**) for pod yield per plant followed by P_2 X P_5 with SCA 0.157**.

Table 3. Estimates of GCA effects and mean of the parents for different characters in hyacinth bean

Parents	Days to first flower	No. of pods/raceme	No. of pods/plant	Individual pod wt (g)	Pod length (cm)	Pod breadth (cm)	Pod yield/plant (kg)	100-green seed wt (g)	No. of seeds/pod
P_1	-17.81**	8.77ns	8.77ns	0.780**	0.7020**	0.186**	0.275**	3.158**	-0.016**
	50.66	290	290	7.56	9.7	2.53	2.18	43.5	3.46
P_2	-20.38**	-8.09ns	-8.09ns	-0.380**	-0.6713**	0.011ns	-0.185**	3.065**	0.070**
	51.33	298.33	298.33	5.28	7.0	2.1	1.57	44.73	4.13
P_3	25.58**	27.30**	27.30**	0.920**	2.04**	-0.25**	0.506**	-3.648**	0.094**
	129.66	420	420	8.03	12.33	1.43	3.37	36.0	4.14
P_4	23.72**	-14.09**	-14.09**	0.610**	0.138**	0.196**	0.117**	6.542**	0.050**
	127.33	338.0	338.0	7.63	8.86	2.48	2.57	66.0	3.36
P_5	-11.11**	-13.92**	-13.92**	-1.930**	-2.21ns	-0.133**	-0.712**	-9.118**	-0.199**
	77.33	286.66	286.66	2.33	4.6	1.8	0.04	17.86	3.4
Se (gi)	1.36	2.22	2.22	0.055	0.08	0.02	0.03	0.45	0.05

*, **= Indicates significant at 5% and 1% level of probability, ns= not significant

Table 4. Estimates of SCA effects of crosses for different characters in hyacinth bean

Crosses	Days to flower	No. of pods/raceme	No. of pods/plant	Individual pod wt (g)	Pod length (cm)	Pod breadth (cm)	Pod yield/plant (kg)	100-green seed wt (g)	No. of seeds/pod
P_1 X P_2	-10.32**	0.05**	50.26*	0.473**	0.144**	0.036**	0.520**	5.714**	0.509**
P_1 X P_3	20.71**	0.20**	-6.64ns	0.042**	0.581**	0.005**	0.0003ns	-0.655ns	-0.014**
P_1 X P_4	12.91**	-0.60**	8.22ns	0.164**	-0.232**	0.001**	0.117**	0.021ns	0.062**
P_1 X P_5	-10.25**	0.40**	15.26ns	-0.530**	-0.315**	-0.145**	-0.140**	-1.902**	-0.287**
P_2 X P_3	10.94**	0.22**	-23.77ns	-0.144**	-0.562**	-0.034**	-0.251**	-2.695**	-0.467**
P_2 X P_4	14.81**	0.50**	-19.24ns	-0.466**	0.041**	-0.113**	-0.239**	-4.802**	-0.157**
P_2 X P_5	-9.18**	-0.25**	17.79ns	0.231**	0.474**	0.072**	0.157**	3.541**	-0.107**
P_3 X P_4	-19.15**	0.86**	-1.47ns	-0.059**	0.494**	0.088**	-0.041**	-4.988**	0.136**
P_3 X P_5	8.36**	-0.87**	6.06ns	0.125**	-0.288**	0.061**	0.063**	5.404**	0.202**
P_4 X P_5	9.88**	-0.11**	-14.07ns	0.117**	-0.418**	-0.002ns	-0.043**	-2.785**	0.162**
Se(Sij)	1.64	0.01	4.57	0.12	0.02	0.002	0.08	0.88	0.014

*, **= Indicates significant at 5% and 1% level of probability, ns= not significant

Only three cross combinations (P_1 X P_2, P_3 X P_5 and P_2 X P_5) indicated heterosis by recording significant and positive SCA for 100-green seed weight where P_1 X P_2 had the highest positive significant SCA effect (5.714**). Out of ten cross combinations, P_1 X P_2 recorded highly significant and positive SCA (0.509**) for number of seeds per pod in hyacinth bean.

D. Reciprocal effect

The reciprocal effects presented in table 5 indicated reciprocal differences for the characters measured. Khan (2000) and Vijay and Nath (1977) reported significant reciprocal effect for various characters in yard long bean and in various quantitative characters of eggplant, respectively and indicated that the effects were under cytoplasmic influence.

The cross combination P_3 X P_2 showed significant reciprocal effect for earliness (-12.83**) where as P_5 X P_3 exhibited heterotic effect not only for late flowering (highest significant positive reciprocal effect for days to first flower) but also recorded highest significant and positive reciprocal effect for number of pods per raceme (1.150**) and number of pods per plant (67.0*).

The reciprocal effect for individual pod weight was highly significant and positive for hybrids between P_5 X P_4 (1.75**) followed by P_5 X P_3 (1.603**) combinations. Out of 10 hybrids, six showed significant positive reciprocal effects for pod length, of which P_5 X P_3 produced the highest reciprocal effect (2.850**) but reciprocal effect for pod breadth of this cross was found negative and significant. However, the cross P_5 X P_2 produced the highest significant and positive reciprocal effect for pod breadth.

The parental combination, P_5 X P_3 had the highest positive reciprocal effect for pod yield per plant whereas P_3 X P_1 produced highest negative reciprocal effect.. For the character The highest positive and significant reciprocal effect was observed for 100-green seed weight by P_5 X P_1 (14.166**) followed by P_5 X P_2 (9.850, P_5 X P_3 and P_5 X P_4 . The cross combination P_5 X P_3 was the best reciprocal combination for number of seeds per pod since it produced highly significant and positive reciprocal effect followed by P_2 X P_1 (0.266**).

Table 5. Estimates of reciprocal effects of crosses for different characters in hyacinth bean

Crosses	Days to flower	No. of pods/raceme	No. of pods/plant	Individual pod wt (g)	Pod length (cm)	Pod breadth (cm)	Pod yield/plant (kg)	100-green seed wt (g)	No. of seeds/pod
P_2 X P_1	-1.16ns	0.250**	0.500ns	0.713**	1.483**	0.250**	0.280**	2.466ns	0.266**
P_3 X P_1	-6.16*	-1.850**	-72.33*	-0.366**	-1.566**	0.400**	-0.688**	1.983ns	-0.500**
P_4 X P_1	-2.83ns	-1.083**	2.5ns	0.016ns	0.583**	0.123**	-0.030**	-3.916**	0.260**
P_5 X P_1	-1.83ns	0.133**	-6.33ns	0.933**	1.516**	0.166**	0.301**	14.166**	0.200**
P_3 X P_2	-12.83**	-1.183**	-18.33ns	-1.023**	-1.716**	0.425**	-0.465**	2.850**	-0.133**
P_4 X P_2	-1.16ns	-0.433**	-22.83ns	0.283**	-0.116**	-0.076**	-0.278**	-0.166ns	-0.066**
P_5 X P_2	-2.33ns	0.416**	-24.66ns	0.408**	0.533**	0.066**	-0.11ns	9.850**	0.133**
P_4 X P_3	-0.50ns	0.416**	61.33*	0.633**	1.416**	-0.393**	0.698**	0.933ns	-0.250**
P_5 X P_3	9.66**	1.150**	67.0*	1.603**	2.850**	-0.096**	0.926**	9.000**	0.400*
P_5 X P_4	4.83ns	0.983**	12.50ns	1.75**	1.083**	0.253**	0.580**	7.000**	0.150**
Se(rij)	1.77	0.22	5.53	0.138	0.2	0.11	0.10	1.14	0.146

*, **=Indicates significant at 5% and 1% level of probability, ns= not significant

From the above discussion it might be concluded that the parent P_1 and P_2 could be used as the best general combiner for promoting earliness; P_3 for number of pods per plant, individual pod weight and pod yield while P_4 for 100-green seed weight. Among the crosses, P_1 X P_2 was the best specific cross for most of the economic traits like earliness, number of pods per plant, individual pod weight and pod yield per plant. Therefore, the combination P_1 X P_2 may be selected for exploitation of heterosis for higher yield of hyacinth bean.

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