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A STUDY ON CONTRIBUTION OF WOMEN IN RAISING LIVESTOCK IN SOME SELECTED AREAS OF BANGLADESH

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ABSTRACT

In this study an attempt was made to determine the contribution of women in raising livestock for generating family income and employment in rural Bangladesh. For this purpose 600 households from 6 districts were selected randomly for in-depth investigation. Results showed that participation of women were 37.34%, 44.48%, 46.70% and 55.80% for large, medium, small and landless farms, respectively. It was observed that participation of men in livestock raising activities increased with the increase in farm size but that of women increased with the decrease in farm size. Factors that motivated women to participate in livestock raising activities were increasing family income (79.45%) and increasing personal income (52.72%). In the case of livestock processing activities only 9.67% of women were found involved. No involvement of women in livestock processing activities, was found in small and landless farm categories. In decision making process of livestock production, the women's participation in raising livestock was higher (53.40%). It was highest for selling eggs (82.33%), followed by raising chicken/duck (77.17%), sale of chicken/duck (72.83%), sale of milk (61.33%), and tending animals (27.17%). In order to encouraging women in livestock raising activities, the highest proportion of women suggested for providing training (75.14%), followed by ensured veterinary services (57.33%), supply of improved variety of livestock and poultry (44.90%) and provision of credit facilities (43.43%).

Key words : Women's participation, Livestock raising, Household income, Farm size.

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INTRODUCTION

There are about 18 million households in Bangladesh, of which 66 per cent are farm households and the rest are non-farm households. Seventy two per cent of the farm households have bovine animals, 52 per cent have sheep/goats, and most of the farm households have ducks and poultry. These animals and birds belong to the head of households, his wife /wives, sons and daughters. In all the farming households wives, sons, daughters and daughter in-laws act as the labour force for raising livestock. In reality, livestock keeping is mainly accompanied with family labours, especially women being the pivot.

Women play the most dominant part in raising livestock. They are primarily responsible for feeding the animals, giving water to animals, cleaning of the sheds and milking of cows. In most of cases women are solely responsible for keeping goats/sheep and poultry. They also take care of health of the animals. A large number of poor women have established dairy and poultry farms and depend entirely on income generated from those farms. They also work as hired labours in commercial dairy and poultry farms (Alam *et al.*, 1995; 1998).

In recent years, a number of NGO's have been providing loans to rural women for livestock raising (Alam, 1997). It is the policy of the government to utilize idle women labour for employment and income generating activities, particularly with livestock rearing. Studies show that both livestock and poultry farming are profitable to female entrepreneurs and will help alleviation of poverty in rural areas (Alam, 1995; 2002).

In this study an attempt was made to identify the activities done by women in raising livestock and determine their contribution to family income from livestock sources. The study was conducted to achieve the following objectives :

- a. To determine the contribution of women in animal husbandry;
- b. To determine the contribution of women in family income through livestock raising;
- c. To determine the incentive that motivate the family members to participate in livestock raising and processing activities;
- d. To ascertain the magnitude of consumption of livestock products from own source;
- e. To analyse the livestock processing activities carried out by women;
- f. To suggest suitable policy measures for encouraging women's participation in livestock rearing and processing.

MATERIALS AND METHODS

Six upazillas, namely Mehendigonj for coastal area from Barisal district, Tanore for barind tract area from Rajshahi district, Naikhongchhari for hilly area from Bandarban district, Chuadanga for high Ganges river flood plain area from Chuadanga district, Modhupur for

Modhupur tract area from Tangail district and Sylhet sadar for eastern piedmont plains area from Sylhet district have been selected purposively for this study. A preliminary survey was conducted in five villages of each of the selected areas to prepare a cluster of sample households raising livestock and poultry.

A total of 3040 households were surveyed. The livestock and poultry raising households were grouped into four categories: large (5.01 and above acres), medium (2.01-5.00 acres), small (0.51-2.00 acres) and landless (0.0-0.50 acres) in all the villages. From this cluster a total of 100 farm households were selected randomly from each area. The selection of households was done with proportional allocation to different farm size groups in each of the villages. Thus, 600 farm households from 6 areas have been selected for in-depth investigation.

For conducting an in-depth investigation, a set of survey schedule was finalized after the field-test. With the help of these survey schedules data on time spent for livestock raising activities by family members by sex, decision making process, milk processing activities etc. had been collected by quarterly visits. Data were collected in the year 1999. The collected data were analysed using M-STAT Personal Computer Programme.

Estimation Procedure

- a) Time spent for different livestock raising activities by species per day by men and women were summed up to estimate the total time spent for livestock production per day.
- b) Man-days were calculated as 1 day=8 labour hours.

RESULTS AND DISCUSSION

Socio- economic characteristics of livestock raising farms

Results of the field investigation showed that the average size of landholdings per farm was 1.96 acres. It was 9.70 acres, 2.98 acres, 1.11 acres and 0.16 acres for large, medium, small and landless farms, respectively. Average size of family per household was 6.16. The average size of family varied from 5.07 to 8.56. A positive relationship was found with the size of family and landholdings.

The major livestock reared by the farms in all areas were cattle, goat, chicken, duck and pigeon. The number of buffalo, sheep, pig and goose were found very insignificant. The average number of cattle, buffalo, goat, sheep, pig, chicken, duck, goose and pigeon per farm for all categories of farms were 2.79, 0.04, 1.22, 0.15, 0.05, 12.46, 2.52, 0.17 and 1.55, respectively.

Participation of family members in management practices by species

The different management practices carried out for livestock production were identified as cleaning of shed, feeding, tending, collection of grass, taking care of pregnant animals, collection of milk and eggs, selling of milk and eggs, purchase of animals, selling of animals, nursing of diseased animal, putting animals and birds into shelter, taking them out of shelter and others. The participation of men and women in different management practices for production of major types of livestock varied depending on the type of management practice and livestock owned. It can be observed from Table 1 that on average, the involvement of both male and female family labourers per household for raising livestock and poultry was 149.05 man-days per year of which men's and women's contributions were 52.54% and 47.46%, respectively. It is evident from the table that the involvement of male labour was 61.73, 10.96, 2.80 and 2.82 man-days for rearing cattle/buffalo, goat/sheep, chicken/duck/pigeon and pig, respectively, while that of female labour was 34.47, 11.42, 13.71 and 11.15 man-days for cattle/buffalo, goat/sheep, chicken/duck/pigeon and pig, respectively. For cattle and buffalo the percentage of participation of male labour was higher (64.17%) but for rearing goat/sheep, chicken/duck/pigeon and pig the involvement of female labour was higher (51.03%, 83.04% and 79.81%). It appears that women are more involved in rearing small animals and birds, while men are more involved in rearing large animals.

It can also be observed from the table that time spent for rearing livestock was the highest for feeding, tending, collecting grass (88.80 man-days of which male 56.41 and female 32.39), followed by cleaning of shed (17.63 man-days, where male 1.69 and female 15.94), taking animals into and out of shed (16.50 man-days), taking care of pregnant animals (12.39 man-days), selling animals (5.38 man-days), milking and collection of eggs (2.97 man-days), nursing of diseased animals (2.32 man -days), selling milk and eggs (1.72 man-days), purchasing animals (1.33 man-days), and was the lowest for others (0.01 man-days) per year.

Involvement of women in management practices for livestock varied depending on the type of management practices and also on categories of farm families. The participation of men and women in different management practices for livestock production by farm size is shown in Table 2. It can be observed from the table that participation of men in different activities was 62.66%, 55.52%, 53.30% and 44.20% for large, medium, small and landless farms, respectively.

On the other hand, participation of women for those activities was 37.34%, 44.48%, 46.70% and 55.80% for large, medium, small and landless farms, respectively. It is evident that participation of men in livestock raising activities increased with the increase in farm size but that of women increased with the decrease in farm size. Women are contributing significantly to increase the family income from livestock sources in all categories of farms, particularly in small and landless farms.

Table 1. Activity and species wise distribution of labour (man-days)

Activity	Cattle/Bufalo		Goat/sheep		Chicken/duck/pigeon		Pig		Total		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total
Cleaning of shed	1.60 (1.66)	11.31 (11.76)	0.06 (0.27)	1.29 (5.76)	0.03 (0.18)	2.64 (15.99)	-	0.71 (5.08)	1.69 (1.13)	15.94 (10.69)	17.63 (11.82)
Feeding,tending, collection of grass	44.97 (46.75)	10.48 (10.89)	8.51 (36.42)	7.76 (34.67)	0.11 (0.67)	4.20 (25.44)	2.82 (20.19)	9.95 (71.22)	56.41 (37.85)	32.39 (21.73)	88.80 (59.58)
Taking care of pregnant animals	5.16 (5.36)	4.56 (4.74)	0.15 (0.67)	0.83 (3.71)	0.15 (0.92)	1.50 (9.09)	-	0.04 (0.29)	5.46 (3.66)	6.93 (4.65)	12.39 (8.31)
Collection of milk and eggs	1.65 (1.72)	0.66 (0.69)	-	-	0.005 (0.04)	0.65 (3.94)	-	-	1.66 (1.11)	1.31 (0.88)	2.97 (1.99)
Selling of milk and eggs	0.89 (0.92)	0.15 (10.16)	-	-	0.33 (2.00)	0.35 (2.12)	-	-	1.22 (0.82)	0.50 (0.34)	1.72 (1.16)
Purchasing of animals	1.24 (1.29)	0.09 (0.09)	-	-	-	-	-	-	1.24 (0.83)	0.09 (0.06)	1.33 (0.89)
Selling of animals	0.95 (0.99)	0.12 (0.12)	1.67 (7.46)	0.09 (0.40)	2.16 (13.09)	0.39 (2.35)	-	-	4.78 (3.21)	0.60 (0.40)	5.38 (3.61)
Nursing of diseased animals	0.11 (0.11)	2.21 (2.30)	-	-	-	-	-	-	0.11 (0.07)	2.21 (1.48)	2.32 (1.55)
Putting animals into shelter/taking out of shelter	5.16 (5.36)	4.89 (5.08)	0.57 (2.55)	1.44 (6.43)	0.01 (0.06)	3.98 (24.09)	-	0.45 (3.22)	5.74 (3.86)	10.76 (7.22)	16.50 (11.08)
Others	-	-	-	0.007 (0.03)	-	0.004 (0.02)	-	-	-	0.01 (0.01)	0.01 (0.01)
Total	61.73 (64.17)	34.47 (35.83)	10.96 (48.97)	11.42 (51.03)	2.80 (16.96)	13.71 (83.04)	2.82 (20.19)	11.15 (79.81)	78.31 (52.54)	70.74 (47.46)	149.05 (100)

Figures in parenthesis are percentages

Table 2. Activities done by farm size (man-days)

Activities	Large farm		Medium farm		Small farm		Landless farm		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Cleaning of shed	12.12 (5.32)	35.17 (15.42)	1.58 (0.97)	18.67 (11.52)	0.62 (0.40)	13.43 (8.68)	0.11 (0.09)	11.67 (10.00)	1.69 (1.13)	15.94 (10.69)
Feeding, tending, collection of grass	100.30 (43.99)	29.58 (12.97)	61.26 (37.78)	35.56 (21.92)	61.37 (39.70)	30.52 (19.75)	38.36 (32.86)	32.68 (27.99)	56.41 (37.85)	32.39 (21.73)
Taking care of pregnant animals	12.43 (5.45)	7.63 (3.35)	7.86 (4.84)	8.87 (5.58)	4.72 (3.05)	7.13 (4.62)	2.87 (2.46)	5.38 (4.61)	5.46 (3.66)	6.93 (4.65)
Collection of milk and eggs	3.46 (1.52)	1.75 (0.77)	3.43 (2.12)	1.40 (0.86)	1.06 (0.68)	1.05 (0.68)	0.60 (0.51)	1.37 (1.17)	1.66 (1.11)	1.31 (0.88)
Selling of milk and eggs	1.68 (0.74)	0.43 (0.19)	1.29 (0.79)	0.45 (0.28)	1.10 (0.71)	0.40 (0.26)	1.17 (1.00)	0.61 (0.52)	1.22 (0.82)	0.50 (0.34)
Purchasing of animals	0.36 (0.16)	-	1.93 (1.19)	0.02 (0.01)	1.52 (0.98)	0.11 (0.07)	0.79 (0.68)	0.15 (0.13)	1.24 (0.83)	0.09 (0.06)
Selling of animals	3.54 (1.55)	0.03 (0.01)	4.66 (2.87)	0.13 (0.08)	5.69 (3.68)	0.55 (0.36)	4.37 (3.74)	1.08 (0.93)	4.78 (3.21)	0.60 (0.40)
Nursing of diseased animals	0.01 (0.004)	-	0.44 (0.27)	0.18 (0.12)	0.03 (0.02)	6.92 (4.48)	-	-	0.11 (0.07)	2.21 (1.48)
Putting animals into shelter/taking out of shelter	8.97 (4.93)	10.56 (4.63)	7.61 (4.69)	6.81 (4.20)	6.27 (4.06)	11.92 (7.71)	3.33 (2.86)	12.18 (10.43)	5.74 (3.86)	10.76 (7.22)
Others	-	-	-	0.02 (0.01)	-	0.16 (0.10)	-	0.02 (0.02)	-	0.01 (0.01)
Total	142.87 (62.66)	85.15 (37.34)	90.06 (55.52)	72.11 (44.48)	82.38 (53.30)	72.18 (46.71)	51.60 (44.20)	65.14 (55.80)	78.31 (52.54)	70.74 (47.46)
										149.05 (100)

Figures in parenthesis are percentages

Contribution of women in family income through livestock raising

The contribution of male and female labour to gross income from livestock sources is shown in Table-3. The share of livestock income to total household income accounted for 30.82 per cent of which men's participation and women's participation constituted 52.54 per cent and 47.46 per cent, respectively.

Table 3. Share of male and female labour to livestock income (Taka)

Farm size	Male	Female	Total
Large	5837.94 (62.66)	3478.91 (37.34)	9316.85 (100)
Medium	3527.00 (55.52)	2825.67 (44.48)	6352.67 (100)
Small	2950.63 (53.30)	2585.27 (46.70)	5535.90 (100)
Landless	1736.88 (44.20)	2192.72 (55.80)	3929.60 (100)
All farms	2885.89 (52.54)	2611.25 (47.46)	5492.74 (100)

Source: Field survey, 1999.

It can be observed from the table that for large, medium, small and landless farms, the share of males to total livestock income was Tk. 5837.94, Tk. 3527.00, Tk. 2950.63 and Tk. 1736.88, respectively. The share of females to total livestock income was Tk. 3478.91 for large farms, Tk. 2825.67 for medium, Tk. 2585.27 for small and Tk. 2192.72 for landless farms. It can be noticed that the share of women to total livestock income increased with the decrease in farm size. The contribution of women in livestock income was found higher in landless farms (55.80%), followed by small (46.70%), medium (44.48%) and large farms (37.34%). This confirms the notion that women are playing a dominant role in generating family income by raising livestock and poultry, especially in the case of landless farms. However, they receive a significantly lower wage rate than their male counterparts in rural areas (Alam *et al.*, 2001; Jaim and Rahman, 1988; Karim & Begum, 1998).

Factors that motivate women to participate in livestock rearing

The factors that motivate women to participate in livestock raising activities is presented in Table 4. The influencing factors were economic and non-economic. The economic factors were increasing additional income for the family and increasing personal income of the female family members. The non-economic factors include utilization of idle women labour,

increasing women's status, supply of nutrition to family members, and to assist male family members in livestock raising activities. For all farms, the highest percentage of women opined for increasing family income (77.45%) followed by increasing personal income of the female members (52.72%).

Table 4. Factors motivating women to participate in livestock rearing

Factors	Percentage of respondents				
	Large	Medium	Small	Landless	All farms
Increasing personal and family income	58.50	70.13	72.73	90.74	77.45
Utilization of idle women labour	9.26	23.83	45.22	58.18	41.82
Supplying family nutrition through raising livestock	24.07	24.09	40.42	42.75	36.05
Increasing the status of female family members	34.54	44.20	55.56	60.11	52.72
Livestock rearing is easier for women than other economic activities	25.80	29.26	31.17	33.64	31.15
Assisting male members in livestock rearing activities	14.89	35.94	48.18	68.52	49.83

Source: Field survey, 1999

The opinions regarding increasing family income through livestock raising was the highest for landless farms (90.74%) followed by small (72.73%), medium (70.13%) and large farms (58.50%). It seemed that women in landless farms are more aware of increasing family income. The attitude of women in increasing income varied inversely with the farm size. Similar trend was also found in the case of increasing personal income of the women. It relates to the social security of women in the poor family. The percentage of respondents was the highest for all these motivating factors in landless farms, followed by small, medium and large farms. The factors were directly related with the involvement of women in different management practices for livestock production.

Consumption of livestock products from own source and on purchase

Consumption of livestock products from own sources is shown in Table 5. It is depicted from the table that three types of livestock products such as egg, milk and meat were consumed by the farm families under study. The average number of eggs, chicken, duck and pigeon consumed per family per month were calculated to be 3.68, 0.38, 0.02 and 0.07, respectively. The consumption of beef and pork were 0.0003 and 0.0004 kg per family per month, respectively and consumption of milk was 3.28 litres. The consumption of livestock product per family increased with the increase in farm size.

Table 5. Consumption of livestock products from own source per month

Farm sizes	Egg (No.)	Milk (litre)	Meat				
			Chicken (No.)	Duck (No.)	Pigeon (No.)	Beef (Kg.)	Pork (Kg.)
Large	8.69	5.93	1.08	0.05	0.28	0.004	0.02
Medium	5.51	5.43	0.43	0.03	0.11	-	-
Small	2.93	2.86	0.32	0.03	0.05	-	-
Landless	1.93	1.94	0.22	0.004	0.005	-	0.007
All farms	3.68	3.39	0.38	0.02	0.07	0.0003	0.0004

Source: Field survey, 1999.

Consumption of livestock products on purchase is shown in Table 6. The number of eggs, chicken, duck and pigeon consumed were 0.76, 0.12, 0.06 and 0.06, respectively per month. Consumption of beef, mutton and pork were 0.07kg, 0.04kg and 0.006kg, respectively. Consumption of milk on purchase was 0.60 litres. A positive relationship was found between farm size and consumption of livestock products on cash purchase. It revealed from the table that the quantity of eggs, milk, chicken and pigeon consumed from own sources was higher than that of purchased ones. On the other hand, consumption of duck meat, beef, mutton and pork from own source was lesser than that of purchased ones.

Table 6. Consumption of livestock products on purchase per month

Farm sizes	Egg (No.)	Milk (Litre)	Meat					
			Chicken (No.)	Duck (No.)	Pigeon (No.)	Beef (Kg)	Mutton/ Shaven (Kg)	Pork (Kg)
Large	2.53	2.94	0.35	0.10	0.21	2.66	0.26	-
Medium	0.78	0.65	0.12	0.09	0.08	1.24	0.07	0.02
Small	0.68	0.38	0.10	0.06	0.05	0.79	0.03	-
Landless	0.37	0.19	0.08	0.03	0.03	0.46	0.01	0.01
All farms	0.76	0.60	0.12	0.06	0.06	0.70	0.04	0.006

Source: Field survey, 1999.

Involvement of women in livestock processing activities

The different livestock processing activities such as preparation of curd, ghee, butter and butter-milk was analysed and results are presented in Table 7. The involvement of farm families in livestock processing activities was found very low. It was 55.56% for large farms and 20.29% for medium farms. It reveals that there have been more women's participation in curd making (18.52%) and butter milk processing (18.52%) activities in large farm group. No

involvement of women in livestock processing activities was found in small and landless farms. On average, the participation of women in livestock processing activities was only 9.67%.

Table 7. Livestock processing activities carried out by women by farm size (Number of household)

Items	Large	Medium	Small	Landless	All farms
Curds	10 (18.52)	10 (7.25)	-	-	20 (3.33)
Ghee	5 (9.26)	4 (2.90)	-	-	9 (1.50)
Butter	5 (2.66)	4 (2.90)	-	-	9 (1.50)
Butter-milk	10 (18.52)	10 (7.25)	-	-	20 (3.33)
Total	30 (55.56)	28 (20.29)	-	-	58 (9.67)

Source: Field survey, 1999. Figures in parenthesis are percentages.

Decision making process in rearing livestock and poultry

In decision making process of livestock production, many aspects such as, raising and selling of chicken/duck, goat/sheep, selling milk and eggs, treatment of animals and birds and tending the animals were considered. The respondents opinion regarding the decision making process is presented in Table 8. It can be observed from the table that for all farm families, the proportion of women's participation in decision making process for raising livestock was higher (53.40%). Women's participation in decision making was the highest for selling eggs (82.33%), followed by raising chicken/duck (77.17%), sale of chicken/duck (72.83%), sale of milk (61.33%), and was the lowest in the case of tending animals (27.17%). In most of the cases, decisions were made either by male or by female independently and instances of joint decisions were very low. The role of women in decision making was directly related with their magnitude of involvement in different management practices. Higher the rate of participation in different management practices for livestock production, higher was the rate of participation in decision making process. On the other hand, the rate of participation of men in decision making process was higher for rearing large animals. The rate of participation in decision making was directly related with the involvement of men and women in different management practices.

Table 8. Decision making process in rearing livestock by all categories of farms

Decision criteria	Rate of participation		
	Male	Female	Both
Chicken/Duck raising	20.17	77.17	2.66
Chicken/Duck selling	24.83	72.83	2.34
Goat/Sheep raising	40.33	58.17	1.50
Goat/Sheep selling	46.83	51.00	2.17
Milk selling	38.67	61.33	-
Egg selling	17.67	82.33	-
Cattle/Buffalo raising	61.50	37.00	1.50
Cattle/Buffalo selling	69.50	30.00	0.50
Livestock treatment	60.67	37.00	2.33
Tending animals	69.83	27.17	3.00
Average	45.00	53.40	1.60

Source: Field survey, 1999.

Suggestions for encouraging women in livestock rearing activities

Suggestions made by the farmers for the development of livestock and the measures to be undertaken to encourage the women in participating livestock rearing activities are presented in Table 9. The highest proportion of women opined for providing training facilities (75.14%), followed by ensuring veterinary services (57.33%), availability of improved variety of livestock and poultry (44.90%) and provision of credit facilities (43.43%). Provision of training facilities was supported by 57.14% large farms, 68.20% medium farms, 70.71% small, and 87.69% landless farms.

Table 9. Suitable policy measures for encouraging women's participation in livestock rearing and processing activities

Suggestions made by respondents	Percentage of respondents				
	Large	Medium	Small	Landless	All farms
Providing training facilities to the farmers	57.14	68.20	70.71	87.69	75.14
Extending credit facilities	10.05	20.82	50.21	60.02	43.43
Ensuring availability of improved variety of livestock & poultry	25.28	27.60	45.42	60.12	44.90
Ensuring veterinary services	18.78	32.35	68.95	70.08	57.33

Source: Field survey, 1999.

CONCLUSION

Although women participate extensively in raising livestock, they remain invisible in official statistics. Consequently, very little attention has been given to women's contribution in increasing agricultural production and thus agricultural programs have failed to exploit the potentiality of women. In order to improve the conditions of women in raising livestock the following suggestions are made:

- I) Women's participation in raising livestock should be properly accounted for the national income statistics. This will assist policy makers to integrate women's involvement into the mainstream of livestock programs, such as extension, research and credit.
- II) Women are playing a dominant role in poultry raising (contributing 83% of the total labour). Therefore, specialized extension services, credit facilities and market access for women should be ensured for generating income through poultry rearing.
- III) More studies on women's participation in rearing poultry under intensive, semi-intensive, backyard and SLDP/PLDP systems should be undertaken to determine their role in employment creation, income generation and poverty alleviation in future.
- IV) Government should provide supervised livestock credit without security at low rate of interest to small and landless farmers.

- V) The DLS and Non-Governmental Organizations should strengthen their programs on livestock management, animal health care, sanitation and marketing techniques on priority basis to assist women in making their production process profitable.
- VI) Appropriate arrangements should be made for farms run by women to ensure veterinary services, viz. vaccination, treatment, artificial insemination and supply of medicine in time.
- VII) Discrimination in wages between male and female members should be checked through interventions to be made by the Government and Non-Government Organizations.

REFERENCES

- Alam, J. (1995). *Livestock resources in Bangladesh : Present status and future potential*. Dhaka : University Press Limited.
- Alam, J. (1997). Impact of smallholder livestock development project in Bangladesh. *Livestock Research for Rural Development*, 9 (3).
- Alam, J. (2002). Smallholder livestock development project in Bangladesh : A socio- economic impact. *Bangladesh Journal of Livestock Research*, 7&8 (1&2).
- Alam, J., Yasmin, F., Sayeed, M. A., & Rahman, A. (1995). Economics of mini dairy farms in selected areas of Bangladesh. *Asian-Australasian Journal of Animal Science*, 8 (1).
- Alam, J., Sayeed, A., Rahman, A., Yasmin, A., & Begum, J. (1998). An economic study on poultry farms in Bangladesh. *Bangladesh Journal of Livestock Research*, 1 (2) to 5 (2).
- Alam, J., Sayeed, A., & Ray, S. K. (2001). *Women's participation in raising livestock in Some selected areas of Bangladesh*. Savar, Dhaka : Bangladesh Livestock Research Institute.
- Jaim, W.M.H., & Rahman, M.L (1988). Participation of women and children in agricultural activities : A micro level study in an area of Bangladesh. *Bangladesh Journal of Agric. Econ.*, 11 (1).
- Karim, R., & Begum, S. A. (1988). *Women's role in milch cow rearing : A study of two villages*. Kotbari, Comilla : Bangladesh Academy for Rural Development.

COLD TOLERANCE OF SOME EXOTIC RICE (*Oryza sativa* L.) AND ITS YIELD

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ABSTRACT

Cold injury of Boro (dry season irrigated crop) rice is a common physiological condition for northern part of Bangladesh. So far only one high yielding Bangladesh Rice Research Institute (BRRI) variety, BRRI dhan36, is reported cold tolerant. Therefore, exotic rice varieties were screened to use in breeding cold tolerant HYV at Rangpur Regional station of BRRI during 1999 through 2002. Out of seventy exotic rice varieties two entries could be released as future variety in Bangladesh. The entry IR61728-4B-2-1-1 significantly and consistently gave higher grain yield than BRRI dhan36 having almost similar growth duration. Grain yield of Sijung10 was statistically similar to BRRI dhan36 but matured earlier by about 10 days.

Key words: Boro rice, Cold tolerance, Yield, Randomized Complete Block Design.

INTRODUCTION

In the introduction of varieties from one country to another, day length and temperature variations are of primary concern together with pest reactions. Many of the photoperiod insensitive rice varieties could be grown year-round in a flood free land with irrigation facilities provided they are tolerant to high and/or low temperatures. However, low temperatures (5-10 °C) can become a limiting factor for growth of rice plants, especially at seedling and reproductive phases. Seedlings often show severe stunting, yellowing or death because of sudden fall of temperature below critical limit. For example, about 3.07% area of boro seedbed was damaged in greater Rangpur-Dinajpur regions during 1997-98 because of cold spell (6-11 °C) for about 10 consecutive days (Banik, 2001).

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Rice is most easily affected by low temperature ($<15^{\circ}\text{C}$) during the period from panicle initiation to end of blooming stage and the formation of pistil and stamen primordia (Vergara & Lilis, 1968). These causes delayed heading, incomplete panicle exertion, spikelet sterility and formation of abnormal grains (Banik, 2001). However, seedling height, root length and dry matter accumulation at seedling stage are also influenced by cold spell (BRRI, 2001). More details of low temperature ($7\text{--}15^{\circ}\text{C}$) effects on rice have been reported by Ishizuka et al. (1973).

Bangladesh Rice Research Institute has so far released 41 varieties, but only one of them is reported cold tolerant (BRRI, 2001). This indicates that more cold tolerant varieties are needed with other desirable traits for drier and cooler regions of the country. Therefore, experiments were conducted with exotic rice varieties to find out cold tolerant rice genomes and to determine its agronomic performance in regards to grain quality, yield and growth duration.

MATERIALS AND METHODS

The experiment was conducted at Rangpur Regional station of Bangladesh Rice Research Institute during 1999 through 2002. Rice varieties were used as treatments. Seventy exotic rice genotypes were evaluated for cold tolerance and compared with BRRI dhan36. A Randomized Complete Block Design (RCBD) was used with two replications. Fertilizer was applied @ 120-26-50-30 kg/ha of N-P-K-S, respectively from urea, Triples Super Phosphate (TSP), Muriate of Potash (MP) and gypsum. Full dose TSP, MP and gypsum was applied at final land preparation. Urea was applied in three equal doses, one third at 15 Days After Transplanting (DAT), one third at 55 DAT and the rest at 70 DAT. Sixty-day-old single seedling was transplanted on 18 February at 30 x 10- cm spacing. Cold tolerant score was determined following standard evaluation system for rice (IRRI, 1996) and only 8 genotypes were selected initially for further evaluation.

In 2000/2001, selected eight entries were grown in a randomized complete block design with 3 replications for determination of agronomic performance in relation to grain yield and growth duration. Fertilizers were applied similarly except the rate of urea, which was used at 100 kg N/ha. This lower N rate was used based on previous year's experience of excessive vegetative growth of rice. Thirty-day-old 3-4 seedlings/hill was transplanted on 4 December 2000 at 20 x 20- cm spacing. In few genotypes viviparous germination was observed, so only 4 entries were selected and was further evaluation in 2001/02 Boro season. Forty-day-old seedlings were transplanted on 20 January. Other cultural practices of second year (2000/2001) were followed in 2001/02 Boro season.

Plant height, panicle number, panicle exertion, grain yield and growth duration was recorded. Grain yield was adjusted at 14% moisture content. Collected data were analyzed by IRRISTAT and means were compared following DMRT.

RESULTS AND DISCUSSION

Low temperature below critical level of 10 °C generally prevails during December and January in Rangpur regions (Fig. 1.). As a result Boro rice suffered from cold injury at different

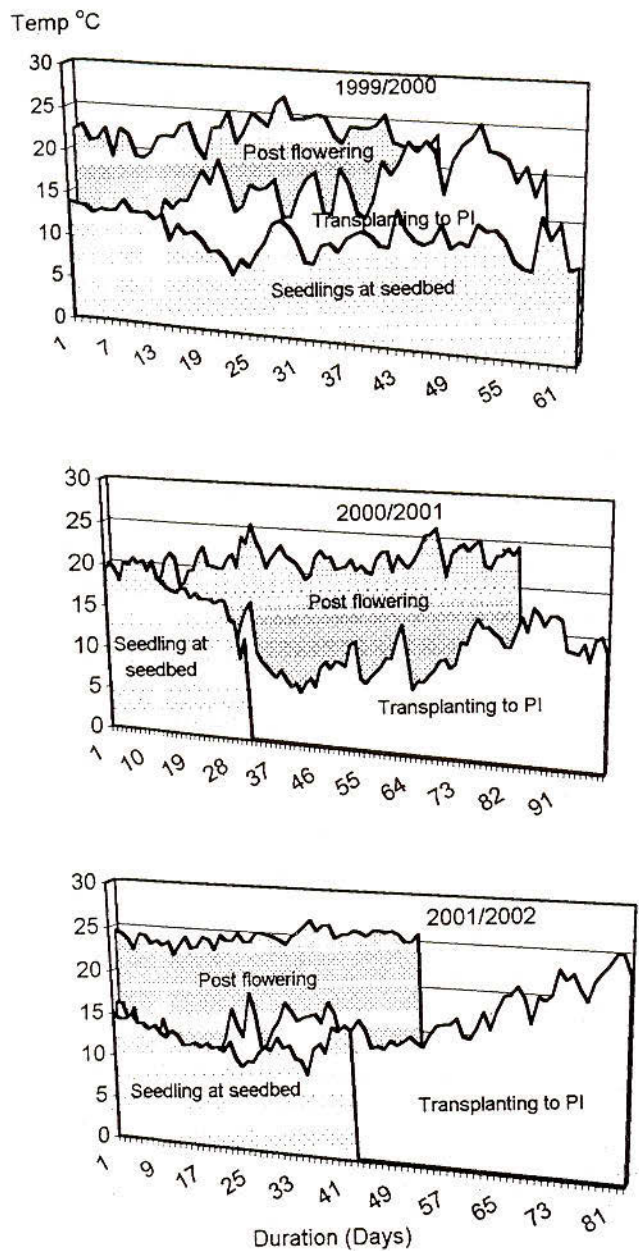


Fig. 1. Duration of minimum temperature at different growth stages of rice plant.
(Source: Weather station, Rangpur)

growth stages depending upon crop establishment. Because of prevailing low temperature different genotypes showed variable response to low temperature. Considering seedling height and color, panicle exertion score, spikelet fertility score, grain yield and phenotypic acceptability 8 genotypes were selected in first year. The genotype IR61728-4B-2-1-1 showed more cold tolerant score and produced higher grain yield than BRRI dhan36 (Table 1). The highest grain yield was recorded in Yungeng135 followed by H257-2-1-1, IR61728-4B-2-1-1 and Akenohashi (Table 1). These genotypes were superior to BRRI dhan36 in terms of grain yield.

Table 1. Grain yield and some other characteristics of selected exotic rice genomes, Boro, 1999/2000. BRRI, Rangpur

Genotype	Seedling height (cm)	Color of seedling	Plant height (cm)	Panicle (No/hill)	Panicle exertion score	Spikelet fertility score	Grain yield (g/hill)
H231-23-1-1	14.4	Green	95	10	1	3	20.11
H257-2-1-1	15.2	Light green	103	7	1	1	29.30
K78-13	23.0	Dark green	96	10	1	3	19.00
IR61728-4B-2-1-1	17.4	Dark green	98	15	1	1	23.59
IR64630-16-2-3	25.8	Light green	98	9	1	3	19.84
Sijung10	23.8	Green	88	9	1	3	21.18
Yungeng135	25.4	Dark green	106	8	1	3	47.56
Akenohashi	13.0	Dark green	79	14	1	3	22.40
BRRI dhan36	14.2	Green	86	8	1	3	20.75

Grain yield of IR61728-4B-2-1-1 was significantly and consistently higher than BRRI dhan36 with almost similar growth duration (Table 2 & 3). However, Sijung10 matured a few days earlier than BRRI dhan36 having statistically similar grain yield (Table 2 & 3). Plant heights were significantly higher in exotic rice compared to local check (Table 2 & 3). More fertile grains were found in exotic rice than local check (Table 3). Grains of all selected rice genomes are of bold type. Growth duration varied greatly (Table 2 & 3) because of variation in exposure duration of rice plants to cold temperature (Fig. 1) indicating that some exotic rice tolerate cold spell but not resistant to cold temperature.

From this trial it is concluded that IR61728-4B-2-1-1 and Sijung10 performed better than the existing cold tolerant BRRI dhan36 variety in terms of grain yield or growth duration in cooler and drier part of Bangladesh.

Table 2. Agronomic performance of some selected cold tolerant rice genome, Boro 2000/2001. BRRI, Rangpur.

Genotype	Plant height (cm)	Partially exerted panicle (No/hill)	Panicle (No/hill)	Grain yield (t/ha)	Growth duration (Days)
H231-23-1-1	102.1c	0.8	19.5ef	6.02c	189
H257-2-1-1	110.7e	1.1	14.6c	6.84d	189
K78-13	109.5e	1.0	16.4cd	5.20b	178
IR61728-4B-2-1-1	106.1d	0.6	22.3g	7.12d	186
IR64630-16-2-3	103.4cd	0.4	16.7d	7.14d	186
Sijung10	105.0cd	0.2	12.4b	6.24c	170
Yungeng135	120.4f	1.6	9.7a	3.68a	178
Akenohashi	75.6b	1.2	18.1de	5.82c	182
BRRI dhan36	72.0a	0.7	20.6fg	6.17c	178
CV(%)	1.8	-	6.8	5.2	-

Letters in a column compare means at 5% level by DMRT.

Table 3. Agronomic performance of selected cold tolerant rice, Boro 2000/2001. BRRI, Rangpur

Genotype	Plant height (cm)	Panicle (No/hill)	Grains/panicle	Sterile spikelet/panicle	Grain yield (t/ha)	Growth duration (Days)
H257-2-1-1	104.3d	8a	151c	13b	5.72a	160
IR61728-4B-2-1-1	102.3cd	13b	113a	9a	6.85b	160
IR64630-16-2-3	98.2bc	11b	132b	19c	6.11a	160
Sijung10	92.7b	11b	145bc	11b	5.89a	144
BRRI dhan36	75.0a	12b	107a	15bc	6.09a	160
CV(%)	2.8	5.6	7.8	10.2	6.7	

Letters in a column compare means at 5% level by DMRT.

Correlation coefficients of some parameters

	Grains/panicle	Grain yield
Panicle/hill	-0.717*	0.714*
Grains/panicle		-0.713*

REFERENCES

- Banik, M. (2001). Cold injury problems in boro rice. *In proceedings of the Workshop on Modern Rice Cultivation in Bangladesh* (pp 37-43). Gazipur : Bangladesh Rice Res. Inst.
- Bangladesh Rice Research Institute (BRRI). (2001). *Annual Internal Review for July 2000 – June 2001*. Gazipur : Plant Physiology Division, Author.
- International Rice Research Institute (IRRI). (1996). *Standard Evaluation System for Rice* (4th ed). Los Baños, the Philippines : Author.
- Ishizuka, Y., Shimazaki, Y., Tanaka, A., Satake, T., & Nakayama, T. (1973). *Rice growing in cool environment*. Taiwan : Food and Fertilizer Technology Centre.
- Vergara, B. S., & Lilis, R. (1968). Studies on the response of the rice plant to photoperiod : Effect of temperature during photo-induction. *Philippine Agriculturist*, 52 (2), 66-71.

FARMER'S PREFERENCES AND INDIGENOUS PRACTICE OF FODDER TREES IN COMILLA FLOOD PLAIN AREA OF BANGLADESH

M. D. MIAH¹ AND M. K. NOMAN¹

ABSTRACT

*This article focuses on the indigenous practice of the use of fodder trees in the flood plain area of randomly selected 40 households sampled from Homna Upazilla of Comilla District, Bangladesh. The study was to find farmer's ranking of fodder tree species of their choice, their criteria for assessing fodder trees, uses, management, niches and ways of establishment. Kapila (*Garuga pinnata*) and Mandar (*Erythrina indica*) were the first and second most preferred fodder tree species by all categories of households. The most frequently mentioned criteria were palatability and the ability of the fodder to satisfy the hunger of the animal. Among delayed leaf senescence is considered as an important criteria of selection of fodder trees. Fodder trees were mostly used to feed the goat and sheep especially during the rainy season. All the households used the top most two preferred fodder species as live stake and support tree for climber like vegetable plant and over 90% of the farmers used these two species as live fence. Most of the fodder trees were found in home compounds established naturally. Satisfactory management techniques for fodder species were not followed by any household category. The study has helped to identify the species for further research and development activities, with the aim of improving their productivity and disseminating them among the farmers.*

Key words: Fodder trees, Indigenous knowledge, Feeding season, Flood plain area.

INTRODUCTION

Bangladesh has a predominantly agrarian economy in which livestock management forms an integral part of its farming systems. The contribution of livestock sub-sector to the

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country's GDP is around 3% and to agricultural GDP around 9%. Livestock contributes 72% (BBS, 1996) of drought power to agriculture and provides full time employment to about 20% of the rural population generating cash income for the rural poor with a small amount of investment (BBS, 1996). But there is a severe shortage of fodder to maintain the livestock in Bangladesh. The cultivation of fodder crops has been decreasing day by day. In the past, livestock of the country had to depend mostly on the natural pastures of rural areas and the rice straw. But due to increasing pressure of human population, most of these pastures have now been brought under agricultural cultivation. Now ruminants of Bangladesh are normally fed with rice straw, field weeds and by products of other agricultural crops. The feed they receive is not only insufficient, but also inferior in quality. The nutritive value of crop residues and by products is very low compared to that of feeds used in the developed countries. Per capita land holding in Bangladesh is approximately 0.12 ha which is one of the lowest in the world (BBS, 2001). Due to flood devastation, agricultural residues are often spoiled and all types of grazing lands are inundated. Hence, the large gap between the availability and requirements of animal feeds in Bangladesh can be supplemented by the utilization of fodder trees as feed sources.

Many of the tree leaves are usually nutritious because deep root system of trees allow them to draw nutrients from deeper parts of the soil. Fodder trees are often used as a buffer to overcome feed gaps that arise from seasonal fluctuations of the productivity of other feeds. For example, grasses and other herbs may die moisture during the dry season or in times of drought, some species stay green and provide green forage rich in protein, minerals and vitamins. Most often better than herbaceous crops. Fodder trees are also the important source of green forage during the flood period when all types of communal grazing land and pasture areas are inundated as well as post flood period when fodder shortage is acute. Some of the leguminous species are important both in providing fodder for livestock and in enhancing soil fertility for crops.

Indigenous knowledge is important not just in terms of the description, proper management and harvesting of a product, but also in terms of the maintenance of the ecological processes and biodiversity linked to traditional economic activities. Recognizing harmonious relationship with nature, indigenous sustainable development strategies and cultural values are to be preserved to support farming. Most of the fodder trees are multipurpose in nature for traditional farming systems in Bangladesh. Over the past two decades, the importance of farmer's indigenous knowledge in managing their natural resources has gained increasing recognition from the scientific community (Rist, 1991) and rural development planners are paying particular attention to use of such local knowledge (Chambers *et al.*, 1989). An increasing volume of literature exists that documents indigenous systems for the management of natural resources by local people, and illustrates how such knowledge could be usefully applied in the development context (Thapa, 1994). However, relatively little work has so far been conducted on farmer's indigenous practice on fodder trees and shrubs in the flood plain areas of Bangladesh. Traditional knowledge and management fodder trees offer relevant techniques and insights for foresters and other relevant scientists. Roothaert (2000) hypothesized that knowledge of individual farmers are consistent enough to form a basis for

selecting the most useful fodder species. In addition, farmer's preferences and cultural practices also need to be considered when species are screened for their appropriateness. Farmers in some parts of the world have some practical knowledge about the quality of fodder trees (Bayer, 1990 and Thapa *et al.*, 1997). Taping this knowledge would be much faster and cheaper than carrying out elaborate analysis in laboratories for the purpose of screening the nutritive values of trees. However, previous studies in this field have shown variable correlation between farmer's knowledge and laboratory assessment (Thapa *et al.*, 1997). It was hypothesized that there is a strong relation between farmer's assessment and the combination of laboratory analysis, and that farmer's assessment could be used more often in future to save time and costs (Roothaert, 2000).

The economy of Comilla region is mainly agro based as the other floodplain areas of Bangladesh. Of the total 6,72,620 holdings of the district 71.73 per cent have farms that produce varieties of crops. Besides crops, rearing of livestock and poultry are also the main sources of household income. The total population of bovine animal in the Comilla region is around 7,11,900 which was 3.16 per cent of the country, and goat-sheep was 413,889 which is 2.83 per cent of Bangladesh (BBS, 1996). Livestock is an integral part of farming systems in the Comilla region and forms the main source of drought power for most of the agricultural operations in the villages of Comilla district. Comilla region is affected by flood almost every year. All types of grazing land are inundated as well as field crops are destroyed. As a result feed shortage is the major constraint to the rearing of livestock during the rainy season in Comilla region. Fodder trees may be a good alternate source of green forage during the flood and post-flood periods. Investigation on indigenous practice of the use of fodder trees in the Comilla region is to be done to show the contribution of the fodder trees. Comilla region has important fodder trees and particular indigenous practice to rear the livestock in the feed scarcity period. Taking this hypothesis, the study was undertaken to assess the farmers' dependence on fodder trees during the feed scarcity i.e. mainly during the rainy season and post flood periods and also to assess the farmer's indigenous knowledge on the use of fodder trees and shrubs.

Study area: The study was conducted in Homna Upazilla of Comilla district, Bangladesh. Homna Upazilla occupies an area of 180.13 sq km including 13.16 sq km river area. It is situated in the northwest portion of the Comilla district and at the distance of approximately 66 km from the district town. Homna Upazilla is located between 23° 37' and 23° 45' north latitudes and between 90° 38' and 90° 53' east longitudes (BBS, 1995). Homna Upazilla includes the tropical monsoon climate. Rainy season generally lasts from the month of May to October. The lowest temperature is observed in the months of December and January with an average of 19.5°C. Mean annual temperature is 25.5°C. The average rainfall is 69 mm in winter season and the annual rainfall is 2131mm (SRDI, 1999). The lowest humidity recorded in the month of February was 77%. From April to next January humidity remains above 80% (BBS, 2001). The whole Homna Upazilla is included in the Middle Meghna River Floodplain. The middle Meghna Floodplain soils are occurring in the north as grey sandy loams of the *Tanger-Char-Fuldi* association, in the middle as *Barela-Silmandi* grey silty clays and in

the south as Tanger–Char- Border gray sandy loams. The soil pH ranges from 4.9 to 6.9 (SRDI, 1999). Homna Upazilla has a population of 211,563 of which 106,222 are males and 105,341 are females. The density of population is 1,174 per sq km. The sex ratio of the Upazilla is 101 males per 100 females. In Homna Upazilla, 64.68% of the dwelling households own and 35.32% don't own agricultural land. In the Upazilla, 57.35% of the dwelling households depend on agriculture as the main source of household income with 42.40% on cultivation/share cropping, 3.07% on livestock, forestry and fishery, 0.13% on pisciculture and 11.75% as agricultural labor. Other sources of household income are non-agricultural labor (2.00%), business (11.17%) and employment (4.48%) (BBS, 1995).

Sampling method: From the middle Meghna River Floodplain landscapes, Comilla region was selected in this study. There were 13 Upazillas in Comilla District. Out of the 13 Upazillas, one (Homna Upazilla) was selected purposively. The reason is that the study area is low-lying and three sides of the area are surrounded by the river and is a regularly flooded during monsoon. So farmers to depend on fodder trees during rainy season for rearing their livestock. There were 10 unions in Homna Upazilla; one village from each union was selected at random i.e. a total of 10 villages were studied. In each of the villages stratified random sampling technique was adopted. As rearing of livestock and production of fodder trees are the functions of household farming, the farmers were stratified into marginal (0.21-0.50 ha), small (0.51-1.00 ha), medium (1.01-2.00 ha) and large (above 2.00 ha). Out of this stratification, 40 households, 4 from each village of which one belongs to each stratum i.e. overall 10 from each stratum were then selected randomly forming a total of 40 households. Farmers without cows and goats were excluded from the survey.

Data collection: Study was conducted to collect data by interview method using a pre-sorted questionnaire during June–August, 2001. Interviews began with a tour to the households to find the principal fodder trees used by farmers. Data were collected from male heads or other important respondents and related socio-economic information were also collected. Farmers were asked to rank their ten most important fodder tree species in order of importance through the method of tree use matrix. Total score of each species was then determined.

Data processing: The surveyed questionnaire was processed through a database program. Tabular methods of analysis were used to present the data.

RESULTS AND DISCUSSION

Farmer's most preferred fodder trees: Kapila (*Garuga pinnata*) and Mandar (*Erythrina indica*) was the first and second most preferred species in all types of household securing the score of highest and second highest respectively; because of their palatability, availability and ease of propagation (Table 1). Menda (*Litsea polyantha*) was the third most

Table 1. Farmer's most preferred top ten fodder trees at Homna Upazilla, Comilla, Bangladesh

Farm category											
Marginal			Small			Medium			Large		
Species	No. of respond- ents ^a	Score ^b	Species	No. of respond- ents ^a	Score ^b	Species	No. of respond- ents ^a	Score ^b	Species	No. of respond- ents ^a	Score ^b
Kapila (<i>Garuga pinnata</i>)	10	94	Kapila(<i>Garuga pinnata</i>)	10	89	Kapila (<i>Garuga pinnata</i>)	10	95	Kapila (<i>Garuga pinnata</i>)	10	92
Mandar (<i>Erythrina indica</i>)	10	85	Mandar (<i>Erythrina indica</i>)	10	83	Mandar (<i>Erythrina indica</i>)	10	80	Mandar (<i>Erythrina indica</i>)	10	81
Menda (<i>Litsea polyantha</i>)	9	60	Menda (<i>Litsea polyantha</i>)	8	63	Menda (<i>Litsea polyantha</i>)	8	67	Bot (<i>Ficus benghalensis</i>)	9	70
Sheora (<i>Streblus asper</i>)	8	49	Sil Koro (<i>Albizia procera</i>)	7	44	Dumur (<i>Ficus racemosa</i>)	6	39	Menda (<i>Litsea polyantha</i>)	7	51
Sil Koro (<i>Albizia procera</i>)	8	36	Sherora (<i>Streblus asper</i>)	10	32	Sheora (<i>Streblus asper</i>)	9	35	Sheora (<i>Streblus asper</i>)	10	38
Jiban (<i>Trema orientalis</i>)	6	30	Bamboo (<i>Bambusa spp.</i>)	5	24	Bot (<i>Ficus benghalensis</i>)	6	23	Bamboo (<i>Bambusa spp.</i>)	9	28
Bamboo (<i>Bambusa spp.</i>)	6	21	Jiban (<i>Trema orientalis</i>)	5	19	Bamboo (<i>Bamusa Spp.</i>)	5	17	Dumur (<i>Ficus racemosa</i>)	6	22
Am (<i>Mangifera indica</i>)	5	19	Dumur (<i>Ficus racemosa</i>)	4	17	Silkoroi (<i>Albizia procera</i>)	5	15	Boroi (<i>Ziziphus mauritiana</i>)	6	18
Boroi(<i>Ziziphus mauritiana</i>)	5	12	Am (<i>Mangifera indica</i>)	6	17	Ipil-ipi(<i>Leucaena leucocephala</i>)	4	14	Jiban (<i>Trema orientalis</i>)	5	18
Dumur (<i>Ficus racemosa</i>)	4	11	Boroi (<i>Ziziphus mauritiana</i>)	5	14	Jiban (<i>Trema orientalis</i>)	6	14	Ipil-ipil (<i>Leucaena leucocephala</i>)	5	15

Note: ^a Number of respondents who included the species in the top ten. Sample size was 10 in each household category.

^b If a farmer ranked the species first, it received a score of ten, if second, a value of 9, if third, a value of 8 etc. Scores shown are sums of individual farmer's score

preferred species in all categories of farmers except the large category because naturally grown Menda (*Litsea polyantha*) was available both in homestead as well as roadsides of the study area and the palatability was also high. Sheora (*Streblus asper*) was the fifth most preferred species in small, medium and large farmers sheora was the fourth preferred species among the marginal farmers because this species was self-shown and available in the study area. Leaves of Sheora have better palatability and Sheora has other uses.

Only two fruit species such as Am (*Mangifera indica*) and Boroi (*Ziziphus mauritiana*) appeared in the top most ten preferred fodder species rating the lower score because it was reported that due to the lessening of fruit production, fodder was not collected frequently from the horticultural trees. Am (*Mangifera indica*) was included in the top most ten preferred fodder species only in marginal and small farmers due to fodder constraints and ranked eighth and ninth, respectively. No exotic species appeared in the top most ten desired species of marginal and small farmers. Only one exotic tree, Ipil-ipil (*Leucaena leucocephala*) appeared in the list of top most ten preferred fodder species of medium and large farmers rating the lowest score. The reason for not preferring the exotic species as fodder may be that farmers were not familiar with the palatability and other quality of that. It was also reported that Kanthal (*Artocarpus heterophyllus*) was one of the top most preferred fodder species but farmers did not rank them due to its non-availability. During the last two floods in 1988 and 1999, almost all the Kanthal species died. All or most of the Kanthal species found in the study area were in sapling stage and in recent times farmers were reluctant to plant Kanthal (*A. heterophyllus*) because of frequent flood. Thus the study infers that not only palatability but also availability affects the preference and ranking of fodder trees in the study area.

Farmer's evaluation of fodder trees: Farmer's criteria for evaluating fodder trees were either animal-related (e.g. palatability or affects on animal nutrition) or tree-related (such as drought resistance or no dropping of leaves) as shown in the Table 2. In all farm categories, the most frequently mentioned criteria were palatability and the ability of the fodder to satisfy the hunger of the animal among the different animal-related criteria. Contributions to the animal health were also important. Effect on milk production was not important to the marginal and small farmers but important to the medium and large farmers. Among the tree-related criteria, no dropping of leaves was the most frequently mentioned criterion in all types of household. Compatibility with other crops was also important. Drought resistance of the tree and effect on soil fertility were not important to the marginal and small farmers but had importance to the medium and large farmers. Even though farmers did not define those criteria, they found them relatively easier to assess and were consistent in their assessments.

Feeding and other uses: All of the farmers used the top most two preferred fodder trees to feed their goat and sheep. Other fodder species as shown in the Table 3 were also fed to the goat by all of the farmers except Bamboo (*Bambusa spp.*), Ipil-ipil (*Leucaena leucocephala*), and Dumur (*Ficus racemosa*). All of the farmers fed the Kanthal (*Artocarpus heterophyllus*) and Bot (*Ficus benghalensis*) to their sheep and over 50% of the farmers used all other species to feed the sheep except Ipil-ipil (*L. leucocephala*). Bamboo (*Bambusa spp.*) was

fed to the cattle and buffalo by all of the farmers and no other species were fed to the buffalo but Sheora (*Streblus asper*) and Dumur (*Ficus racemosa*) were fed to the cattle by 45% and 75% of the farmers, respectively (Table 3). Study indicates that fodder trees were mostly used to feed the goat and sheep.

Table 2. Criteria used by the farmers to evaluate the fodder trees and percentages of respondents in each farm category

Criteria	Farm category			
	Marginal	Small	Medium	Large
Animal-related	(Percentage of respondents)			
Satisfies hunger of animals	100	100	100	100
Improves health of animal	60	70	80	80
Palatability	100	100	100	100
Improves milk production	0	0	30	20
Tree-related				
Drought resistance	0	0	10	30
Compatibility with other crops	90	80	90	90
Improves soil fertility	0	0	20	30
No dropping of leaves	100	100	100	100

All of the farmers used all the fodder trees during the rainy season and only Bamboo (*Bambusa spp.*) throughout the year. 25 to 60% of the farmers used some selected evergreen fodder species such as Mander (*Erythrina indica*), Menda (*Litsea polyantha*), Sheora (*Streblus asper*), Kanthal (*Artocarpus heterophyllus*), Boroï (*Ziziphus mauritiana*), Am (*Mangifera indica*), Dumur (*Ficus racemosa*) and Bot (*Ficus benghalensis*) etc. throughout the year (Table 3). The most common parts of the selected species eaten are the twigs and leaves. For some species, some farmers preferred to feed only the leaves. Fruit wastes (rind) of Jackfruit/Kanthal (*Artocarpus heterophyllus*) were fed by all livestock of the farmers and Am wastes (skins of ripen mango) were eaten by 60% of the cattle of the farmers (Table 3).

Nearly all species were reported to have other uses (Table 3). Among the most preferred fodder species, all were used for fuel wood. Kanthal (*A. heterophyllus*), Bamboo (*B. spp.*), Ipil-ipil (*L. leucocephala*) and Silkroï (*A. procera*) were used by the 100% of the farmers for timber, poles, construction etc. Over 90% of the farmers used top most two preferred fodder species such as Kapila (*Garuga pinnata*) and Mandar (*Erythrina indica*) as live fence. All of the households used the two most preferred fodder species as live stake and support for climbers like vegetable plant e.g. bean, pumpkin, cucumber, groundnut etc. Feeding of bamboo leaf to the cow after delivery (calving) was done by all the farmers as indigenous treatment, which enhances the removal of placenta from the uterus. Other uses of fodder trees and shrubs include fruit and seeds.

Table 3. Fodder management and other uses of reported fodder trees at Homna Upazilla, Comilla, Bangladesh.

Parameters	Name of the species												
	Kapila (<i>G. pinnata</i>)	Mandar (<i>E. indica</i>)	Menda (<i>L. polyantha</i>)	Sheora (<i>S. asper</i>)	Kanthal (<i>A. heterophyllus</i>)	Boro (<i>Z. mauritiana</i>)	Am (<i>M. indica</i>)	Bamboo (<i>B. spp.</i>)	Ipil-ipl (<i>L. leucocephala</i>)	Silkoroi (<i>A. procera</i>)	Dumur (<i>F. racemosa</i>)	Bot (<i>F. benghalensis</i>)	Jiban (<i>T. orientalis</i>)
Animal feed							(Percentage of respondents)						
Cattle	0	0	0	45	0	0	0	100	0	0	75	0	0
Goat	100	100	100	100	100	100	100	60	77	100	85	100	100
Sheep	100	100	80	82.5	100	90	72	55	47	50	82	100	60
Buffalo	0	0	0	0	0	0	0	100	0	0	0	0	0
Feeding season							(Percentage of respondents)						
Rainy season	100	100	100	100	100	100	100	100	100	100	100	100	100
Throughout the year	0	50	30	55	35	52.5	32.5	100	0	0	60	25	0
Parts fed							(Percentage of respondents)						
Leaves only	0	0	100	0	100	100	100	0	0	0	0	100	0
Twigs and leaves	100	100	0	100	0	0	0	100	100	100	100	0	100
Fruits or Pods	0	0	0	0	100	0	60	0	0	0	0	0	0
Other uses							(Percentage of respondents)						
Timber, poles, construction	30	0	32	0	100	90	70	100	100	100	0	0	0
Fuel wood	100	100	100	100	100	100	100	100	100	100	100	100	100
Live fence	92	90	25	10	0	0	0	0	0	0	0	0	0
Live stake/support tree	100	100	12.5	0	0	95	10	0	0	0	0	0	0
Medicine (human, vet., antidote)	0	0	0	47	0	0	0	100	0	0	0	0	0
Fruit	0	0	0	0	100	100	100	0	0	0	75	0	0
Seeds	0	0	0	0	100	0	0	0	80	0	0	0	0
Fibers, ropes	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: Percentage was determined only in case of respondents possessing the specific type of species and livestock. The analysis of all the household categories is combined, as the results of all the parameters are almost similar.

Niches, establishment and management: Niches varied considerably among the species (Table 4). In the study site, fodder trees were not found scattered in grazing land or cropland. External farm boundaries (margin of crop field close to the homestead) were important for indigenous fodder trees, especially for Kapila (*Garuga pinnata*), Mandar (*Erythrina indica*), Am (*Mangifera indica*) and naturalized Menda (*Litsea polyantha*). The first two were grown in hedges and served as live fence. Most of the fodder species were found in home compounds or off the farm (Table 4).

Most of the indigenous fodder trees were established naturally (Table 4), once planted they were protected and allowed to grow. In the study area, Kapila (*Garuga pinnata*) and Mandar (*Erythrina indica*) were established through the planting of large branch/stem cuttings by all households. All the farmers propagated bamboo (*Bambusa spp.*) through the planting of cut culm with rhizome (Table 4). Farmers were also aware of other propagation methods. For some species farmers were aware that they could be planted using seeds or seedling/sapling.

Pruning was common in the study area, where farmers pollarded the branches for the purpose of harvesting of animal feed (Table 4). Maximum farmers pruned their trees primarily with the hope to get more fruits in future and also for straight pole, while pruning for animal feed was comparatively less. Some farmers also harvested twigs and leaves for feeding their livestock. Farmers did not coppice for the purpose of harvesting animal feed at height, which seems to be related to the potential height of the tree. Most of the farmers also harvested fodder in unsystematic way (indiscriminate lopping), which ultimately affected on the fruit production and re-growth of the plant. Browsing of fodder was not common and cut-and-carry system was mostly practiced.

Parameters	Name of species												
	Kapila (<i>G. pinnata</i>)	Mandar (<i>E. indica</i>)	Menda (<i>L. polyantha</i>)	She ora (<i>S. asper</i>)	Kanthal (<i>A. heterophyllus</i>)	Boroi (<i>Z. mauritiana</i>)	Am (<i>M. indica</i>)	Bamboo (<i>B. spp.</i>)	Ipil-ipil (<i>L. leucocephala</i>)	Koroi (<i>A. Procera</i>)	Dumu (<i>F. racemosa</i>)	Bot (<i>F. benghalensis</i>)	Jiban (<i>T. orientalis</i>)
Niche	(Percentage of respondents)												
External farm boundary	67	75	42	10	0	15	20	0	0	10	0	0	0
Within the home compound	100	82	85	100	100	95	97	100	100	100	100	5	100
Scattered within the food crops	0	0	0	0	0	0	0	0	0	0	0	0	0
Scattered within grazing land	0	0	0	0	0	0	0	0	0	0	0	0	0
Establishment	(Percentage of respondents)												
Natural	0	15	100	100	67	85	80	0	0	52	100	100	100
Cuttings/Budding	100	100	0	0	0	25	0	100	0	0	0	0	0
Other known propagation methods	(Percentage of respondents)												
Seed/Seedling	0	0	0	0	85	37	100	0	100	90	0	0	0
Roots	0	0	0	0	0	0	0	0	0	0	0	0	0
Cutting management	(Percentage of respondents)												
Small branches with leaves/Pollard/Pruned branches	70	100	100	100	100	100	100	100	100	100	100	100	100
Twigs and leaves (Rachis)	95	45	0	0	0	0	0	65	0	0	0	0	0
Coppice at knee height	0	0	0	0	0	0	0	0	0	0	0	0	0
Coppice above 1 meter	0	0	0	0	0	0	0	0	0	0	0	0	0
Browsing	0	0	0	25	0	0	0	22	0	0	0	0	0

Note: Percentage was determined only in case of respondents possessing the specific type of species. The analysis of all the household categories is combined, as the results of all the parameters are almost similar.

CONCLUSION

Traditional ecological knowledge is the basis for local-level decision-making in areas of contemporary life, including natural resource management, nutrition, food preparation, health, education, and community and social organization (Warren *et al.*, 1995). The study has provided important information from farmers of a selected floodplain area of Bangladesh for setting priorities among indigenous and exotic fodder trees for research and development. The indigenous knowledge on fodder trees explored from the flood plain area of Comilla region may be an important tool to plan the livestock management in respect of nutrition, especially setting priorities in the crisis period. The policy maker, livestock professionals and foresters may use this knowledge to develop the livestock resources in Bangladesh. The present findings represent that indigenous knowledge on fodder trees may be important part for the development of fodder status through the proper combination of researcher's scientific knowledge with the farmer's indigenous knowledge. More research is also needed on chemical composition, nutritive and antinutritive qualities and toxicity of the fodder trees and shrubs available in the study area. The relationship between farmer's assessments of fodder trees and laboratory nutritive analysis is required. The potentiality of livestock feeds that can be obtained from trees is not well perceived by the farmers. Therefore, these valuable feeds are not utilized to their full extent for feeding all types of livestock.

There is an urgent need to quantify available biomass from trees and shrubs at the farmer's level and to incorporate these into the rations of village ruminants for improving straw-based diets. Research is needed to arrive at recommended inclusion levels of tree fodder in the diets of livestock using tree species that have proved compatible in the farming system of other countries.

REFERENCES

- Soil Resource Development Institute (SRDI), Ministry of Agriculture, Government of the People's Republic of Bangladesh. (1999). *Bhumi and Mrithika Sampad Bebahr Nirdeshika, Homna Upazilla, Comilla* (in Bangla). Dhaka : Author.
- Bayer, W. (1990). Use of browse by *Fulani* cattle in Central Nigeria. *Agroforestry Systems*, 12, 217-228.
- Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh. (1995). *Bangladesh population census 1991, Zilla Comilla*. Dhaka : Author.
- Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh. (1996). *Census of Agriculture 1996, Zilla series Comilla*. Dhaka: Author.
- Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh. (2001). *Statistical Year Book of Bangladesh-1999*. Dhaka : Author.
- Chambers, R., Pacey, A., & Thrupp, L. A. (1989). *Farmers first: Farmers innovation and agricultural research*. London : Intermediate Technology Publication.
- Rist, S. (1991). Participation, indigenous knowledge and trees. *Forest, Trees and People*, 10, 30-36.

- Roothaert, R.L. (2000). *The potential of indigenous and naturalized fodder trees and shrubs for intensive use in central Kenya*. Doctoral thesis, Wageningen University, Netherlands.
- Thapa, B. (1994). *Farmer's indigenous ecological knowledge about propagation, cultivation, management and use of farmland tree fodder in the mid -hills of Eastern Nepal*. Ph. D., Thesis. University of Wales, Bangor, UK.
- Thapa, B., Walker, D.H., & Sinclair, F. L. (1997). Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science and Technology*, 67, 97-114.
- Warren, D. M., Slikkerveer, L. J., & Brokensha, D. (1995). *The cultural dimension of development: Indigenous knowledge systems*. London : Intermediate Technology Publication.

FIELD PERFORMANCES AND EXTENT OF USE OF JUTE GEOTEXTILES AS IRRIGATION LINER IN BANGLADESH

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ABSTRACT

Geo-Textile mat prepared from raw-dry jute ribbon after chemical treatment was tested for water loss as an irrigation liner and compared with respect to earthen channel. Tests were conducted in the experiment field at Research Station of Bangladesh Jute Research Institute (BJRI), Experimental Field of Bangladesh Rice Research Institute (BRRI) and Pabna-Natore-Sirajgonj (PANASI) Project area of Bangladesh Agricultural Development Corporation (BADC). In addition, predetermined special type of rubberized jute based irrigation liner prepared with industrial collaboration was also tested similarly at the above mentioned experiment fields. Water discharge measuring device, 90°-V notches, were designed and fabricated in the BJRI's workshop. Out of the two types of irrigation liner (1) jute ribbon mats (treated with Grease, Bitumen, Silicate and Rubber) and (2) rubberized Hessian cloth, the later (rubberized Hessian cloth) performed better and no water has been found to be lost through seepage and percolation. Due to the higher cost involvement in other types of lining materials, the irrigation liner prepared from rubberized Hessian cloth has an excellent potential to save irrigation water in the conveyance system.

Key words : Jute Geo-textile, Irrigation liner.

INTRODUCTION

Water management and irrigation are the very important inputs for sustainable and productive agriculture development (Rahman et al., 1996). All other yield-increasing inputs perform their adequate role if irrigation is provided in proper way. Like HYV, seed, fertilizer,

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insect-pest and disease control, and irrigation is also an important component of improved technological packages (Rahman *et al.*, 1996).

Canal lining is very important in small-scale irrigation water supply system as surface water distribution is the most popular distribution system and extensively practiced in our agriculture, which do not imbalance the ecology by any means (Biswas & Mondal, 1993). Water loss in the form of seepage through earthen canals in different soils is very high particularly, in loamy-sand and sandy soils (Biswas *et al.*, 1984). This loss can be minimized to some extent by soil compaction. Pre-cast sections reduced the water loss to a considerable amount and it is also more durable, but costly. For sustained water conveyance at high efficiency, compacted earth channels need careful construction and maintenance (Khair *et al.*, 1980). Improper compaction during construction will lead to instability of channel banks and channel side slopes. Irrespective of water source, it was observed that 60 percent of irrigation water is lost in distribution system mainly by seepage and percolation through canal system (Matin, 1991). Pacca (cc), semi-pacca and earthen (kacha) are the general type of lining of irrigation canals constructed in Bangladesh. All of them have limitations, either in effectiveness or cost of construction (Kraatz & Mohajan, 1975).

Considerable attention is currently being given to increase agricultural production in Bangladesh. Water resources play a significant role in agricultural production but, until recently, limited importance has been given to their development (Rahman & Azad, 1992). Groundwater is a very important source of irrigation water and crop production dependent on it can be made more productive through its efficient utilization (ICID, 1968). At present, the country's existing irrigation facilities, utilizing earthen channels for water conveyance are inefficient and it was felt necessary to study ways to increase their efficiency (Jaim, 1992).

Water loss through earthen canals in minor irrigation projects is of great concern. As reported in the recent literature, this loss is generally as high as 50 percent of the total water pumped /delivered, although it varies from soil to soil (Biswas *et al.* 1984). Canal water loss causes extra expenditure to pump water for irrigation. Among minor irrigation technologies, Deep Tube Well (DTW) is grossly under utilized. Government as well as donor agencies are much concerned about un-utilization as well as under-utilization of such a capital-intensive technology in a poor country like Bangladesh (Jaim, 1992). Therefore, some kinds of on-farm water control measures for avoiding water losses in the irrigation distribution system are realized important because of high cost-energy inputs in lifting water for irrigation.

Water losses in irrigation distribution networks with earthen canals occur in various ways; of these, steady state losses, transient losses and wastage are the major components (Biswas *et al.* 1984). The steady state losses include seepage into bed, bank soils (normal infiltration and excess seepage into holes and cracks), visible leakage's through and over the banks (overtopping and leakage's through banks and closed outlets) and evaporation from water surface. Of these losses, visible leakages, short-term leakages, and wastage can greatly be reduced through efficient water management. Dead storage as well as evaporation from the water surface in a small sized canal as prevailing in the minor irrigation projects may be

negligible. But seepage as a whole could be minimized through improvement of canals (Biswas & Islam, 1975). It may be worthwhile to mention that a major portion of seepage loss occurs through the sides and bottom of the earthen irrigation canals. To avoid such a situation, lining of canal bed is important (Biswas & Mondal, 1993). The traditional lined canals made of brick and concrete are commonly used as well as asked for by the users in the irrigation fields. In Bangladesh, the cost of these types of linings becomes prohibitive due to high initial cost and they cannot logically be recommended at the farmer fields in a minor scale irrigation project unless fully subsidized (Jones, 1982).

To avoid such a huge national investment, alternative low cost lining techniques for reducing water losses are needed. In order to study promising techniques of water conveyance, jute Geo-Textile (developed at BJRI) may be a promising liner of irrigation channel (Abdullah et al., 1986; 1992; 1993). So, it is necessary to study the technical and economical feasibility of jute Geo-Textile in field condition as well as its acceptance to the producer level. In the mean time Geo-Textile has been successfully used in civil construction as in embankment, retaining wall etc. (Abdullah, 1994; 1995) which ultimately draw attention to the present study. Based on the information so far gathered it is revealed that it is utmost necessary to:

- (i) reduce the conveyance losses and expansion of the existing command area of small irrigation projects,
- (ii) the irrigation system and the lining technique should be able to attract the jute farmers to supply the raw material of Geo-Textile produced by them and encourage the irrigators /farmers to replicate the technique in the farmer's fields.

More specifically the objectives of this study can be explained as:

- (b) Successful means of saving of costly irrigation water,
- (c) Reduction of construction and maintenance cost for irrigation channel,
- (d) Expanding the command area of small scale irrigation projects,
- (e) Diversification of jute use and
- (f) Stimulate small and cottage industries in rural areas through the production of jute Geo-Textile irrigation liner.

MATERIALS AND METHODS

CVL-1 variety jute crop was grown at Central Research Station, Manikganj and Jute Research Regional Station, Rangpur. At 110 days of maturity plants were harvested and green ribbons were extracted using Bamboo Hook Ribboner developed by BJRI. The fiber was then dried in sunlight. About 1500 sft of jute mats were prepared manually with dry jute ribbons.

These mats were then treated with various chemical agents like hydrocarbon, grease, chromate, sulphate, silicate, bitumen, rubber in a definite manner by composite formulation manually for converting jute ribbon mat into jute geo-textile irrigation liner. Jute ribbon mats,

treated with bitumen is termed as, "Bitumen treated jute geo-textile mat". Similarly jute mat treated with grease is termed as, "Grease treated geo-textile mat". Likewise, silicate treated geo-textile mat", and "Rubber treated jute geo-textile mat have been prepared. Moreover, predetermined special size and type of Hessian cloth treated and coated with rubber is termed as "Rubberized Hessian geo-textile irrigation liner" samples, which has been prepared by the help of Mirpur Agricultural Workshop and Training School (MAWTS)-Dhaka and Bangladesh Rubber Industry (BRI), Dhaka, Bangladesh.

Design and fabrication of 90° -V notches were completed at BJRI mechanical workshop for measuring the irrigation water, lost through the irrigation liners as well as through earthen channel. Irrigation channels were also renovated and necessary cases prepared for testing the jute geo-textile irrigation liner in the selected locations in Central Research Station of BJRI at Manikganj, research field of BRRI at Gazipur and PANASI project site of Bangladesh Agriculture Development Corporation (BADC) at Pabna.

For every cases (different types of irrigation liners) 60m section of irrigation channel was taken and three 90° -V notches were placed at channel section with equal intervals at station -1, -2 and -3 respectively. Developed Irrigation liners were then placed at first 30m section (between station 1 & 2) and next 30m section (between station 2 & 3) remained as unlined channel. Depths of flow of water were measured at three points (station -1, -2 and -3) by measuring sticks placed 1m upstream from 90° -V notches. Flow of water then interpreted against depth of water from the table given in "Small Hydraulic Structures" by-D.B. Kraatz and I. K. Mohajan, Irrigation and Drainage Paper, Food & Agriculture Organization of United Nations. Difference of water flow between the first and second stations represented the water loss through irrigation liner, similarly flow difference between second and third stations represented the water loss at unlined channel.

In the field, experiment for measuring the irrigation water loss through seepage and percolation using both ribbon mat and rubberized hessian irrigation liner has been tested and compared the same with the unlined channel.

Cost of production for lining materials were compared with the cost of construction of pacca (CC) irrigation channel section collected from PANASI project.

RESULTS AND DISCUSSION

Manually fabricated jute ribbon mats treated with different type of chemical composites were then prepared for irrigation liner and were tested for water loss through each in comparison to unlined channel. Similarly, rubberized hessian cloth liner was also tested for water loss in comparison to unlined channel. The results obtained (table 1 to 7) from the experiments are summarized in the table 8. The geo-textile mats and rubberized Hessian clothes were used as irrigation liner to save loss of water through seepage and percolation during application of irrigation in a project.

The percentage loss of diverted irrigation water during irrigation through different geo-textile irrigation liner (a) chemically treated ribbon mats irrigation liner, (b) rubberized hessian geo-textile irrigation liner are mentioned as follows:

- (a) i. Bitumen treated jute geo-textile mat liner; 38.60 %
- ii Grease treated jute geo-textile mat liner; 24.66 %
- iii Silicate treated jute geo-textile mat liner; 95.12 %
- iv. Rubber treated jute geo-textile mat liner; 9.98 %
- (b) Rubberized Hessian geo-textile irrigation liner; 3.88 %

The experimental results mentioned in different tables showed that the water loss through the different Jute ribbon mats as modified irrigation liner, on an average, is much higher (42.09%) than that of rubberized Hessian geo-textiles (4.89%). The mean water loss through unlined channel was 54.88%, whereas, through the chemically treated Jute ribbon mat irrigation liner was 42.09% and rubberized hessian irrigation liner was negligible i.e., 4.89%. Irrigation water saved by Hessian-rubberized liner (90.41%) is almost three times than that through chemically treated hand made ribbon mat liner (33.95%).

Table 1. Comparative water loss in channel section with Rubberized Hessian geo-textile irrigation liner and the unlined channel at Central Research Station, Manikganj of BJRI

Parameter	Water flow at V-Notch, Station-1		Water flow at V-Notch, Station-2		Water flow at V-Notch, Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.0677	0.108	0.066	0.396	0.1224	0.468
2nd 10 min.	0.0954	0.3	0.1388	0.605	0.106	0.315
3rd 10 min.	0.158	0.83	0.0913	0.21	0.0799	0.15
Average	0.107	0.413	0.0987	0.404	0.1028	0.311
Water Loss	-		2.18%		23.02%	

Net water saved compared to unlined channel : 90.53%

Table 2. Comparative water loss in channel section with Rubberized Hessian geo-textile irrigation liner and the unlined channel at BRRI, Gazipur Experimental Field

Parameter	Water Flow at V-Notch Station-1		Water Flow at V-Notch Station-2		Water Flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.091	0.220	0.088	0.196	0.054	0.060
2nd 10 min.	0.113	0.360	0.091	0.210	0.064	0.086
3rd 10 min.	0.089	0.206	0.112	0.350	0.014	0.048
Average	0.087	0.262	0.089	0.252	0.044	0.065
Water Loss	-		3.82%		74.21%	

Net water saved compared to unlined channel: 94.85%

Table 3. Comparative water loss in channel section with Rubberized Hessian geo-textile irrigation liner and the unlined channel at PANASI, Pabna Farmers Field

Parameter	Water flow at V-Notch Station-1		Water flow at V-Notch Station-2		Water flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.039	0.048	0.031	0.048	0.034	0.048
2nd 10 min.	0.075	0.132	0.069	0.102	0.049	0.048
3rd 10 min.	0.088	0.192	0.088	0.192	0.051	0.050
Average	0.067	0.124	0.063	0.114	0.045	0.049
Water Loss	-		8.06%		57.02%	

Net water saved compared to unlined channel : 85.86%

Table 4. Comparative water loss in channel section with Rubber treated jute geo-textile mat liner and the unlined channel at JAES, Manikganj of BJRI

Parameter	Water flow at V-Notch Station-1		Water flow at V-Notch Station-2		Water flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.1424	0.7094	0.1046	0.3698	0.0945	0.2394
2nd 10 min.	0.0700	0.0968	0.1215	0.4029	0.0630	0.0799
3rd 10 min.	0.0895	0.2066	0.0725	0.1390	0.0575	0.0660
Average	0.1006	0.3376	0.0995	0.3039	0.0716	0.1284
Water Loss	-		9.98%		57.74%	

Net water saved compared to unlined channel : 82.72%

Table 5. Comparative water loss in channel section with Grease treated jute geo-textile mat liner and the unlined channel at JAES, Manikganj of BJRI

Parameter	Water flow at V-Notch Station-1		Water flow at V-Notch Station-2		Water flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.0940	0.2388	0.0875	0.1963	0.0654	0.0918
2nd 10 min.	0.1061	0.3088	0.0884	0.1959	0.0872	0.1935
3rd 10 min.	0.1100	0.3284	0.1030	0.2678	0.0850	0.1887
Average	0.1034	0.2920	0.0963	0.2200	0.0792	0.1580
Water Loss	-		24.66%		36.80%	

Net water saved compared to unlined channel : 32.98%

Table 6. Comparative water loss in channel section with Bitumen treated jute geo-textile mat liner and the unlined channel at JAES, Manikganj of BJRI

Parameter	Water flow at V-Notch Station-1		Water flow at V-Notch Station-2		Water flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.1029	0.3436	0.0846	0.1725	0.0592	0.0722
2nd 10 min.	0.1053	0.3022	0.0862	0.1810	0.0718	0.1170
3rd 10 min.	0.0986	0.2558	0.0902	0.2002	0.0707	0.1123
Average	0.1023	0.3005	0.0870	0.1845	0.0671	0.1005
Water Loss	-		38.60%		45.53%	

Net water saved compared to unlined channel: 15.22%

Table 7. Comparative water loss in channel section with Silicate treated jute geo-textile mat liner and the unlined channel at JAES, Manikganj of BJRI

Parameter	Water flow at V-Notch Station-1		Water flow at V-Notch Station-2		Water flow at V-Notch Station-3	
	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)	Height (m)	Discharge (cum./min)
1st 10 min.	0.0350	0.0120	0.0130	0.0060	Almost all of the flowing	
2nd 10 min.	0.0400	0.2400	0.0300	0.0060	Water was lost in the	
3rd 10 min.	0.0400	0.2400	0.0350	0.0120	Channel section-1, between	
Average	0.0380	0.1640	0.0260	0.0080	Station-1 and 2. Therefore,	
Water Loss	-		95.12%		No reading at station-3	

Table 8. Comparison of water save (%) and loss (%) through the different type of jute geo-textile irrigation liner with unlined irrigation channel

Sl. No. & Type of Irrigation Liner	Hessian clothe		Handmade mat		Unlined channel
	Save (%)	Loss (%)	Save (%)	Loss (%)	Loss (%)
A. Rubberized Hessian					
1. At PANASI site					
2. At BRRI site	85.86	8.06	-	-	57.02
3. At BJRI site	94.85	3.82	-	-	69.19
MEAN	90.53	2.18	-	-	23.02
	90.41	4.69			49.74
B. Treated Jute Mat					
1. Silicate Treated	-	-	4.88	95.12	100.00
2. Bitumen Treated	-	-	15.22	38.60	45.53
3. Grease Treated	-	-	32.98	24.66	36.80
4. Rubber Treated	-	-	82.72	9.98	57.74
MEAN			33.95	42.09	60.02
GRAND MEAN	90.41	4.69	33.95	42.09	54.88

Note: Handmade Jute Mat (Jute Geo-textile) treated with different chemicals were tested in Central Research Station, Manikganj of BJRI only. Water save (%) showed above is in comparison to unlined channel and water loss showed through seepage and percolation.

Table 9. Cost of irrigation lining materials and different type of irrigation channel

Sl. No.	Type of channel / Lining material	Cost per foot (Tk.)	Comments
1.	Jute Hessian Rubberized Liner	50.00	Less than half of pacca channel
2.	Unlined (Earthen) Channel	37.50	Almost same to irrigation liner
3.	Pacca Channel	110.00	More than double to irrigation liner

Source : Unlined and Pacca Channel construction cost: Project Director, Pabna Natore Sirajganj (PANASI) Project, BADC, Pabna.

CONCLUSION

Rubberized Hessian geo-textile irrigation liner is technically acceptable as irrigation liner, as it saves considerable amount of irrigation water compared to other conventional method of water saving techniques (Table 8).

Per unit cost of jute Hessian rubberized irrigation liner is lower (less than half) than that of pacca channel (Table 9). Even adding the cost of unlined (earthen) channel preparation to the cost of rubberized Hessian irrigation liner, the total cost yet remain much lower than pacca channel. Though the cost of rubberized Hessian irrigation liner is higher than that of unlined (earthen) channel, but rubberized irrigation liner has got other household benefits as, it can be used in threshing and drying of farm crops.

Therefore, it can be concluded that the rubberized Hessian geo-textiles may be recommended, as irrigation liner, for use.

Again, rubberized Hessian geo-textiles used as irrigation liner can also be used in different farmyard works like, threshing and drying of cereal grains and other crops.

It is recommended to take extensive program to conduct seminar/symposium in farmers field to show them practically the benefits of geo-textile liner use and make them interested to use jute geo-textile liners in their irrigation channel.

REFERENCES

- Abdullah, A. B. M., Habibur, R., & Badear Rahman, S. M. (1986). Studies on differently treated jute fabrics for geo-textile uses. Part-I, *B. J. of J. & Fib. Res.*, 11 (1&2), 35-38.
- Abdullah, A. B. M., Rahman, H., Rahman, B., Lutfar, L. B., & Ahmed, H. (1992). Studies on the properties of geo-jute/geo-textile. *J. of Bang. Ac. of Sc.*, 16 (2), 235-240.
- Studies on the properties of composite treated geo-jute/geo-textile. *Bang. J. Chem. Soc.*, 5 (1), 53-57.
- Abdullah, A. B. M. (1993). Research and development in jute geo-textiles in Bangladesh. *J. & J. Fab. Bang.*, 19 (7), 4-5.
- Abdullah, A. B. M. (1994). *Jute geo-textiles and their soil erosion control and stabilization mechanism*. Paper presented at the ICS regional seminar on application of Jute, IJO/UNIDO.
- Abdullah, A. B. M. (1995). Some environmental effect of synthetic geo-textiles. *Bang. J. of Env.*, 2, 73-77.
- Biswas, M. R., & Islam, A. F. M. (1975). *Seepage reduction in the irrigation ditches with clay soil and cow-dung*. Paper presented at the seminar on Integrated Rural Development. Dhaka, Bangladesh : Institution of Engineers.
- Biswas, M. R., Khair, A., & Dutta, S. C. (1984, July). Low cost canal lining for water losses to achieve efficient water distribution at farm level irrigation system. *Proceeding of the Workshop on Improved Distribution System for Minor Irrigation in Bangladesh*. Dhaka : Bangladesh Agricultural Research Council.
- Biswas, M. R., & Mandal, M. A. S. (1993). *Irrigation management for crop diversification in Bangladesh*. Dhaka, Bangladesh : The University Press Limited.

- ICID. (1968). *Controlling seepage losses from irrigation canals: World wide survey*. New Delhi, India : Author.
- Jaim, W. M. H. (1992, October). *Existing status of deep tube well utilization in Bangladesh*. Paper presented at the Seminar on Potentials for Deep Tube Well Utilization in Bangladesh. Bogra : Winrock International and Rural Development Academy.
- Jones, R. W. (1982). *Cost and benefits of canal lining, on-farm irrigation and water management problems*. Mymensingh, Bangladesh : Bureau of Socio-Economic Research and Training, BAU.
- Khair, A., Dutta, S. C., & Rahman, M. A. (1980). *Development and application of low-cost technology to minimize water losses due to seepage in irrigation canals: The case of Bangladesh*. Working Paper WEP 2-22/WP69. Geneva : ILO.
- Kraatz, D. B., & Mohajan, I. K. (1975). *Small hydraulic structures irrigation and drainage*- Paper 26/2. Rome: Food and Agriculture Organization of the United Nations.
- Matin, M. A. (1991, March). *Improved water distribution system developed by the RDA for small scale irrigation project*. Paper presented at the Seminar on Irrigation Issues in Bangladesh. Dhaka. Bangladesh.
- Rahman, M. L., Rahman, M. M., Azad, A. K., Nuruzzaman, M., & Siddique, A. B. (1996). Relative contribution of component technologies in jute production. *B. J. of Jute and Fib. Res.*, 21 (1&2), 1- 8.
- Rahman, M. M., & Azad, A. K. (1992). Irrigation in jute production. *Jute and Jute Fab. Bang.*, 18 (9), 5-8.

GENETIC DIVERSITY IN RAINFED LOWLAND RICE

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ABSTRACT

Genetic diversity of 26 BRRI released MV and advanced line of rainfed lowland rice varieties were studied through Mahalanobis D² statistic. The genotypes were grouped into five clusters. The cluster III contained the highest number of genotypes (9) and the cluster I and IV contained the lowest (3). The highest intra cluster distance was noticed for the cluster III and the lowest for cluster IV. The highest inter cluster distance was observed between cluster I and cluster II followed by cluster IV and cluster II, cluster V and cluster I, cluster III and cluster I and the lowest between cluster IV and cluster I. Days to flowering and duration are the most positive contributors based on the latent vectors. But the highest cluster means for yield and other four yield contributing characters were obtained from cluster IV. One highest and four second highest means for yield and yield contributing characters were also found in cluster I and the lowest cluster mean for yield in cluster II. Therefore more emphasis should be given on cluster IV for selecting genotypes as parents for crossing with the genotypes of cluster II which may produce new recombinants with desired traits.

Key words: Genetic diversity, D² analysis, Cluster analysis, Rice.

INTRODUCTION

Rice is the main cereal crop of Bangladesh. Among other ecosystem, rainfed lowland (Transplanted Aman) is the most suitable for growing rice in this country. Area under transplanted aman is the largest comparing to others. In Bangladesh, T. aman rice contributes 45% of the total rice production and about 53% area of total rice production is cultivated under this ecosystem (BBS, 2001). Genetic divergence is a useful tool for an efficient choice of parents for hybridization to develop high yield potential cultivars. Such a study also permits to select the genetically divergent parents to obtain the desirable recombinants in the segregating generations. The understanding of association of characters is of prime importance in

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developing an efficient breeding programme. With the development of advanced biometrical techniques such as multivariate analysis based on Mahalanobis (1936) Statistic, quantification of degree of divergence among the biological population and assessing of relative contribution of different components to the total divergence intra and inter cluster levels have now become possible. Inclusion of more diverse parents (within a limit) is believed to increase the chances of obtaining stronger heterosis and gives broad spectrum of variability in segregating generations (Joshi & Dhawan, 1966; Anand & Murty, 1968). An attempt was made in the present study to analyze the genetic divergence of 26 rainfed lowland (Transplanted Aman) rice genotypes.

MATERIALS AND METHODS

Twenty-six rice genotypes from Bangladesh Rice Research Institute (BRRI) and local sources were grown in the farmer's field at Chuadanga site in transplanted aman season, 2001. The trial was conducted in Randomized Complete Block (RCB) design with three replications. Thirty day old seedlings were transplanted in a 5 sq.m plot following 25X15 cm spacing between rows and plants respectively. Single seedling was used for per hill. Fertilizers were applied at the rate of 80:60:40:12:3.5 kg N,P,K,S and Zn per hectare. All the recommended fertilizers except N were applied at final land preparation. Nitrogen was applied in three equal splits at 15, 30 and 50 DAT. Intercultural operations and pest control measures were done as and when necessary. The experiment was conducted on rainfed situation and no irrigation was applied. Ten plants from each entry were randomly selected for recording data. Data were collected on days to flowering, maturity duration, plant height (cm), panicle length (cm), flag leaf length (cm), number of tiller per hill, number of panicle per hill, spikelets per panicle, sterile spikelets per panicle and yield (t/ha).

Genetic diversity studied following Mahalanobis (1936) generalized distance (D^2) extended by Rao (1952). Based on the D^2 values, the varieties were grouped into clusters following the method suggested by Tocher (Rao, 1952). Intra and inter cluster distances were calculated by the methods of Singh and Chaudhury (1985). Statistical analyses were carried using IBM computer at BRRI, following Genstat programme.

RESULTS AND DISCUSSION

Analysis of variance showed that the differences among the 26 genotypes were significant for all the ten characters under study indicating the presence of notable genetic variability among the genotypes. The principal component analysis showed that the first two components accounted for 83.83% of the total variation.

Based on cluster the twenty-six genotypes were grouped into five clusters (Table 1). Maximum 9 entries were grouped into the cluster III, followed by 7 and 4 in clusters II and V, respectively. Three entries were grouped into both clusters of IV and I.

Table 1. Rice genotypes in different clusters

Cluster No.	Line/ variety code number	No. of Population	Genotypes
I	3,9,16	3	BRRI dhan30, Pajam II, BR6187-38-2-4
II	7,14,18,22,23,25,26	7	BRRI dhan39, BR5777-11-2-4-1, BR6577-1-2, BR6420-13-1-5, BR6420-13-1-4, BR6390-34-2-2, BR6390-24-1-6
III	6,10,11,12,13,19,20,21,24	9	BRRI dhan33, BR6398-12-2, BR6004-75-4-H7, BR6004-75-4-H2, BR5771-11-7-1-H8, BR6420-48-12-1, BR6420-13-3-2, BR6420-13-1-6, BR6396-1-3-2
IV	1,4,17	3	BR11, BRRI dhan31, BR6128-24-1-3-4
V	2,5,8,15	4	BR25, BRRI dhan32, Latishail, BR6415-22-3

Intra and inter cluster distance are presented in Table 2. The inter cluster distance in all of the cases was larger than the intra cluster distance indicating that wider diversity was present among genotypes of distance groups. The intra cluster distances were comparatively low for all the five clusters with the range of 0.45 in cluster IV to 2.112 in cluster III which indicated homogeneous nature of the genotypes within the cluster. This result was supported by the findings of Iftekharruddaula *et al.* (2002) in rice. Regarding inter cluster distance, cluster II showed maximum genetic distance (11.88) from cluster I followed by cluster II and cluster IV (10.13), cluster V and cluster I (9.36) and cluster I and cluster III (8.15) suggesting wide diversity between them (Saini & Kaiker, 1987) and the genotypes in these clusters could be used as parents in hybridization programme for getting transgressive segregates. Moderate or intermediate inter cluster distance was observed between cluster III and cluster IV (7.2) followed by cluster II and cluster V (7.18), cluster III and cluster V (7.00) and cluster IV and cluster V (6.00). The minimum inter cluster divergence was observed between cluster II and cluster III (4.06) and cluster I and cluster IV (3.56) indicating that the genotypes of these clusters were genetically closed.

Table 2. Intra (bold) and inter cluster distances (D^2) for 26 rice genotypes

Clusters	I	II	III	IV	V
I	0.643	11.881	8.150	3.564	9.356
II		1.493	4.055	10.127	7.178
III			2.112	7.200	6.989
IV				0.450	5.998
V					0.942

The mean values of cluster I ranked first for spikelets per panicle and second for yield, number of panicles per hill, flag leaf length and plant height (Table 3) while cluster mean for panicle length and number of tillers/hill and sterile spikelets per panicle was the lowest. Cluster II had the highest cluster mean value for panicle length and flag leaf length and ranked

second for number of tillers per hill and sterile spikelets per panicle on the other hand cluster mean for days to flowering, maturity duration, spikelets per panicle and yield was the lowest. Cluster III ranked lowest for plant height and flag leaf length and none for highest value. The cluster IV had the highest cluster mean values for days to flowering, maturity duration, plant height, sterile spikelets per panicle and yield and second for panicle length and spikelets per panicle while lowest for panicle per hill. The cluster mean of V ranked first for number of tillers per hill and number of panicles per hill and second for days to flowering and maturity duration.

Table 3. Cluster means for ten characters in rice

Characters	I	II	III	IV	V
Days to flowering	114.67	108.43	112.56	116.67	116.25
Duration	139.33	134.43	137.11	143.33	143.25
Plant height (cm)	106.40	90.54	88.96	106.83	105.25
Panicle length (cm)	22.67	24.54	23.71	24.13	23.58
Flag leaf length (cm)	28.83	32.54	27.82	28.57	28.40
No. of tiller/ hill	9.00	9.96	9.47	9.23	10.32
No. of panicle/ hill	8.30	8.23	8.27	7.90	9.10
Spikelets/ panicle	139.47	69.46	95.10	126.37	84.30
Sterile spikelets/ panicle	20.80	25.66	25.34	31.53	29.83
Yield (t/ha)	2.70	2.13	2.29	3.00	2.60

A two dimension scatter diagram was constructed using component I as X axis and component II as Y axis, reflecting the relative position (Fig. 1). As per scatter diagram the genotypes were apparently distributed into five clusters. It was also revealed that the genotypes of cluster I was more diversified from the genotypes of cluster II.

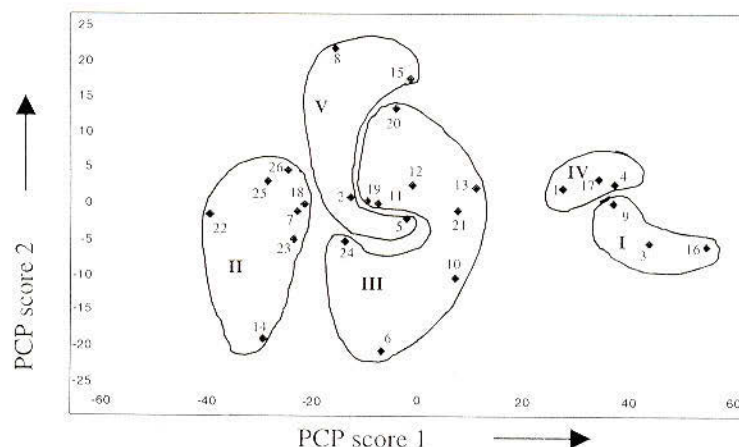


Fig. 1. Distribution of 26 rice genotypes in a two-dimensional scatter diagram based on PCP scores superimposed with clusters

Contributions of the characters towards divergence are presented in Table 4. The canonical variety analysis revealed that the vectors (Vector I and II) for days to flowering and maturity duration were positive. Such results indicated that these two characters contributed maximum towards divergence. The similar result was observed by Kadir *et al.* (1997) in wheat. It is interesting that the greater divergence in the present materials due to these two characters will offer a good scope for improvement of yield thorough rational selection of parents for producing heterotic rice hybrids.

Table 4. Relative contributions of the ten characters to the total divergence of the rice

Trait	Vector I	Vector II
Days to flowering	0.4486	0.1294
Duration	0.4327	0.1942
Plant height (cm)	0.1911	-0.3059
Panicle length (cm)	-0.1566	0.4467
Flag leaf length (cm)	-0.3007	0.2731
No. of tiller/ hill	-0.3747	-0.3542
No. of panicle/ hill	-0.2578	-0.4342
Spikelets/ panicle	0.3048	-0.2181
Sterile spikelets/ panicle	-0.0635	0.4143
Yield (t/ha)	0.3952	-0.2111

It is assumed that, maximum amount of heterosis will be manifested in cross combinations involving the parents belonging to most divergent clusters. However, for a practical plant breeder, the objective is not only high heterosis but also to achieve high level of production and reducing the life duration. In the present study the maximum distances existed between cluster I and cluster II. But considering the yield and duration, crosses involving cluster II and cluster IV may exhibit high heterosis for earliness and yield. Mian and Bahl (1989) reported that the parents separated by D^2 values of medium magnitude generally showed higher heterosis. Keeping this in view, it appears that the crosses between the genotypes / parents belonging the cluster II with that of cluster IV and cluster I and cluster V would exhibit high heterosis as well as earliness and higher level of production. So based on this result, the genotypes under cluster II and cluster IV and cluster I and cluster V have been selected for future breeding programme.

REFERENCES

- Anand, I.J., & Murty, B.R. (1968). Genetic divergence and hybrid performance in linseed. *Indian J. Genet. and Plant Breeding*, 28, 178-185.
- Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh. (2001). *Statistical yearbook of Bangladesh*. Dhaka : Author.
- Iftekharuddaula, K. M., Akter, K., Bashar, M. K., & Islam, M. R. (2002). Genetic parameters and cluster analysis of panicle traits in irrigated rice. *Bangladesh J. Pl. Breed. Genet.*, 15 (1), 49-55.
- Joshi, A.B., & Dhawan, N.L. (1966). Genetic improvement of yield with special reference to self fertilizing crops. *Indian J. Genet. and Plant Breeding*, 26, 101-113.
- Kadir, M., Shamsuddin, A.K.M., Islam, M.S., Islam, M. N., & Ali, M.M. (1997). Genetic divergence of bread wheat (*T. aestivum*). *Bangladesh J. Pl. Breed. Genet.*, 10 (1&2), 41-44.
- Mahalanobis, P.C. (1936). On the generalized distance of statistics. In *Proceedings* 2 (pp. 49-55). India : National Institute of Science.
- Mian, M.A.K., & Bahl, P.N. (1989). Genetic divergence and hybrid performance in chickpea. *Indian J. Genet.*, 49 (1), 119-124.
- Rao, C.R. (1952). *Advanced statistical method in biometrics research*. New York : John Wiley & Sons.
- Saini, H. C., & Kaicker, U. S. (1987). Genetic diversity in opium poppy. *Indian J. Genet.*, 47, 291-296.
- Singh, R.K., & Chaudhury, B.D. (1985). *Biometrical methods in quantitative genetic analysis*. New Delhi : The Kalayoni Publishers.

ION SORPTION BEHAVIOUR UNDER DIFFERENT MOISTURE REGIMES IN GHATAIL SOIL SERIES OF BANGLADESH

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ABSTRACT

The experiment was conducted to know the ions [viz., K^+ , Ca^{2+} , NH_4^+ , P ($HPO_4^{2-} + H_2PO_4^-$), NO_3^- and SO_4^{2-}] sorption behaviours under different moisture regimes in the soils of Ghatail series. During the first 5 hours a good sorption was noted for Ca^{2+} and NH_4^+ at low concentration (5 cm standing water). But the sorption of K^+ was almost nil. The sorption of K^+ and NH_4^+ increased between 5-24 hours while the Ca^{2+} was decreased. At medium concentration (saturated condition) the sorption of all cations remarkably increased over the low concentration and the NH_4^+ sorption rate was highest. But the sorption of NH_4^+ was seriously decreased at high concentration (field capacity). Like cations, anions sorption rate also raised to maximum level within 5 hours at low concentration and showed a decreasing trend up to 10 hours. At medium concentration the sorption of anions showed same trend of low concentration. The sorption of NO_3^- and P strongly increased and reached the maximum level at initial 5 hours. But concomitantly a decrease of SO_4^{2-} and P was noted at 10 hours. The sorption of all anions increased at high concentration.

Key words: Anion, Cation, Field capacity, Moisture, Saturated.

INTRODUCTION

Ion sorption in soil has been a subject of much investigation during the past few decades. But literature on ion sorption in Bangladesh soils is scanty. In Bangladesh no systematic works have yet been conducted on ion sorption. But it has attracted the attention of many soil scientists and agriculturists where agriculture has been faced with problem of fertility management. Fertilizers undergo various changes after application in the soils for crop production (Tian-ren, 1985; Hartikainen & Koivunen, 1990; Rolston *et al.*, 1990). When the

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fertilizers are added to the soils the natural, physical, chemical as well as biological equilibrium are disturbed and a new equilibrium is established after adsorption, desorption, fixation, transformation, losses, uptake by crops (Verloo, 1993). In addition to temperature and other soil and climatic factors, moisture regimes of soils greatly influence the gravity and extent of these changes. Lumbanraja and Evangelou (1990) reported that the rate and magnitude of Nitrogen losses are fairly dependent on the rate of release of NH_4^+ and NO_3^- by soil practices. Higher nutrient sorption occurred by soils at field capacity than at saturated condition. But the amount to be sorbed is largely determined by sorption capacity of soil at any condition (Ali *et al.*, 1990).

It's a question for almost all concern that the fertilizers we normally apply to our soils are taken up by the crops or retained in soils. For sustaining the fertility retention a part of added fertilizers are rather preferred at least to supplement the amount taken up by the growing crops from soil reserve. A qualification of the different forms of added fertilizer is necessary to get an idea of the above mentioned problems.

Soils of Ghatail series occur in the lower ridge of Old Brahmaputra Floodplain covering almost 15% of the total area. This low permeable silty-clay to clay soils are mainly used for cultivating transplanted aman rice. Nutrient management in this soil is an important task for sustaining fertility.

Thus, the study was aimed at evaluating the amount of nutrient ions sorbed by the soils of Ghatail series when recommended doses of fertilizers are applied at various moisture regimes i.e., 5 cm standing water (low concentration), saturated condition (medium concentration) and field capacity (high concentration).

MATERIALS AND METHODS

The experiment was conducted in the laboratory of the Department of Soil Science at Bangladesh Agricultural University, Mymensingh at different moisture regimes i.e. 5 cm standing water (low concentration), saturated condition (medium concentration) and field capacity (high concentration) with a view to knowing the ions [viz. NH_4^+ , K^+ , Ca^{2+} , P (HPO_4^{2-} + H_2PO_4^-), SO_4^{2-} , NO_3^-] sorption behavior of soils under Ghatail soil series (Aeric Haplaquept).

Collection and preparation of soil samples

Soil samples at a depth of 0-15 cm were collected from the farmers field. This site belongs to the Agro-ecological Zone of Old Brahmaputra Floodplain and its extent in Bangladesh is about 2,27,016 ha (SRDI, 1975). The collected soils were air dried, ground and passed through a 2 mm sieve. Weeds, stubbles, plant roots etc. were removed from the samples before grinding. Subsequent sample was preserved in polythene bags with proper labeling to conduct the study. The soil was silty clay, with poorly drained conditions, having pH 6.98, available P 8.13 mg kg⁻¹ and organic matter content 2.5%. Available S content 11.50 mg kg⁻¹.

exchangeable K & Ca 0.18 and 8.35 me 100^{-1} g of soil respectively, CEC 16.40 me 100^{-1} g soil, $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ was 2.33 and 14.00 mg kg^{-1} respectively.

Determination of moisture content at different moisture regimes:

Separate soil samples at a depth of 5-8 and 8-11cm were collected with the help of core samplers. These were saturated with water for 24 hours and weighed. The saturated samples were kept in a soil moisture extractor at 0.33 bar pressure until an equilibrium condition was established. The moisture content at field capacity was then determined gravimetrically. The water content at saturated condition was also calculated considering the differences in weight between saturated condition and oven dry weight of soil. Finally the amount of water that remain in soil at saturated and field capacity per square meter up to 15 cm depth was calculated on volume basis considering the density of water 0.992 gcm^{-3} at 28°C . The volume of water per square meter at 5 cm water depth was added with volume of water at saturated condition to get the water content at 5 cm standing water.

Preparation of multi-ion solution:

Ion solutions of NH_4^+ , K^+ , Ca^{2+} , P ($\text{HPO}_4^{2-} + \text{H}_2\text{PO}_4^-$), SO_4^{2-} and NO_3^- of three different concentrations were prepared by dissolving calculated amounts of NH_4NO_3 , $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ and KCl salts in water (Table-1). The concentrations were chosen considering the concentration that retained in soil solutions when recommended doses of N, P, K and S fertilizers are added to soil at field capacity (high conc.), saturated conditions (medium conc.) and at 5 cm standing water (low conc.). The different doses of fertilizers considered for this study were 100 Kg N ha^{-1} , 60 Kg P ha^{-1} , 40 Kg K ha^{-1} and 30 Kg S ha^{-1} . As this salt contained NO_3^- and Ca^{2+} the concentrations of these ions in solutions were also calculated and their sorption also studied.

Sorption study methods:

Five sets of plastic bottles with three replications were prepared for 5 different times i.e., 5, 10, 24, 48 and 72 hours for each of low, medium and high concentrations. As a result $3 \times 5 \times 3 = 45$ bottles were used for the study. Eight gram of soil was taken in each of 45 bottles. Of these 45 bottles, 15 were earmarked for sorption solution of low concentration, 15 for medium concentration and 15 for high concentration. 80 ml of respective sorption solution was added to each of 15 bottles, shaken for 30 minutes in a horizontal shaker and allowed to stand for above mentioned time for sorption. Three separate bottles were kept for each time. At the end of allocated time, the suspensions were filtered through a retentive filter paper.

The concentration of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in the extract was determined by distillation method using successively MgO and Deverda alloy for $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ respectively (Page *et al.*, 1982).

Available phosphorus was estimated by extracting the soil P with 0.5 M NaHCO_3 solution having pH 8.5. The extracted P was then determined calorimetrically by SnCl_2 reduced phosphomolybdate blue colour method (Olsen *et al.*, 1954).

Available sulfur was determined by extracting the soil samples with CaCl_2 solution (0.15%) as described by Page *et al.*, 1982. The amount of S in the extract was estimated turbidimetrically by spectrophotometer at 420 nm.

Exchangeable K and Ca were determined by flame photometer from the NH_4OAc extract following method described by Jackson (1962).

Table 1. Concentration of different ions in solutions prepared for sorption study

Moisture regime	Water content up to 15 cm depth	NH_4^+ (mg L^{-1})	K^+ (mg L^{-1})	Ca^{2+} (mg L^{-1})	P ($\text{HPO}_4^{2-} + \text{H}_2\text{PO}_4^-$) (mg L^{-1})	SO_4^{2-} (mg L^{-1})	NO_3^- (mg L^{-1})
5 cm standing water (low conc.)	150	42.9	25.0	50.8	40.0	60.0	147.6
Saturated (medium conc.)	100	64.3	40.0	76.2	60.0	90.0	221.4
Field capacity (high conc.)	80	80.4	50.0	95.3	75.0	112.5	276.8

RESULTS AND DISCUSSION

The difference in nutrient concentrations between the initial sorption solution and equilibrium soil solution was taken as the amount sorbed by soil.

Cation sorption: A different behaviour of cation sorption was noted in the soils of Ghatail series. During the first 5 hours a good sorption was noted for Ca^{2+} and NH_4^+ but in case of K^+ the sorption was almost nil when solution of low concentration was added to the soil (Fig.1). Between 5 and 24 hours the sorption of K^+ and NH_4^+ increased while a decrease of sorbed Ca^{2+} was noted. During the rest of the periods only NH_4^+ sorption was found to increase in negligible amount. It is further noted from Fig.1 that, in general, the difference between sorbed NH_4^+ and K^+ was much wider when compared with the sorption of NH_4^+ and Ca^{2+} although the amount of sorbed Ca^{2+} was the highest.

At medium concentration (saturated condition) the sorption of all cations remarkably increased over the low concentration (Fig. 2). The rate of sorption of NH_4^+ was very high and superseded the sorption of Ca^{2+} . Maximum sorption was noted up to 5 hours, afterwards no remarkable increase or decrease was noted up to 72 hours.

The situation again changed when sorption solution of high concentration was added. The sorption of NH_4^+ decreased very seriously from almost 1100 mg kg^{-1} soil at saturated condition to less than 600 mg kg^{-1} soil at high concentration (Fig. 3). However the sorption of Ca^{2+} increased from almost 800 mg kg^{-1} soil at medium concentration to nearly 1200 mg kg^{-1} soil at high concentration. The sorption of K^+ also increased by about 150 mg kg^{-1} soil over the medium concentration. It appears that the total increase of K^+ or Ca^{2+} together was nearly 550 mg kg^{-1} soil over the medium concentration. At low concentration the sorption of Ca^{2+} was stronger than either K^+ or NH_4^+ whereas at medium concentration the sorption of NH_4^+ was stronger than either K^+ or Ca^{2+} but at higher concentration both Ca^{2+} and K^+ suppressed the NH_4^+ sorption. The strong correlation between Ca^{2+} and K^+ suppressed the NH_4^+ sorption. The strong correlation between Ca^{2+} and K^+ ($r = 0.982$) and very poor correlation of NH_4^+ with Ca^{2+} ($r = 0.402$) and K^+ ($r = 0.263$) also indicates that the Ca^{2+} and K^+ competed with the NH_4^+ for sorption sites in soils of Ghatal series.

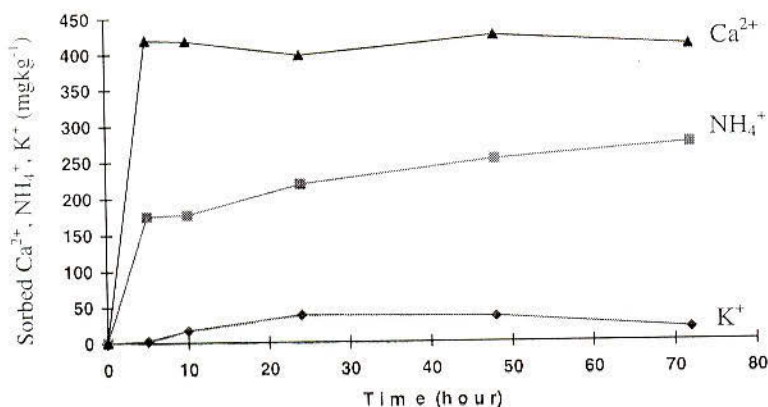


Fig.1: Cation sorption (mgkg⁻¹) in Ghatal soil at low conc.(5 cm standing water)

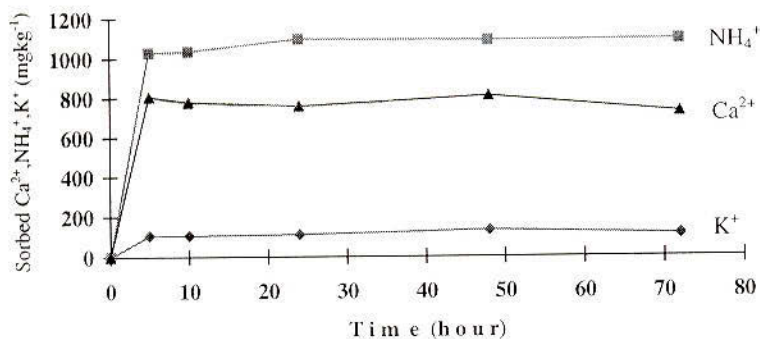


Fig.2: Cation sorption (mgkg⁻¹) in Ghatal soil at medium conc. (saturated condition)

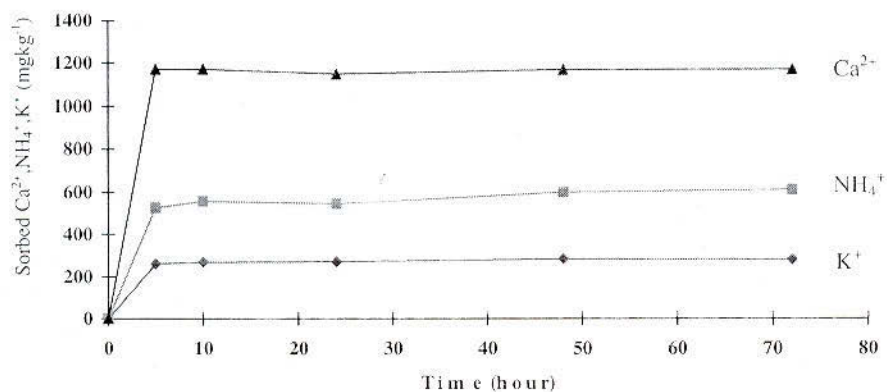


Fig.3: Cation sorption (mgkg⁻¹) in Ghatail soil at high con. (field capacity)

Anion sorption: The sorption of anions by soils of Ghatail series at low concentration reached almost the maximum level within 5 hours and then show a decreasing trend up to 10 hours (Fig.4). Afterwards, the sorption was almost stable up to 72 hours showing a slight increasing trend in SO_4^{2-} and P sorption at 24 hours. The reasons for such increase or decrease is not clear, but it seems that probably some other anions such as organic anions competed with other anions at the sorption sites.

It is apparent from the Fig. 4 that sorbed P, NO_3^- and SO_4^{2-} increased from almost 440-480, 340-438 and 43-100 mg kg^{-1} respectively at low concentration. At medium concentration the sorption of anions by Ghatail soils showed nearly the same trend of low concentration but the amount increased considerably (Fig. 5). The sorption of P, NO_3^- and SO_4^{2-} increased from 750-800, 630-700 and 350-400 mg kg^{-1} respectively at medium concentration. During the initial 5 hours the NO_3^- and P sorption strongly increased and reached almost the maximum sorption level. But concomitantly a decrease of SO_4^{2-} and P was noted at 10 hours over the 5 hours at the expense of an increase of NO_3^- (Fig. 5). After 10 hours, however, the sorption of anions was near to stop although some increase/decrease was noted.

The sorption of all anions further increased over the medium concentration when solution of higher concentration was added (Fig. 6). A sorption of nearly 1200 mg P kg^{-1} soil occurred during the first five hours and then remained stable up to 72 hours. At low and medium concentration, the sorption of NO_3^- was always lower than P but at high concentration the NO_3^- sorption superseded the P sorption. Its sorption continued further increasing from 5-24 hours but a desorption of sorbed SO_4^{2-} was noted in this period. During the rest of the periods an alternate sorption/decrease was noted for these anions.

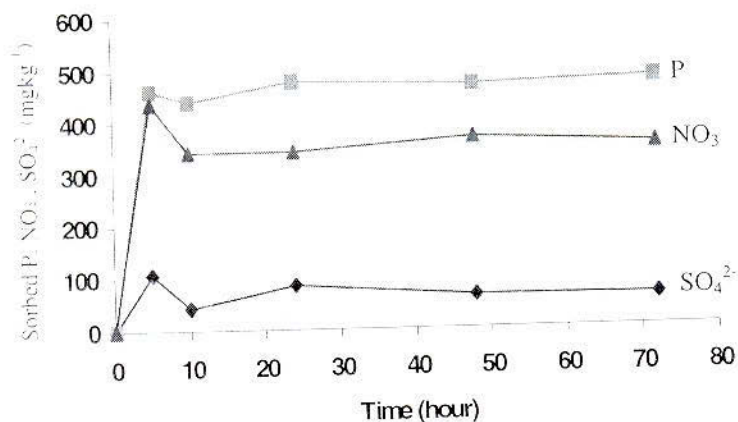


Fig.4: Anion sorption (mgkg⁻¹) in Ghatail soil at low conc. (5 cm standing water)

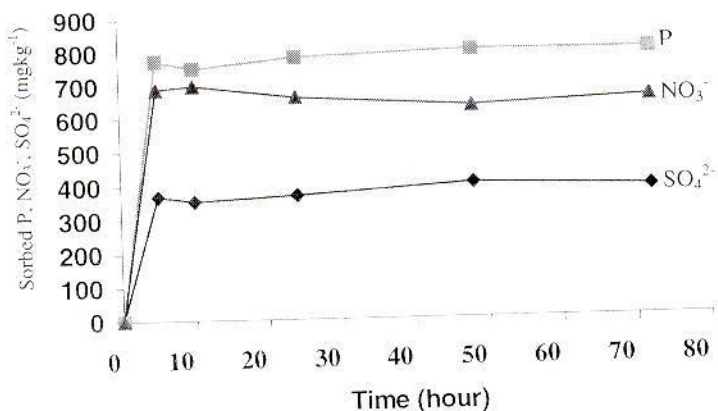


Fig.5: Anion sorption (mgkg⁻¹) in Ghatail soil at medium conc. (saturated condition)

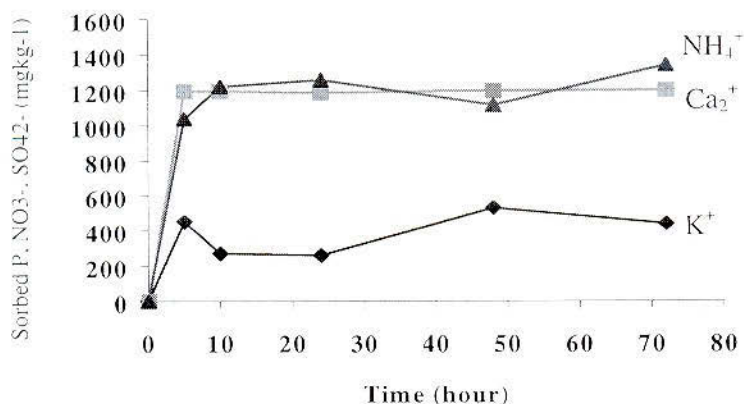


Fig.6: Anion sorption (mgkg⁻¹) in Ghatail soil at high conc. (field capacity)

CONCLUSION

Fertilizer application practices are done by various soil moisture level and ion sorption rate are varied due to the wide changes of soil moisture regimes. It was found from the study that lesser amount of nutrients were sorbed at water logging condition as the ionic strength was low, whereas, higher amount of ions were sorbed at field capacity level. Maximum sorption of ions was found at initial 5 hours. Afterwards, an increase/decrease trend was noted with the changes of concentration and time. Sometimes cations or anions seemed to compete with each other at their sorption sites. The reason for increasing/decreasing trend of ions in different concentration and time is not clear. Further, study is necessary to come to a conclusion in this respect.

REFERENCES

- Ali, M. I., Hoque, M. Q., & Rahman, M.S. (1990). *Potassium studies in soils and crops of Bangladesh : Ann. Project Report, 1989-90*. Dhaka : BARC.
- Hartikainen, H., & Koivunen, M. (1990). Mobilization of soil phosphorus as influenced by urea hydrolysis. (Trans). In *Proceedings of the 14th. Int. Cong. Soil Sci.* (pp 204-209). Kyoto. Japan : Int. Cong. Soil Sci.
- Jackson, M. (1962). *Soil chemical analysis*. NY, USA : Prentice Hall, Inc.
- Lumbanraja, J., & Evangelou, V.P. (1990). Adsorption-desorption of potassium and ammonium at low cation concentrations in three kentucky subsoils. *Soil Sci.*, 157 (5), 269-278.
- Olsen, S.R., Cole, C.V., Watanable, F.S., & Dean, L.A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. Washington DC : USDA.

- Page, A.L., Miller, R.H., & Keeney, D.R. (1982). *Methods of soil analysis* (2nd Ed.). Madison, USA : Am. Soc. Agron., Inc.
- Rolston, D.E., et al. (1990). Simulation of nitrogen toansport processes in flooded rice soils. (Trans). In *Proceedings of the 14th. Int. Cong. Soil Sci.* (pp 314-319). Kyoto, Japan : Int. Cong. Soil Sci.
- Soil Resource Development Institute (SRDI), Ministry of Agriculture, Government of the People's Republic of Bangladesh. (1975). *Reconnaissance Soil Survey reports of the various districts of Bangladesh*. Dhaka : Author.
- Tian-ren, Y. (1985). *Physical chemistry of paddy soils*. Beijing : Science Press.
- Verloo, M. (1993). Chemical aspects of soil pollution. In *Proceedings of Refresher Course : New waves Soil Sci.* Yogyakarta, Indonesia.

PERFORMANCE OF GROUNDNUT(*Arachis hypogaea* L.) UNDER DIFFERENT LEVELS OF BRADYRHIZOBIAL INOCULUM AND NITROGEN FERTILIZER

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ABSTRACT

A field experiment was carried out to investigate the effect of different levels of Bradyrhizobial inoculum and nitrogen on nodulation, growth, yield and N content in seed of groundnut. Treatments comprised of five levels of Bradyrhizobial inoculum viz. I₀, I₁, I₃, I₅ and I₇ at the rate of 0, 1, 3, 5, and 7 g of peat inocula/100 g of seed, respectively and six levels of nitrogen viz. N₀, N₁₀, N₂₀, N₃₀, N₄₀ and N₅₀ at the rate of 0, 10, 20, 30, 40 and 50 kg/ha, respectively. The results showed that increased levels of inoculum significantly increased nodule number, nodule weight, plant height, shoot weight, root weight, pod yield and N content in seed. The treatment I₇ produced the highest pod yield of the crop. Nitrogen treatments also exhibited significant influence on all the parameters studied. Significant reductions in nodule number and nodule weight were observed with increasing levels of nitrogen application. The highest plant height, dry matter production and pod yield were obtained from the N₅₀ treatment. There was positive correlation of nodule weight, plant height, shoot weight, root weight, pod yield and N content in seed with total number of nodules due to inoculum application. The data indicate that groundnut production can be enhanced considerably through supply of effective Bradyrhizobial inoculum to the farmers.

Key words: Groundnut, Bradyrhizobial inoculum, Nitrogen fertilizer.

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the 4th important oil seed crop after rape/mustard, sesame and linseed on the basis of annual cultivated area and production in Bangladesh constituting about 7% of the total area under oilseed crops and 9% of the total oilseeds production (BBS, 1996). The scope of expanding the cultivation of rape/mustard, sesame and linseed is very limited. But there is an ample scope for expanding groundnut cultivation specially in the shoals without affecting the major crops. In recent years, groundnut production per hectare has decreased due to low N content in Bangladesh soil and also less availability of effective indigenous *Bradyrhizobial* strains. As a result, the high yield target of groundnut could not be achieved under farmer's conditions mainly due to poor plant growth. It has been reported quite earlier that peanut can fix as much as 40-80 kg N per hectare per year (Alexander, 1977) and that rhizobial inoculant is necessary on new land or in areas where effective rhizobia are absent (Islam & Noor, 1982). Research results on groundnut are not available regarding the comparative effect of different levels of bradyrhizobial inoculum and various doses of nitrogen application under a particular environmental condition. Therefore, the present investigation was undertaken to study the nodulation, growth, yield and protein content of Zhingabadam variety to different levels of bradyrhizobial inoculum and nitrogen fertilizer.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University Campus in 1992-93, Mymensingh under rainfed condition where groundnut has not been grown previously. The experimental field belongs to the Sonatala soil series under the Agro-ecological zone of Old Brahmaputra Floodplain. The soil was silty loam having pH 7.52, organic matter 1.383%, total N 0.076%, available P 14.0 ppm and exchangeable K 1.074 m.e/100 g soil. Five levels of bradyrhizobial inoculum viz. I_0 , I_1 , I_3 , I_5 and I_7 at the rate of 0, 1, 3, 5, and 7 g of peat inocula/100 g of seed, respectively and six levels of nitrogen viz. N_0 , N_{10} , N_{20} , N_{30} , N_{40} and N_{50} at the rate of 0, 10, 20, 30, 40 and 50 kg/ha, respectively were tested in a split-plot design with three replications assigning nitrogen in main plots and bradyrhizobial inoculum in sub plots. The unit plot size was 4.0 m x 3.0 m. The land was finally cultivated and fertilized with 60 kg P_2O_5 /ha in the form of TSP, 45 kg K_2O /ha in the form of MP and 18 kg S/ha in the form of gypsum. Nitrogen was applied in the plots as per treatment before sowing seeds in the form of urea and mixed well with the soil by spading. The seeds were sown singly 15 cm apart in furrows maintaining a distance of 40 cm in between the rows. A seed rate of 100 kg/ha of unshelled groundnut was used. Three weeding were done at 20, 50 and 80 days after emergence. Earthing up was done during second and third weeding.

At 60 days after sowing, 5 plants were uprooted randomly from each unit plot leaving the border rows and harvest area. The roots along with the nodules were washed in water and the plant height was measured. The nodules were removed from the roots and counted. Then the nodules, shoots and roots were oven dried and their weights were recorded.

At maturity, 5 plants were randomly selected and harvested from each unit plot to record the plant height, shoot and root weight. For measuring pod yield, an area of 4 m² (2.0 m x 2.0 m) of each plot was harvested. A representative seed samples were taken from each treatment

to determine total nitrogen in seeds through Micro Kjeldahl method. All the collected data were analyzed statistically and mean differences were adjudged by Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Nodulation

Bradyrhizobial inoculum as well as nitrogen significantly influenced the nodule number and nodule weight at 60 days of crop growth (Table 1). Nodule number and nodule weight were found to increase with increasing levels of inoculum application. The highest nodule number and nodule weight (98.89/plant and 46.16 mg/plant, respectively) were recorded in I_7 treatment, which were statistically similar to those of I_5 and I_3 treatments. The lowest nodule number and nodule weight were observed in uninnoculated plant (83.67/plant and 39.88 mg/plant, respectively). These results are in conformity with the findings of Rungratanakasin *et al.* (1985) who found that increased levels of inoculum significantly increased nodule number and nodule weight. In the present study total nodules of the crop was found to be strongly correlated with total weight of nodules (Table 2). On the other hand, the nodule number and nodule weight of fertilized plants decreased with increasing nitrogen levels. The highest nodule number and nodule weight (102.00/plant and 48.13 mg/plant, respectively) were obtained from the control treatment (N_0), which decreased with the highest levels of nitrogen application. The treatment consisting N_{50} produced the lowest nodule number and nodule weight (85.06/plant and 39.40 mg/plant, respectively). Decreased nodule number and nodule weight with increasing nitrogen levels might be due to the lower nodulation in fertilizer applied plants. The results are in agreement with the findings of Huang (1991) who found delayed nodulation and decreased nodule dry weight with increasing nitrogen application in groundnut.

Plant height

Plant height differed significantly for inoculum application at maturity stage of the crop. A progressive increasing trend in plant height was also observed with the increasing levels of inoculum at 60 days of growth (Table 1). The highest plant height of 13.63 and 109.47 cm were obtained from the highest level of inoculum (I_7) at both the growth stages, respectively. The control treatment produced the lowest plant height at both the growth stages. Higher plant height with higher levels of inoculum application might be due to more nitrogen fixation and utilization by the plant. Chomchalow (1970) reported that inoculated seedlings of groundnut were significantly taller than uninnoculated control. Nodule number showed strong positive correlation with plant height at both the growth stages (Table 2). The highest plant height was recorded in the highest level of nitrogen application i.e. 50 kg N/ha at 60 days of growth and maturity stage of the crop (13.87 and 110.67 cm, respectively) followed by 40 kg N/ha (13.83 and 110.23 cm, respectively) and 30 kg N/ha (13.62 and 109.48 cm, respectively) which were statistically identical (Table 1). The control treatment produced the lowest plant height of 12.78 and 103.61 cm at both the growth stages, respectively. The Higher plant height found in higher levels of nitrogen application might be due to the higher amount of nitrogen uptake by the

plant. Jakhro (1984) observed that plant height at 15, 30, 60 and 90 days after sowing of groundnut increased with increasing nitrogen application upto 60 kg N/ha.

Dry matter weight of shoot

Dry matter weight of shoot was significantly influenced by bradyrhizobial inoculum at 60 days of growth and at maturity stage (Table 1). It was the lowest in uninoculated control treatment (I_0) at 60 days of growth (3.26 g/plant) which was gradually increased to 3.47 g by highest level of inoculum (I_7) application. A similar trend of increasing dry matter weight of shoot was also observed at maturity stage. It was observed that dry matter weight of shoot was 6% higher in the highest level of inoculum application over the control treatment at both the growth stages, respectively. The higher dry matter weight of shoot might be due to more nitrogen fixation and uptake and taller plant by higher level of inoculum application. Rahman *et al.* (1992) reported that inoculation with *Rhizobium* in groundnut increased dry weight of plants significantly. A strong positive correlation was observed between the total nodule number and dry matter weight of shoot at both the growth stages (Table 2). Application of nitrogen had also significant effect on both the growth stages (Table 1). The lowest dry matter weight was obtained from the control treatment (3.14 g/plant) at 60 days of growth, which was gradually increased to 3.55 g/plant by 50 kg N/ha. A more or less similar trend of increasing dry matter weight of shoot was observed at maturity stage. It was observed that dry matter weight was 10.75% higher in 50 kg N/ha than control (0 kg N/ha) at both the growth stages, respectively. However, the treatment 30, 40 and 50 kg N/ha did not differ significantly in dry matter weight at both the growth stages. The higher dry matter weight of shoot might be due to more nitrogen uptake by the plants and higher plant height in higher levels of nitrogen application. Jakhro (1984) had also found that plant dry weight at 30, 60 and 90 days after sowing increased with increasing nitrogen application upto 60 kg N/ha.

Dry matter weight of root

Bradyrhizobial inoculum had a significant effect on dry matter weight of root at 60 days of growth and at maturity stage (Table 1). The lowest dry matter weight of root was obtained from the uninoculated control treatment at both the growth stages (0.148 and 1.08 g/plant, respectively) which was increased with higher levels of inoculum application at both the growth stages. It was observed that dry matter weight of root was 7.40% higher in the highest level of inoculum (I_7) over uninoculated control at both the growth stages, respectively. It might be due to more nitrogen fixation and uptake by higher levels of inoculum application. Dry matter weight of root at both the growth stages showed significant positive correlation with total number of nodules (Table 2).

There was a significant effect of nitrogen on dry matter weight of root at 60 days of growth and maturity stage (Table 1). The highest dry matter weight of root was observed in 50 kg N/ha at both the growth stages (0.161 and 1.180 g/plant, respectively) which were 11.03 and 10.28% higher than the control treatment (0 kg N/ha), respectively. Root weight was higher in 50 kg N/ha because there was more available nitrogen present in the soil during the growing period of the plant.

Table 1. Effect of Bradyrhizobial inoculum and nitrogen on nodulation, growth, yield and nitrogen content in seed of groundnut.

Treatment	Nodule number/plant	Nodule weight (mg/plant)	Plant height (cm)		Shoot weight (g/plant)		Root weight (g/plant)		Pod yield (kg/ha)	Nitrogen content in seed (%)
			60 days of growth	Maturity	60 days of growth	Maturity	60 days of growth	Maturity		
Bradyrhizobial inoculum										
I ₀	83.67e	39.88c	12.97	104.45b	3.26b	32.62b	0.148d	1.08b	2589c	3.83d
I ₁	89.94d	41.77b	13.24	106.62ab	3.30b	34.62ab	0.150c	1.11ab	2782b	3.92c
I ₃	95.94abc	44.72a	13.44	108.92a	3.39ab	35.40a	0.156b	1.14a	2988a	4.01b
I ₅	96.89ab	45.27a	13.60	109.47a	3.44a	35.46a	0.158ab	1.15a	3042a	4.08ab
I ₇	98.89a	46.16a	13.63	109.47a	3.47a	35.64a	0.159a	1.16a	3067a	4.10a
Nitrogen										
N ₀	102.00a	48.13a	12.78d	103.61c	3.14c	33.01d	0.145e	1.07c	2726c	3.80d
N ₁₀	98.20ab	46.46a	13.01cd	105.69c	3.26bc	33.52cd	0.149d	1.09bc	2798bc	3.86d
N ₂₀	95.73bc	43.66b	13.24bcd	107.04bc	3.31b	34.64bc	0.155c	1.11b	2862b	3.98c
N ₃₀	90.66cd	42.33bc	13.52abc	109.48ab	3.46a	35.85ab	0.157bc	1.16a	2968a	4.05b
N ₄₀	86.73de	41.40c	13.83ab	110.23ab	3.52a	36.12ab	0.159ab	1.17a	2993a	4.11ab
N ₅₀	85.06e	39.40d	13.87a	110.67a	3.55a	36.56a	0.161a	1.18a	3015a	4.14a

Means followed by uncommon letter(s) in a column are not significantly different at 1% level by DMRT.

I₀, I₁, I₃, I₅ and I₇ @ 0g, 1g, 3g, 5g, 7g of peat bradyrhizobial inocula/100g of seed. N₀, N₁₀, N₂₀, N₃₀, N₄₀ and N₅₀ @ of 0, 10, 20, 30, 40, 50 kg N/ha

Table 2. Correlation co-efficient between total number of nodules and other crop characters

Characters	Correlation co-efficient (r value)
Total number of nodules Vs dry weight of nodules at 60 days of growth	0.993**
Total number of nodules Vs plant height at 60 days of growth	0.988**
Total number of nodules Vs plant height at maturity stage	0.993**
Total number of nodules Vs shoot weight at 60 days of growth	0.966**
Total number of nodules Vs shoot weight at maturity stage	0.968**
Total number of nodules Vs root weight at 60 days of growth	0.972**
Total number of nodules Vs root weight at maturity stage	0.997**
Total number of nodules Vs pod yield	0.997**
Total number of nodules Vs nitrogen content in seed	0.982**

** Significant at 1% level of probability

REFERENCES

- Alexander, M. (1977). *Introduction to soil microbiology*. New York : John Wiley & Sons.
- Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh (1996). *Statistical Yearbook*. Dhaka : Author.
- Chomchalow, S. (1970). The effectiveness of introduced *Rhizobium* strains on Rayong peanut. *Field Crops Abst.*, 28 (4), 191.
- Huang, X.Z. (1991). The effects of different nitrogen level on nodulation, nitrogen supply and yield of groundnuts. *J. South China Agric. Univ.*, 12 (1), 68-72.
- Islam, M.S., & Noor, S. (1982). Performance of groundnut under different levels of Phosphatic fertilization in Grey Floodplain soils of Jamalpur. *Bangladesh J. Agril. Res.*, 7 (1), 35-50.
- Jakhro, A.A. (1984). Growth, nodulation and yield of groundnut as affected by nitrogen rates. *Planter.*, 60, 149-153.
- Loc, N.B. (1996). Comparison of the influence of inoculation with *Bradyrhizobium* sp. and nitrogen fertilizer application on yield of *Arachis hypogaea* cultivated on two different soils. *Field Crop Abst.*, 49 (2), 128.
- Mali, A.L., Verma, R.R., Rathope, P.S., & Sharma, H.S. (1988). Nutrient uptake in groundnut as influenced by dates of planting and phosphorus and nitrogen fertilization. *Madras Agric. J.*, 75 (9), 356-358.

- Rahman, M.H.H., Khanam, D., & Hossain, A.K.M. (1992). Effect of inoculation and fertilizer on growth and yield of some varieties of groundnut. *Legume Res.*, 15 (3), 137-140.
- Rajeswari, V.R. (1991). Influence of applied nitrogen and rhizobial inoculation on nodulation, root nitrogenous and leaf nitrate reductase activity in groundnut. *Ann. Plant Physiol.*, 5(2) 142-147.
- Rungratanakasin, V., Vadeesirisak, P., & Tananuson, V. (1985). Responses of groundnut cultivar Taiwan 9 to rates and methods of Rhizobium inoculation. In *Proceeding of the Fourth Thailand National Groundnut Research Meeting for 1984* (pp. 419-422). Khonkaen, Thailand.



STUDY OF CLIMATE VARIABILITY AND ITS IMPACT ON RICE YIELD IN BANGLADESH

DEWAN ABDUL QUADIR¹, TARIQ MASOOD ALI KHAN¹,
MD. AKRAM HOSSAIN¹ AND ANWAR IQBAL²

ABSTRACT

The agriculture in Bangladesh is highly dependent on the rainfall but more than normal rainfall causes floods. The severity of the damage in the crop production is expressed in terms of inundated area, flood depth and duration of flood. Considering the severity of problem, the rainfall variability and trends over a few stations of Bangladesh and in the upper catchments areas of the Ganges, the Brahmaputra and the Meghna (GBM) river system, have been studied. The trend analysis is formed on the Sylhet, Rangpur, Dhaka, Cherrapunji, Patna and Kathmandu precipitation data to investigate the area inundated during summer monsoon flooding. In another experiment, the rainfall of Dhaka is investigated with respect to Southern Oscillation Index (SOI) to explore the influence of El Niño Southern Oscillation (ENSO) forcing on the rainfall over Bangladesh. The analysis is made for the flood events during the strong El Niño (strong negative SOI) and strong La Niña (strong positive SOI) conditions as well as for the transition. The Aman rice yield anomalies of Bangladesh have also been investigated with respect to SOI and Dhaka rainfall. The fluctuations of rainfall show correspondence with SOI variability but the phase is found to be changing in the most recent decades. The floods occur in the years of La Niña or during the period of rapid transition from El Niño to La Niña events. As a result, the higher yields of Aman rice are obtained for normal situations and yield reductions occur both for strong El Niño and La Niña events, which are associated with droughts and floods respectively. The analysis of the country average Aman rice yield anomaly against the monsoon rainfall of Dhaka indicates that the Aman rice crop yield follows a quadratic relationship with monsoon rainfall.

Keywords : El Niño Southern Oscillation, Monsoon rainfall, Floods, Bangladesh, Climate variability, Rice yield.

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INTRODUCTION

Bangladesh is an agricultural country and agriculture is highly dependent on the rainfall. However, there are very little rainfall in the winter (December-February) and the winter rice (Boro-rice) is mainly grown using the irrigation water. The normal rain during pre monsoon and summer monsoon seasons helps the Aus rice and Aman rice production, as these crops are not generally dependent on artificial irrigation. However, more than normal rainfall causes flooding and damages the crops.

The prediction of the weather in Bangladesh is still a challenging task. It has been reported that the El Niño Southern Oscillation (ENSO) acts as a dominant force to the variation of monsoon in the subcontinent (Bjerknes, 1969; Wyrski, 1975; Parthasarathy & Pant, 1985; Webster, 1981; Glantz *et al.*, 1991; Choudhury, 1994; Mooley, 1997; Slingo & Annamalai, 2000). This is further to note that, the climate of this region has begun to show some changes due to global warming (Choudhury *et al.*, 1997; Karmakar & Shrestha, 2000). Quadir *et al.* (2001, 2002) have shown that warming in some areas and cooling over the others in and around the Bay of Bengal region are taking place, which again have substantial seasonal variations. Considering the above, the monsoon rainfall variability and trends over a few stations of Bangladesh and in the upper catchments of the Ganges, the Brahmaputra and the Meghna (GBM), namely, Sylhet, Rangpur and Dhaka in Bangladesh, Cherrapunji and Patna in India and Kathmandu in Nepal have been studied in the present paper. The Figure 1 shows the map of Bangladesh and the surrounding areas of the neighbouring countries whereas the solid dots show the location of meteorological stations, mentioned above. The historical data of the area of inundations due to floods in Bangladesh have also been analyzed. As the monsoon activities have some links with the ENSO forcing, the rainfall of Dhaka has been analyzed with respect to Southern Oscillation Index (SOI) to investigate the possible relationship between these parameters.

The impact of El Niño and climate variability on rice crop production in Nepal has been investigated by Gill *et al.*, 1998. According to their study, the rainfall decreased substantially in most part of Nepal during El Nino years and caused droughts. In 1992-93, the Tarai districts, which produces surplus rice during the normal years, was found to be heavily affected by El Niño associated droughts resulting in a severe crop loss. Though in some areas the total monsoon rainfall was normal, but the rainfall peak, which usually occurs in July shifted to August or September affecting the plantation dates.

In the present study, the response of the SOI and associated rainfall variability have been investigated in order to understand the nature of the impact of these climate variability on rice production *i.e.*, area and yields for Bangladesh. Attempts have been made for developing the functional relations of the Aman crop yield with monsoon rainfall that might be useful to estimate the crop losses due to droughts and floods.

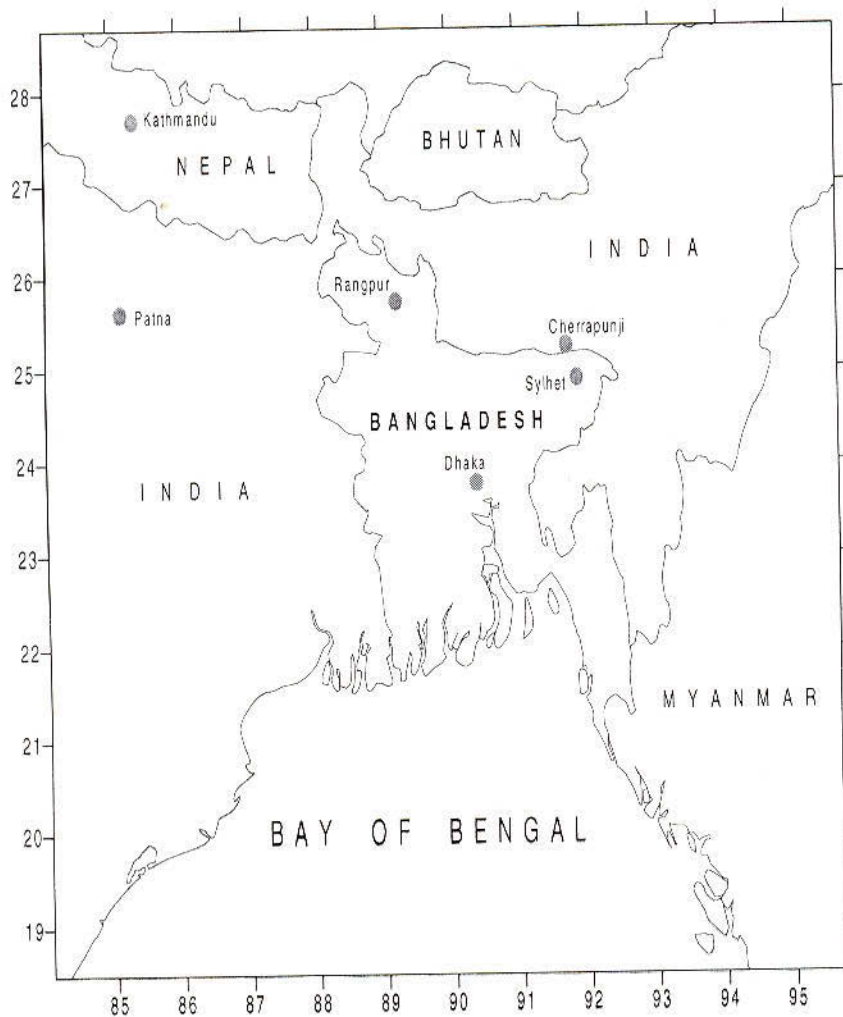


Figure 1: Map of Bangladesh and surrounding areas. The meteorological stations have been shown as solid dots.

MATERIALS AND METHODS

The long term monsoon rainfall data (1961-1999 or as available) of six stations in the catchment areas of the GBM system namely, Kathmandu of Nepal, Patna and Cherrapunji of India and Sylhet, Rangpur and Dhaka of Bangladesh have been analyzed to investigate the inter-annual variability and trends of rainfall (the historical flood record data were collected from Bangladesh Water Development Board). The values of SOI have been obtained from

(NOAA, USA). The rice area and production statistics from 1969 to 2000 was obtained from Bangladesh Bureau of Statistics.

The temporal data of rainfall for the monsoon season have been plotted for the above mentioned six stations. The linear regression analysis has been performed to find out the trends of the rainfall. The thick solid lines represent the trend of rainfall. The inter-annual variations in rainfall have also been discussed. The correlation analysis has been performed by using 11 years moving window to investigate the temporal variation of the nature of ENSO forcing over the rainfall of Bangladesh.

The temporal characteristics of Aman rice area, production and yields have been investigated. At the beginning, the temporal data of the yield has been plotted. It shows that there is a linear increasing trends of the yield which is in fact related to the technological factors such as, improved seeds, improved varieties of crops and better agricultural management. An equation for this trend has been developed using a linear regression analysis. The trend term from the yield has then been eliminated from the time series of yield and the resultant yield anomalies were investigated against rainfall. A functional relation of yield anomaly with the rainfall has then been derived using the fourth order regression analysis.

RESULTS AND DISCUSSION

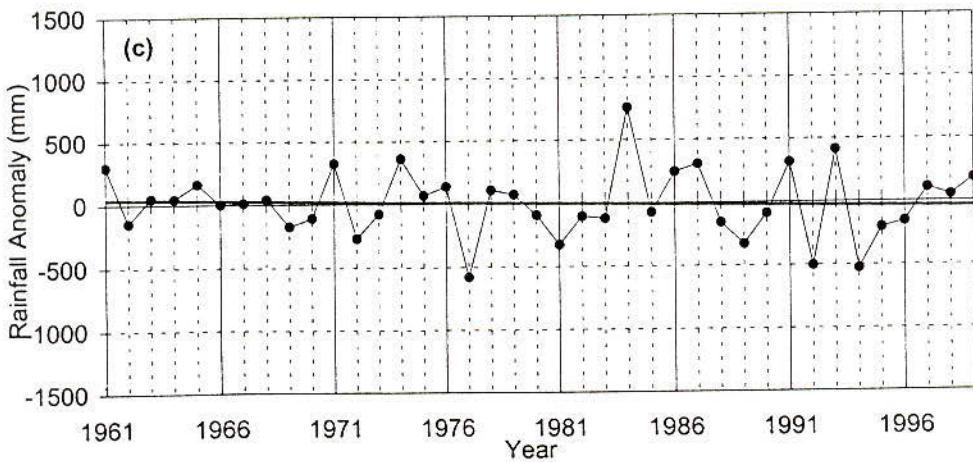
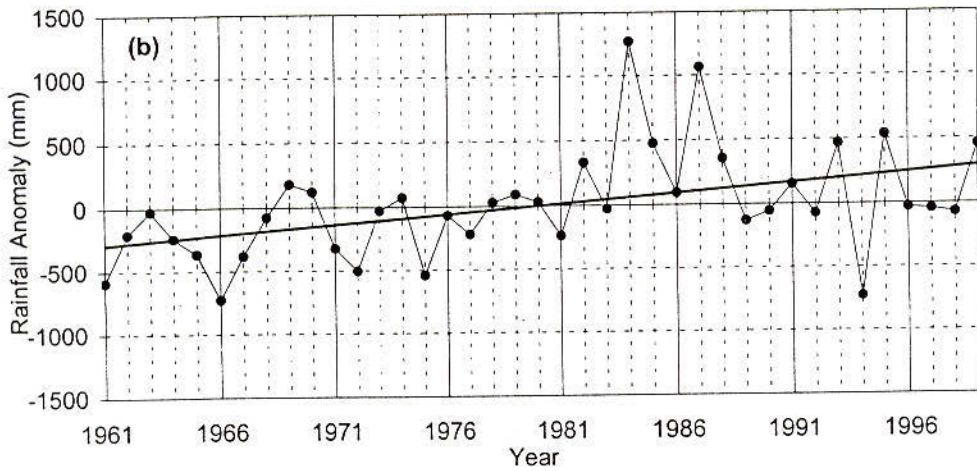
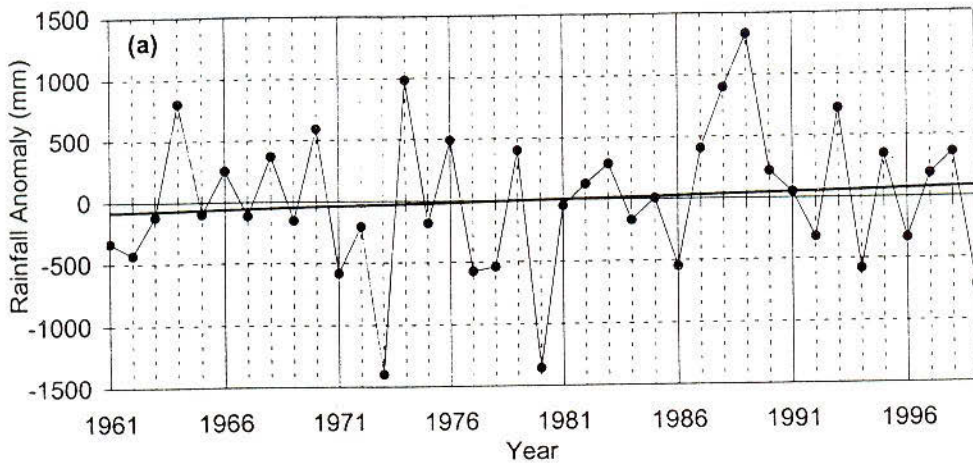
Inter-annual Variability of Rainfall and Trend Analysis: Both the excess and deficit of rainfall affect the rice production of Bangladesh. The pre-monsoon droughts are managed to some extent using the surface and ground water irrigation, but the flash floods in the months of May and June cause lot of damage to the winter (Boro) rice in mature condition and Aus rice in the early part of the growth stage. The Aman rice mostly grows in rain-fed condition in Bangladesh; as a result, the lack of rainfall (drought) affects this crop most. Again, the floods have tremendous impact on yield and cause the severe yield reduction, which depends on the duration and depth of flooding. Some recent studies (Choudhury *et al.*, 1997; Karmakar & Shrestha, 2000) have reported that the rainfall has been increasing over Bangladesh. The study (Quadir *et al.*, 2001) using the most up to date data has shown that the rainfall over Bangladesh and over the neighbouring countries to its north has been increasing with considerable rate and the axis of maximum increasing trends is oriented over the northern Bangladesh and the adjacent territories of India in the east-west direction. Surprisingly, a narrow zone of southeastern Bangladesh shows a decrease of monsoon rainfall.

The rainfall of monsoon season for the 6 stations (3 in Bangladesh, 2 in India and 1 in Nepal) lying in the GBM river basins have been plotted in Figure 2 (a-f). Analysis of these figures indicates that there are strong inter-annual variations having a period around 3-6 years (ENSO period fluctuations) and the extreme events occur with an intervals of 10-12 years (Sun spot period). Similar results have also been found in the spectral analysis of rainfall by Nahrin *et al.*, 1997. The mean and trends of rainfall in mm/year and % changes in rainfall per decade are shown in Table 1. During the monsoon period, the yearly increasing trends of 34.3 mm at

Cherrapunji, 13.8 mm at Patna, 2.5 mm at Kathmandu, 4.0 mm at Sylhet, 15.4 mm at Rangpur have been observed. Dhaka exhibits a negligible decreasing trend (-2.0 mm/year). The estimation of % change in rainfall at every station helps to understand the relative strength of the trends.

Table 1. Showing the mean monsoon rainfall and its trends

Stations	Period	Mean (mm)	Trend (mm/year)	% change/decade
Sylhet	1961-1999	2723.80	4.31	1.58
Rangpur	1961-1999	1591.30	15.36	9.65
Dhaka	1961-1999	1361.40	-2.14	-1.57
Kathmandu	1962-1996	1085.31	2.46	2.27
Patna	1961-1990	964.22	13.79	14.30
Cherrapunji	1961-1990	8635.86	34.35	3.98



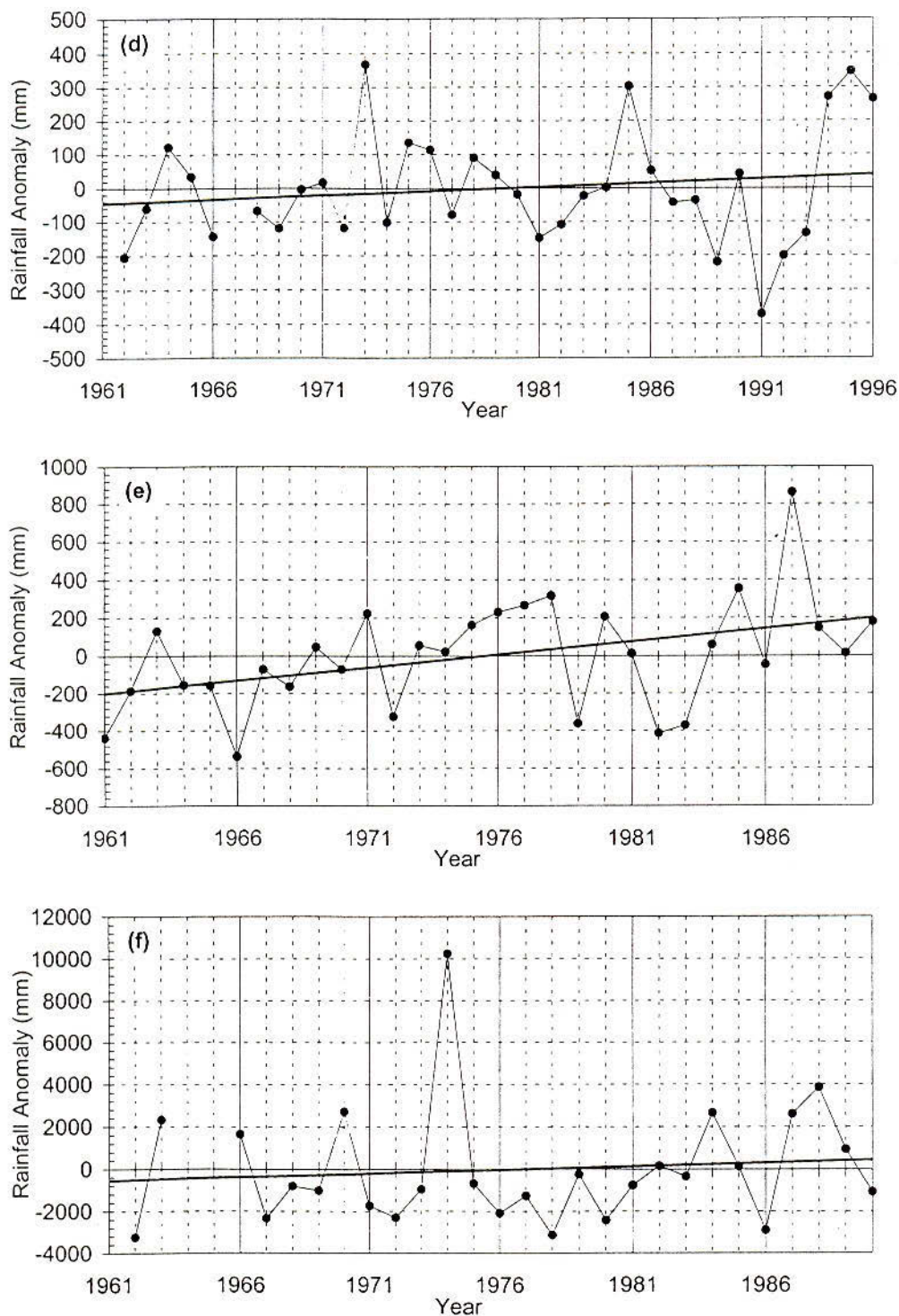


Figure 2(a-f). The inter annual variation and linear trends of summer monsoon rainfall (a) Sylhet, (b) Rangpur, (c) Dhaka, (d) Kathmandu, (e) Patna and (f) Cherrapunji.

The rapid increase of rainfall has been taking place in the northern region of Bangladesh and the adjacent areas of India. This increase may be attributed to climate change with the above increase of rainfall caused by climate change over the GBM catchments more severe floods in the future are likely to occur. The historical data of flood inundations have been shown in Figure 3. This shows that the area of the big floods have been increasing since 1974. At the same time, the frequency of the medium flooding have been found to decrease since 1974. The increasing trend of rainfall in the upper catchments of GBM is one of the major causes of having increasingly more severe floods in Bangladesh in the recent decades. The other causes may be drainage, congestions, deforestation in the upstream regions and enhanced snow and ice melting over the Himalayas due to rapid warming in those areas. The warming over the Himalayas has been reported by Shrestha *et al.*, 1999 and Quadir *et al.*, 2001, 2002.

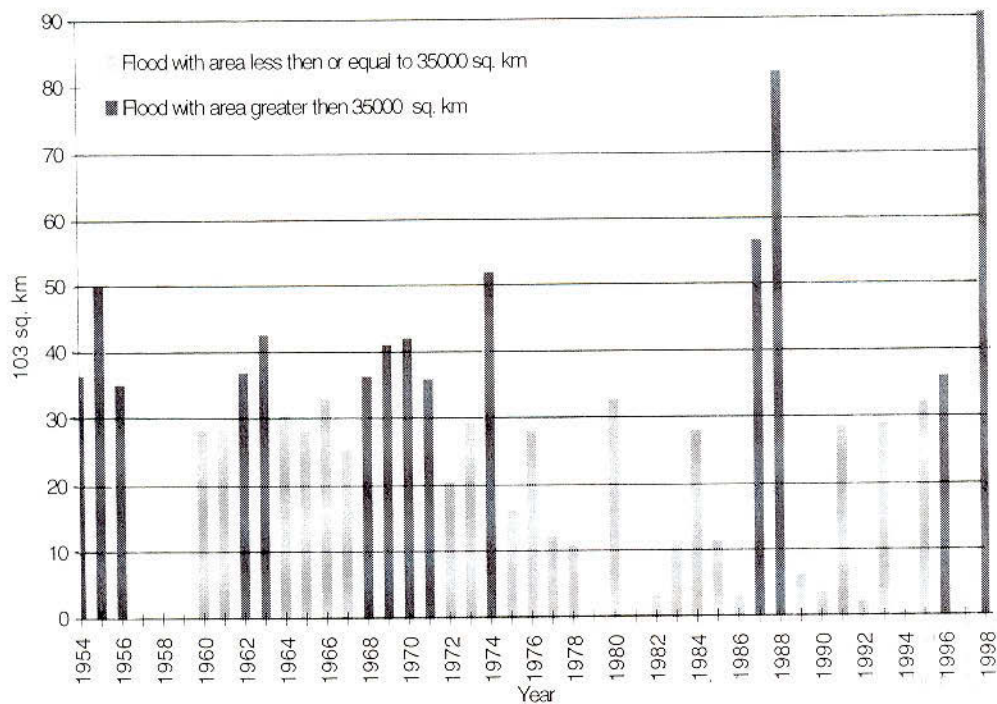


Figure 3. Area of inundation due to floods in Bangladesh from 1954-1998

Rainfall Variability and ENSO: The temporal distribution of monthly rainfall anomalies for Dhaka and SOI values from 1961-1999 and CCs are shown in Figure 4(a-b). The years 1963, 1965, 1969-70, 1972, 1977, 1982-83, 1987, 1991-95 and 1997 were the El Niño years, whereas 1970-71, 1973-74, 1975-76, 1988-89 and 1998-99 represent very strong La Nina years. From the plots it appears that rainfall and SOI were more or less in the similar phase of variations up to the end of 1976 beginning from 1963. Before 1963 (during 1961-62) and from 1978 onwards

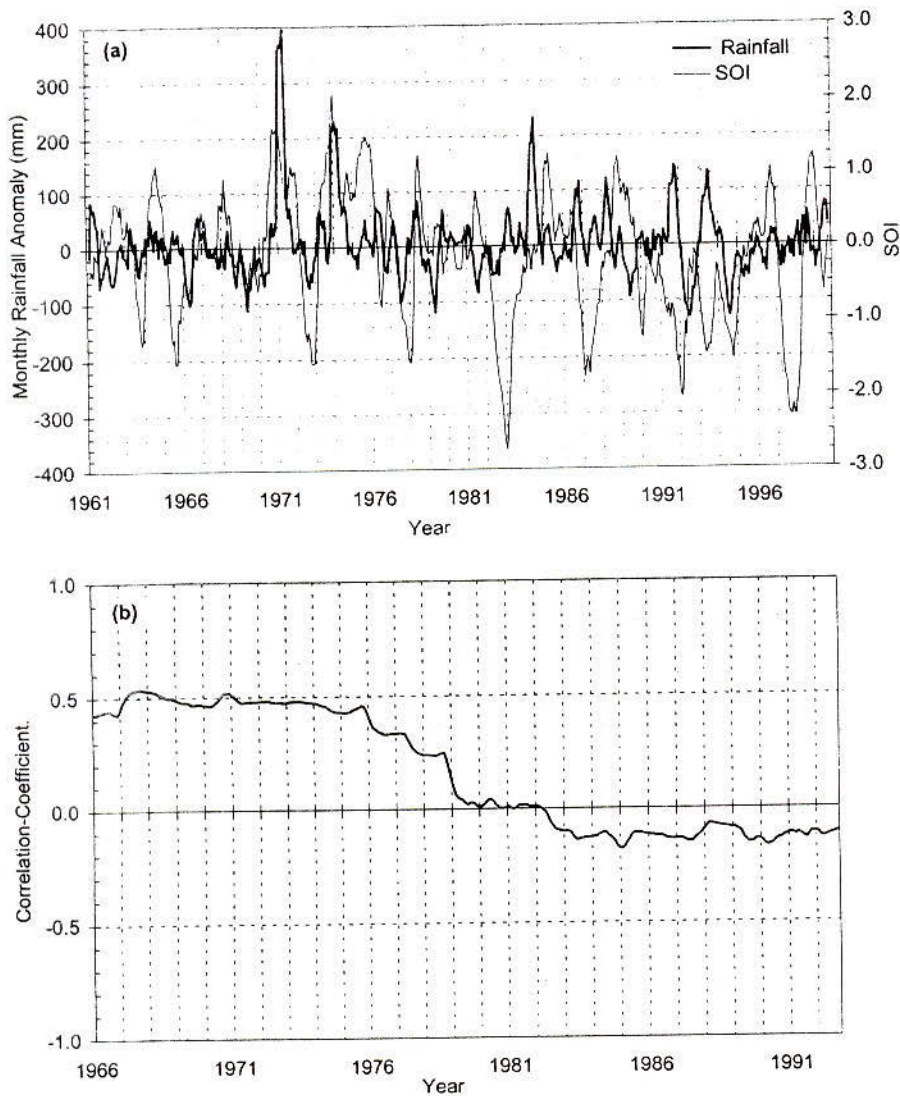


Figure 4. Temporal distribution of (a) monthly rainfall anomalies for Dhaka and SOI (b) correlation coefficient of rainfall with SOI using 132 months (11 years) moving window. The seasonal mode has been eliminated from time series of monthly rainfall. Both SOI and rainfall anomalies have been smoothed using 5 months moving average technique

up to 1990 the variations were out of phase. The heavy monsoon rainfall in 1984 occurred during the transition from El Niño of 1983 to La Niña condition of 1985. Similarly, the heavy rainfall of 1987, 1988 and 1998 occurred during the El Niño to La Niña transition phase. However, the rainfall of 1991 and 1993 were in the opposite phase of SOI. The correlation of rainfall over Dhaka with SOI during this period (1961-1999) is about 0.16. However, the correlation estimated by using moving window (Figure 5b) shows that the correlation coefficients are relatively high (~ 0.5) for the early half of the time series up to 1977. This shows that the influence of ENSO on Bangladesh monsoon varied over time and has changed phase beginning from 1978. From the temporal distribution of SOI, it can be seen that the SOI had an overall lower level of values since 1976 as compared with the SOI of the previous period and very strong El Niño events have occurred since then. The extreme floods of 1987, 1988 and 1998 and associated heavy rainfall occurred during the transition phase from strong El Niño to strong La Niña. Thus from the data of SOI and rainfall it is clear that the rainfall is high during the strong La Niña or in the transition phase from El Niño to La Niña.

Relation of Aman Rice Yield with ENSO and Rainfall : In this section, the weather crop relationship is investigated for Aman rice, which grows during the period around July-November. The monthly rainfall of Dhaka and SOI has been considered as the weather parameters for this study. The crop area, production and yields data 1969-1999 are used in this study. Figure 5(a-c) shows the year-wise Aman rice area, production and yield of Bangladesh.

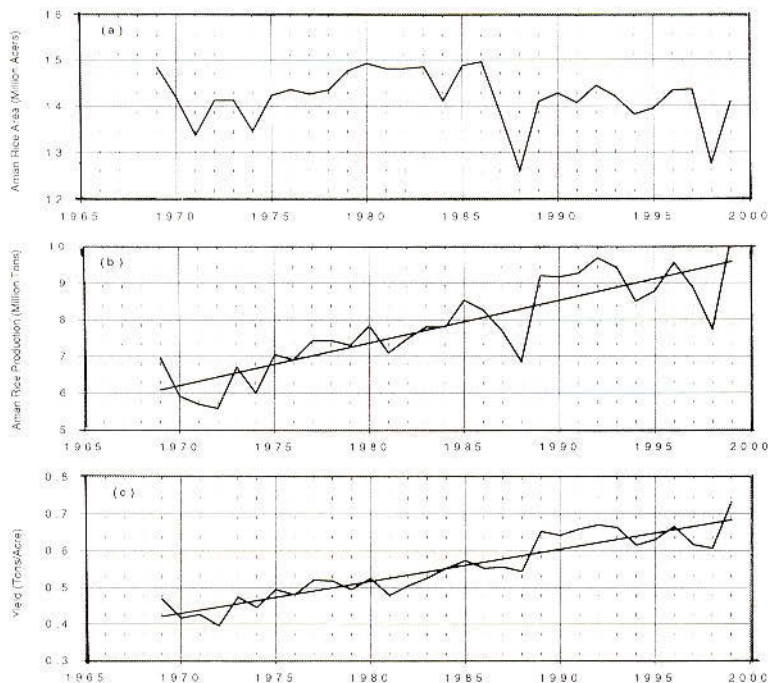


Figure 5(a-c). Temporal plots showing the (a) Aman rice area, (b) production (c) yield during 1969 to 1999.

It is seen that the rice area is quite variable from one year to another 1971, 1974, 1987, 1988 and 1998 had low rice area coverage of which 1974, 1987, 1988 and 1998 were flood years. Very low values in rice area have coincided with the big floods of 1988 and 1998. It has been mentioned earlier that the floods or the heavy rainfall episodes coincided with La Niña phase or with the transition phase from El Niño to La Niña events. A very important characteristic of the temporal distribution is that the variation is prominent in the ENSO time scale of around 3-4 years. The rice area does not have any temporal trend like the rice production or yield, which have positive trends. The thick straight lines show these trends. The increment in trends may be due to factors related to the development of technology, management, and knowledge and information system in agricultural fields. In experiment the trend terms are then subtracted the original series to find the anomalies of the respective variables, which may be free from the contribution of technological and management advances in the agriculture field.

To investigate the yields, the trend equation for the yield has been investigated and is shown below.

$$Y_{trend} = 0.0087534 * Year - 16.8149195 \quad (1)$$

$R^2 = 0.85$; the *Year* begins from 1969. The above equation is useful to predict rise of the yield due to the technological and related other development. This empirical equation may be updated from time to time to incorporate the nonlinear development in the future. The trend term *T*, which as technology dependent is eliminated from the original time series of yield so as to give the yield which is weather dependent only.

$$Y' = Y - Y_{trend} \quad (2)$$

Where Y' represents the yield trend, which is weather dependent only. The weather dependent yield trend and production are shown in figure 6 (a-c). The yield has been plotted along with the SOI in Fig. 6d to analyze the variation of the yield anomaly with respect to SOI and flood events (Fig. 3).

The very low yields in 1972, 1981, 1986, 1994 and 1997 were due to the El Niño related droughts. On the other hand, the low yields of the years 1974, 1987, 1988 and 1998 occurred due to the La Niña related floods. This and the earlier discussions depict that SOI influences the major weather activities related to severe droughts and floods during the monsoon season, which affects the Aman rice area and yields.

The crop yield has further been investigated against the rainfall of Dhaka using the scatter diagram and fourth order regression analysis. The trend free (without technology contribution) yield anomaly was used as the dependent variable and rainfall (*p*) as the independent variable. The scatter diagram is shown Figure 7. The regression equation is expressed as:

$$\begin{aligned} Y' = & 1.775526342 * 10^{-12} p^4 - 1.035718644 * 10^{-8} p^3 \\ & + 2.187907552 * 10^{-5} p^2 - 1.978263281 * 10^{-2} p \\ & + 6.4283(3) \end{aligned}$$

The coefficient of determination $R^2 = 0.57$

By using equations 1 and 3, the value of Y may be calculated and the equation 2 becomes

$$Y = Y' + Y_{trend} \quad (4)$$

The above equation is the full equation for the crop yield estimation, which takes into account the influence of weather (monsoon rainfall) and technological and management trends.

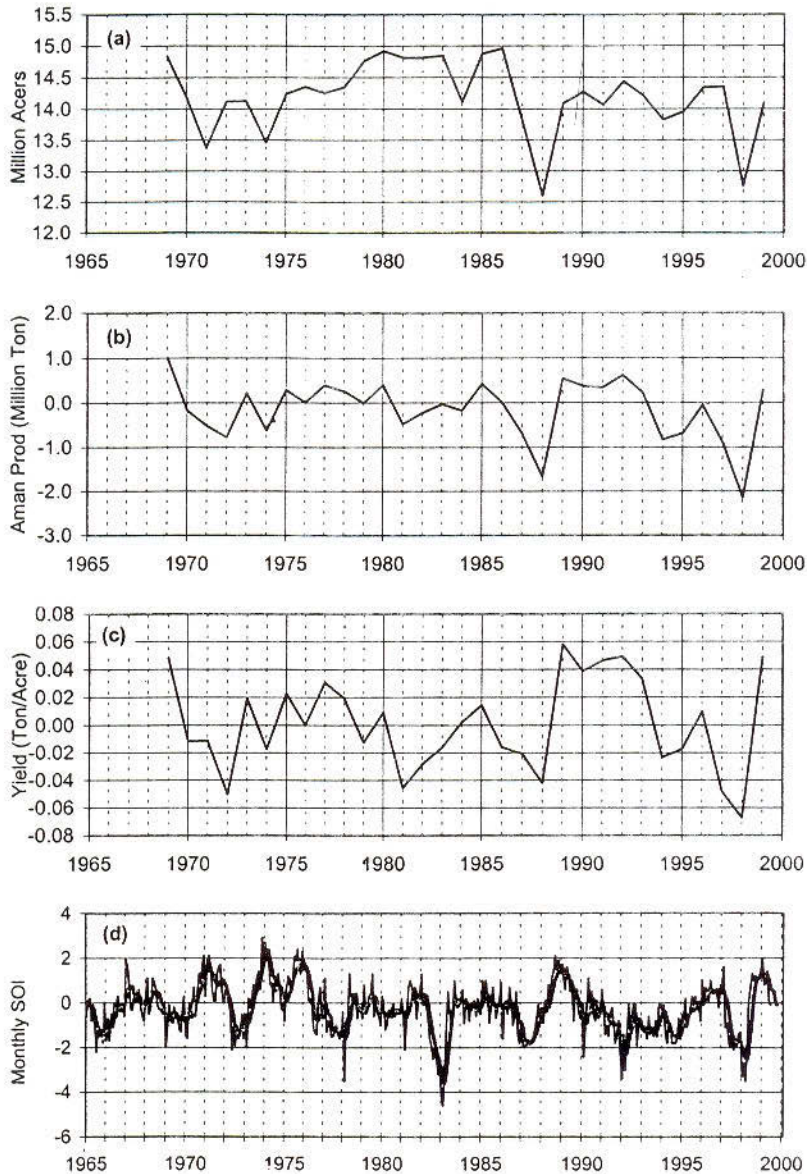


Figure 6(a-d). The temporal plots of the anomalies of (a) Aman rice area, (b) production, (c) yields (trends eliminated) and (d) Southern Oscillation Index (SOI)

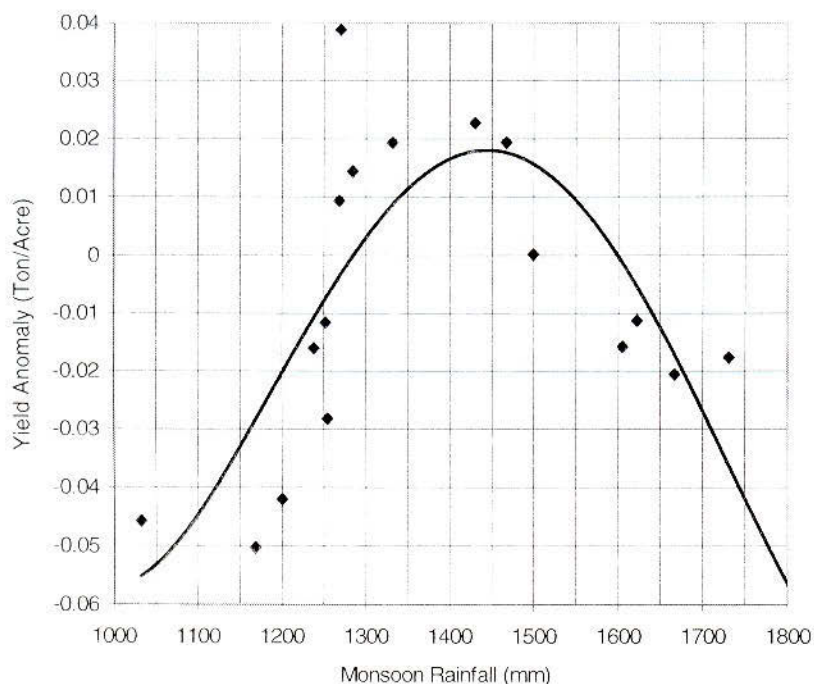


Figure 7. The scatter diagram of yield anomaly of Aman rice and monsoon rainfall at Dhaka. The solid line representing the quadratic function relating the yield anomaly with rainfall.

CONCLUSION

The study shows that the summer monsoon rainfall over Bangladesh and the upstream GBM catchments has increasing trends during the recent decades. One of the major causes of the recent increase of the occurrences and severity of big floods over Bangladesh may be attributed to this increase of monsoon rainfall. The others may be the drainage congestion, deforestation in the upstream regions and enhanced melting of snows and ice over the mountains of Himalayas due to rapid rise of temperature.

The excess rainfall causes floods and the deficit rainfall causes the droughts. Both the phenomena cause countable damage to the crops. It has been found that the rainfall variation in Bangladesh is influenced by ENSO forcing to a large extent. It has also been observed that the droughts are mostly associated with the El Niño situations and the floods with the excess rainfall associated with La Niña. In the past two decades, the relationship of rainfall with ENSO phase has been found to have a phase shift. The floods of 1984, 1987 and 1988 occurred due to the heavy rainfall during the phase of rapid transition from El Niño to La Niña.

The Aman rice area, production and yield have been investigated with respect to SOI. The temporal plots of these variables show that the production and yield have been linearly increasing with time, while the area does not have any temporal trend. The area shows some weather dependent variability and was found to decrease for the strong El Niño and strong La Niña i.e. due to droughts and floods respectively. The trend equations for the production and yield were derived using the regression analysis. The trend terms were then subtracted from the original series to investigate the residual variability with respect to SOI and rainfall. It is very clear from the analysis that the yield reductions were very high during 1988 and 1998 floods.

The regression analysis of the yield anomaly shows that it follows a quadratic relationship with rainfall. This functional relationship of yield with rainfall in combination with the trend equation may be used for assessment of yield of Aman rice. It is recommended that such studies be conducted basin wise to develop more appropriate weather dependent yield equations for practical application.

REFERENCES

- Bjerknes, J. (1969). Atmospheric teleconnection from the equatorial pacific. *Mon. Weather Rev.*, 97, 163-172.
- Choudhury, A.M. (1994, May). *A theory of the El Niño*. Presented at the international conference on monsoon variability and prediction, International Centre for Theoretical Physics (ICTP), Trieste, Italy.
- Choudhury, A.M., Ali, A., & Quadir, D. A. (2002). *Modeling of climate variability and prediction of crop yields in relation to El Niño La Niña Phenomenon. Final Report of the Contract Research Project*. Dhaka : Bangladesh Agricultural Research Council (BARC),
- Choudhury, A.M., Haque, M.A., & Quadir, D.A. (1997). Consequences of global warming and sea level rise in Bangladesh. *Marine Geodesy*, 20, 13-31.
- Gill, G.J., Hobbs, P.R., & Shrestha, M. L. (1998). *Possible impacts of the current El Niño Events on Nepal's 1998 paddy crop*. Policy Outlook, Series No.1. Nepal : HMG Ministry of Agriculture / Winrock International, Policy Analysts in Agriculture and Related Resource Management.
- Glantz, M.H., Katz, R.W., & Nicholls, N. (1991). *Teleconnections linking worldwide climate anomalies*. Cambridge : Cambridge University Press.
- Karmakar, S., & Shrestha, M. L. (2000). *Recent climate change in Bangladesh, Report No. 4*. Dhaka, Bangladesh : SAARC Meteorological Research Centre (SMRC).
- Mooley, D. A. (1997). Variation of summer monsoon rainfall over India in El- Niños. *Mausam*, 48, 413-420.
- Nahrin, Z., Munim, A. A., Begum, Q. N., & Quadir, D. A. (1997). Studies of periodicities of rainfall over Bangladesh. *J. Remote Sensing and Environment*, 1, 43-54.
- Parthasarathy, B., & Pant, G.B. (1985). Seasonal relationships between Indian summer monsoon rainfall and the Southern Oscillation. *Journal of Climatology*, 5, 369-378.

- Quadir, D. A., Shrestha, M.L., Khan, T.M.A., Ferdousi, N., Rahman, M.M., & Mannan, A.M. (2001). Dynamic changes of climate in Bangladesh and the adjacent regions in association with global warming. In *Proceedings of the International Conference on Mechanical Engineering (ICME)*, Vol. 2, Section II (Environment) (pp. 13-18). Dhaka : Department of Mechanical Engineering, Bangladesh University of Engineering and Technology.
- Quadir, D. A., Shrestha, M.L., Khan, T.M.A., Ferdousi, N., Rahman, M.M., & Mannan, A.M. (2002). Variations of annual temperature in and around Bay of Bangal. Accepted for publication in the Special Issue of Natural Hazards.
- Shrestha A.B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalayas and its vicinity: An analysis Based on Temperature records from Nepal for Period 1971-94. *Journal of Climate*, 12, 2775-2786.
- Slingo, J. M., & Annamalai, H. (2000). The El Niño of the century and the response of the Indian summer monsoon. *Monthly Weather Review*, 128, 1778-1797.
- Webster, P.J. (1981). A model of the seasonally Varying Planetary-scale Monsoon In: Sir J Lighthill and R.P. Pearce (Ed.). *Monsoon Dynamics*. Cambridge : Cambridge University Press.
- Wyrtki, K. (1975). El Niño. The dynamic response of the equatorial Pacific Ocean to atmospheric forcing. *Journal of Physical Oceanography*, 5, 572-584.

BIOMATERIALS IN THE RECONSTRUCTION OF ABDOMINAL WALL DEFECTS IN ANIMALS: A REVIEW

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INTRODUCTION

Biomaterials are used in medical devices, particularly in those applications for which the device either contacts or is temporarily inserted or permanently implanted in the body. The National Institute of Health Consensus Development Conference on November, 1982 defined biomaterial as "Any substance (other than a drug) or combination of substances, synthetic or natural in origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replaces any tissue, organ, or function of the body (Boretos & Eden, 1984). In a practical sense, biomaterials are synthetic polymers, metals, ceramics and natural macro molecules that are manufactured or processed to be suitable for use in or as a medical device that comes into immediate contact with proteins, cells, tissues, organs and organ system (Helmus, 1991). Biomaterials can be implanted for long term use (e.g. as an artificial heart valve or hip prosthesis) or for temporary use, such as intravenous (IV) catheter. The biomaterial should not elicit any detrimental effects on the biologic system either locally or systemically, that is, the material must be nontoxic, noncarcinogenic, nonantigenic and nonmutagenic (Von Recum, 1986).

The abdominal wall of an animal is a strong muscular wall which protects the visceral organs from external damage and their herniation. Generally, congenital affections and/or physical trauma to the abdominal wall cause the visceral organs to herniated through the abdominal wall defect. Congenital as well as acquired abdominal wall defects are quite common in domestic animals. Anatomical variations, polygenic inheritance (Robinson, 1977) or infectious diseases are certain etiologies which are apparent as birth defect of the wall. The acquired defects may result from external trauma by blunt object, gore injury, falling or casting on uneven ground, automobile accidents, deep wounds, abscess and physiological disturbances of visceral organs such as straining from constipation, diarrhoea and parturition. Moreover, it may also be the result of previous surgery i.e., ventral middle or paramedian laparotomy, umbilical herniorrhaphy (Vander velden & Klein, 1994). Singh et al. (1989) reported the incidence of hernia in animals. Anatomically, 45.8% umbilical and 32.2% ventral hernias were recorded. Most of the cases of umbilical hernia were congenital in nature. The sex ratio was one male to two females.

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Method of treatment of abdominal wall defect varies with location and size of hernia. If the hernial ring is of moderate size and easily reducible, closure can be effected by conventional method of repair. However, surgical repair of large abdominal wall defects require variable supporting materials to reduce tension and consequent cutting and splitting of suture region of repair. In the modern surgery several types of biological and synthetic materials have been used as prosthesis for repair of abdominal wall defects.

For surgical repair of abdominal wall defects various techniques have been developed. Small defects of ventral wall can be repaired successfully by sutures using different suture techniques, but in cases of large defects, simple apposition of edges and retention by sutures is not possible because of heavy visceral pressure on the suture line. However, by using prosthetic materials in reconstruction of hernial ring the tension over the repaired abdominal wall can be reduced. Although, the use of several prosthetic materials in repair of large abdominal wall defects with different success rates have been reported in different species, even then the use of prosthetic materials in veterinary practice is not so frequent. This review includes some synthetic and biomaterials used in the reconstruction of abdominal wall defects in animals.

SYNTHETIC BIOMATERIALS

Nylon

Polyamide is a large family of different polymers to all of which the term nylon refers. All polyamides are the repeated amide linkages in which CH_2 groups of varying lengths are attached. Nylon is the strongest of the available plastics. In its natural stage it is slightly translucent and yellow in colour. It is chemically resistant to alkalies, easily fabricable and possess excellent mechanical properties.

Moore and Syderney (1955) used single layer fine nylon mesh and three layer impervious sheet of fused nylon and polyethylene for the repair of abdominal wall defects in dogs. Impervious nylon polyethylene graft induced excessive tissue reaction with fluid accumulation. The single layer fine nylon mesh was tolerated well with no fluid accumulation. Nylon 6-polymer mesh as prosthetic material in the repair of umbilical or ventral hernias was used by Wintzer (1962) in 184 cattle. The results of 177 cases were found satisfactory. Out of 7 unsuccessful cases, 2 failure were due to the result of partial loosening of the mesh few days to massive wound infection accompanied by acute or chronic peritonitis which necessitated eventual slaughter. Thoust *et al.* (1967) used nylon mesh as prosthetic material in repair of diaphragmatic hernia in heifer. Out of 3 cases, one was successfully corrected. Weaver (1968) successfully implanted nylon mesh in a clinical case of inguinal hernia in the ewe. The mesh was sutured to the edge of the hernial ring using braided nylon and concluded that nylon mesh was good to close the small hernial ring because it did not produce reaction during the process of repair.

Joshi (1971) used fine nylon nets, plastic mesh and vitafil for the repair of ventral hernia in 15 buffalo calves and found that all these three synthetic materials were suitable for

the repair of hernia. Nylon mesh has also been used in the surgical repair of hernia in cattle (Bouisset et al., 1982). Kanade et al. (1988) repaired abdominal defects by stainless steel and nylon mesh implants in buffaloes after creating 6 x 8 inch defect. Histological observation revealed comparatively less inflammation and early appearance of fibrous tissue and collagen in defects repaired by nylon mesh. Increased deposition of collagen and greater mucopolysaccharide activity was seen in nylon mesh implanted defects as compared to stainless steel implanted defects. Sen and Paul (1989) also reported successful repair of ventral hernias in one and half year old buffalo calf having hernial ring of 26 cm in diameter and in a heifer having hernial ring of 21 cm by using nylon mosquito mesh. Nylon mosquito mesh was found cheap, strong, easily available without tearing effect and induced minimum tissue reaction. William et al. (1989) successfully treated a case of reticular hernia in a crossbred heifer using nylon mesh. No complications were observed.

Varshney and Singh (1991) described the surgical management of ventral hernia with nylon mesh prosthesis in a buffalo heifer. The inlay graft technique was used to implant the nylon net. The animal showed an uneventful recovery. Naveen Kumar et al. (2002) reported two cases of hernia repaired by nylon mesh in a buffalo and heifer. In buffalo the swelling was located in the right ventrolateral aspect of abdomen and about 12" in diameter, whereas in heifer about 6" in diameter large swelling at the umbilical region was observed. The inlay grafts technique was used to implant two folds of nylon net (2x2) cm larger than hernial ring) in the defect. Mattress sutures were placed to secure the nylon net with the hernial ring.

Polypropylene and Polyethylene (marlex)

Polypropylene is a thermoplastic polymer that is so well tolerated when implanted *in vivo* that, it is used as a standard of comparison in toxicity testing of biomaterials. It is resistant to all acids, alkaloids and inorganic chemicals and is insoluble at room temperature. It has a very low coefficient of friction and outstanding wearing resistance.

Usher et al. (1959) injected pellets of polypropylene mesh (marlex mesh) in the abdominal cavity of dogs and studied the tissue reaction. Later, this mesh was used in repair of abdominal wall defect. To study the effect of infection on the mesh, the diluted fecal solution was injected into the surgical wound immediately after implantation of the mesh in few animals. The dogs survived in spite of infection without exhibiting any sign of rejection of mesh by the tissue. It was observed that propylene mesh induced minimum tissue reaction in both infected and non-infected wounds. Koontz and Kimberly (1960) implanted marlex mesh and tantalum mesh in the repair of artificially induced abdominal wall defects in dogs. The fibroblastic infiltration was excellent in defect repaired with marlex mesh as compared to tantalum. Further, marlex mesh did not cause any problem in the presence of infection. Collins (1965) implanted interwoven polyethylene mesh for the repair of inguinal hernia in 3 dogs. The mesh did not cause any discomfort to patient. Johnson (1969) used the polypropylene tefetta weave knitted mesh (marlex mesh) to repair the tissue defects in the abdominal wall of ponies. The mesh became incorporated with the tissue with minimal foreign body reaction. The skin

incisions healed by first intension. Grossly, the abdominal wall at the implant site was seen slightly thickened on a cross section.

Phillip (1970) implanted marlex mesh over the defect using marlex braided sutures in 3 cases of ventral and umbilical hernias. The results were found satisfactory. Phillip (1970) repaired hernia by different techniques using different prosthetic materials in 47 experimental dogs. Among different techniques, overlapping body wall technique was observed ideal for anatomic closure. For hernioplasty, marlex mesh among the synthetic material was proved better. Later, ventral hernias were corrected by using plastic, celluloid, marlex and mersilene meshes in experimental dogs. Marlex and mersilene meshes were found best while plastic and celluloid were most unsuited for hernioplasty (Phillip & Hattangady, 1972). Rajendran *et al.* (1974) used polyethylene mesh for the repair of porcine umbilical hernia. The implanted polyethylene mesh was found interwoven with fibrous tissue and was indistinguishable from the surrounding tissue.

Matera *et al.* (1976) successfully repaired umbilical hernia by lateral overlapping, with propylene mesh in six female and three male cattle. The aponeuroses of the rectus abdominus muscle were sutured with propylene mesh. Good recovery was obtained in all the animals. Elliot and Juler (1979) compared marlex mesh and microporous Teflon sheet (PTFE) in hernial repair in rabbit. PTFE retained its position and shape without local or peritoneal reaction. In contrast, marlex mesh showed marked inflammatory reaction and scarring with complete distortion of the graft. Matera *et al.* (1981) successfully treated unilateral perineal hernia in five male dogs and a bitch by suturing polypropylene mesh to surrounding muscle.

Jenkins *et al.* (1983) used patches of polypropylene mesh (marlex), polyglactin 910 mesh (vicryl), expanded polytetrafluoroethylene (Goretex), dacron reinforced silicon rubber (silastic), Preserved Human Dura (PHD) and polypropylene mesh overlying gelatin film (marlex and gel film respectively) were used to repair the abdominal wall defects in rats. Adhesions formation was moderate to maximal for marlex and goretex. Among all the prosthetic materials used, absorbable prosthetic vicryl provided best long-term protection against adhesions. Tulleners and Fretz (1983) repaired large abdominal wall defects using knitted polypropylene in horses and food animals (cattle). The mesh was found effective in repairing large facial defects. However, some complications like infection and irreversible peritonitis were noted in 4.5% and 9% cases respectively. Fox *et al.* (1988) employed marlex mesh as a prosthetic material to repair tissue defects in dogs. The mesh was proved strong and resistant to infection because of its biological inertness. Granulation tissue and capillaries grew through mesh and provided a healthy granulation bed for skin or muscle flap grafts. Clarke (1989) used polypropylene mesh to reinforce the pelvic diaphragm in 17 dogs with perineal hernia. Suture sinus in two dogs and recurrence in one dog were observed postoperatively.

Tyrell *et al.* (1989) compared two permanent (polypropylene and polytetrafluoroethylene) and two absorbable (polyglactin and polyglycolic acid) meshes to repair the standard abdominal wall defects in rabbits. Each of the material provoked only a minimal inflammatory response. Adhesions were more marked with the permanent mesh, polypropylene than with

polytetrafluoroethylene. There was no difference in the development of adhesions when two absorbable meshes were compared. Polypropylene had the greater tensile strength in comparison to others. Vandervalden and Klein (1994) described the repair of the large abdominal wall defects by using polypropylene mesh in horses. Implantation of mesh on the outside of the hernial ring was found simple and very suitable technique. Bowman et al. (1998) found seroma formation as a common complication following implantation of polypropylene mesh in dogs and cats however, it resolved with treatment. It was concluded that implantation of polypropylene mesh facilitated the reconstruction of large tissue defects and was not associated with any serious complications. Greenwalt et al. (2000) repaired full thickness defect of abdominal wall using polypropylene mesh, bard composite (PP/ePTFE) or sepra mesh biosurgical composite prosthesis (PPM coated on one side with chemically modified sodium hyaluronate and carboxymethyl cellulose) in rabbits. In sepra mesh group, there was a significant reduction in the percentage of surface area covered by adhesions and significant reduction in the percentage of surface area covered by adhesions and significant increase in the percentage of animals with no adhesions compared to standard materials. Cylindrical polypropylene mesh prosthesis was inserted and fixed in the inguinal canal by laparoscope in 9 stallion in standing position. Subsequent adhesion formation resulted in an obliterated inguinal canal with in 2 weeks (Marien, 2001). Lidbetter et al. (2002) evaluated polypropylene mesh for reconstruction of lateral thoracic body wall respected following fibrosarcoma in six cats. Follow up examination from 12 to 21 months revealed that none of the cats had recurrence and out come was judged good to excellent in all cats.

Carbon mesh

Carbon occurs in a number of forms displaying an extraordinary wide range of properties. Carbon fibres are made by the pyrolyzation of polymer fibres such as polyacrylonitrile or rayon at very high temperatures in an inert atmosphere. They can be felted, woven into cloth (mesh) or used as monodirectional filaments. They exhibit outstanding biocompatibility. The carbon fibres present a highly wet able surface to body fluids, thus tissue growth which serves to stabilize the implants take place rapidly.

Johnson-Nurse and Jenkins (1980) used flexible carbon fibres in the repair of experimental large abdominal incisional hernias in sheep. Carbon fibre was well tolerated by animal tissue. Tayton et al. (1982) studied long term effects of carbon fibres on soft tissues in rats. There was no sign of any malignant change in soft tissues. Marlex mesh induced a chronic inflammatory response with disorganized collagen, whereas, the carbon fibres were well tolerated and acted as a scaffold for well organized and oriented collagen. Greenstein et al. (1986) used polylactic acid carbon mesh for repair of ventral hernia in rats. The polylactic acid filamentous carbon cloth composite acted as a biocompatible scaffold. After implantation of the mesh, there was no evidence of wound infection or serosal collection. Runnels and Trampel (1986) used carbon/polycaprolactone composite in reconstruction of full thickness thoracic and abdominal wall defects in dogs. The implant was well tolerated.

Gangwar (2002) experimentally evaluated carbon fibres and carbon sheet for the repair of 2 X 3 cm defect in ventral abdominal wall of rabbits. Clinical, macroscopical, immunological, histopathological and histochemical studies revealed that both of these materials can be used in the repair of abdominal wall defect. Both carbon fibres and carbon sheet behaved more or less in the same manner as implants.

Successful use of carbon mesh in surgical management of large umbilical hernia in a cross bred heifer has been reported by Naveen Kumar *et al.* (2002, a) The hernial ring was 10x8 inch in size. Carbon mesh was applied as inlay graft with vetafil sutures. The animal made an uneventful recovery. Naveen Kumar *et al.* (2002, b) also reported two cases of large umbilical hernia in cross bred male calves. In both the animals the hernial ring was about 20 x 8 cm in size. The carbon mesh was applied as inlay grafts with vetafil. The hernial ring was doubly reinforced by overlapping vest over pant sutures of vetafil. Both the animals made an uneventful recovery.

POLY TETRA FLUORO ETHYLENE (PTFE)

Poly Tetra Fluoro Ethylene (PTFE) are basically fluorocarbons in which all or most of the hydrogens in a hydrocarbon are substituted by fluorine. A direct reaction between polyethylene and fluorine converts polyethylene into PTFE. It is probably the most inert of the plastic materials and has lowest coefficient of friction.

Brown *et al.* (1985) used Polypropylene Mesh (PPM) and Poly Tetra Fluoro Ethylene patches (PTFE) for abdominal wall reconstruction in the presence of contamination and infection. PTFE produced less bacterial adherence in an intraoperative contamination model and created fewer adhesions in control wound, contaminated wound and peritonitis. In addition, PTFE did not appear to worsen the course of peritonitis when used as abdominal wall prosthesis. Lally *et al.* (1993) evaluated different prosthetic materials (oxidized, cellulose, polyglactin mesh and 1 mm PTFE) patch for diaphragmatic reconstruction in growing Sprague-Dawley rats. All patch materials were sewn around the ribs circumferentially and into the membranous portion of the central diaphragm. PTFE pulled away from the chest wall in the animals leaving a fibrous remnant anteriorly.

Polyester (Dacron)

The only polyester used in surgery is Polyethylene-terephthalate (Terylene or Dacron). This material is generally used in knit arterial prosthesis. It is quite stable as an implant material but cause more tissue reaction than other implant material encouraging the growth of tissue into open weave structures and promoting quick fixation.

George and Mohammad (1993) reported diaphragmatic herniorrhaphy using different prosthetic materials (Nylon, dacron and stainless steel mesh). Dacron was found most suitable. Shoukry *et al.* (1997) used Commercial Polyester Fabric (CPF) for the reconstruction of major

abdominal hernias and defects in experimental and clinically affected animals. An appropriate price of sterilized CPF was implanted either in two layers in small animals or in four layers (folded) in large animals in the abdominal wall defect. The techniques of implantation used were retroperitoneal/subfascial, intraperitoneal (either with or without omentalisation) and double sandwich. The intraperitoneal and subfascial implantation technique gave satisfactory results. However, intraperitoneal implantation without omentalisation gave poor results as it was often associated with peritoneal adhesions. CPF give encouraging results in repair of major abdominal wall defects in terms of final tensile strength, non-recurrence and non-dehiscence. Seroma was the only complication related to mesh herniorrhaphy. Koller et al. (1992) used polyester mesh to repair abdominal wall ruptures in the ventral flank in 16 cows under general anaesthesia. The most frequent postoperative complication observed was subcutaneous seroma, which was successfully treated by incision and drainage. All the animals except one healed satisfactory. The functional as well as the cosmetic results were good to excellent.

Miscellaneous

Many other synthetic biomaterials have been used for the repair of abdominal wall defects. Koontzan and Kimberly (1950) implanted tantalum mesh and stainless steel wire mesh in experimental dogs and rabbits. Tantalum mesh produced a normal fibroblastic reaction and soft wound. The fibrous tissue was seen growing around and through the mesh. The steel mesh was covered with dense scar tissue, which did not infiltrate the mesh and produced a hard tumour like effect. Tantalum mesh caused no contracture as puppies grew well. Stapp (1960) repaired umbilical hernia using plastic screen for several years in colts and obtained good results, without undesirable complications. The advantage of this method of repair was its immediate strength. Numan and Wintzer (1964) employed three types of net (mersilene, nylon and polyamide fibre i.e. perlon) in 299 abdominal hernias. There was extensive fibroblastic proliferation through the mersilene mesh than the nylon and polyamide mesh. Mersilene was proved best among the three materials used. Larsen (1966) used plastic mesh. in repair of perineal hernia in 14 dogs. Incidence of recurrence was very low. There was only one recurrent hernia. Hamilton et al. (1974) used tantalum mesh for repair of ventral abdominal hernia in a horse. The mesh was placed between the muscle sheath of the abdominal wall and peritoneum and sutured in position. Tantalum did not cause any foreign body reaction. Ripley and McCarnan (1974) reconstructed umbilical hernia satisfactorily with mersilene in bitch. The technique was also recommended in repair of severe umbilical hernia. Cerise et al (1975) repaired abdominal wall hernias by using mersilene mesh in rats. The mesh had increased the strength of healing wound with low morbidity and recurrence. Touloukian (1978) created hemidiaphragmatic defect in ten pups and repaired with silastic sheeting (Dow-corning 0.007 U) to determine long term results of prosthetic replacement of the diaphragm in growing subjects. All pups survived, grew and developed normally without complication. The prosthesis was located in extreme left anterolateral sulcus in nine of the ten dogs studied by sequential chest x-ray. One animal developed an asymptomatic posterolateral diaphragmatic hernia at nine month following operation.

BIOLOGICAL BIOMATERIALS

Autologous dermis

Phillip (1970) conducted experiments in 47 experimental dogs for the repair of ventral hernia by different techniques using different prosthetic materials. Autologous dermis graft among the biological implants was proved better. Kumar *et al.* (1979) reconstructed diaphragmatic hernia using autologous skin graft in bovines with uneventful recovery. Bhattacharya and Bose (1998) used autologous full thickness skin and dermis as a suturing material and graft in repair of ventral hernia in canines. Autologous dermal graft appeared to be more efficacious than whole thickness autologous skin graft. Yavru *et al.* (1999) reconstructed large hernial defects with skin autograft in sheep, goat, calves and cow. The outer epidermal layer of hernial sac was used as a graft material. The material was found suitable.

Acellular Dermis

Chaplin *et al.* (1999) and Eppely (2001) assessed the revascularization of acellular human dermis for soft tissue augmentation in rabbits. Acellular human dermis was found capable of significant revascularization of its compact collagen composition in the early post operative period. However, the rate and completeness of vessel ingrowth was predictably slower.

Muscle and Fascial Flaps

Johnson (1963) repaired umbilical hernia in horses with sliding fascial flaps. In this method fascia of the abdominal tunic was used to repair the defect and maintained the obliteration of ring. If the defect was unusually large than the repair was reinforced by metallic or plastic gauze. Weaver and Onamegbe (1981) treated perineal hernia in dogs. The superficial gluteal muscle was reflected and sutured into the hernial defect (gluteal flap). Complications included the superficial and deep wound infections, partial or complete sciatic paralysis, rectal prolapse and recurrence of the hernia following breakdown of the repair as well as occurrence of the hernia on the opposite side. However, castration with hernial repair resulted in a lower recurrence rate.

Black (1983) employed internal obturator muscle in the repair of perineal hernia in dog. Purdy (1987) used *Fascia lata* autograft as an adjunct for hernia repair in pony. Ventral abdominal hernia at least 10 cm long created in 6 ponies were closed using two horizontal mattress sutures of polyglycolic acid. The repair area was reinforced with a sheet of fascia lata (7 x 12 cm) taken from lateral hip surface. The fascia lata was sewn to the abdomen using as much tension as possible. All hernias healed without complication. Alexander *et al.* (1991) used external abdominal oblique myofascial flap for repairing 10 x 10 cm defect of abdominal wall in dogs with good results. Werthern *et al.* (1996) used pectineus muscle flap successfully for reinforcement of caudal abdominal hernia in dogs and cats. Goud and Raghavender (1997)

reconstructed the abdominal wall with external abdominal oblique myofascial flap in dogs. Seroma was the most common postoperative complication encountered in all animals.

Allogenic Pericardium

Deshpande et al. (1983) evaluated the efficacy of certain biological and synthetic materials used for the repair of diaphragmatic defects in bovine. Four different materials viz. autogenous fascia, allogenic preserved fascia, allogenic preserved dermis and teflon were used in hernioplasty for correcting diaphragmatic defects in buffalo calves. On the basis of macroscopic and microscopic studies, together with general consideration of its practicability the preserved allogenic fascia, was best suited material and worth giving trial in clinical cases.

Becker et al. (1985) repaired experimentally created 7 cm diameter epigastric defect in the region of umbilicus with specially prepared pericardial tissue of bovine origin in 10 calves. Postoperatively 2 to 6 months after operative no case of hernia or any adhesions with abdominal organs was reported. Becker and Ehrensperger (1986) reported the histocompatibility of a new bovine pericardial graft. A bovine pericardial preparation suitable for closing peritoneal defect in calves was applied to an artificial defect of umbilical area in ten calves. An inflammatory foreign body type granulomatous reaction did not lead to rejection. Deokiouliyar et al. (1988) studied evaluation of glycerol preserved allogenic pericardium for hernioplasty in buffalo calves. The pericardial implant was proved suitable prosthetic material as it became firmly incorporated in the host tissue. The growth of the surrounding collagenous tissue produced a firm union between the graft and host tissue. The graft was gradually invaded by collagen fibres and had been almost completely replaced by 16 weeks. Varshney et al. (1990) repaired abdominal wall defects by using diaphragm, pericardium, tensor fascia lata and peritoneum in buffalo calves. The healing was evaluated clinically, mechanically and microscopically. Inflammatory reactions were observed during first postoperative week and complete healing of skin over the graft occurred in all implanted defects by 14th to 18th day. On day 90, grafts, were enveloped with firm fibrous tissue and it was difficult to distinguish from healing tissue. Matsumoto et al. (1996) used canine pericardium treated with polyepoxy compounds as a patch graft for the correction of diaphragmatic defect in dog. Patch graft showed excellent tissue affinity. Singh and Dhablania (2001) repaired experimentally created perineal hernia in mongrel dogs using chromic catgut, polypropylene mesh, pericardial allograft and by transposition of superficial gluteus muscle. Both polypropylene mesh and pericardial allografts were well accepted on 25th day. Sinus formation in two dogs with polypropylene mesh was observed.

Miscellaneous

Joshi (1971) used fine nylon nets, plastic mesh and vitafil for the repair of ventral hernia in 15th buffalo calves. The graft was fixed by using inlay, onlay and reinforcement techniques. All the three synthetic materials were found suitable. The onlay and reinforcement techniques were reported useful in all types of hernia except where the hernial ring could not be

estimated due to irregularities in shape and size. In cases of irregular shape and size, onlay graft was observed useful. Rodgers et al. (1981) evaluated long term functional and histological results of the use of preserved human dura for closure of abdominal wall and diaphragmatic defects in six dogs. The graft was appeared firmly incorporated into the host tissue. Preserved human dura was found an excellent material for closure of body wall defects. It appeared to be well tolerated by host tissue with maintenance of its strength over prolonged period of time.

Frankland (1986) used porcine dermal collagen in the repair of perineal hernia in dog with moderate success rate. The material was well tolerated. Kanade et al. (1986) used allogenic piece of diaphragm as a prosthetic material for the repair of ventral body wall defects in bovine. Breaking and tensile strength, wound extensibility and energy absorption at the junction of graft with the healthy tissue was maximum at 90 postoperative day.

Urinary bladder implant was used for herniorrhaphy in 2 Merino sheep to find out its efficacy in ventral hernia. The bladder was stretched and applied to the defect in onlay manner. The wound healed without any complication and thus indicated the successful acceptance of the implant (Hussain et al., 1990). Iqbal et al. (1994) employed autogenous jejunal grafts to repair the experimentally created full thickness abdominal wall defect in flank region of dog. The results indicated that a viable intestinal segment can be used to repair the larger defect of abdominal wall. Yung et al. (1998) used omental pedicle flap for repair of large abdominal wall defect in dog.

REFERENCES

- Alexander, L.G., Pavletic, M.M., & Engler, S.J. (1991). Abdominal wall reconstruction with a vascular external abdominal oblique myofascial flap. *Veterinary Surgery*, 20, 379-384.
- Becker, M., & Ehrensperger, F. (1986). The histocompatibility of a new bovine pericardial graft. *Research in Experimental Medicine*, 186, 221-227.
- Becker, M., Kaegi, B., & Waxenberger, M. (1985). Use of bovine pericardial tissue for closing abdominal wall defects in the calf. *Schweizer Archiv fur Tierheilkunde*, 127, 379-383.
- Bhattacharya, S., & Bose, P.K. (1998). Autologous full thickness skin and dermis as suture and graft in dogs. *Indian Veterinary Journal*, 75, 1028.
- Black, A.P. (1983). Use of internal obturator muscle in the repair of perineal hernia in dog. *Australian veterinary practitioner*, 13, 27-28.
- Bortos, J.W., & Eden, M. (1984). *Contemporary biomaterials, material and host response, clinical applications: New technology and legal aspects*. Park Ridge, N.J.: Noyes Publications.
- Bouisset, S., Daniaud L., & Giron, H. (1982). Nylon mesh in the surgical repair of hernias in cattle. *Point Veterinaire*, 14, 47-50.
- Bowman, K.L.T., Birchard, S.J., & Bridht, R.M. (1998). Complications associated with the implantation of polypropylene mesh in dogs and cats; a retrospective study of 21 cases (1984-1996). *Journal of American Animal Hospital Association*, 34, 225-233.
- Brown, G.L. et al. (1985). Comparision of prosthetic material for abdominal wall reconstruction in the presence of contamination and infection. *Annals of Surgery*, 201, 705-711.

- Cameron, A.E.P., & Taylor, D.E.M. (1985). Carbon-fibre versus marlex mesh in the repair of experimental abdominal wall defects in rats. *British Journal of Surgery*, 72, 648-650.
- Cerise, E.J., Busuttill, R.W., Craighead, C.C., & Ogden, W.W. (1975). The use of mersilene mesh in repair of abdominal wall hernias. *Annals of Surgery*, 181, 728-734.
- Chaplin, J.M. et. al. (1999). Use of an acellular demal allograft for dural replacement: an experimental study. *Neurosurgery*, 45, 320-327.
- Clarke, R.E. (1989). Perineal herniorrhaphy in the dog using polypropylene mesh. *Australian Veterinary Practitioner*, 19, 8-14.
- Collins, D.R. (1965). Interwoven polyethylene mesh prosthesis in surgical repair of inguinal hernia in dogs. *Veterinary Medicine*, 60, 377-381.
- Deokiouliyar, U.K., Khan, A.A., Sahay, P.O., & Prasad, R. (1988). Evaluation of preserved homologous pericardium for hernioplasty in buffalo calves. *Journal of Veterinary Medicine Animal Physiology Pathology and Clinical Veterinary Medicine*, 35, 391-394.
- Deshpande, K.S., et al. (1983). Efficacy of certain biological and synthetic materials used for repair of diaphragmatic defects in bovines. *Indian Journal of Animal Science*, 53, 830-834.
- Elliot, M.P., & Juler, G.L. (1979). *Comparison of marlex mesh and microporous Teflon sheets when used for hernia repair in the experimental animal*, 137, 342-344.
- Eppley, B.L. (2001). Experimental assessment of the revascularization of acellular human dermis for soft tissue augmentation. *Plastic and Reconstructive Surgery*, 107, 757-762.
- Fox, S.M., Woody B.J., Bright, R.M., & Hammond, D.L. (1988). Reconstruction of tissue defects with marlex mesh. *Compendium of Continuing Education Practitioner Veterinary*, 10, 897-904.
- Frankland, A.L. (1986). Use of procine dermal collagen in the repair of perineal hernia in dog. A preliminary report. *Veterinary Record*, 119, 13-14.
- Gangwar, A.K. (2002). Biomaterials in repair of abdominal wall defects in rabbits and their clinical application. M.V.Sc. thesis, Submitted to deemed University, IVRI, Izatnagar.
- George, R.S., & Mohammad, M.S.D. (1993). Studies on diaphragmatic herniorrhaphy with different prosthetic materials. *Indian Veterinary Journal*, 70, 255-257.
- Goud, J.A.K., & Raghavender, K.B.P. (1997). Abdominal wall reconstruction with external abdominal oblique myofascial flap in dogs: An experimental study. *Indian Journal of Veterinary Surgery*, 18, 12-14.
- Greenstein, S.M., Murphy, T.F., Rush, B.F., & Alexander, H. (1986). Evaluation of polylactic acid-carbon mesh for repair of ventral herniorrhaphy. *American Journal of Surgery*, 151, 635-639.
- Greenwalt, K.E. et al. (2000). Evaluation of sepramesh biosurgical composite in a rabbit hernia repair model. *Journal of Surgical Research*, 94, 92-98.
- Hamilton, D.P., Nelson, D.R., & Hardenbrook, H.J. (1974). Repair of the ventral abdominal hernia in a horse using Tantalum mesh. *Journal of American Veterinary Medical Association*, 164, 1204-1205.
- Helmus, N.M. (1991). Overview of biomedical materials, *Materials Research Society Bulletin*, 16, 33-38.
- Hussain, S.S., Moulvi, B.A., Zaman, M.M.S., & Buchoo, B.A. (1990). Efficacy of homologous urinary bladder implant for herniorrhaphy in two merino sheep. *Indian Veterinary Journal*, 67, 90-91.
- Iqbal, M., Isma, A., Khan, M.A., Azim, F., & Ahmed, I.G. (1994). Reconstruction of the abdominal wall defect with a jejunal graft in the dog. *International Journal of Animal Science*, 9, 147-148.

- Jenkins, S.D., Klamer, T.W., Parteka, J.J., & Condon, R.K. (1983). A comparison of prosthetic materials used to repair abdominal wall defects. *Surgery*, 94, 392-398.
- Johnson, J.H. (1969). An evaluation of polypropylene implants in ponies. *Journal of American Veterinary Medical Association*, 154, 779-785.
- Johnson, L.E. (1963). Hernia repair with sliding fascial flaps. *Modern Veterinary Practice*, 44, 52-53.
- Johnson-Nurse, C., & Jenkins, D.H.R. (1980). The use of flexible carbon fibre in the repair of experimental large abdominal incisional hernias. *British Journal of Surgery*, 67, 135-137.
- Joshi, N.R. (1971). Studies of the use of different prosthetic materials in the repair of abdominal hernias in buffalo calves. M.V.Sc. Thesis, R.A.U., Pusa.
- Kanade, M.G., Kumar, A., & Sharma, S.N. (1988). Diaphragm as a prosthetic material for the repair of ventral body wall defects in bovine. *Indian Journal of Veterinary Surgery*, 7, 8-14.
- Kanade, M.G., Kumar, A., & Sharma, S.N. (1988). Repair of abdominal defects by stainless steel and nylon mesh implants in buffaloes: histological and histochemical evaluation. *Indian Journal of Animal Science*, 58, 415-419.
- Kanade, M.G., Mantri, M.B., & Kudale, M.L. (1984). Comparative evaluation of techniques of repair of umbilical hernia in calves. *Indian Journal of Veterinary Surgery*, 5, 103-106.
- Koller, V., Lischer, C.L. & Auer, J.A. (2001). Implantation of synthetic mesh for the repair of abdominal wall ruptures in the ventral flank in cows: A review of 16 cases. *Schweizer Archiv für Tierheilkunde*, 143, 351-358.
- Koontz, A.R., & Kimberly, R.C. (1950). Tissue reaction to tantalum mesh and wire. *Annals of Surgery*, 131, 666-686.
- Koontz, A.R., & Kimberly, R.C. (1960). Tantalum and marlex mesh (With a note on marlex thread). An experimental and clinical comparison-preliminary report. *Annals of Surgery*, 151, 796-804.
- Kumar, R., Prasad, B., Singh, J., Sharma, S.N., & Kohli, R.N. (1979). Bovine diaphragmatic hernioplasty using autologous skin grafts. *Modern Veterinary Practice*, 60, 907-908.
- Kumar, R.V.S. (2001). Repair of umbilical hernia involving rumen in a crossbred calf. *Indian Journal of Veterinary Surgery*, 22, 134.
- Lally, K.P., Chew, H.W., & Vazquez, W.D. (1993). Prosthetic diaphragm reconstruction in the growing animals. *Journal of Pediatric Surgery*, 28, 45-47.
- Larsen, J.S. (1966). Perineal herniorrhaphy in dogs. *Journal of American Veterinary Medical Association*, 149, 277-280.
- Lidbetter, D.A., Williams, F.A. Jr., Krahwinkel, D.J., & Adams, W.H. (2002). Radical lateral body wall resection for fibrosarcoma with reconstruction using polypropylene mesh and a caudal superficial epigstric axial pattern flap: A prospective clinical study of the technique and results in 6 cats. *Veterinary Surgery*, 31, 57-64.
- Marien, J. (2001). Standing laproscopic herniorrhaphy in stallions using cylindrical polypropylene mesh prosthesis. *Equine Veterinary Journal*, 33, 91-96.
- Matera, A., Barros, P.S. de, Stopiglia, A.J., & Randi, R.E. (1981). Perineal hernia in the dog and its repair with polypropylene mesh. *Revista-d-Faculdade-de-Medicina-Veterinaria-e-Zootecnia-da-Universidade-de-Sao-Paulo*, 18, 37-41.
- Matera, A. (1976). Surgical treatment of umbilical hernia in cattle: Technique of lateral overlapping with polypropylene mesh reinforcement. *Revista-da-Faculdade-de-Medicina-Veterinaria-e-Zootecnia-da-Universidade-de-Sao-Paulo*, 13, 339-346.

- Matsumoto, H. et al. (1996). The use of epoxy patch graft for the repair of experimentally created diaphragmatic defect in dogs. *Journal of Veterinary Medical Science*, 58, 685-687.
- Moore, T.C., & Syderney, S. (1955). The use of pliable plastic in the repair of abdominal wall defects. *Annals of Surgery*, 142, 973-979.
- Naveen Kumar, Kinjavdekar, P., Aithal, H.P., Amar Pal & Pawde, A.M. (2002). Surgical Management of unusual large hernia with nylon mesh: A report of two cases. *Intas Polivet*, 3 (1), 86-87.
- Naveen Kumar, Sharma, A.K., Gangwar, A.K., Maiti, S.K., & Kumar, N. (2002). a. Successful use carbon sheet in surgical management of large umbilical hernia in crossbred heifer. Submitted for presentation in 90th Indian Science Congress to be held at Bangalore during 3-7 January, 2003.
- Naveen Kumar, Sharma, A.K., Gangwar, A.K., Maiti, S.K., & Kumar, N. (2002). b. Use of carbon mesh in surgical management of large umbilical hernia. Presented in 26th Annual Conference of ISVS to be held at Mumbai during 9-11 November, 2002.
- Numan, S.N., & Wintzer, H.J. (1964). Umbilical and ventral hernia, implant of plastic nylon and mersilene. *Cirugia Veterinaria*, 243-245.
- Parrah, J.D., & Makhdooni, D.M. (2001). Perineal herniation and torsion of urinary bladder in a cow. *Indian Journal of Veterinary Surgery*, 22, 127-128.
- Phillip, P.J. (1970). Hernioplasty using marlex mesh. *Indian Veterinary Journal*, 50, 83-87.
- Hernioplasty in ventral hernia in animals. M.V. Sc. Thesis. Submitted to Konkan Krishi Vishwavidyalaya, Parel, Bombay-400012 (Maharashtra).
- Phillip, P.J., & Hattangady, S.R. (1972). Hernioplasty using artificial materials in ventral hernia in dogs. *Kerala Journal of Veterinary Science*, 3, 13.
- Purdy, C.M. (1987). The use of fascia lata autograft as an adjunct to hernia repair in the pony. *Equine Practice*, 9, 24-27.
- Rajendran, E.I., Gopal, M.S., & David, G. (1974). Prosthetic hernioplasty with polyethylene mesh in porcine umbilical hernia. *Indian Veterinary Journal*, 51, 67-69.
- Ripley, W.A., & McCarnan, H.R. (1974). Umbilical hernia repair with mersilene mesh. *Canadian Veterinary Journal*, 15, 357.
- Robinson, R. (1977). Genetic aspect of umbilical hernia incidence in cats and dogs. *Veterinary Record*, 100, 9-10.
- Rodgers, B.M., Maher, J.W., & Talbert, J.L. (1981). The use of preserved dura for closure of abdominal wall and diaphragmatic defects. *Annals of Surgery*, 193, 606-611.
- Runnels, C.M., & Trampel, D.W. (1986). Full thickness thoracic and abdominal wall reconstruction in dogs using carbon/polycaprolactone composite. *Veterinary Surgery*, 15, 363-368.
- Sen, T.B., & Paul, M.K. (1989). Further studies on the use of nylon mosquito net mesh in hernioplasty in bovine. *Indian Journal of Animal Health*, 28, 65-66.
- Shoukry, M., El-Kiey, M., Hamouda, M., & Gadallah, S. (1997). Commercial polyester fabric repair of abdominal hernias and defects. *Veterinary Record*, 140, 606-607.
- Singh, A.P., Eshoue, S.M., Rifat, J.F., & Fatehea, N.G. (1989). Hernia in animals: A review of 59 cases. *Indian Journal of Veterinary Surgery*, 10, 28-31.
- Singh, P., & Dhablania, D.C. (2001). *Perineal herniorrhaphy in dogs: An experimental study* presented in the Silver Jubilee Annual Congress and National Symposium on Clinical Orientation of Research in Veterinary Surgery.
- Stapp, R.W. (1960). Repair of umbilical hernias with plastic screen. *Modern Veterinary Practice*, 41, 60.

- Tayton, K., Phillips, G., & Ralis, Z. (1982). Long-term effects of carbon fibre on soft tissues. *Journal of Bone and Joint Surgery*, 64-B, 111-114.
- Thouast, H.F., Fessler, J.F., Page, E.H., & Amstutz, H.E. (1967). Thoracic repair of a diaphragmatic hernia in a heifer. *Veterinary Record*, 85, 87-89.
- Touloukian, R.J. (1978). A new diaphragm following prosthetic repair of experimental hemidiaphragmatic defects in the pup. *Annals of Surgery*, 187, 47-51.
- Tulleners, E.P., & Fretz, P.B. (1983). Prosthetic repair of large abdominal wall defects in horses and food animals. *Journal of American Veterinary Medical Association*, 82, 258-262.
- Tyrell, J., Silberman, H., Chandrasoma, P., Niland, J., & Shull, J. (1989). Absorbable vs permanent mesh in abdominal operation. *Surgery Gynecology and Obstetrics*, 168, 227-232.
- Usher, F.C., Fries, J.G., Ochsner, J.L., & Tuttle, L.L.D. (1959). Marlex mesh, a new plastic mesh for repairing tissue defects. II. Clinical studies. *Achieves of Surgery*, 78, 138.
- Vandervelden, M.A., & Klein, W.R. (1994). A modified technique for implantation of polypropylene mesh for the repair of external abdominal hernias in horses: A review of 21 cases. *Veterinary Quarterly*, 16, S108-S110.
- Varshney, A.C., & Singh, B. (1991). Surgical management of ventral hernia with nylon mesh prostheses in a buffalo heifer. *Indian Veterinary Medical Journal*, 15, 65-66.
- Varshney, A.C., Jadon, N.S., & Kumar, A. (1990). Repair of abdominal wall defects by biological grafts in buffaloes: An experimental study. *Indian Journal of Animal Science*, 60, 929-932.
- Von Recum, A.F. (1986). *Hand Book of Biomaterials Evaluation, Scientific, Technical and Clinical testing of Implant Materials*. New York : Macmillan.
- Weaver, A.D. (1968). Inguinal hernia in the ewe: Two case reports. *Veterinary Record*, 83, 170-171.
- Weaver, A.D., & Omamegbe, J.D. (1981). Surgical treatment of perinial hernia in the dog. *Journal of Small Animal Practice*, 22, 749-758.
- Werthern, C.J., Von, Montavon, P.M., & Von Warthern, C.J. (1996). Reinforcement of caudal abdominal hernia repair by a pectineus muscle flap in dogs and cats. *Kleintierproxis*, 41, 169-176.
- William, B.J., Balachandran, S., & Dawson, J.T. (1989). Herioplasty for reticular hernia in a crossbred heifer. *Indian Veterinary Journal*, 66, 1070.
- Wintzer, H.J. (1962). Methods of surgical treatment of bovine abdominal hernias. *Journal of American Veterinary Medical Association*, 141, 131-134.
- Yavru, N., Alkan, F., Koc, B., Auki, S., & Arican, M. (1999). Large hernial defect fixed with skin autograft. *Veteriner-Cerrahi-Dergisi*, 5, 24-27.
- Yung, C.R., Chang, S.H., & Lin, A.C. (1988). *Repair of large abdominal wall defect with an omental pedicle flap in the dog*. Memoirs of the College of Agriculture, National Taiwan University, 28, 46-53.

CROP DIVERSIFICATION THROUGH LAND MODIFICATION IN CANAL IRRIGATION COMMAND OF EASTERN INDIA

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ABSTRACT

A field study was conducted during dry season 2001-2002 at Balipatna under the Nimapara Branch Canal Irrigation command to study the feasibility of growing vegetable crops adjacent to rice in the same field. For this purpose, the land was modified into alternate raised and sunken beds by digging soil to the depth of 30 cm and putting it on the adjacent raised bed. Rice was grown in the sunken beds and different vegetable sequences were grown on the adjacent raised beds. Conventional paddy field with no modification of land also included as control. The highest rice equivalent yield (21.6 t/ha) was achieved in raised and sunken bed system with rice + cabbage-malabar spinach crop sequence which was followed by rice + tomato-ridge gourd sequence. Conventional rice cultivation yielded the least (3.19 t/ha). The highest benefit cost ratio (3.01) was recorded in Rice + Cabbage – malabar spinach sequence.

Key words: Sunken and raised bed, Crop diversification, Land utilization index, Economics, Water use efficiency, Coastal Orissa.

INTRODUCTION

Crop diversification is an agricultural development concept towards intensive utilization of land in cultivating more than one type of crops to reduce risk of crop failure and improve productivity and income especially in smaller holdings. Wet season rice (June-November) followed by dry season rice (February-May) is the cropping sequence being followed in canal irrigation commands of coastal Orissa. High rainfall and water table condition forces the farmers to include rice as a compulsory option in wet season. In dry season also, though rice cultivation is not remunerative, farmers in the canal irrigation command have no other option except to grow rice crop since fields remain invariably saturated to over-

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saturated with water. This condition some times leads the farmers to keep their field fallow. Crop diversification in such area is possible by land modification (Siddiq & Kundu, 1993). Present investigation was conducted in the Nimapara Branch Canal Irrigation Command at Balipatna block in Khurda district of Orissa with the objectives of diversification and intensification of crops, increase the employment opportunity and better economic return by modification of microenvironment through land shaping.

METHODOLOGY

The experiment was carried out in dry season 2001- 2002 in the farmers' fields at Balipatna block, Khurda district of Orissa (India) which comes under Nimapara Branch Canal of Mahanadhi Delta. The area lies at 20° 21' N latitude and 85°54'E longitude and above 50 m MSL. The soils of the area was deep, poorly drained, fine, mixed, loamy, hyperthermic, Aeric Tropaquept of alluvial origin. It was sandy clay loam, having 58.7 per cent sand, 20.9 per cent silt and 20.4 per cent clay. The pH, EC and organic carbon content was 5.9–6.7, 0.1–0.16 dS/m and 0.3–0.4 per cent respectively. The entire field was converted into alternate sunken and raised beds (50:50) each of 30-meter length and 5 meter width. The top 30 cm soil was dug to make sunken beds and the dugout soil was used to prepare adjacent raised beds in the fields. The raised beds were thus 60-cm higher than the adjacent sunken beds (Fig. 1). The experiment was conducted in a Randomized Block Design with three replications. The treatments were: T₁, conventional system (rice crop only with no land modification); T₂, alternated sunken and raised bed system with rice in the sunken bed and cabbage (*Brassica oleraceae*) in the raised bed; T₃, rice in the sunken bed and cabbage followed by malabar spinach (*Basella alba*) in raised bed; T₄, rice in the sunken bed and brinjal (*Solanum melongena*) in the raised bed; T₅, rice in the sunken bed and tomato (*Lycopersicon esculentum*) followed by ridge gourd (*Luffa acutangula*) in the raised bed. Rice variety "Lalat" was transplanted at 20cm x 10cm spacing in the sunken bed in case of modified land. The spacing given for tomato (variety BT-10), brinjal (variety long green), cabbage (late large drum head), malabar spinach (local), ridge gourd (local) were 60cm x 45cm, 90cm x 60cm, 60cm x 45cm, 45cm x 30cm and 200cm x 100cm, respectively. The detailed cropping calendar is given in Fig. 2. All the crops were irrigated according to their recommended schedules. Yields of various crops, their rice equivalent under different treatments and the economics were calculated on the basis of prevailing market rates. Cultivated Land Utilization Index (CLUI) was used for assessing land use by the following formula (Chuang, 1973)

$$CLUI = \frac{\sum_{i=1}^n a_i d_i}{A \times 225}$$

where, n = total number of crops; a_i = area occupied by the i-th crop; d_i = days that i-th crop occupied a_i; A = total cultivated land area available during dry season (225 days).

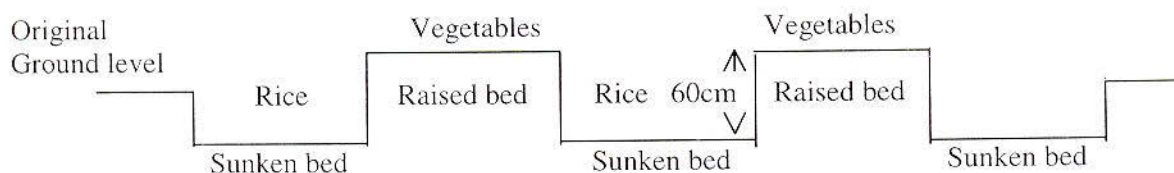


Fig. 1. Schematic diagram of alternate sunken and raised bed system

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.
Original land (T₁)							summer rice				Kharif rice	
Modified land												
Sunken bed rice							summer rice				Kharif	
Raised bed												
T ₂				Cabbage							Veg. cowpea	
T ₃				Cabbage				Malabar spinach			greens	
T ₄							Brinjal				greens	
T ₅							Tomato			Ridge gourd	Okra	

Fig. 2. Crop calendar under different systems of cultivation

RESULTS AND DISCUSSION

Productivity

The system Rice Equivalent Yields (REY) for all the crop sequences was significantly higher in the modified land than that for rice in non-modified land (Table 1). It was due to high potential yield obtained from various vegetables grown in the raised beds. Among different cropping sequences in modified land, rice + cabbage and malabar spinach produced the highest

rice equivalent yield. This was followed by the rice + tomato and ridge gourd sequence. Rice equivalent yields recorded under T_2 and T_5 were comparable. Though there was only one vegetable crop grown in raised bed in T_2 compared to two vegetable sequences in T_5 , its rice equivalent yield was comparable with T_5 . This was due to the high yield potential of cabbage and market price during the season. Rice + brinjal produced the least REY among all the modified land systems due to low yield of brinjal. But its REY was significantly higher than the conventional system where only rice was grown without any modification of land. The use of alternate raised and sunken beds in crop diversification in paddy field was earlier reported by (Tomar *et al.*, 1996).

Table 1. Productivity, LUI and WUE of different crop sequences under conventional and modified cultivation methods

Treatments	Yield t/ha	System yield (50:50),t/ha	Rice equivalent yield (REY),t/ha	Total system REY, t/ha	LUI	Irrigation water use, mm/ha	Irrigation water use efficiency, kg/ha -cm
Conventional							
T_1	3.19	3.19	3.19	3.19	0.53	1200	26.6
Modified land							
T_2 . Rice + Cabbage	2.95 27.32	1.48 13.66	1.48 13.66	15.14	0.53	760	186.91
T_3 . Rice+ Cabbage- Malabar spinach	2.96 27.32 34.4	1.48 13.66 17.25	1.48 13.66 64.66	21.61	0.79	1015	212.86
T_4 . Rice+ Brinjal	2.93 17.79	1.46 8.89	1.46 11.12	12.58	0.61	920	129.74
T_5 . Rice+ Tomato- Ridge gourd	2.99 33.20 11.16	1.49 16.60 5.58	1.49 12.45 2.79	16.74	0.79	1060	157.88
MSE				0.88			
CD(P=0.05)				2.88			

Land utilization

Data on Land Utilization Index (LUI), the measure of land utilization per unit time show that 79 per cent of the total 225 days available could be utilized with the rice + cabbage-malabar spinach and rice + tomato – ridge gourd cropping sequences in modified land. It was

possible due to the creation of favourable microenvironment by modifying land for growing short duration vegetable crops in dry season. The period between two rice crop (November to middle of January) was utilized for taking cool season crops by land modification and third crop along with the rice could be taken up in raised bed from January to April (Fig. 2). Because of its longer duration, brinjal grown in the raised bed along with rice in the sunken bed recorded higher LUI compared to rice + cabbage.

Irrigation water use efficiency

Different cropping systems consumed varied quantities of irrigation water (Table 1). Total irrigation water use was maximum in rice alone in unmodified land (T_1). This was followed by rice + tomato-ridge gourd sequence and rice + cabbage-malabar spinach sequence. The highest water expense under rice-alone system was due high water requirement of rice crop compared to other vegetables. The highest irrigation Water Use Efficiency (WUE) was recorded in the treatment T_3 .

This was due to higher production potential and low water requirement of cabbage and malabar spinach, which replaced 50 per cent rice crop in the total area. This was followed by rice + cabbage and rice + tomato-ridge gourd sequences. Low WUE of rice + brinjal treatment was due to low yield recorded in brinjal compared to other vegetables. But it recorded four times higher water use efficiency compared to monocropping of rice (T_1) which recorded the least irrigation water use efficiency.

Economics

The highest Net return and Benefit Cost Ratio (BCR) was recorded in rice + cabbage-malabar spinach sequence (Table 2). It was followed by the rice + tomato- ridge gourd sequence. The BCR of rice + cabbage was comparable to rice + tomato-ridge gourd sequence, because of higher price of cabbage compared to tomato during the season. Highest crop productivity under rice-cabbage crop sequence in the Eastern region of India was also reported by (Nanda et al., 1999).

The least BCR and Net return was recorded in conventional system (T_1). In the raised and sunken bed system, rice + brinjal sequence produced lesser. However, this BCR was significantly higher than that recorded for rice only in unmodified land.

Table 2. Economics of different crop sequences under two system of cultivation

Treatments	Total Cost, Rs.	Gross return, Rs.	Net return, Rs.	BCR
Conventional				
T₁	11700	13252	1552	1.13
Modified land				
T₂ . Rice + Cabbage	23123	60790	37666	2.62
T₃ . Rice + Cabbage- Malabar spinach	28717	86427	57710	3.01
T₄ . Rice + Brinjal	23550	50340	26790	2.13
T₅ . Rice + Tomato- Ridge gourd	24200	66944	42744	2.76

CONCLUSION

Crop diversification is possible in high rainfall, shallow water table areas of canal command is possible with the adoption of alternate raised and sunken bed system. This system also helps in increasing cropping intensity, profitability and water use efficiency. This leads to generation of employment through out the year, availability of balanced diet and production of vegetable not at the cost of staple food paddy. However, its suitability to different kind of soil and soil water movement between the sunken and raised bed need to be thoroughly investigated for better understanding of this system.

REFERENCES

- Chuang, F.T. (1973). *An analysis of change of Taiwan's cultivated land utilization for recent years : Report 21*. Taipei, Taiwan : . Rural Econ.Div. JCRR.
- Nanda, S.S., Patro, G.K., Alim, M.A., & Mohnanda, N. (1999). Efficiency of rice (*Oryza sativa*)-based crop sequences under coastal ecosystem. *Indian Journal of Agronomy*, 44 (3), 452-455.
- Siddiq, E.A., & Kundu, D.K. (1993). *Production strategies for rice-based cropping systems in the Humid Tropics* (pp. 155-162). WI 53711, USA : International Crop Science Society of America.
- Tomar, S. S., Terbe, G.P., Sharma, S.K., & Tomar, V.S. (1996). Studies on some land management practices for increasing agricultural production in vertisols of Central India. *Agricultural Water Management*, 30, 91-106.

INSTITUTE VILLAGE LINKAGE PROGRAMME-A PARTICIPATORY APPROACH FOR FARMERS' UPLIFTMENT

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ABSTRACT

In the process of technology generation farmers' participation along with their resources, social and economic aspects and perception were often ignored particularly in case of the resource poor farmers. This has resulted in inappropriate technology generation. Realizing this, a participatory research was conducted on farmers' field representing semi arid agro-ecosystem. Through participatory approach, farmers' problems were identified using matrix analysis and then prioritized as per their need and available resources. Farmers along with scientists team in participatory mode developed technical modules that can intervene their problems. Experiments were designed to test the technology for intervening the causes to solve the problem of farmers. In all, two treatments viz., T_1 farmers' practices and T_2 improved practices in case of verification trials and three treatments viz., T_1 farmers' practices and T_2 and T_3 improved practices in case of on-farm trials were tested on farmers' field under their own management and resources situation and replicated to 10 to 25 farmers' field. The participatory approach enabled the farmers to produce considerable amount of additional tonnage as well as the revenue from crop and sheep based interventions.

Key words: Brainstorming, Matrix analysis, Participatory technology development, Participatory research, Sheep technology.

INTRODUCTION

India has made remarkable progress in agriculture research and development since independence. The fruits of these development efforts have been harvested mostly by the farmers responsible for green revolution production systems. This is so because of the fact that technologies generated under different situations of soil, climate, inputs and other requirements which mostly suit the irrigated area and green revolution production systems not for diversified,

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complex and risk prone farming systems. Further, in the process of technology generation farmers' participation along with their resources, social and economic aspects and perception were often ignored particularly in case of resource poor farmers (ICAR, 1999). Keeping all above consideration in view, Indian Council of Agricultural Research, New Delhi initiated a pilot project on Technology Assessment and Refinement through Institute Village Linkage Programme (TAR-IVLP) in the country in July 1995. The concept behind this project lies in a faster technology adoption by the way of testing technologies under situations where it is to be adopted with full involvement of its ultimate client with their resources. Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India has been selected as one important implementing centre of the project. The institute is working on this project since April, 1997 representing semi arid agro-eco system.

MATERIALS AND METHODS

The participatory research was conducted on farmers' field representing semi arid agro-ecosystem. Firstly, agro-eco-system was analyzed using latest Participatory Learning and Action (PLA) technique, earlier known as PRA. Through participatory approach farmers' problems were identified using matrix analysis with sufficient triangulation. Subsequently, prioritization of problems was done. Each problem was discussed in detail by the group of farmers and subject matter specialist and their causes were delineated at first, second and third order. The causes were divided into two categories: socio-economic and biophysical. Possible solutions were obtained through brainstorming. The farmers were facilitated by scientists in searching the solution with the help of available technology identified to be tested to intervene the cause and solve the problem. The solutions in relation to those problems were studied on the basis of varying situations of resources and the farmers were classified into different categories. Experiments were designed and conducted on the farmers' field to test the technology for intervening the causes to solve the problem of farmers with different resource characteristics. In all, two treatments viz., T_1 farmers' practices and T_2 improved practices in case of verification trials and three treatments viz., T_1 farmers' practices and T_2 and T_3 improved practices in case of on-farm trials were tested on farmers' field under their own management and resources situation and replicated to 10 to 25 farmers' field. The trials were conducted for three consecutive years during (1998 to 2001) involving farmers with their resources as active participants.

RESULTS AND DISCUSSION

It is evident from Table 1 that yield of wheat (grain and straw) was increased due to appropriate variety (25.0 and 25.0%), termite management (17.61 and 13.08%) and weed management (16.38 and 12.01%) over farmers' practices. Balance use of fertilizer gave 18.6 and 13.85; 29.22 and 14.82 and 22.78 and 14.78 higher grain and straw yield in comparison to farmers' practices for barley, sorghum and pearl millet, respectively. Improved variety gave

20.28 and 13.05; 20.00 and 16.96; 23.90 and 46.26 % more grain and straw yield in case of barley, pearl millet and mustard respectively and 17.23 % green fodder yield in Lucerne over traditional practices. Similarly, termite and white grub management in groundnut yielded 14.03 and 15.67 % grain and 13.11 and 16.39 % straw which were higher than the control. These findings were also supported by Dhaka and Mann, 2002.

Table 1. Percent increase in grain and straw yield of crops over farmers' practices

Practices	No. of replications	Treatments	Average of two years					
			Grain			Straw		
			Yield (q/ha)	Addl. Yield		Yield (q/ha)	Addl. Yield	
				(q/ha)	%		(q/ha)	%
Termite management in Wheat (<i>Triticum aestivum</i> L.)	20	Control	25.40			37.87		
		Seed treatment with endosulfan @ 700 ml /100 Kg Seed	29.87	4.47	17.61	42.82	4.95	13.08
Management of weed in Wheat (<i>Triticum aestivum</i> L.)	10	Control	26.4			38.52		
		Application of 2,4D @750 ml/ha	30.72	4.32	16.38	43.15	4.63	12.01
Field-testing of improved variety of barley (<i>Hordeum vulgare</i> L.)	25	Local variety	24.4			37.77		
		RD-2035	29.35	4.95	20.28	42.7	4.93	13.05
Balanced use of fertilizer in barley (<i>Hordeum vulgare</i> L.)	25	No use of fertilizer	25.4			39.44		
		60KgN+20Kg P ₂ O ₅ /ha	30.12	4.72	18.60	44.9	5.46	13.85
Field testing of improved variety of Lucerne (<i>Medicago sativa</i> L.)	20	Local Variety	-			725.35		
		Anand-2	-	-	-	850.37	125.02	17.23

Table 1 (Continued)

Practices	No. of replications	Treatments	Average of two years					
			Grain			Straw		
			Yield (q/ha)	Addl. Yield		Yield (q/ha)	Addl. Yield	
				(q/ha)	%		(q/ha)	%
Field testing of improved variety of Pearl millet (<i>Pennisetum typhoideum</i> L.)	24	Local Variety	16			118.75		
		ICMH-356	19.20	3.20	20.00	139.60	20.15	16.96
Balance use of fertilizer in Sorghum (<i>Sorghum vulgare</i>)	25	No use of fertilizer	11.12			107.12		
		40KgN+20Kg P ₂ O ₅ /ha	14.37	3.25	29.22	123.00	15.88	14.82
Balance use of fertilizer in Pearl millet (<i>Pennisetum typhoideum</i> L.)	25	60 KgN+30Kg P ₂ O ₅ /ha (used by farmers)	11.50			110.12		
		90 KgN+45Kg P ₂ O ₅ /ha	14.12	2.62	22.78	126.40	16.28	14.78
Field-testing of improved variety of mustard (<i>Brassica juncea</i> L.)	24	Local variety	6.15			17.4		
		Pusa Jaikisan	7.62	1.47	23.90	25.45	8.05	46.26
		RH-30	6.8	0.65	10.56	20.22	2.82	16.23
Field-testing of improved variety of Wheat (<i>Triticum aestivum</i> L.)	25	Local variety	20.00			25.00		
		Raj-3077	25.00	5.00	25.00	31.25	6.25	25.00
		Raj-3765	24.00	4.00	20.00	30.00	5.00	20.00
Termite & white grub management in groundnut (<i>Arachis hypogea</i> L.)	25	Control	09.12			30.50		
		Application of forate @25 Kg/ha	10.75	1.43	15.67	35.50	5.00	16.39
		Seed treatment with chloripyrophos	10.40	1.28	14.03	34.40	4.00	13.11

The comparison of growth performance of genetically improved rams distributed to the farmers' under the project and base line was made at farmers' level and results are summarized in Table 2. From these results it is evident that the performance of progeny of genetically improved rams was better than the base line under local feeding system. These results clearly establish the superiority of genetically improved rams over local bred under local conditions.

In addition to routine grazing made by the farmers, the concentrate supplementation @ 1 % of the body weight as sheep feed supplements for improving the body weight of lambs was successfully demonstrated at different production stages. Supplementation to sheep during later part of pregnancy resulted in 31.54 % increase in birth weight of lambs over the control which gave Rs.493.00 as net return with 3.95 B:C ratio followed by supplementation during early part of lactation and supplementation throughout later quarter of pregnancy to early part of lactation (Table 3). It is clear that economic returns are very high of this simple and easy to adopt technology. Similar observations were also observed by Chaturvedi et al., (2000) in a participatory research under field condition.

Table 2. Growth performance of progeny from distributed improved rams as compared to base line information (kg)

Traits	Birth weight		3 month weight	
	Base line	Progeny of distributed sire	Base line	Progeny of distributed sire
Male	3.50 (204)	3.78 (112)	13.63 (76)	14.69 (46)
Female	3.24 (216)	3.34 (106)	13.41 (120)	13.53 (56)

Table 3. Effect of improved feeding practices on the body weight of lambs

Treatments	Birth weight(Kg)	% Increase in birth weight over the control	Net return (Rs./animal)	B:C ratio
Control	2.98	-	315	-
Supplementation during later part of pregnancy	3.92	31.54	493	3.95
Supplementation during early part of lactation	3.50	17.45	425	2.85
Supplementation throughout later part of pregnancy to early part of lactation	4.07	36.58	487	2.42

CONCLUSION

Based on the above findings it may be concluded that the Institute Village Linkage Programme paved a new way for economic upliftment to resource poor farmers through participatory approach. The farmers generated additional revenue from their available resources. The crop and sheep based interventions enabled the farmers to produce considerable amount of additional tonnage as well as the revenue.

REFERENCES

- Indian Council of Agricultural Research. (1999). *Progress report of pilot project on technology assessment and refinement through institute village linkage programme*. Pusa, New Delhi: Division of Agricultural Extension, ICAR.
- Dhaka, B. L., & Mann, J. S. (2002). Participatory way to increase production : Extend summaries. In *Proceedings of the Second International Agronomy Congress on Balancing Food and Environmental Security- A Continuing Challenge*. Vol.2 (p. 1490). New Delhi : Ind.Soc.Agron.
- Chaturvedi, O.H., Mishra, A. S., Karim, S. A., & Jakhmola, R. C. (2000). Effect of supplementary feeding on the growth performance of lambs under field condition. *Indian Journal of Small Ruminants*, 6 (2), 110-112.

MORPHOGENETIC RESPONSE OF CITRUS IN VITRO TO VARYING SUCROSE LEVEL

B. N. HAZARIKA¹

ABSTRACT

The influence of in vitro preconditioning of Citrus plantlets with varying level of sucrose (0, 7.5, 15, 30 and 60 g/l) in the rooting medium on ex vitro survival was investigated. Sucrose 30 g/l in the medium showed the highest shoot and root growth in vitro and also promoted subsequent establishment of plantlets in the greenhouse. Maximum values for plant weight were obtained after 4 weeks when conditioned with 15 and 30 g/l sucrose in the medium. Highest ex vitro survival (89.2-97.3%) was recorded with sucrose 30 g/l while rooting medium without sucrose showed the lowest value for plant weight and also declined ex vitro survival (43.8-52.1%).

Key words : Acclimatization, Sucrose, Citrus, In vitro, Ex vitro.

INTRODUCTION

Substantial number of micropropagated plants do not survive transfer from **in vitro** conditions to greenhouse or field conditions because the heterotrophic mode of nutrition and poor mechanism to control water loss render micropropagated plants vulnerable to transplanting shock (Westzstein & Sommer, 1982). Apart from these, the factors affecting photosynthesis may play an important role in the acclimatization and survival of micropropagated plants. *Ex vitro* acclimatization can be expensive in terms of labour, controlled environment facilities and plant losses. Manipulating the culture environment to alter culture induced phenotypes towards photoautotrophy and hardening could abbreviate or eliminating the *ex vitro* acclimatization period and reduce the overall costs of micropropagation (Donnelly & Tisdall, 1993). The benefit of reducing or omitting sucrose in the medium include the promotion of autotrophy, costs saving on materials and reduced biological contamination (Kozai, 1991). But studies carried out with micropropagated strawberry plantlets showed that they did not fix enough carbon to sustain independent growth in the absence of added sucrose in the culture medium (Grout and Price, 1987). Grout and Aston (1978) reported that formation of chlorophyll in culture was dependent on an external supply of sucrose in the growth medium. By amending the sucrose level in the culture medium prior to *in vitro* transfer it may

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therefore be possible to improve the quality of established plantlets derived from aseptic culture.

This study contains the results on the influence of different sucrose concentration on *in vitro* growth of Citrus plantlets and their *ex vitro* survival on transfer to greenhouse.

MATERIALS AND METHODS

Terminal shoot cuttings (1.5-2.0 cm long) were taken from *in vitro* proliferating culture of four different Citrus species viz. *Citrus reticulata* Blanco (KM), *C. Volkameriana* Ten and Pasq (CV), *C. reshni* Tanaka (CLM), *C. nobilis* x *C. deliciosa* (KIN) and were aseptically cultured on MS salt (1962) supplemented with different concentration of sucrose (0, 7.5, 15, 30 and 60 g/l). The cultures were maintained at $25 \pm 1^{\circ}\text{C}$, 16 hrs photoperiod under 2000 lux at cultures level. Observations were recorded after four weeks and plants were transferred to bottle (450 ml capacity) containing sterile soilrite. Caps were loosened gradually and after two weeks these plants were transferred to greenhouses in polythene bag containing 1:1 soil and well rotten Farm Yard Manure (FYM) under 75% shade net. Survival percent was recorded after 1 week. Stomatal index was estimated following the method of Dhawan and Bhojwani (1978). The experiment was laid out in a factorial design with five replications.

RESULTS AND DISCUSSION

The response of micro shoots to different concentration of sucrose had shown significant influence on their growth (Table-1). Most of the growth parameters except stomata index showed increase with increasing sucrose concentration in the medium upto sucrose 30 g/l. But interestingly at 60 g/l sucrose, the growth was less than that of maximum values except shoot length. A similar effect was found by Wainright and Scrace (1989) with *Potentilla fruticosa*, 'Tangerine'. The lowest shoot as well as root growth was recorded on medium containing no sucrose. Lane (1978) also reported that *in vitro* root initiation was decreased proportionally with decreasing sucrose level in apple.

Interaction between Citrus species and different level of sucrose on morphogenetic response of *in vitro* shoot (Table 2) showed that sucrose 30 g/l in the medium recorded higher values for most of the growth parameter in all the four Citrus species studied. However different Citrus species respond differently to variable level of sucrose in the medium because of difference in their morphology. Data were further subjected to principal component analysis (Table 3.) Principal component scores for different sucrose concentration showed higher positive loading for factor 1, 2 and 4 in sucrose 30 g/l indicating superiority over other sucrose concentrations. Latent vectors revealed that plant weight, leaf weight and stomatal index are some of the important contributors for factor 1 and it's orthogonal axis i.e., PC 2. The seven variables contributed to about 97% of variance through first three factors. The highest *ex vitro* survival percent for all the Citrus species was recorded in plantlets obtained from medium with sucrose 30 g/l while the lowest *ex vitro* survival percent was recorded in plants obtained from

medium with no sucrose. Apart from 0 g/l sucrose, ex vitro survival percent was higher in medium with sucrose, Zimmerman (1983) was also in agreement that shoots rooted without sucrose did not survive when moved to glasshouse.

Table 1. Morphogenetic response of Citrus plants to different sucrose concentration

Sucrose (g/l)	Plant weight (mg)	Shoot length (cm)	Leaf No.	Leaf weight (mg)	Root length (cm)	Root weight (mg)	Stomatal index (%)
0	74.16	2.43	3.36	31.90	20.58	11.06	8.86
7.5	80.14	2.56	3.44	31.48	2.60	11.90	8.81
15.	83.21	2.59	3.44	33.10	2.69	12.97	9.52
30.0	87.26	2.67	3.68	34.48	2.75	13.03	8.97
60.0	75.03	2.68	3.43	31.39	2.65	12.65	8.80
SEm	0.889	0.035	0.064	0.438	0.039	0.212	0.397
CD (0.05)	2.464	0.097	0.177	1.214	0.108	0.588	NS

Table 2. Interaction between Citrus species and sucrose level

Species	Sucrose (g/l)	Plant weight (mg)	Shoot length (cm)	Leaf No.	Leaf weight (mg)	Root length (cm)	Root weight (mg)	Stomatal index (%)
KM	0	74.74	2.38	3.35	29.17	2.36	10.67	8.57
	7.5	80.79	2.43	3.65	29.81	2.62	12.25	9.19
	15.0	80.65	2.72	3.60	31.78	2.64	12.98	8.60
	30.0	87.37	2.76	3.60	39.58	2.42	13.66	9.05
	60.0	74.08	2.75	3.50	33.68	2.45	12.20	8.67
KIN	0	73.95	2.50	3.25	33.37	2.77	10.65	9.28
	7.5	81.07	2.82	3.35	33.96	2.72	12.28	8.32
	15.0	82.29	2.64	3.40	33.40	2.79	12.36	8.38
	30.0	87.68	2.62	3.75	31.99	3.16	12.14	8.78
	60.0	73.22	2.92	3.16	31.28	3.05	13.25	8.85
CV	0	75.57	2.39	3.35	30.23	2.68	11.16	8.82
	7.5	78.40	2.57	3.30	30.24	2.47	11.43	8.80

Table 2 (Continued)

Species	Sucrose (g/l)	Plant weight (mg)	Shoot length (cm)	Leaf No.	Leaf weight (mg)	Root length (cm)	Root weight (mg)	Stomatal index (%)
CLM	15.0	83.84	2.53	3.25	30.89	2.74	11.83	8.85
	30.0	85.49	2.65	3.80	31.33	2.78	13.36	8.93
	60.0	76.29	2.63	3.55	28.49	2.52	12.07	8.82
	0	72.40	2.47	3.50	34.83	2.50	11.77	8.76
	7.5	80.31	2.44	3.45	31.92	2.57	11.65	8.89
	15.0	86.09	2.46	3.50	36.35	2.59	14.72	12.23
	30.0	88.52	2.61	3.55	35.02	2.63	12.95	9.10
	60.0	76.55	2.41	3.53	32.12	2.57	13.07	8.85
SEm		1.778	0.0699	0.1277	0.8705	0.0778	0.4239	0.7944
CD(0.05)		NS	0.194	0.175	2.418	0.216	1.177	2.207

Table 3. Principle component score for sucrose concentration

Sucrose Conc. (g/l)	PC 1	PC 2	PC 3	PC 4
0	52.642	22.894	-24.462	44.504
7.5	55.334	23.553	-25.452	49.421
15.0	57.871	24.855	-26.148	51.159
30.0	60.120	25.305	-28.044	53.749
60	53.571	22.579	-23.677	45.433

Table 3a. Latent vectors and latent roots for certain variable of Citrus as influenced by sucrose

Variables	PC 1	PC 2	PC 3	PC 4
Plant weight (mg)	0.409	0.161	-0.262	0.790
Shoot height (cm)	0.329	-0.520	0.444	0.0770
Leaf No.	0.397	-0.277	-0.421	0.006
Leaf weight (mg)	0.395	0.234	-0.424	-0.425
Root length (cm)	0.446	-0.004	0.046	-0.437
Root weight (mg)	0.408	-0.090	0.467	0.027
Stomatal Index (%)	0.213	0.751	0.397	0.015
Latent root	4.86	1.15	0.82	0.15
% Variance	69.47	16.42	11.83	2.27
Cumulative variance	69.47	85.89	97.73	100.00

The possible explanation may be that rooting of microcutting with high concentration of sucrose increase the amount of carbohydrate stored at leaves, which act as a nutritive function and increase the utilization energy available to plantlets when undergoing acclimatization. Another explanation of the lower *ex vitro* survival at lower sucrose medium is that although leaves of plants derived from lower sucrose medium have a greater ability to photosynthesize due to promotion of autotrophy, the acclimatization environment may be not allow appreciable photosynthesis to occur

Improvement of photosynthesis may be possible by increasing the environment with CO₂ and supplementary lighting (Desjardins et al., 1987). The result shows conformity with the report of Wainwright and Scrase (1989) and Rahman and Blake (1988) in *Potentilla fruticosa* and Jackfruit respectively. In contrast with the report of Langford and Wainwright (1987) and Short et al., (1987), the present result indicate that an optimum amount of sucrose in the medium i.e., 30 g/l was required for in vitro growth of Citrus plants which promoted subsequent establishment of plantlets in greenhouse.

REFERENCES

- Desjardins, Y., Gosselin, A., & Yelle, S. (1987). Acclimatization of ex-vitro strawberry plantlets in CO₂ enriched environments and supplementary lighting. *J. Amer. Soc. Hort. Sci.*, 112, 846-851.
- Dhawan, V., & Bhojwani, S.S. (1987). Hardening in vitro and morphological changes in the leaves during acclimatization of micropropagated plantlets of *Leucaena leucocephala* (Lam). *De Wit. Pl. Sci.*, 83, 65-72.
- Donnelly, d. J., & Tisdall, L. (1993). Acclimatization strategies for micropropagated plants. In: M.R. Ahuja (Ed.). *Micropropagation of woody plants* (pp.153-166). Boston : Kulwer academic Publishers.
- Grout, B.W.W., & Aston, M.J. (1978). Transplanting of cauliflower plants regenerated from meristem culture. II. Carbondioxide fixation and the development of photosynthetic ability. *Hort. Res.*, 17, 65-71.
- Grout, B.W.W., & Price, F. (1987). *The establishment of photosynthetic independence in strawberry cultures prior to transplanting. Plant micropropagation in horticultural industries* (pp.55-60). Belgium : Proc. Symp. Florizel 87; Plant Propagation Hort. Ind Arlon.
- Kozai, T. (1991). Micropropagation under photosynthetic conditions in P.C. Debergh & R.H. Zimmerman (Eds). *Micropropagation technology and application* (pp.447-459). Boston : Kluwer Academic Publishers.
- Langford, P.J., & Wainwright, H. (1987). Effect of sucrose concentration on the photosynthetic ability of rose shoots in vitro. *Ann. Bot.*, 60, 663-640.
- Lane, W.D. (1978). Regeneration of Apple plants from shoot meristem tips. *Plant Sci. Lett.*, 13, 281-285.

- Rahman, M.A., & Blake, J. (1988). The effect of medium composition and culture conditions on *in vitro* establishment of Jackfruit (*Artocarpus heterophyllus* Lam). *Plant Cell Tiss. Org Cult.*, 13, 189-200.
- Short, K.C., Warburton, J., & Robert, A.V. (1987). In vitro hardening of cultured cauliflower and chrysanthemum plantlets to humidity. *Acta Hortic.*, 212, 329-334.
- Wainwright, H., & Scrace, J. (1989). Influence of in vitro preconditioning with carbohydrate during rooting of microcuttings on in vitro establishment. *Scientia Hortic.*, 38, 261-267.
- Wetzstein, H.Y., & Sommer, H.E. (1982). Leaf anatomy of tissue cultured *Liquidambar styraciflua* (Hamamelidaceae) during acclimatization. *Amer. J. Bot.*, 69, 1579-1586.
- Zimmerman, R.H. (1983). Factors affecting in-vitro propagation of apple cuttings. *Acta Hortic.*, 131, 171-178.

NITROGEN MINERALIZATION POTENTIAL OF RICE-WHEAT SOILS AMENDED WITH ORGANIC MANURES AND CROP RESIDUES

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ABSTRACT

*Nitrogen mineralization potential of soils as influenced by amending the soils with organic manures and crop residues on short- and long-term basis was studied to help find a breakthrough in arresting the yield decline in rice. Mineralization potential (N_0), was estimated by incubating the soils for 12 weeks at $35 \pm 2^\circ\text{C}$. In 18 samples of soil, N_0 ranged from 21.5 to 61.1 mg N kg⁻¹ soil and was significantly related to organic C and clay content of the soils. It was found that a quick (q) reaction was almost completed during 0 to 4 weeks, whereas a slow (s) reaction continued till the end of incubation period. When three soils differing in texture and organic C content were amended with different organic materials, the highest values of both N_{0s} and N_{0q} were observed for green manure (*Sesbania aculeata*) and the lowest values for wheat straw. The N_0 followed the trend in C/N ratio of the amendments. Amending the soil with different organic manures enhanced N_0 in the order: Farmyard manure (FYM) > green manure > poultry manure > press mud (waste from sugar industry). Application of wide C:N ratio organic materials such as crop residues year after year may increase organic C content of the soil, but not necessarily the potentially mineralizable N. Interestingly when both rice and wheat crops were amended with crop residues, no rapidly mineralizable fraction of N could be found in the soil.*

Key words : Nitrogen mineralization, Rice-wheat system, Organic manures, Crop residues.

INTRODUCTION

In the Indo-Gangetic Plain of South Asia spread over 12 million ha in India, Pakistan, Nepal, and Bangladesh, rice followed in sequence by wheat is a cropping system dating back thousands of years (Woodhead et al., 1994). During 1960 to 1990, genetic improvements in

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rice and wheat and improved management strategies resulted in a rapid increase in area under this system. After a dramatic rise in productivity and production during the eighties, the system is showing signs of fatigue and is no longer exhibiting increased production with increases in input use. When manures and fertilizers are applied to the soil to maintain efficient plant cover, decline in organic matter is arrested and this in turn leads to sustainable crop yields. Long-term experiments conducted in India have shown that integrated use of organic manures including green manure and chemical fertilizers can maintain high productivity and provide sustained stability in crop production.

In the coming decades, a major issue in designing sustainable agricultural system will be the management of soil organic matter and the rational use of organic inputs such as animal manures, crop residues, green manures, sewage sludge and food industry wastes. Among organic manures, Farm Yard Manure (FYM) is the most commonly used manure by the rice-wheat farmers in the Indo-Gangetic plain. The rate and periodicity of application of FYM, however, depends on its availability with the farmers. Diagnostic surveys carried out in Indian part of the Indo-Gangetic plain (Yadav *et al.*, 2000) reveal that while 15-20 t FYM ha⁻¹ is applied at an interval of 3-5 years in Trans Gangetic plain and Upper Gangetic plain, the average rates of FYM application are low in the Middle Gangetic plain (5-6 t ha⁻¹ at an interval of 2-3 years) and Lower Gangetic plain (2-4 t ha⁻¹ at 2-3 years interval). Since organic manures cannot meet the total nutrient needs of modern agriculture, integrated use of nutrients from fertilizers and organic resources seems to be a need of the time. The basic concept underlying the integrated nutrient management system, nevertheless, is the maintenance and possible improvement of soil fertility for sustained crop productivity on long-term basis and also to reduce fertilizer input cost. The different components of integrated nutrient management possess great diversity in terms of chemical and physical properties and nutrient release patterns.

In intensive rice based cropping systems, Cassman *et al.* (1995) and Olk *et al.* (1996) have hypothesized a decline in the supplying capacity of N from soil organic matter over time, despite constant or increasing total soil N levels. Olk *et al.* (1996) also reported that increasing the number of flooded rice crops per year from rice - soybean to rice - rice to rice - rice - rice system resulted in a more phenolic character of soil organic matter, which may be related to decreased net N mineralization. Soil organic matter concentrations in the rice - wheat tract of the Indo-Gangetic plains have declined to very low levels (Nambiar, 1994). The role of soil organic matter in the sustainability of this system is related to nutrient supply for rice and wheat as well as to soil tilth for wheat (Bronson, 1998). Whether yield declines in rice - wheat systems are due to low soil organic matter or changes in quality of soil organic matter is not clear. Therefore, studies on the dynamics of N mineralization in these soils are of great significance.

Indications that soil N supplying capacity may be changing in Asian rice soils comes from on-farm studies which have shown that there is poor correlation between total soil N and N uptake by rice in plots not receiving N fertilizer (Cassman *et al.*, 1996). Similarly, poor correlations between soil organic matter and N uptake in "minus-N" plots in rice - wheat

systems have also been reported in Bangladesh and Nepal (Adhikari et al., 1999). Laboratory studies, on the other hand, of 39 air-dry rice soils by Sahrawat (1983) did show strong positive correlation between anaerobic N mineralization and soil organic matter concentration. Few studies, however, have examined N mineralization in rice - wheat soils.

MATERIALS AND METHODS

Eighteen representative surface (0-15 cm) soil samples collected from semiarid regions of northwestern India were air dried, passed through a 2 mm sieve and stored in polyethylene bags. The soils varied widely in pH, texture and organic matter content (Table 2). The incubation leaching technique of Stanford and Smith (1972) with some modifications was used to study mineralization in the soils. A round piece of Whatman No. 42 filter paper was placed over the perforated base of porcelain Buchner funnel with 10 cm internal diameter. A 1 cm thick pad of glass wool was placed over it. fifty g of soil samples and an equal weight of quartz sand passed through 2 mm sieve were moistened using a fine spray of distilled water, mixed thoroughly and were transferred into Buchner funnel. A round piece of Whatman No. 2 filter paper was placed over the soil to avoid dispersing the soil when solution was poured into the Buchner funnel. Mineral N initially present in the soil was recovered by leaching the soil-sand mixture with 100 ml of 0.01 M CaCl_2 in 15-20 ml increments followed by 25 ml nutrient solution devoid of N (0.002M $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$; 0.002M MgSO_4 ; 0.005M $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$; and 0.0025M K_2SO_4). The Buchner funnels were incubated at $35^\circ \pm 2^\circ\text{C}$ for 12 weeks, followed by intermittent leaching at 1, 2, 3, 4, 6, 8 and 12 weeks. Loss of water during incubation was replenished daily (on weight basis) by addition of water to near optimal soil water contents. Total volume of leachates was made 250 ml and the samples were stored in 250 ml plastic bottles. Mineral N (NH_4^+ -N and NO_3^- -N) in the leachates was determined by steam distillation method.

The first estimates of potential N mineralization capacity were obtained by fitting linear regression between $1/\text{N}_t$ and $1/t$ based on cumulative N mineralized (mg kg^{-1}) during 1, 2, 3, 4, 6, 8 and 12 weeks (Stanford and Smith, 1972) using the following equation:

$$1/\text{N}_t = 1/\text{N}_0 + b/t$$

where N_t = N mineralized in mg kg^{-1} (cumulative) during the specified period of time, t = time in weeks, b = slope, N_0 = N mineralization potential (mg N kg^{-1} soil). The hypothesis that the rate of mineralization is proportional to the amount of potentially mineralizable N, is expressed by the equation, $d\text{N}/dt = -k\text{N}$ (Stevenson, 1965). Integration of this expression gives:

$$\log(\text{N}_0 - \text{N}_t) = \log \text{N}_0 - k/2.303(t)$$

This equation was employed to arrive at final values of N_0 . From observing the curves obtained by plotting $(\text{N}_0 - \text{N}_t)$ vs t on semilog graph paper, it was apparent whether the chosen N_0 was less than (convex), greater than (concave) or approximately equal to the N_0 denoting the best fit (linear). Finally, the N_0 giving the best fit was found by an iterative process involving successive evaluation of $\log(\text{N}_0 - \text{N}_t)$ vs t , by regression analysis, based on different choices of

N_0 . The values of N_0 were those giving the highest value of r^2 for linear fits.

Single and double first order reaction model as described by Inubushi *et. al.* (1985) was used for computing N_0 . For single first order reaction, equation of the form given below was fitted to the experimental data to compute A and B:

$$\log(N/t) = \log A - Bt$$

Values of A and B were used to determine N_0 and k for the first order rate equation defined as:

$$N = N_0 [1 - \exp(kt)]$$

where $N_0 = A/B \ln 10$ and $k = B \ln 10$. As the experimental data deviated considerably from the linear relationship at the start of incubation and gradually approached the linear relationship with time, it was considered that two different reactions were proceeding in parallel in these soils i.e. a quick reaction and a slow reaction. The quick reaction was almost completed during 1 to 4 week period whereas the slow reaction continued till the end of incubation. The slow reaction was mathematically formulated from the linear relationship in the later period of incubation. The amount of mineral N experimentally determined from the amount of the mineral N, which was calculated from the slow reaction and the difference, was used for mathematical formulation of the quick reaction. It was found that the quick reaction was another first order reaction. Finally, the following formula was derived:

$$N = N_{oq}[1 - \exp(-k_q t)] + N_{os}[1 - \exp(-k_s t)]$$

where, N_{oq} and N_{os} are amounts of potentially mineralizable N and k_q and k_s are rate constants for quick and slow reactions, respectively.

Mineralizable N under the influence of long term application of organic manures:

Surface soil samples were collected one month after transplanting of rice. The incubation-leaching techniques as described above were used to estimate potentially mineralizable N in soil samples collected from plots to which organic amendments such as green manure, farmyard manure, poultry manure, pressmud, and crop residues had been applied on long term basis. Respectively, 5 and 6 plots were selected from two long-term experiments in which different organic manures and crop residues have been continuously applied for 5 and 8 years. The previous management of selected treatments and chemical properties of soils are shown in Table 3. Mineralization potential following single first order reaction as used by Stanford and Smith (1972) and double first order reaction model as given by Inubishi (1985) were worked out as described above.

Mineralizable N in the soil under the influence of short-term application of organic materials: The incubation-leaching technique of Stanford and Smith (1972) was used with some modifications to estimate kinetics of N mineralization in three soils viz., sandy loam, loam and silty clay. These soils were amended with green manure, crop residue, farmyard manure, press mud and poultry manure at levels those commonly applied under field situations in northwestern India. Nitrogen was added at the rate of 300 mg kg^{-1} soil in the form of organic

manures. Manures were finely powdered and mixed with soil at the beginning of the experiment. Incubation-leaching experiment was carried out as already described for 12 weeks with intermittent leaching at 1, 2, 3, 4, 6, 8 and 12 weeks interval. The treatments employed were: no N (control), green manure (GM), poultry manure (PLM), farmyard manure (FYM), pressmud (PM) and crop residues (CR). Some of the properties of these organic amendments are shown in Table 1. Buchner funnels containing 50g soil was incubated at $35 \pm 2^\circ\text{C}$ for twelve weeks at optimal soil moisture contents. The quantity of N mineralized at 1, 2, 3, 4, 6, 8 and 12 weeks after incubation was estimated by leaching the soil-sand mixture placed in funnel by CaCl_2 solution followed by rinsing the soil with nutrient solution devoid of N. Loss of water during incubation was restored by daily addition of water on weight basis to near optimal soil water contents. The values of N_0 , N_{eq} and N_{os} were computed as described above.

Table 1. Some properties of organic amendments

Organic manures	Total N (%)	Organic C (%)	C/N ratio
Green manure	2.8	34.0	12.1
Poultry manure	2.4	33.6	14.0
Farmyard manure	1.8	39.9	22.2
Pressmud	2.2	35.4	16.1
Crop residue	0.75	46.8	62.4

RESULTS AND DISCUSSION

Mineralization potential (Stanford and Smith, 1972), a capacity factor and an estimate of total quantity of soil organic N at time zero that is susceptible to mineralization in infinite time, ranged from 21.5 to 61.1 mg N kg⁻¹ soil (Table 2) and was significantly related to organic carbon and clay content of the soils. When data were plotted in the form of equation: $\log (\bullet N/\bullet t) = \log A - Bt$, the plots deviated considerably from the linear relationship for 8 out of 18 soils suggesting that two different reactions were proceeding in parallel in these soils. From the plots it was found that a quick reaction was almost completed during 0 to 4 weeks, whereas slow reaction continued till the end of incubation period. The slow reaction was mathematically formulated from the linear relationship in the later period of incubation. The amount of mineral N calculated from the slow reaction was subtracted from the experimentally determined mineral N during the 0 to 4 weeks and the difference was used for mathematical formulation of the quick reaction. It was found that quick reaction was another first order reaction. So in 8 soils, double first order reaction model for mineralization of N as given by Inubishi (1985) explained the process in a better manner. The two mineralization potentials using this model

are described in Table 2. The sum of N_{0q} and N_{0s} always turned out to be more than the N_0 calculated using single first order reaction as used by Stanford and Smith (1972).

Table 2. Cumulative mineral N released and N mineralization potential estimated

Soil	Textural class	Clay (%)	Org. C (%)	Cumulative mineral-N (mg N kg ⁻¹ soil) after weeks							N ₀ (mg N kg ⁻¹ soil)		
				1	2	3	4	6	8	12	a	b	c
1	Silt loam	19	0.65	5.6	10.5	14.7	17.5	21.0	23.8	26.6	31.4	29.6	5.8
2	Loam	12	0.50	6.3	10.5	13.3	15.4	18.2	20.3	22.4	25.7	-	-
3	Loam	15	0.60	7.0	11.9	14.7	16.8	19.6	22.4	25.9	31.7	29.5	15.7
4	Silty clay	48	0.85	7.7	13.3	17.5	21.0	25.2	28.7	32.2	39.5	36.1	7.3
5	Silty clay	51	1.05	9.8	17.5	23.1	28.0	33.6	39.2	45.5	61.1	54.8	14.1
6	Silt loam	14	0.70	8.4	13.3	16.8	18.2	21.7	24.5	27.3	32.0	-	-
7	Silt loam	12	0.40	4.9	8.4	11.2	12.6	15.4	17.5	20.3	25.8	-	-
8	Loam	16	0.31	4.2	7.0	9.1	10.5	13.3	15.4	16.8	21.5	-	-
9	Loam	26	0.75	5.6	11.2	15.4	18.9	23.1	26.6	30.8	39.6	37.0	8.0
10	Loamy sand	13	0.65	10.5	14.7	18.9	21.0	23.8	25.9	28.7	32.4	23.8	20.9
11	Sandy loam	20	0.70	7.0	12.6	16.8	20.3	24.5	28.0	31.5	38.8	36.1	6.2
12	Sandy loam	18	0.63	6.3	11.2	14.7	17.5	21.0	23.8	26.6	31.8	29.6	6.7
13	Loamy sand	11	0.44	7.7	11.9	14.7	16.8	19.6	21.7	23.8	27.1	-	-
14	Loamy sand	14	0.60	7.0	11.9	14.7	16.8	19.6	22.4	25.9	31.7	29.5	15.2
15	Loamy sand	10	0.55	4.2	7.7	10.5	11.9	14.7	17.5	19.6	25.2	-	-
16	Sandy loam	16	0.50	4.2	8.4	11.9	14.7	17.5	19.6	22.4	26.6	23.8	12.7
17	Loamy sand	10	0.44	4.9	8.4	11.2	12.6	15.4	18.2	20.3	25.9	-	-
18	Loamy sand	11	0.46	4.9	8.4	11.2	13.3	16.1	18.2	20.3	24.6	-	-

a = Stanford and Smith (1972)

b = Slowly mineralizable fraction (N_{0s})

c = Rapidly mineralizable fraction (N_{0q})

The concept of slowly and rapidly mineralizable N potential has proved particularly useful when soils are amended with different types of organic materials on a short- or long-term basis. As shown in Table 3, when three soils differing widely in texture and native organic C content were amended with different organic materials, the mineralization of N was described both by quickly and slowly mineralizable fractions of soil organic matter (Table 3). Values of N_{0s} were conspicuously less than N_{0q} for all the amendments. The highest values of both N_{0s} and N_{0q} were observed for green manure and the lowest values for wheat straw. In fact, the values of mineralization potential followed the trend in C/N ratio of the amendments. Lowest

C/N ratios resulted in highest N_0 values. Frankenberger and Abdelmagid (1985) have already reported similar results. Pathak and Sarkar (1994) were able to observe significant coefficients of correlation for N_0 versus total N content, lignin content and C/N ratio of organic amendments. Although trend in N_0 was similar in the three soils, mineralization potential was higher in fine textured soils than in coarser ones; the role of native organic C content, however, cannot be ruled out.

Effect of organic amendments on mineralization potential of soils is different when these are applied on a long-term basis for several years as in long-term experiments on rice-wheat system. Estimation of mineralization potential in samples of soils taken from different plots of two long-term field experiments to which manures and crop residues have been applied for 5 and 8 years (Table 4) reveal that unlike when applied freshly, the organic amendments do not influence mineralization potential as per their C/N ratio. Amending the soil with different organic manures enhanced N_0 in the order: FYM > green manure > poultry manure > press mud. In case of organic manures, N_{0s} was found to be significantly correlated with organic C content of the soil. A comparison between short-term and long-term amendment of soils with organic manures reveals that FYM can enhance the mineralization potential to a greater extent than green manure, which exhibits the highest N_0 values when applied freshly. Since samples from long-term experiments were taken about one month after application of green manure, it did not affect N_0 as in soils freshly amended with green manure.

Application of wide C:N ratio organic materials such as crop residues year after year may increase organic C content of the soil (Table 4), but not necessarily the potentially mineralizable N. Soil amended with crop residues for 8 years recorded N_{0q} values even less than those for unamended control. Interestingly when both rice and wheat crops were amended with crop residues, no rapidly mineralizable fraction of N could be found in the soil.

Table 3. Nitrogen mineralization potential (mg N kg⁻¹ soil) of slowly (N_{0s}) and rapidly (N_{0q}) mineralizable fractions in three soils amended with different organic manures and crop residues

Organic amendment*	Silty clay soil, pH 7.9, Org. C 1.05 %		Loam soil, pH 8.0, Org. C 0.75 %		Sandy loam soil, pH 8.1, Org. C 0.50 %	
	N_{0s}	N_{0q}	N_{0s}	N_{0q}	N_{0s}	N_{0q}
No amendment	37.0	24.3	35.7	11.3	28.0	23.2
Green manure	110.9	53.8	91.2	39.8	70.9	58.3
Poultry manure	87.4	40.6	81.0	40.0	64.6	38.2
Farmyard manure	75.4	-	61.3	24.5	49.6	21.2
Pressmud	87.3	-	71.2	39.8	62.4	25.3
Wheat straw	43.3	20.1	31.8	19.5	36.3	26.2

* Organic amendments were applied @ 300 mg N kg⁻¹ soil

Table 4. Effect of long-term application of organic manures and crop residues on nitrogen mineralization potential of the soil under rice-wheat cropping system

Treatment to		Number of years	pH	Organic C (%)	N ₀ (mg N kg ⁻¹ soil)	
Wheat	Rice				SMF (N _{0s})	RMF (N _{0q})
No N	No N	5	8.0	0.46	17.2	6.3
FYM (200 kg N ha ⁻¹)	GM (120 kg N ha ⁻¹)	5	7.6	0.76	46.4	21.7
Poultry manure (200 kg N ha ⁻¹)	GM (120 kg N ha ⁻¹)	5	7.5	0.70	33.9	17.7
FYM (200 kg N ha ⁻¹)	Poultry manure (200 kg N ha ⁻¹)	5	7.3	0.92	43.2	19.7
Urea (150 kg N ha ⁻¹)	GM (150 kg N ha ⁻¹)	5	7.5	0.53	28.0	12.8
Urea (90 kg N ha ⁻¹)	No N	8	7.9	0.44	22.9	11.9
Urea (90 kg N ha ⁻¹)	GM (150 kg N ha ⁻¹)	8	7.6	0.56	28.0	15.2
Urea (90 kg N ha ⁻¹)	Wheat straw (6t ha ⁻¹) + GM (150 kg N ha ⁻¹)	8	7.5	0.56	22.8	9.9
Urea (90 kg N ha ⁻¹) + rice straw (5 t ha ⁻¹)	Wheat straw (6t ha ⁻¹) + Urea (150 kg N ha ⁻¹)	8	7.9	0.50	23.2	-
Urea (90 kg N ha ⁻¹)	FYM (12 t ha ⁻¹ , fresh)	8	7.6	0.63	40.1	17.8
Urea (90 kg N ha ⁻¹)	FYM (12 t ha ⁻¹ , fresh) + GM (150 kg N ha ⁻¹)	8	7.4	0.67	43.0	23.7

CONCLUSION

Soils under rice-wheat cropping system in the subtropical semiarid conditions of northwestern India contain part of the organic matter fraction in active form and thus exhibit simultaneously occurring slow and quick N mineralization reaction kinetics. In soils freshly amended with different organic materials, N mineralization potential of the soil was determined by the C/N ratio of the material; low C/N ratio materials such as green manure and poultry manure resulted in higher values than wide C/N ratio materials like farmyard manure. However, farmyard manure rather than green manure can lead to higher N mineralization potential if the soils are amended with organic materials on a long-term basis.

REFERENCES

- Adhikari, C. et al. (1999). On-farm N supply and N nutrition in the rice-wheat system of Nepal and Bangladesh. *Field Crops Research*, 64, 273-286.
- Bronson, K.F., Cassman, K.G., Wassmann, R., Olk, D.C., van Noordwijk, M., & Garrity, D.P. (1998). Soil carbon dynamics in different cropping systems in principal ecoregions of Asia. In R. Lal, J. Kimble, R. Follett and B.A. Stewart (Eds.), *Management of Carbon Sequestration in Soil* (pp.35-57). Boca Raton, FL : CRC Lewis Publishers.

- Cassman, K.G. et al. (1995). Yield decline and the nitrogen economy of long-term experiments on continuous, irrigated rice systems in the tropics. In R. Lal and B.A. Stewart (Eds.). *Soil management: experimental basis for sustainability and environmental quality* (pp. 181-222). Boca Raton : Lewis/CRC Publishers.
- Cassman, K.G. et al. (1996). Soil organic matter and the indigenous soil nitrogen supply of intensive irrigated rice systems in the tropics. *Plant and Soil*, 182, 267-278.
- Frankenberger, W.T., & Abdelmagid, H.M. (1985). Kinetic parameters of nitrogen mineralisation rates of leguminous crops incorporated into soil. *Plant and Soil*, 87, 257-271.
- Inubushi, K., Wada, H., & Takai, Y. (1985). Easily decomposable organic matter in paddy soils. Kinetics of N-mineralization in submerged soils. *Soil Science and Plant Nutrition*, 31, 563-573.
- Nambiar, K.K.M. (1994). *Soil fertility and crop productivity under long-term fertilizer use in India*. New Delhi : Indian Council for Agricultural Research.
- Olk, D.C., Cassman, K.G., Randall, E.W., Kinchesh, P., Sanger, L.G., & Anderson, J.M. (1996). Changes in chemical properties of organic matter with intensified rice cropping in tropical lowland soil. *European Journal of Soil Science*, 47, 293-303.
- Pathak, H., & Sarkar, M.C. (1994). Nitrogen supplying capacity of an Ustochrept amended with manures, urea and their combinations. *Journal of the Indian Society of Soil Science*, 42, 261-267.
- Sahrawat, K.L. (1983). Mineralization of soil organic nitrogen under waterlogged conditions in relation to other soil properties of tropical soils. *Australian Journal of Soil Research*, 21, 133-138.
- Stanford, G., & Smith, S. J. (1972). Nitrogen mineralization potentials of soils. *Soil Science Society of America Journal*, 36, 465-472.
- Woodhead, T., Huke, R., & Huke, E. (1994). Areas, locations, and ongoing collaborative research for the rice-wheat system of Asia. In R.S. Paroda, T. Woodhead. and R.B. Singh (Eds.) *Sustainability of rice-wheat production systems in Asia* (pp. 68-96). Bangkok, Thailand : FAO.
- Yadav, R.L. et al. (2000). Management of irrigated ecosystem. In J.S.P. Yadav and G.B. Singh (Eds.). *Natural resource management for agricultural production in India* (pp.775-870). New Delhi, India : Indian Society of Soil Science.

PEDO-TRANSFER FUNCTIONS FOR ASSESSING SOIL MOISTURE AND NITROGEN AVAILABILITY IN THE INDIAN SOILS

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ABSTRACT

The soil moisture constants and soil nitrogen availability are important for scheduling of water and nitrogen to maximize yield of crops. The available methods for determining these constants are tedious, time consuming and expensive. In this paper, an attempt has been made to derive these soil constants from easily determinable soil characters. Point observations of surface layer for diverse locations in the country (600 points) were compiled from the published literature. Pedo-transfer functions were developed for evaluating moisture retention, release and transmission characters, bulk density and available soil nitrogen from soil texture (proportion of sand, silt and clay) and organic carbon content. The predictability for these soil moisture constants was statistically significant, and the functions developed can be used for deriving soil moisture and N-fertility constants for water and nitrogen management.

Key words : Pedo-transfer functions, Field capacity, Wilting point, Organic carbon, Bulk density, Hydraulic conductivity, Available nitrogen.

INTRODUCTION

Soil needs to be characterized for moisture retention, release and transmission characteristics. The existing methods for determination of these moisture constants are tedious, time consuming and expensive. There is a need to derive these constants from the easily determinable soil characters, such as proportion of sand, silt and clay. Within a textural class, there exists a large variability in soil water and fertility characteristics. The information on the soil moisture constants can aid in scheduling of irrigation water to enhance water use efficiency by crops by minimizing drainage loss. Two soils, having similar values of available water range, may release water with different manner depending on the pore size distribution. There

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is a need to judge soil moisture release characteristics by following a simple procedure. Soil moisture transmission is characterized through hydraulic conductivity, which changes multi-fold when the moisture content decreases by a small amount. The hydraulic conductivity is primarily dependent on soil texture and structure and soil moisture content. This parameter is important for computing inter-layer water movements, as well drainage. Few of the soil scientists measures hydraulic conductivity, so there is a need to derive this on the basis of easily available soil parameters.

Assessing available soil nitrogen on the basis of organic carbon content can serve the purpose from view point of nitrogen management of the crop yields. Though response of nitrogen to yield of crops depends on the mineral nitrogen availability during the course of crop growth, but the computation of this parameter from available nitrogen or organic carbon is difficult. But the trend of nitrogen response to yield of crops is noticed in the most of the situations.

Information on soil texture, structure, moisture retention & transmission characteristics and fertility status are available and inter-relationships in some cases have been worked out in the past (Ali *et al.*, 1966; Bharambe *et al.*, 1990; Datta *et al.*, 1990; Gupta, 1992; Gupta *et al.*, 1984; Gupta & Larson, 1979; Rawls & Brakensiek, 1982; Satyavathi *et al.*, 1994; Talati *et al.*, 1975; Velayutham & Raj, 1971; Rudra *et al.*, 1991). But simple and readily acceptable relationships for this region are not available for their subsequent use in identification of suitable water and nutrient management options for sustained productivity.

An attempt has been made in the present study to generate the pedo-transfer functions to evaluate the soil moisture retention, release and transmission behaviour and available soil nitrogen, on the basis of the soil data-sets compiled from different agro-ecological regions of the country.

MATERIALS AND METHODS

The soil dataset, having around 600 points (mostly of the surface layer), was compiled from the reported literature in different regions of the country. This database has information on soil texture (proportion of sand, silt and clay), bulk density, organic carbon, available nitrogen, moisture retained at various suctions and saturated hydraulic conductivity. Descriptive statistics for various soil characters of the used soil data set (in terms of range, mean, standard deviation) are given in Table 1. Pedo-transfer functions were generated by using correlation and multiple regression technique, as suggested by Gomez and Gomez (1984) with the intention of deriving the functions on the basis of readily available characters. The transfer functions to evaluate moisture retained at field capacity and permanent wilting point, available, moisture release constants, hydraulic conductivity, bulk density and available soil nitrogen were derived for discussing about their suitability in water and nitrogen management and crop modeling.

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Table 1. Descriptive statistics for various soil parameters of the soil data set used in the study

Parameter	Number of locations	Range	Mean	SD
Sand (%)	600	0.5-97.0	39.7	24.5
Silt (%)	600	0.2-70.0	35.2	12.8
Clay (%)	600	2.0-78.6	40.3	16.2
Organic carbon(%)	500	0.02-3.8	0.88	0.67
Bulk density (Mg/m ³)	550	1.1-1.74	1.47	0.13
Available nitrogen (kg/ha)	140	61-400	198	95
Hydraulic conductivity (mm/h)	250	0.5-194	40.9	48.9
Moisture content at field capacity (%. vol.)	600	4.7-65.7	30.6	11.64
Moisture content at wilting point (cm3/cm3)	600	1.5-45.8	13.41	7.84

RESULTS AND DISCUSSION

Soil moisture retained at 33 kPa

Moisture retained at field capacity helps in deciding the amount of irrigation water to be applied for recharging the rooting depth to its capacity, also ensuring negligible drainage loss and thus enhancing the applied water use efficiency. Though, field capacity for the sandy soil is at soil water suction value of 10 kPa, but in the present study the pedo-function for moisture retained at kPa has been developed, irrespective of the soil texture.

SiCl - when silt & clay are considered, not silty clay loam, if should be written as either Si+C. The symbol 'SiCl' stands for silty clay loam, a textures class with specific renzes of 4 sand(s), silt (Si) & clay © fractions.

The moisture retained at 33 kPa of soil water suction was regressed against silt plus clay content (Si+C) % and results are shown in Fig. 1. The error associated with this pedo-transfer function was 47%, which was within tolerable limits, seeing the large number of data-set points (600 location points), indicating the suitability of this function for use under situation where moisture retention characteristics are not available.

The multiple regression analysis for computation of soil moisture retained at 33 kPa (FC, % vol.) from proportion of sand, silt and clay was developed from the data-set, and the relationship obtained is given below:

$$Fc (\%, \text{vol.}) = 0.1462 * \text{sand} (\%) + 0.3742 * \text{Silt} (\%) + 0.5801 * \text{Clay} (\%)$$

The predictability for the field capacity was to the extent of 55%, which improved over the transfer function of field capacity where Si+C was taken. The value of the regression coefficient was higher for clay, followed by silt and sand, respectively, indicating increased field capacity in the soils having finer sized particles (silt and clay).

Soil moisture retention at 1500 kPa

The Wilting Point is generally referred to as the moisture retained at soil water suction of 1500 kPa. It should be 'above' if the force of suction is considered, which the water availability to roots for its uptake ceases. Evaporation loss from the soil surface continues till air dry moisture content limit reaches.

The moisture retained at 1500 kPa of soil water suction was regressed against silt plus clay content (Si+C) and results are shown in Fig. 2. The function developed could account for 68 per cent variability, which was within the significant limit (600 data-set points). The prediction of Wilting Point was relatively better than for field capacity.

The multiple regression analysis for computation of soil moisture retained at 1500 kPa (WP, % vol.) for proportion of sand, silt and clay was developed, and the relationship is given below:

$$WP (\%, \text{vol.}) = 0.245 * \text{sand} (\%) + 0.1099 * \text{silt} (\%) + 0.3816 * \text{clay} (\%)$$

The predictability for the Wilting Point was to the extent of 64%, which could not improve over the prediction of the Wilting Point from silt plus clay content. The regression efficient followed similar trend as noticed in case of field capacity i.e. sand < silt < clay. Air-dry moisture content is generally not reported in literature, which can be taken as a fraction (0.7-0.85) of the Wilting Point.

Available water in the soil

The available water refers to the range in which water is available to the roots for their uptake. But in this range, water is not equally available to roots for the uptake, and availability to roots decreases as the soil water suction increases. Apart from the moisture content, the availability to plants also depends upon the root growth and distribution, atmospheric evaporativity demand and soil moisture release and transmission pattern. In the present study, the soil available water has been predicted on the basis of silt plus clay content (Si+C). In general, the available water increased with the increase in Si+C or Si & C but the slope

decreased gradually with shift towards heavier texture. The pedo-function developed could account for 52% of the variability, with a polynomial fit of degree 2 (Fig. 3.).

Soil moisture release characteristics

The available water content may have similar values within a textural class as well as neighbor textural classes, but there may exist differential moisture withdrawal. This is due to moisture release pattern, which mainly is governed by the pore size distribution. A sandy soil, having relatively bigger sized pores, tends to release the moisture rapidly in the beginning due to majority of water goes out of the root zone as a drainage loss. Whereas, a sandy loam soil releases water slowly and gradually and meets the crop's water demand in a judicious manner. It becomes important to characterize the moisture release behaviour, which can aid in scheduling of irrigation in a scientific way.

The soil water suction can be related to respective soil moisture content as given below:

$$\psi = a * e^{-b * \theta}$$

where ψ is soil water suction (expressed in cm of water), a and b are moisture release constants and θ is moisture content (% vol). Determination of moisture retention characteristics, by pressure plate and membrane apparatus, is tedious, time consuming as well as costly. At some locations, moisture retention characteristics have been reported, and qualitatively related with the soil texture and structure. Compilation in this regard was also done, and the moisture release constants, i.e. ' a ' and ' b ', were computed for each location. The constants ' a ' and ' b ' were subsequently were related with the soil texture (per cent sand content).

Soil moisture release constant, ' a ' (on log scale, as the range of values was very large) decreased with the increase in the sand content (Fig. 4). This implies that as the texture becomes coarser, the value of ' a ' decreases. Whereas, the relationship obtained for constant ' b ' plotted against the percent sand content showed a significant linear behaviour, with a positive slope (Fig. 4). The values of ' a ' and ' b ' can be useful for estimating moisture retained at various soil water suction, as well as in understanding of the moisture release behaviour. This technique can be highly useful in soil water balance and modeling studies.

Soil moisture transmission characteristics

Hydraulic conductivity depends upon soil permeability and the fluidity. Most of the time, water moves under unsaturated conditions. Unsaturated hydraulic conductivity decreases multifold with slight decrease in the soil moisture content. The rate, with which water moves under saturated condition, is saturated hydraulic conductivity (K_s), which usually is measured with constant pressure head technique. There is a need to evaluate K_s on the basis of soil texture. As the soil becomes heavier, the value of K_s decreases. Relationships have already been developed to assess unsaturated hydraulic conductivity from K_s and moisture content. In

this paper, we developed relation of Ks with Si+C (Fig 5). Ks decreased sharply from about 194 mm/hr to 29 mm/hr as the Si+C content increased from 5 to 28%. Thereafter the hydraulic conductivity decreased slowly and subsequently became very low. Results also showed that the variability was high under lower values of Si+C, i.e. for coarse textured soils. The power fit, which became the significant function to predict Ks, could account for 77.4% of variability.

Bulk Density of the soil

Bulk Density (BD), an important soil physical parameter, is usually determined by most of the soil physicists and agronomists. A relationship was tried to compute the BD on the basis of proportion of sand, silt and clay contents. For this purpose, 550 data set points were used. Multiple regression analysis, as obtained to estimate BD from the soil texture, is given below:

$$\text{Bulk Density (Mg/m}^3\text{)} = 0.0163 * \text{sand (\%)} + 0.144 * \text{silt} + 0.0116 * \text{clay (\%)}$$

This relationship could account for 53% of the variations. The Si+C (%) was also plotted against BD (Fig. 6), and the results showed that the density value decreased linearly with increase Si+C (%). The pedo-transfer function could account for 60% of the variations.

Soil available nitrogen

Nitrogen availability in the soil is characterized through total nitrogen, available nitrogen and mineral nitrogen. The growth and yield of crops is significantly related to the mineral nitrogen. availability, which is highly dynamic and difficult to determine. This availability depends upon organic carbon content, soil edaphic and aerial environments and soil microbial activity. Total nitrogen content is relatively more static. Usually the fertility of the soil is expressed with available nitrogen, and depending on its status the amount of nitrogen application to maximize crops' yield is decided.

Estimating soil available nitrogen from organic carbon content was done (Fig. 7). Results indicated that a polynomial curve fit could account for 78% of the variations. The transfer function was also generated for estimation of available nitrogen from soil texture and soil organic carbon content, on the basis of 70 data set points. The results indicated that available nitrogen was linearly related with sand (%) and organic carbon (%), and the relationship is given below:

$$\text{Available nitrogen (kg h}^{-1}\text{)} = 352.9 * \text{OC} + 0.5922 * \text{sand (\%)}$$

This predictive equation could account for 74% of the variations, but still there is a need to work in greater details on this aspect, as the data set points for developing this function were less.

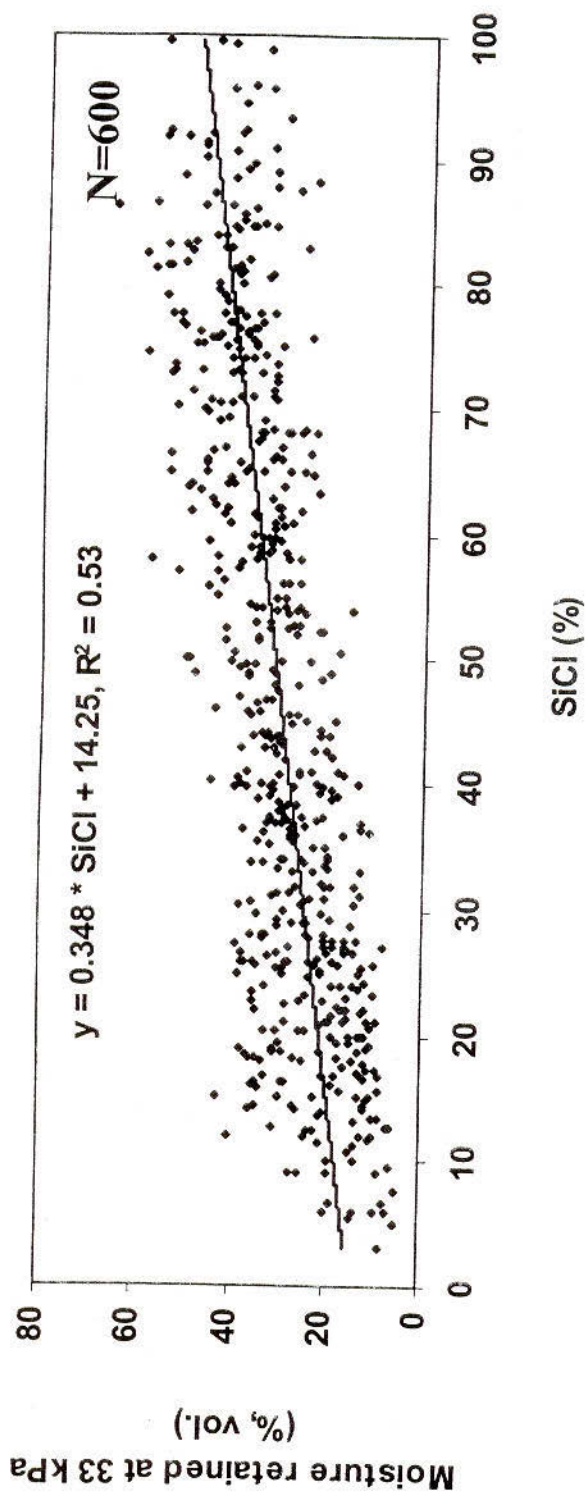


Fig. 1. Moisture retained at field capacity as related to silt plus clay content (Si+Cl)

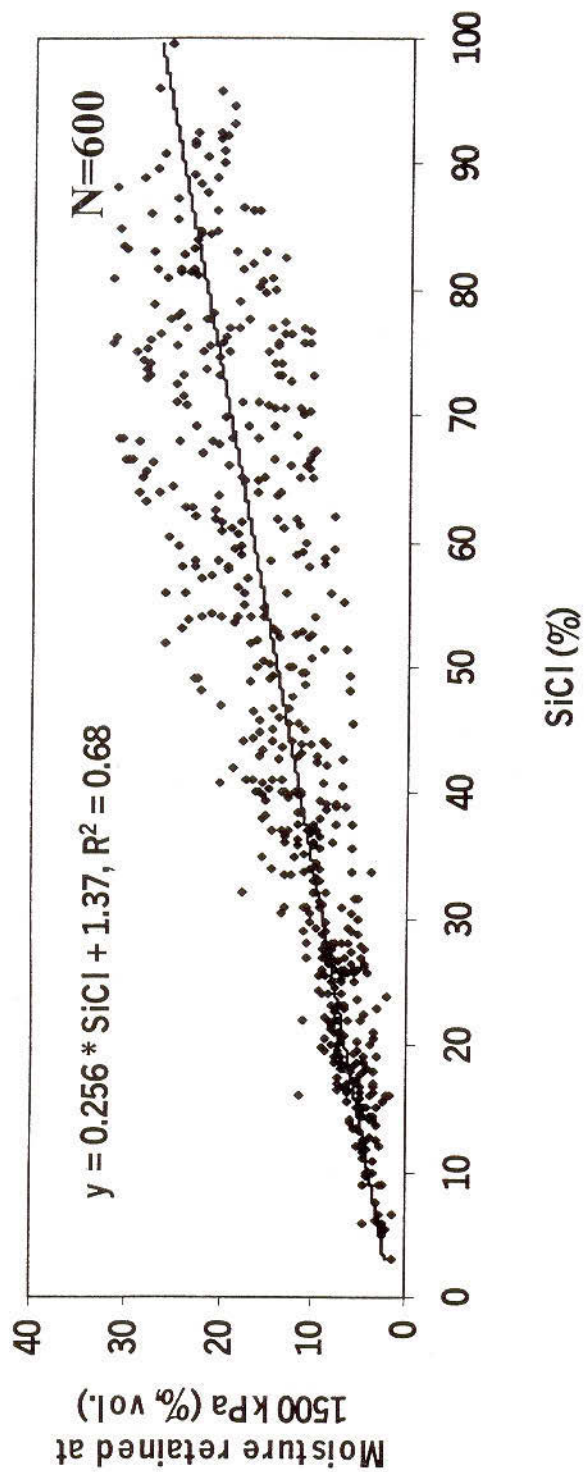


Fig. 2. Moisture retained at wilting point as related to silt plus clay content (Si+Cl)

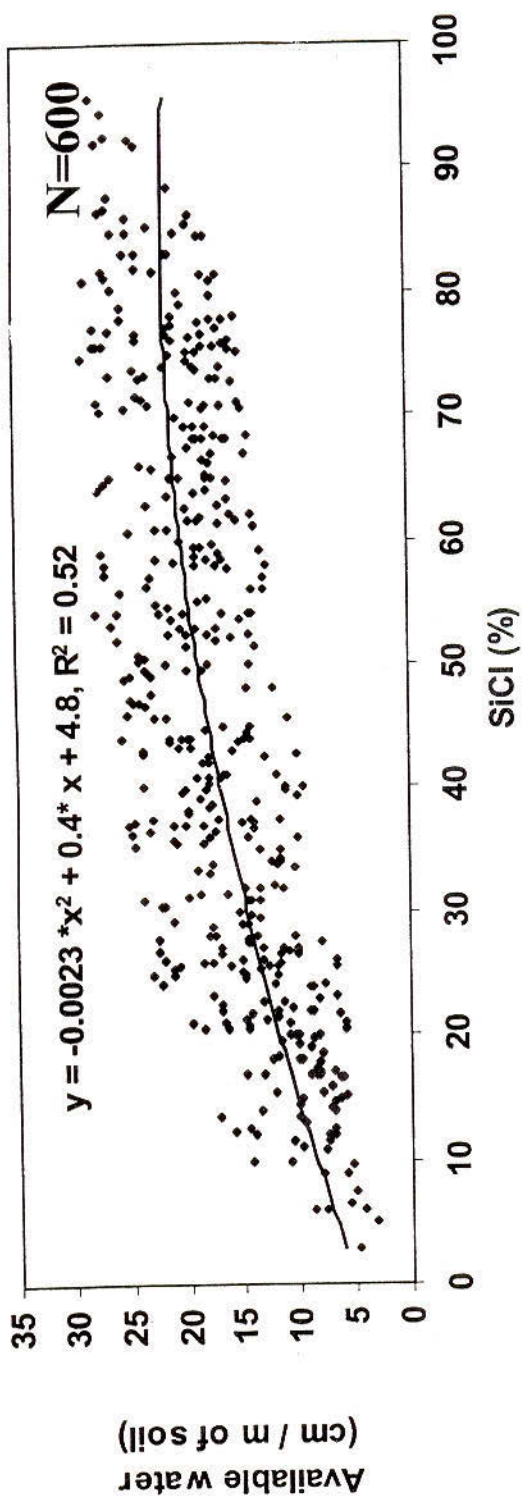


Fig. 3. Available water in the soil profile as related to silt plus clay content (Si+Cl)

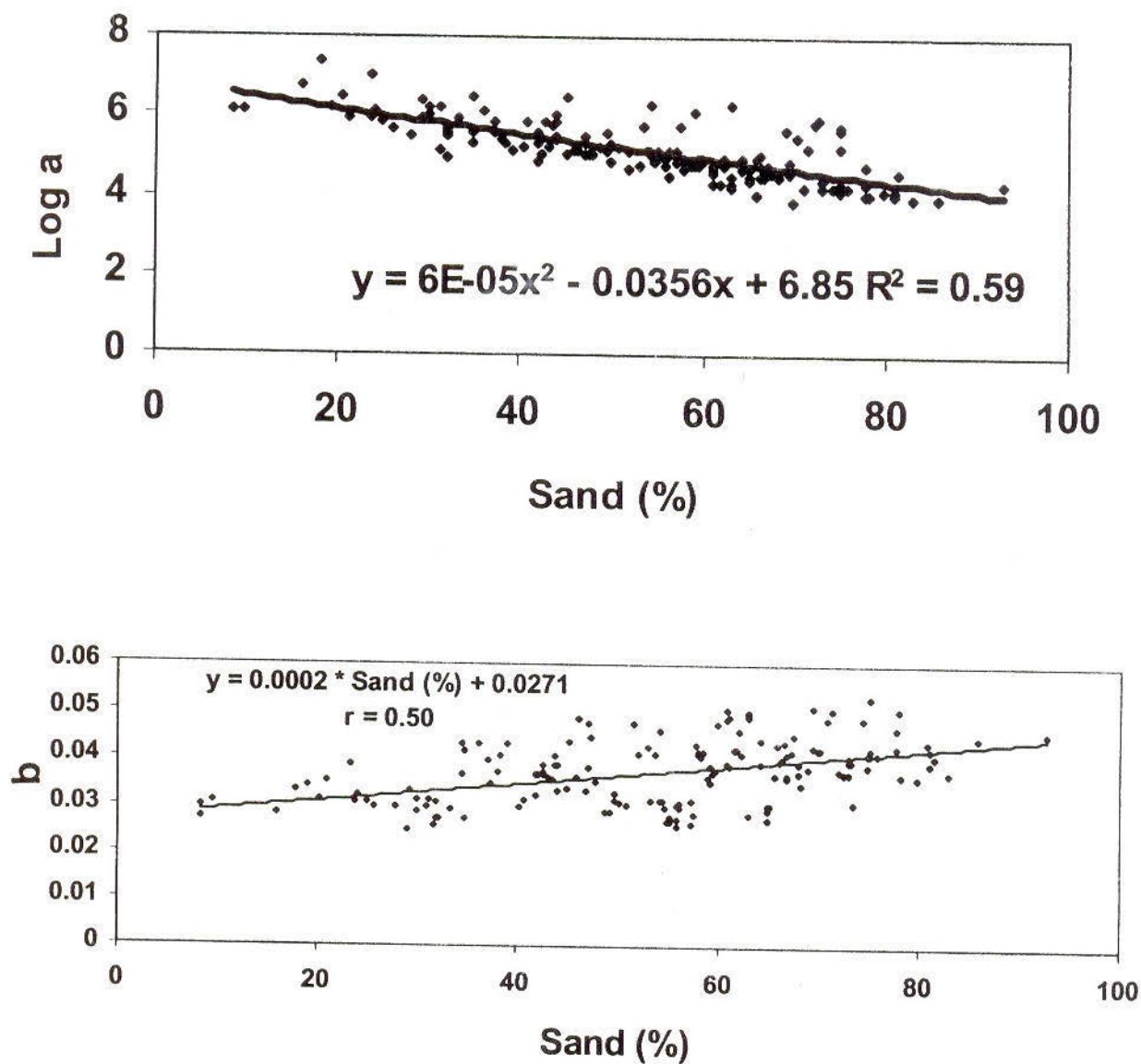


Fig. 4. Soil moisture release constants as related to sand

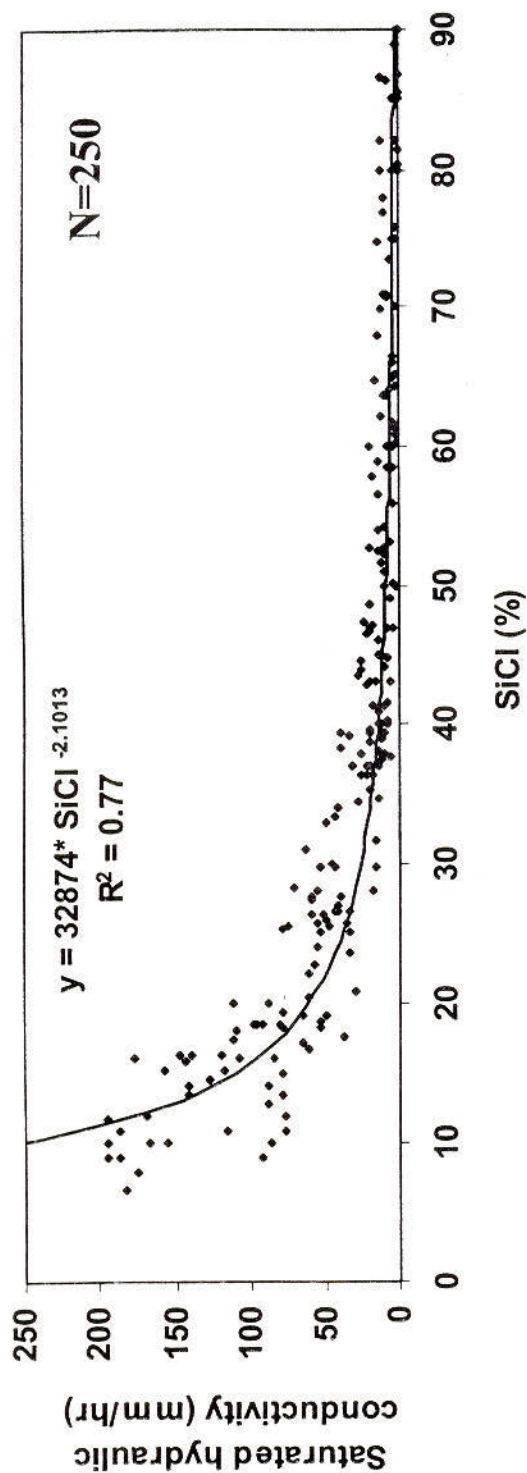


Fig. 5. Saturated hydraulic conductivity as related to silt plus clay content (Si+Cl)

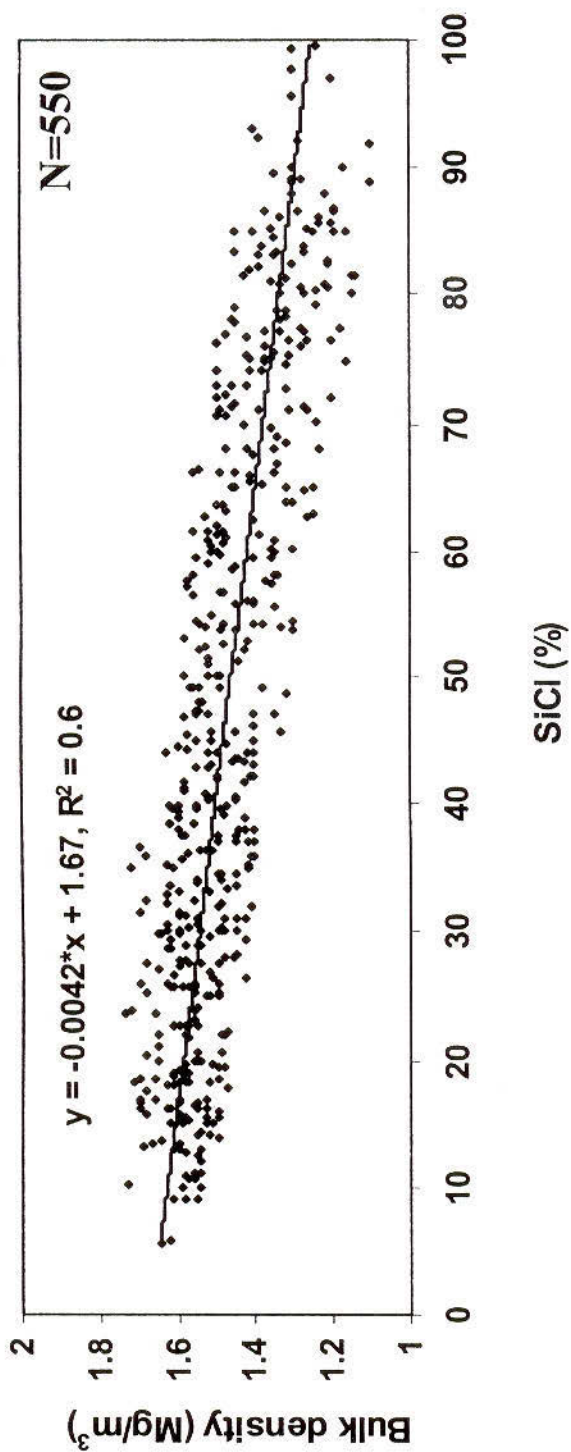


Fig. 6. Bulk density as related to silt plus clay content (Si+Cl)

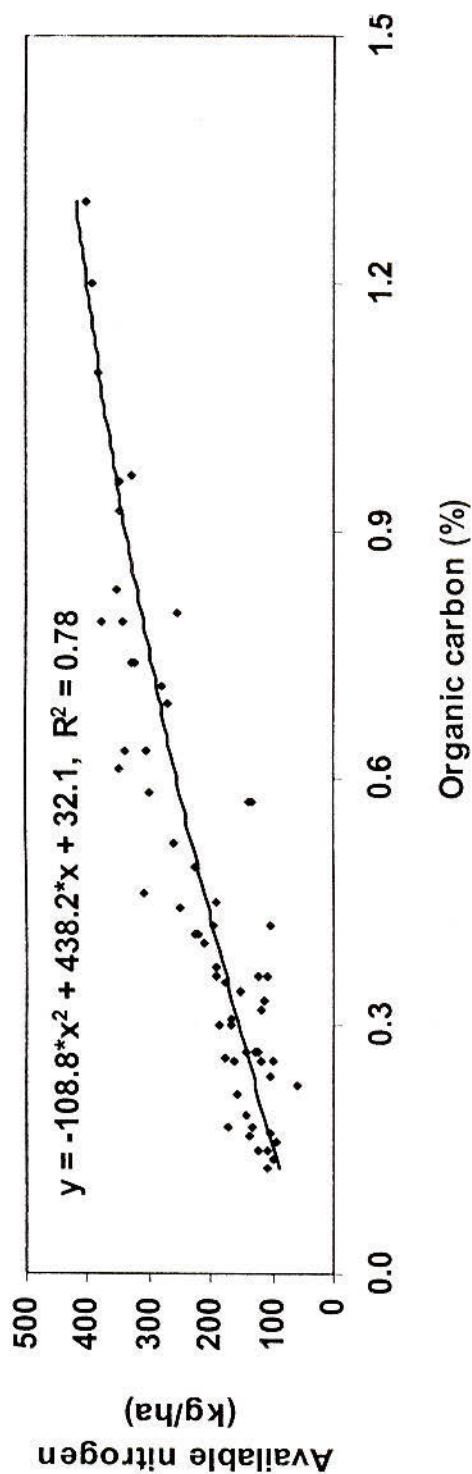


Fig. 7. Relationship between organic carbon content and soil available nitrogen

CONCLUSION

Basic soil characters, such as soil texture and organic carbon, which are usually available at the most of the locations can be utilized to assess soil moisture constants and soil fertility by using pedo-transfer functions. In this paper, soil data set compilation of 600 loctions was used to evaluate soil moisture retention, release and transmission characteristics. These soil moisture constants can be used in water, nutrient and other agronomic management to enhance growth and yield of crops. Soil nitrogen availability was also derived through soil texture and organic carbon content. Performance of pedo-transfer functions generated in this study was within statistically significant limits, and furthermore suggests to adopt this approach in characterization of soils in various agro-ecological regions.

REFERENCES

- Ali, M.H., Chatterjee, R.K., & Biswas, T.D. (1966). Soil moisture tendion relationships of some Indian soils. *J. Indian Soc. Soil Sci.*, 14, 51-62.
- Bharambe, P.R., Awasarmal, B.C., Ambegaonkar, P.R., & Rodge, R.P. (1990). Characterization of soils in relation to irrigation in Jayakwadi Command Area. *J. Indian Soc. Soil Sci.*, 38, 488-494.
- Gomez, K.A., & Gomez, A.A. (1984). *Statistical procedures for agricultural research*. New York : Author.
- Gupta, R.P. (1992). Studies on models for evaluation of soil water retention characteristics. In *soil moisture process and modeling* (pp.33-38). Khragpur, India : IIT.
- Gupta, S.C., & Larson, W.E. (1979). Estimating soil water retention characteristics from particle size distribution, organic matter percent and bulk density. *Water Resour. Res.*, 15, 1633-1635.
- Gupta, R.P., Kumar, S., & Singh, T. (1984). *Soil management to increase crop production, Consolidated Report 1967-82 of AICRP on Improvement of Soil Physical Conditions to Increase Agricultural Production of Problematic Areas*. India : ICAR.
- Satyavathi, P.L.A., Sharma, J.P., & Srivastava, R. (1994). Contribution of soil organic matter, clay and silt to the cation exchange capacity of soil. *J. Indian Soc. Soil Sci.*, 42, 14-17.
- Rawls, W.J., & Brakensiek, D.L. (1982). Estimating soil water retention from soil properties. *J. Irrig. Drain. Div. ASCE.*, 108, 166-171.
- Rudra, S.K., Raychaudhuri, M., & Das, S.N. (1991). Physico-chemical environment of Gongha Nala watershed of Bilaspur District of Madhya Pradesh. *J. Soil Wat. Conserv. India.*, 35, 60-73.
- Talati, N.R., Aitri, S.C., & Mathur, S.K. (1975). Moisture retention studies and their relationship with some of the soil characteristics. *J. Indian Soc. Soil Sci.*, 23, 12-17.
- Velayutham, M., & Raj, D. (1971). Interrelationship between soil separates and properties of soils of Tamil Nadu. *J. Indian Soc. Soil Sci.*, 19, 353-361.

PRICE BEHAVIOUR OF SEASONAL VEGETABLES IN UTTAR PRADESH- A COMPARATIVE STUDY OF WESTERN (PLAIN) AND HILL REGIONS

MUKESH K. WADHWANI¹ AND T.S. BHOGAL²

ABSTRACT

An attempt has been made to study comparatively the price behaviour of seasonal vegetables in Western (Plain) and Hill regions of the state of Uttar Pradesh (UP) in India. The study is based on secondary data on wholesale monthly/ weekly arrivals and prices for the period from 1987 to 1996. Inspite of favourable agro-climatic conditions, more remunerative, labour intensive and export potentials, the vegetable crops have received importance in the land use planning, only recently in our country. Their perishable nature also results in inability on the part of producers to manage their supply. The price behaviour of vegetables, spatial and temporal, has definite bearing upon the growers as well as the traders. The study revealed that the prices of vegetables are increasing overtime, though no definite cycle was observed in its fluctuation in most of the vegetables except in ginger and green pea in U.P. plains and onion, cabbage/cauliflower and bottlegourd in U.P. hills. It was also found that the prices of vegetables are negatively influenced by their arrivals in both the regions whereas the arrivals were not found influenced by the prices, which may be due to their perishable nature, their cultivation being mostly concentrated with marginal and small farmers, lack of storage facilities etc.

Key words : Price behaviour, Seasonal vegetables, Uttar Pradesh

INTRODUCTION

The importance of vegetables in the agricultural economy of India can be very well appreciated in terms of their increasing export potential, rising domestic demand, providing better employment and income opportunities to the growers in view of their being labour

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intensive nature and more remunerative. While domestic as well as export demands are steadily rising, the production and supply of vegetables face tremendous uncertainties on several accounts. Their extremely perishable nature results in inability on the part of producers to manage their supply in assembling markets. Seasonal gluts are, therefore, a common phenomenon in the assembling markets during normal production seasons. However, inspite of favourable climatic and social conditions, these crops received importance in land use planning only in recent years.

Vegetables, an important sub-group of horticultural crops, play an important role in human nutrition and contribute to the prosperity of the country. These also constitute an important component in the export basket of our country. However the present level of production is able to supply only 135 gram per capita per day against the ICMR recommended quantity of 285 grams per capita per day. To achieve this level we need to produce over 100 MT of vegetables annually, whereas the present production is about 83 MT from the area of 6 m.ha.

The market imperfections are also proving disincentive to the growers in increasing vegetable production. The price behaviour of vegetables, spatial or temporal, has a definite bearing upon the rationality of decisions by the growers as well as traders. Therefore, the price behaviour of seasonal vegetables needs to be studied. In view of the above situation the present study was conducted with the main objective to study the temporal price behaviour of vegetables in U.P. The Western (Plain) region has vast potential for producing seasonal vegetables whereas the Hill region has the potential for producing seasonal as well as off seasonal vegetables.

METHODOLOGY

The study is based on secondary data collected from Kisi Utpadan Mandi Sammittee, Bareilly and Dehradun for the Plain (Western) and Hill regions of U.P. respectively for the period from 1987-1997. These markets were selected for the study, being the largest vegetable markets in two regions.

The temporal price behaviour of each sample vegetables was studied by computing the trend, seasonal and cyclical variation therein using a **multiplicative model** of following type.

$$P_t = T_t \cdot S_t \cdot C_t \cdot I_t$$

Where, P_t = the time series data on prices

T_t = the trend component

S_t = the seasonal variation

C_t = the cyclical variation

I_t = the irregular variation.

The **seasonality** was estimated using weighted monthly average prices. The price series was deseasonalised by dividing it by the seasonal indices. Then the **trend equations** were fitted in deseasonalised data as-

$$Y = a + b.t$$

Where, y= deseasonalised price series

t= time (t=1,2,... 120)

The analysis has been done for each vegetable separately. Then the deseasonalised series was divided by trend values to have cyclical variations as a residual therein.

The relationship between arrivals of vegetables and prices was analysed in monthly data of 10 years (1987 to 1997) and five year weekly data (1992-1997). Following type of linear functions were estimated to study the relationship-

$$A_t = f(P_t), \text{ i.e., } A_t = a + b. P_t \quad (\text{i})$$

$$P_t = f(A_t), \text{ i.e., } P_t = a + b. A_t \quad (\text{ii})$$

$$A_t = f(P_{t-1}), \text{ i.e., } A_t = a + b. P_{t-1} \quad (\text{iii})$$

Where, A_t = Quantity of vegetable in t^{th} month/week. (in quintals)

P_t = Price of vegetable in t^{th} month/week (Rs/qtl)

P_{t-1} = Price of vegetable in previous week (Rs/qtl)

A = Intercept, b= Regression coefficient.

RESULTS AND DISCUSSION

Most of the farm products are prone to both inter and intra-year price fluctuations. It is more in case of vegetables due to their high degree of perishability. The knowledge of the nature and magnitude of price movements is of utmost importance to the policy makers and those who are engaged at a various levels of their production and marketing. There are four components of price fluctuation viz., seasonal, secular trend, cyclical and irregular variation. The irregular variation has no defined pattern, hence is of no policy importance. Therefore, in the study seasonal movement, secular trend and cyclical movement of prices have been studied.

1.1 Seasonality in prices of vegetables

The results of analysis have been presented in tables 1(A) & 1(B) for the two regions separately.

Potato: The analysis shows that the prices of potato start rising from April till August as by March all the local produce get harvested and arrival decline substantially in plains of Western region. From October the prices again show declining trend as the harvesting of early crop starts in plains. The highest prices are found during July-September months. The

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minimum prices are indicated in February. Whereas in the Hill region, high prices are observed during the months of August to November because of high demand of hill potato in plains in the period. During winter months the seasonal indices of potato prices have been low due to main production season in the plains and Hills areas.

Onion: The same results of seasonality in the onion prices have been observed in both the regions. The maximum value of seasonal index is found in the month of November and from December onward a declining trend is observed as early crop from Nasik start coming. This is continued till May. The prices show upward trend from the month of June in Hill region while from July in the Western region.

Ginger: No seasonality in the prices of ginger has been found in both the regions.

Tomato: The prices of tomato in Western region show rising trend from June to November and start decreasing from December as the produce of main crop of tomato starts coming in the market. The lowest prices are found in May. The prices show rising trend from July to October in Hill region. The prices start decreasing with the arrival of tomato from plains from November onward.

Cabbage/Cauliflower: The time series data of cabbage and cauliflower were maintained as one crop by both the APMCs. Therefore, the indices of these crops have been estimated together. The results show that the prices of these crops are more than average from May to October which were lower than average during November to April, being the main production season. Thus, a definite seasonality is found in the prices of cabbage and cauliflower in both the regions.

Brinjal: The seasonality in the wholesale prices of brinjal is almost absent in Western region as this crop is grown throughout the year in the region. The same phenomenon is also observed in Hill region market because a considerable quantity of brinjal comes in from the plains.

Green Chilli: The analysis shows the prices of chilli rise from July with the maximum in October in plains of U.P. and prices become less than average from March as the produce of main season (*rabi*) crops starts coming in the market. While in the hills, the prices were lower than average during the months of June to September and from January to March. The seasonality in the prices was not very pronounced in both the regions.

Bottlegourd: The seasonal price indices show the peak harvesting/marketing season of the crop from April to September in the U.P. Plains while March to May in the hills as the value of indices are considerably low in these months. In plains, the prices start rising from October with the highest in February.

Pumpkin: The seasonality in the prices of pumpkin was found very weak in both the regions. The lowest price in plains was indicated in May while in the hills it was minimum in July.

Okra: In the plains of U.P., two marketing/harvesting periods are exhibited from the values of indices of okra. One from August-September and another from April to July coinciding with the two seasons of crop i.e., *kharif* and *zaid*, respectively. The highest price of okra was in the month of February. The well marked seasonality is shown in the price of okra from seasonal indices in the Hill region also. They are considerably lower during May to September and lowest during June and July months.

Green pea: The main harvesting/marketing period of green pea in the Plains (Western region) is November to April. Consequently the price indices are below 100 during these months, while the same situation is observed from October to March in Hill region. The lowest prices in the plain markets are found in the months of December and January being the peak harvest season. The highest price of green pea was found in August when the off-seasonal crop starts coming in from hills to the plains.

1.2 Secular trend in the prices of vegetables

The trend equations were estimated on depersonalized series of average monthly wholesale prices. The results are presented in table 2 for both the regions. It is revealed from the table that the trend coefficients of all vegetables was statistically significant except cabbage/cauliflower. The results of Western region show that of potato, tomato, green chilli, okra, green pea and pumpkin the trend coefficients are positive and significant implying thereby that the price of these are increasing overtime in the region.

The results of Hill region reveal that the trend coefficients are significant for the vegetables, like potato, onion, ginger, brinjal, okra green pea, bottlegourd and pumpkin. The prices of all these vegetables have been found increasing overtime in the region.

1.3 Cyclical fluctuation

The cyclical movement in vegetable prices were estimated on monthly wholesal prices after deseasonalising and detrending them. Though the cyclical coefficients were estimated month wise, their values have been averaged for each year. The results of analysis on cyclical fluctuations in prices are presented in tables 3(A) and table 3(B) for the two regions. The results show that no definite cycle is observed in prices of most of the vegetables in both the regions. However, in green pea and ginger relatively more regular cyclical fluctuation is observed in Western region. Whereas in Hill region, the prices of onion, cabbage/cauliflower and bottlegourd, show regular cycle of two years.

Table 1A. Seasonal price indices of vegetables in Western region of U.P.

Vegetables	July	Aug.	Sept.	Oct.	Nov.	Dec.	January	Feb.	March	April	May	June
Potato	135.58	135.89	135.07	132.69	111.88	96.67	69.35	65.74	65.87	69.48	86.09	102.60
Onion	79.18	79.67	96.16	114.22	217.79	133.61	129.37	100.18	79.26	56.63	47.44	46.50
Ginger	100.82	29.90	100.82	98.85	102.75	86.39	105.48	84.53	131.27	133.09	118.98	107.08
Tomato	77.89	119.38	137.00	145.57	185.08	118.38	96.92	78.75	70.48	63.96	46.98	59.62
Cabb./Cauli.	103.75	184.64	208.53	106.35	110.54	58.94	56.63	51.82	50.25	62.78	73.83	77.92
Brinjal	91.62	128.43	121.89	95.10	122.82	92.08	109.95	98.48	104.68	65.95	75.26	93.73
Gr. Chilli	96.89	79.68	106.19	133.65	114.59	102.55	115.86	161.71	96.27	76.55	66.98	49.08
Okra	72.66	61.97	81.46	82.36	114.54	-	212.68	209.17	165.95	93.95	46.33	59.41
Green pea	-	310.05	170.96	119.76	60.20	29.18	36.43	40.90	58.54	73.96	-	-
Bottlegourd	56.25	53.86	50.75	95.76	105.25	111.09	151.72	342.18	77.74	39.25	42.84	41.85
Pumpkin	85.93	83.89	91.30	217.30	150.25	70.29	73.07	129.30	78.17	79.65	67.73	73.13

Table 1B. Seasonal price indices of vegetables in Hill region U.P.

Vegetables	July	Aug.	Sept.	Oct.	Nov.	Dec.	January	Feb.	March	April	May	June
Potato	93.91	126.06	139.66	126.14	107.19	96.28	69.17	66.78	57.75	73.38	79.50	84.12
Onion	71.60	102.99	122.58	142.37	148.08	107.87	104.78	102.78	89.29	85.78	57.07	64.69
Ginger	76.45	97.94	101.47	113.55	130.59	98.27	106.30	103.45	91.54	96.81	89.05	94.54
Tomato	78.80	114.21	125.53	196.30	139.55	109.45	92.53	80.82	83.43	64.68	58.21	56.42
Cabb./Cauli.	139.60	129.60	178.80	179.39	93.28	62.21	40.08	40.81	49.06	77.35	108.76	103.00
Brinjal	82.39	110.78	99.47	106.46	80.59	91.65	98.44	114.88	126.01	97.91	103.30	87.09
Gr. Chilli	57.28	81.65	82.49	148.14	121.10	106.05	98.65	97.69	94.72	100.03	100.55	75.23
Okra	46.78	60.35	67.58	108.70	176.16	146.99	124.58	130.63	128.90	93.16	97.58	113.09
Green pea	126.23	213.89	194.77	138.41	93.32	70.29	48.91	51.17	50.76	61.25	66.68	84.27
Bottlegourd	88.34	82.80	115.42	99.57	109.80	131.38	139.30	142.79	74.62	73.82	61.39	80.71
Pumpkin	63.21	86.67	86.98	96.22	100.04	111.27	124.85	117.40	108.90	93.16	97.58	113.69

Table 2. Estimate trend equations in wholesale prices of vegetables in U.P.

Vegetables	Western Region				Hill Region			
	Constant (a)	Reg.coeff.(b)	SE(b)	r ²	Constant (a)	Reg.coeff.(b)	SE(b)	r ²
Potato	1.2477	0.0105*	0.0020	0.1839	0.7523	0.0119*	0.0021	0.2144
Onion	1.9649	0.0077**	0.0025	0.0717	2.7763	0.094	0.0139	0.0039
Ginger	5.0821	0.02850*	0.0051	0.2058	3.5280	0.0300	0.0050	0.2340
Tomato	2.6080	-0.0009	0.0041	0.0004	2.3570	0.0160***	0.0087	0.0276
Cabb./Cauli.	1.9460	0.0058	0.0037	0.0207	3.1847	-0.0032	0.0078	0.0015
Brinjal	0.9314	0.0069*	0.0020	0.0931	6.7738	0.0031	0.0012	0.0507
Gr. Chilli	2.0669	0.0045	0.0020	0.0336	2.0201	0.0121**	0.0053	0.0421
Okra	2.4086	0.0093***	0.0040	0.0363	2.4362	0.0118*	0.0044	0.6999
Green pea	3.7688	0.0118**	0.0048	0.0488	3.0283	0.0244*	0.0085	0.0955
Bottleghourd	0.7959	0.0121*	0.0019	0.2561	1.3933	0.0194	0.0069	0.0632
Pumpkin	0.6715	0.0052*	0.0013	0.1213	0.7428	0.0027***	0.0015	0.0341

*, ** and *** show significant at 1, 2.5 and 5.0 per cent level of significance.

Table 3A. Cyclical variation in prices of vegetables in Western (Plain) region of U.P.

Vegetables	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
Potato	103.36 (+3.36)	83.64 (-16.36)	86.11 (-13.89)	106.00 (+6.00)	134.43 (+34.43)	80.93 (-19.07)	85.14 (-14.86)	92.16 (-7.84)	120.60 (+20.60)	104.63 (+4.63)
Onion	203.19 (+103.19)	54.46 (-45.54)	37.43 (-62.57)	99.90 (-0.10)	82.23 (-17.77)	50.68 (-49.32)	94.44 (-5.56)	138.28 (+38.28)	166.02 (+66.02)	73.38 (-26.62)
Ginger	108.77 (8.77)	101.41 (+1.41)	104.31 (+4.31)	119.22 (+19.22)	84.60 (-15.40)	73.35 (-22.65)	77.56 (-22.44)	109.50 (+9.50)	116.72 (+16.72)	100.56 (+0.56)
Tomato	113.14 (+13.14)	107.84 (+7.84)	100.44 (+0.44)	80.88 (-19.12)	106.63 (+1.63)	72.90 (-27.10)	84.76 (-15.24)	73.14 (-26.86)	141.15 (+41.15)	124.13 (+24.13)
Cabbage/ Cauliflower	64.91 (-35.09)	94.50 (-5.50)	93.22 (-6.78)	140.40 (+40.40)	113.43 (+13.43)	91.36 (-8.64)	93.71 (-6.29)	129.97 (+29.97)	86.61 (-13.39)	91.87 (-8.13)
Brinjal	107.40 (+7.40)	90.63 (-9.37)	94.56 (-5.44)	112.33 (+12.33)	109.73 (+9.73)	83.55 (-16.45)	80.28 (-19.72)	106.86 (+6.82)	112.77 (+12.77)	101.95 (+1.95)
Green chilli	94.05 (-5.95)	151.82 (+51.82)	129.03 (+29.03)	108.70 (+8.70)	131.55 (+31.55)	60.73 (-39.27)	66.50 (-33.50)	73.66 (-26.34)	106.90 (+6.90)	77.05 (-22.95)
Okra	94.95 (-5.05)	109.93 (+9.93)	96.46 (-3.57)	112.93 (+12.93)	97.51 (-2.49)	92.57 (-7.43)	73.01 (-26.99)	83.63 (-16.37)	108.10 (+8.10)	131.01 (+31.01)
Green pea	97.16 (-3.84)	104.01 (+4.01)	101.24 (+1.24)	92.37 (-7.63)	116.76 (+16.76)	82.42 (-17.58)	112.03 (+12.03)	81.21 (-18.79)	109.02 (+9.07)	103.78 (+3.78)
Bottlegourd	75.14 (-24.86)	110.65 (+10.65)	110.68 (+10.68)	116.71 (+16.71)	125.93 (+25.93)	72.31 (-27.69)	107.70 (+7.70)	86.60 (-13.40)	93.30 (-6.70)	110.98 (+10.98)
Pumpkin	96.64 (-3.36)	103.76 (+3.26)	89.52 (-10.48)	101.99 (+1.99)	106.60 (+6.60)	99.09 (-0.91)	86.73 (-13.27)	112.34 (+12.34)	98.87 (-1.13)	101.10 (+1.10)

Figure in brackets show deviation from 100.

Table 3B. Cyclical variation in prices of vegetables in Hill region of U.P.

Vegetables	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
Potato	122.19 (+22.19)	127.70 (+27.70)	84.77 (-15.23)	98.08 (-1.92)	94.02 (-5.98)	87.11 (-12.89)	85.99 (-14.01)	61.58 (-38.42)	90.25 (-9.75)	148.31 (+48.31)
Onion	150.93 (+50.93)	90.19 (-9.81)	69.53 (-30.47)	109.01 (+9.01)	74.52 (-25.48)	78.91 (-21.09)	125.18 (+25.18)	83.43 (-16.57)	91.82 (-8.18)	126.48 (+26.48)
Ginger	115.59 (+15.54)	122.66 (+22.66)	91.00 (-9.00)	85.98 (-14.02)	95.30 (-4.70)	84.21 (-15.79)	94.63 (-5.37)	91.21 (-8.79)	87.06 (-12.94)	132.41 (+32.41)
Tomato	144.40 (+44.40)	127.30 (+27.30)	90.64 (-9.36)	54.77 (-45.23)	70.37 (-29.63)	91.51 (-8.49)	102.61 (+2.61)	57.81 (-42.19)	68.24 (-31.76)	192.34 (+92.34)
Cabbage cauliflower	120.98 (+20.98)	128.94 (+28.94)	66.48 (-33.52)	75.52 (-24.48)	129.53 (+29.53)	116.16 (+16.16)	64.56 (-35.44)	63.58 (-36.42)	61.83 (-38.17)	172.41 (+72.41)
Brinjal	139.93 (39.93)	126.48 (+26.48)	131.22 (+31.22)	67.96 (-32.04)	68.95 (-31.05)	68.73 (-31.27)	75.76 (-24.24)	52.46 (-47.54)	99.35 (-0.65)	169.44 (+69.44)
Green chilli	93.72 (-6.28)	106.21 (+6.21)	114.80 (+14.80)	90.01 (-9.99)	89.89 (-10.11)	87.89 (-12.11)	150.54 (+50.54)	91.09 (-8.91)	80.45 (-19.55)	104.71 (+4.71)
Okra	129.31 (+29.31)	102.63 (+2.63)	76.71 (-23.29)	77.44 (-22.56)	69.33 (-30.67)	138.25 (+38.45)	123.46 (+23.46)	78.21 (-21.97)	102.94 (+2.94)	101.72 (+1.72)
Green pea	95.52 (-4.48)	135.92 (+35.92)	84.17 (-15.83)	91.28 (-8.72)	86.79 (-13.21)	94.69 (-5.31)	116.88 (+16.88)	96.12 (-3.88)	71.28 (-28.72)	127.36 (+27.36)
Bottlegourd	167.04 (+67.04)	109.51 (+9.51)	94.53 (-5.47)	62.73 (-37.27)	99.40 (-0.60)	139.29 (+39.29)	97.15 (-2.85)	53.56 (-46.44)	93.25 (-6.75)	151.44 (+51.44)
Pumpkin	134.64 (+34.64)	139.17 (+39.17)	86.38 (-13.62)	73.12 (-26.88)	71.30 (-28.70)	100.87 (+0.87)	88.23 (-11.70)	71.58 (-28.42)	74.83 (-25.17)	159.87 (+59.87)

Figure in brackets show deviation from 100.

2.1 Temporal relationship

The results of analysis are presented in tables 4(A) & 4 (B) for Western (Plain) and Hill regions respectively. The table 4(A) reveals that the prices of all vegetables respond negatively to the arrival. That means the price decrease with increase in arrivals and increase with decrease in arrivals as is generally expected. The results of $A_t = f(P_t)$ equation show that the arrival of all the seasonal vegetables respond negatively, i.e. the quantity of arrival decreases with the increase in price which appears to be spurious. The most of vegetables being highly perishable, growers are bound to sell their produce just after harvest and as the arrival in the market increase, prices are ought to decline. This may be the cause of this spurious relationship between arrival and prices.

Table 4A. Estimated regression equation between market arrivals and wholesale price of different seasonal vegetables in Western region (APMC, Bareilly)

Vegetables	$A_t = f(P_t)$				$P_t = f(A_t)$			
	a	B	SE(b)	r^2	a	b	SE(b)	r^2
Potato	53679.01	-164.96**	70.99	0.04	143.93	-0.0003**	0.0001	0.04
Onion	9391.06	-5.874*	2.225	0.06	345.71	-0.0095*	0.0036	0.06
Ginger	129.84	-0.086	0.079	0.01	511.17	-0.1178	0.1096	0.01
Tomato	3130.34	-5.242*	1.468	0.10	288.47	-0.0186*	0.0052	0.10
Cabb./Cauli.	729.26	-0.844**	0.410	0.04	226.47	-0.0443**	0.0215	0.04
Brinjal	977.19	-4.054**	1.628	0.05	101.22	-0.0123**	0.0049	0.05
Green Chilli	1008.89	-0.645	0.447	0.02	261.31	-0.0270	0.0186	0.02
Okra	526.76	-0.693*	0.159	0.16	368.35	-0.2321*	0.0533	0.16
Green Pea	1156.85	-0.827*	0.232	0.16	578.73	-0.1882*	0.0528	0.16
Bottlegourd	2031.72	-5.609*	1.984	0.07	166.01	-0.0124*	0.0044	0.07
Pumpkin	1059.40	-1.529	2.922	0.01	85.98	-0.0018	0.0035	0.01

*and ** show significant at 1 and 5 per cent level of probability.

The table 4(B) shows the results of analysis for Hill region. The results of equation, $p_t = f(A_t)$ reveal that the prices of all the vegetables except potato and pumpkin respond negatively to the arrival thereof which is obviously true. The positive response of potato prices to its arrival appears to be contributed by the factors like high degree of integration between hill (Dehradun) and plain (Bareilly) vegetable markets. The potato is being supplied and received in hill markets from the hills as well as the plains, having different harvesting season. The results of equation, $A_t = f(p_t)$, show that except potato and pumpkin the arrival of all the

vegetables respond negatively, i.e. the supply decreases by the increase in price and vice-versa which also seems to be spurious. The vegetables being highly perishable the producers are bound to sell their produce immediately after harvest and as the arrivals in the market rise, prices are ought to decline. This may be the cause of this spurious relationship between arrival and price in case of vegetables.

Table 4B. Estimated regression equation between market arrivals and wholesale price of different seasonal vegetables in Hill region (APMC, Dehradun)

Vegetables	$A_t=f(P_t)$				$P_t=f(A_t)$			
	a	b	SE(b)	r^2	a	b	SE(b)	r^2
Potato	2481.78	70.54*	10.962	0.25	128.53	0.0037*	0.0006	0.25
Onion	5372.32	-4.28*	1.479	0.07	309.99	0.0155*	0.0053	0.07
Ginger	1000.00	-0.1084	0.348	0.001	699.17	-0.0076	0.0243	0.001
Tomato	10244.30	-12.45*	1.665	0.32	436.58	-0.2580*	0.0035	0.32
Cabb./Cauli.	9038.99	-14.91*	2.416	0.24	318.56	-0.0164*	0.0027	0.24
Brinjal	3646.56	-6.143*	2.213	0.06	163.26	-0.0010*	0.0036	0.06
Green chilli	1380.35	-0.9966	0.883	0.01	246.51	-0.0107	0.0095	0.01
Okra	1779.61	-1.644*	0.511	0.08	375.12	-0.0540*	0.0168	0.08
Green pea	4229.30	-2.51**	0.980	0.05	512.11	-0.0210**	0.0082	0.05
Bottle gourd	4999.07	-11.63*	2.462	0.15	194.44	-0.0137*	0.0029	0.15
Pumpkin	7013.86	2.552	31.822	0.00	97.89	0.00002	0.0003	0.00

*and ** show significant at 1 and 5 per cent level of probability.

2.2 Seasonal relationship

The seasonal relationship between arrival and price of vegetables in the two regions was estimated on weekly data for 5 years (1992-93 to 1996-97) obtained from the two representative markets of the two regions through following linear equations.

$$A_t=f(P_{t-1}), A_t=f(P_t) \text{ \& } P_t=f(A_t)$$

The results of function, $P_t=f(A_t)$ are presented in table 5 for the two regions. The results show that except green pea in Western region and ginger in Hill region all vegetable prices is significantly affected by the market arrivals. Whereas the results of lagged and concurrent weekly price and arrival (Table 6) show negative relationship, which means the weekly prices are not capable of influencing vegetable grower's decision to sell the produce during post-harvest season under existing conditions. The same results were also found in case of Hill region.

Table 5. Regression equation between weekly price and arrivals, $P_t = f(A_t)$ of different seasonal vegetables in U.P.

Vegetables	Western Region				Hill Region			
	Constant (a)	Reg.Coeff. (b)	SE(b)	r ²	Constant (a)	Reg.Coeff.(b)	SE(b)	r ²
Potato	251.72	-0.00014*	0.00004	0.04	256.79	0.0099**	0.004	0.01
Onion	344.06	0.00181*	0.00032	0.11	559.26	-0.102*	0.016	0.13
Ginger	1517.29	-0.64117*	0.15536	0.07	1264.59	-0.060	0.084	0.002
Tomato	564.23	-0.01024*	0.00231	0.07	578.66	-0.047*	0.022	0.14
Cauliflower	241.22	-0.00131*	0.00042	0.08	274.71	-0.038**	0.016	0.03
Cabbage	266.97	-0.00101*	0.00029	0.10	471.90	-0.097*	0.014	0.18
Brinjal	190.76	-0.00049*	0.00010	0.08	333.49	-0.198*	0.033	0.12
Green Chilli	145.99	-0.00080*	0.00026	0.02	828.07	-0.676*	0.125	0.10
Okra	329.93	-0.00166***	0.00098	0.02	356.63	0.067**	0.040	0.02
Green pea	400.79	-0.00119	0.00141	0.01	767.39	-0.162*	0.047	0.07
Bottleghourd	205.13	-0.00142*	0.00048	0.05	298.71	-0.140*	0.015	0.25
Pumpkin	162.56	-0.00068*	0.00019	0.06	218.76	-0.137*	0.013	0.29

*, ** and *** show significant at 1, 5 and 10 per cent level of significance.

Table 6A. Estimated regression equations between weekly arrival and price of seasonal vegetables in Western region of U.P.

Vegetables	$A_t=f(P_{t-1})$			$A_t=f(P_t)$		
	A	b	r^2	A	b	r^2
Potato	105835.9	-264.887* (86.81361)	0.04	109391.6	-279.379* (86.32681)	0.04
Onion	33243.65	-54.1270* (10.95161)	0.09	36222.05	-62.3051* (11.08799)	0.11
Ginger	308.41	-0.09147* (0.02669)	0.05	345.75	-0.11447* (0.02773)	0.07
Tomato	5708.84	-4.82582* (1.67345)	0.03	6991.75	-7.2382* (1.63079)	0.07
Cabbage	27058.58	-49.4616** (20.06865)	0.05	29528.15	-61.2982* (19.70946)	0.08
Cauliflower	42810.22	-74.1991** (29.07048)	0.06	48200.53	-96.7127* (29.93548)	0.10
Brinjal	48916.58	-161.240* (36.0522)	0.08	49935.21	-166.840* (35.86784)	0.08
Green Chilli	8788.88	-26.2510* (0.02669)	0.05	9370.67	-30.2839* (9.97579)	0.02
Okra	7580.94	-8.98890 (7.67693)	0.01	8866.28	-12.87775*** (7.56929)	0.02
Green pea	10717.87	-8.01584 (7.69769)	0.01	11408.93	-7.61805 (9.00748)	0.01
Bottlegourd	16454.91	-30.0245* (11.41750)	0.04	17146.82	-33.4980* (11.32559)	0.05
Pumpkin	21775.01	-88.8925* (26.65954)	0.06	22421.51	-92.3607* (26.61310)	0.06

*, ** and *** shows significant 1, 5 and 10 per cent level of probability

Table 6B. Estimated regression equations between weekly arrival and prices of seasonal vegetables in Hill region of U.P.

Vegetables	$A_t=f(P_{t-1})$			$A_t=f(P_t)$		
	A	B	r^2	A	B	r^2
Potato	2656.31	2.244* (0.849)	0.02	2764.41	1.861* (0.850)	0.02
Onion	2124.28	-0.907* (0.214)	0.06	2255.72	-1.261* (0.206)	0.12
Ginger	155.32	0.017 (0.047)	0.001	219.09	0.033 (0.047)	0.02
Tomato	1067.79	-0.643* (0.158)	0.06	1223.24	-0.984* (0.150)	0.15
Cabbage	789.83	-0.035 (0.386)	0.001	974.57	-0.786** (0.038)	0.03
Cauliflower	1610.12	-1.419* (0.283)	0.10	1759.63	-1.832* (0.028)	0.18
Brinjal	485.67	-0.348* (0.115)	0.04	562.24	0.652* (0.109)	0.13
Green Chilli	219.48	-0.080** (0.029)	0.02	271.81	-0.153* (0.028)	0.10
Okra	389.17	0.008 (0.208)	0.00	505.41	-0.342* (0.205)	0.02
Green pea	755.51	-0.212*** (0.126)	0.02	391.02	-0.420* (0.123)	0.06
Bottlegourd	822.58	-1.541* (0.204)	0.18	879.38	-1.791* (0.195)	0.25
Pumpkin	631.40	-1.827* (0.234)	0.21	693.56	-2.184* (0.218)	0.30

*, ** and *** show significant 1.5 and 10 per cent level of probability

CONCLUSION

The foregoing analysis showed reasonably a high degree of seasonality in the wholesale prices of potato, onion, tomato, cabbage/cauliflower, bottlegourd, green pea, okra and pumpkin. The trend coefficients were also found significantly positive in most of the vegetables in the two regions, thereby implying increase in vegetable prices over time. In most of the vegetables no definite cyclical movement was observed in vegetable prices in both the regions. However, in plains ginger and green pea and in hills onion, cabbage/ cauliflower and bottlegourd showed a relatively more regular cycle.

As in general, the prices are expected to respond inversely to arrivals and arrivals are expected to respond directly to the prices under *Ceteris paribus* conditions. The study revealed that the first section of hypothesis, i.e., prices of vegetables, is negative function of arrival, holds true. However, the second component of the hypothesis, i.e., the arrivals respond directly to prices is not found true for vegetables. This may be due to perishable nature of vegetables, lack of storage facilities and market information. Therefore, it may be concluded from the study that the sale pattern of vegetable is governed by conclusions rather than prices and/or other economic reasons in both the regions of U.P.

REFERENCES

- Acharya, S. S., & Agarwal, N. L. (1994). *Agricultural marketing in India*. New Delhi : Oxford and IBH Publishing Company Pvt.
- Kainth, G. S., & Mehra, P. L. (1988). Seasonality pattern of market arrival and prices of potato in Punjab. *Indian J. of Agril. Marketing*, 2 (1), 113-120.
- Kaul, G. L. (1997). Horticulture in India- Production marketing and processing. *Indian J. of Agril. Economics*, 52 (3), 361-573.
- Talathi, J. M., & Thakur, R. P. (1995). Temporal changes in arrivals and prices of vegetables in Bombay APMC. *The Bihar J. of Agril. Marketing*, 3 (3), 225-263.
- Arora, V. P. S. (1998). *Managing vegetable marketing in hill region of Uttar Pradesh : A study sponsored by DMI, Nagpur*. Pantnagar : GBPUA & T.

SOIL VEGETATION CORRELATION IN SALT AFFECTED SOILS OF WESTERN RAJASTHAN, INDIA

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ABSTRACT

Vegetation and soils of arid and semiarid regions of western Rajasthan were studied with the aim of understanding their inter-relationship under the arid eco-system. Principal component analysis was used to generate a hypothesis that the distribution pattern of vegetation were influenced by variation in soil properties. The hypothesis, tested by simple ANOVA of vegetation components and soil variables, revealed a primary nutrient/salinity factor as explaining species variation on the first principal component. The primary relationship between vegetation and soil variables was confirmed to be in terms of pH, EC and organic carbon variation. Most of the species indicated little or no relation to soil calcium & magnesium and calcium carbonate levels. Precision of prediction of vegetation based on soil properties was found to be seventy per cent.

Key words: Vegetation, Soil variables, Principal component analysis, Discriminant analysis

INTRODUCTION

Salt affected soils cover roughly 10% of the surface of the continents (Szabolcs, 1989) and lie primarily in arid and semi-arid regions. Such soils are also widespread and extensive in the arid regions of India and form a conspicuous part of the landscape. To make best use of these soils, their natural resources and vegetation should be well accounted while making a soil survey. Different types of vegetation indicate different natural conditions and have a strong relation with the soil variables of that area (Toth and Rajkai, 1994). The correlation between vegetation and soil data can be utilized to predict the soil variables (Toth and Kertesz, 1996). Extreme soil salt concentration, sodium level and pH are important parameters indicating ecological factors limiting crop, vegetation of salt affected soils (Waisel, 1972). Toth et al.

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(1995) found a close correlation between semi-natural vegetation cover, salt concentration, pH, penetration resistance and elevation of sites in abandoned crop lands of the Huang-Huai-Hai Plain. The information available on soil-vegetation correlation in arid saline soils is not adequate, hence the present study was undertaken in western Rajasthan with the objectives to work out the correlation between vegetation and soil variables and to predict vegetation categories using soils variables.

MATERIALS AND METHODS

Study area: Western Rajasthan, India is located between 24° to 30.5° N latitudes and 70° to 75.2° E longitudes. It lies to the West of Aravalli mountains, extending up to the Thar desert of Pakistan. It covers nearly 233,100 km² area of Rajasthan. Vegetation survey of Western Rajasthan consisting of three salt basins i.e. Pachpadra, Lunkaransar, Sambar and some of the adjoining salt affected areas i.e. Thob, Hanumangarh, Khajuwala, Jodhpur, Bikaner and Jaipur was conducted. Such salt basins are the characteristic features of the hot desert where evapo-transpiration exceeds rainfall. Rainfall is very low and most of it occurs in summer. The climatic conditions are favourable for the formation of salt basins in low lying areas of hot desert. They contain excess amount of soluble salts comprising NaCl. The distribution of dominant salt tolerant species in different locations of Western Rajasthan has been depicted in Table 1.

Sampling: The vegetation was sampled in 10X10 m quadrants spaced at 20 m interval along transects established on 10 representatives sites from each area selected for the study. Nature and type of plant species at each sampling site along with their density and frequency of distribution was recorded. Soil sampling in the study area was done at or close to the center of each quadrant by means of a soil core or in some cases by means of a profile pit. Each observation consisted of three samples at 10 cm depth increment from surface upto 30 cm.

Analytical methods

Water saturated soil paste was prepared for each sample and analysed for pHs, ECe, Na, Ca+Mg, CO_3^{2-} , HCO_3^- , organic carbon and CaCO_3 . pH was measured potentiometrically and ECe by conductivity bridge. Na content was found by flame photometer. Calcium and magnesium were determined by titration against EDTA using Erichrome black-T indicator. Carbonate and bicarbonate ion concentrations were measured by titration with standard 0.01N H_2SO_4 using phenolphthalein and methyl orange indicators. Organic carbon percentage was found by titration against 0.5N FeSO_4 . CaCO_3 was estimated by Collin's calcimeter. All the estimations were made according to the standard methods given by Jackson (1973).

Statistical analysis

Factor and principal component analyses were employed to find the interrelationship between different variables, whereas discriminant analysis (Marshall, 1987) was used to find the

precision with which the vegetation categories can be predicted using soil variables. For discriminate analysis only those soil characteristics which actually differed significantly among categories of vegetation were considered. The results were expressed in terms of the ratio of matching of the two categories.

Table 1. Distribution of salt tolerant species in different locations in Western Rajasthan.

Species	Nature	Life form	Locations				
			Pach-padra	Lunka-ransar	Hanu-mangarh	Sambhar	Thob
<i>Aeluropus lagopoides</i>	H	He	+	+	+	+	+
<i>Brachiaria Sp.</i>	FH	Th	+	-	-	-	+
<i>Bulbostylis barbata</i>	FH	Cr	+	+	-	-	+
<i>Caparis deciduas</i>	FH	Ph	+	-	-	-	-
<i>Convolvulus microphyllus</i>	FH	He	+	+	-	+	-
<i>Cressa cretica</i>	H	Ch	+	+	+	+	+
<i>Crotolaria burhia</i>	H	Ph	+	+	+	-	-
<i>Cynodon dactylon</i>	FH	He	+	+	+	-	-
<i>Cyperus sp.</i>	FH	Cr	+	+	+	+	+
<i>Dactyloctenium indicum</i>	FH	Ch	+	-	-	+	+
<i>Dichanthium annulatum</i>	FH	Ph	+	+	+	+	+
<i>Eclipta prostrata</i>	FH	Th	+	+	+	+	+
<i>Eragrostis sp.</i>	FH	Th	+	-	+	-	+
<i>Fagonia cretica</i>	FH	Th	+	+	+	+	+
<i>Fimbristylis sp.</i>	FH	Cr	+	-	+	-	+
<i>Haloxylon sp.</i>	H	Ph	+	-	+	-	+
<i>Prosopis juliflora</i>	FH	Ph	+	+	+	-	+
<i>Salsola baryosma</i>	H	Ph	+	+	+	-	+
<i>Salvadora Oleoides</i>	FH	Ph	+	-	+	-	+
<i>S. persica</i>	FH	Ph	+	-	-	-	-
<i>Sporobolus marginatus</i>	FH	Ph	+	+	+	+	+
<i>Suaeda fruticosa</i>	H	Th	+	+	+	+	+
<i>Trianthema triquetra</i>	FH	Th	+	+	+	+	+
<i>Zizyphus nummularia</i>	FH	Th	+	-	+	+	+
<i>Zygophyllum simplex</i>	H	Th	+	-	-	-	+

Note. H = Halophytes, FH= Facultative halophytes, Th = Therophytes, Ph = Phanerophytes, Ch = Chamaephytes, Cr = Cryptophytes, He = Hemi-cryptophytes.

RESULTS AND DISCUSSION

Vegetation-Soil correlation

In the study area 50 plant species were recorded and based on the dominance and co-dominance of species, these were grouped into seven and finally into four vegetation categories. Table 2 shows the mean values of pHs, ECe, Na+Ca+Mg, $\text{HCO}_3^- + \text{CO}_3^{2-}$, CaCO_3 and organic carbon in the seven category system. These soil properties are informative on the limiting ecological conditions of salt affected lands and can be measured inexpensively. The values of all these attributes except $\text{HCO}_3^- + \text{CO}_3^{2-}$ and CaCO_3 increases with depth in all vegetative categories. The content of $\text{HCO}_3^- + \text{CO}_3^{2-}$ and CaCO_3 under various vegetation categories decreased with soil depth. Sustainability of vegetation under increasing soil pH with depth indicates their tolerance for both saline and saline alkali environments. Organic carbon percentage was low and more or less constant with respect to depth and vegetation categories. Per cent organic carbon was maximum (1.0) in soils dominated by *Prosopis juliflora*. The soil under *Aeluropus lagopoides* category had the highest ECe, Na, and Ca+Mg ion concentration. The magnitude of soil variable ECe and Na were lowest in case of *Cressa cretica*. The maximum concentration of CaCO_3 and $\text{HCO}_3^- + \text{CO}_3^{2-}$ was found in soils under *Cressa cretica* and *Suaeda fruticosa* vegetation categories, respectively. *Suaeda fruticosa*, *Aeluropus lagopoides* and *Cressa cretica* were dominant in soils having a higher CaCO_3 content. The distinguishing feature of *Trianthema triquetra* was found to be Ca+Mg, $\text{HCO}_3^- + \text{CO}_3^{2-}$ and ECe content of soil in 20-30 cm layer whereas *Sporobolus marginatus* was distinguished in 20-30 cm layer by high ECe and Na content. *Suaeda fruticosa* and *Aeluropus lagopoides* vegetative covers had almost similar soil properties except $\text{HCO}_3^- + \text{CO}_3^{2-}$ content in 0-10 cm layer which distinguished them.

Prediction of vegetation categories

Vegetation categories depending upon dominant species were grouped hierarchically in three steps finally yielding seven and four categories. Based upon their relationship with soil variables vegetation categories were predicted and classified using discriminant analysis. The classification matrix of the discriminate analysis showed the precision with which the vegetation categories can be reproduced. It was done by comparing the actual cases observed in the field with classification provided by the discriminant scores. The classification matrix showed both the properly classified and misclassified cases for all vegetation categories.

Out of 22 *Suaeda fruticosa* cases observed during sampling, the discriminant function classified eleven (50%) into this category and three into *Aeluropus lagopoides*, two into *Sporobolus marginatus*, two into *Salvadora persica*, two into *Trianthema triquetra*, one into *Cressa cretica*, one into *Prosopis juliflora* (Table 3). Correctly classified cases are placed on the diagonal. Dividing the exact matches of the vegetative categories (located on the left to the right diagonal) by the number of the cases of the original categories (column one), the precision

of classification was found to be (11+10+5+5+4+3+6) out of (22+16+9+9+8+7+7) cases, that is out of cases, i.e. 56%.

Table 2. Mean values of the soil properties of seven categories of vegetation.

Vegetation Category	Cases	pHs	Ece dSm ⁻¹	Na	Ca+Mg	CO ₃ ⁻ + HCO ₃ ⁻	CaCO ₃	OC
						meL ⁻¹	%	gkg ⁻¹
0-10 cm samples								
<i>Suaeda fruticosa</i>	22	8.3	51.0	408	84.7	8.0	29.0	0.4
<i>Aeluropus lagopoide</i>	16	8.5	55.0	445	87.2	3.5	25.0	0.4
<i>Sporobolus marginatus</i>	9	8.0	39.7	332	44.9	2.0	17.0	0.2
<i>Salvadora percsica</i>	9	8.4	48.9	403	67.4	2.0	16.0	0.6
<i>Trianthema triquetra</i>	8	8.4	40.6	305	81.0	6.0	15.0	0.1
<i>Cressa cretica</i>	7	8.6	38.7	295	86.1	5.7	48.0	0.6
<i>Prosopis juliflora</i>	7	8.1	43.0	352	60.4	5.0	16.0	0.8
CD (0.05)		0.19	5.9	52.6	14.9	2.1	0.12	
10-20 cm sample								
<i>Suaeda fruticosa</i>	22	8.50	58.0	491	87.2	2.1	23.5	0.3
<i>Aeluropus lagopoides</i>	16	8.70	69.0	560	88.0	2.7	20.4	0.5
<i>Sporobolus marginatus</i>	9	8.40	49.3	425	48.2	1.3	14.0	0.4
<i>Salvadora persica</i>	9	8.70	55.2	450	73.4	6.4	13.2	0.4
<i>Trianthema triquetra</i>	8	8.90	50.2	385	82.0	5.0	12.4	Tr
<i>Cressa cretica</i>	7	8.80	45.5	365	87.2	5.0	12.4	0.8
<i>Prosopis juliflora</i>	7	8.40	48.0	390	71.9	4.0	14.1	1.0
CD (0.05)		0.18	7.4	64	13.2	1.7	2.8	2.0
20-30 cm samples								
<i>Suaeda fruticosa</i>	22	8.7	62.4	525	88.0	1.2	18.4	0.3
<i>Aeluropus fruticosa</i>	16	8.9	72.3	601	87.4	1.8	15.4	0.4
<i>Sporobolus marginatus</i>	9	8.8	54.9	475	50.6	0.9	12.6	0.3
<i>Salvadora persica</i>	9	9.2	58.7	502	72.5	4.2	10.8	0.4
<i>Thianthema triquetra</i>	8	9.1	55.2	440	81.4	3.9	8.3	Tr
<i>Cressa cretica</i>	7	9.0	48.9	394	87.0	3.0	25.6	0.7
<i>Prosopis juliflora</i>	7	8.8	53.7	435	72.0	2.8	12.3	1.0
CD (0.05)		0.16	6.9	63.4	12.5	1.2	5.3	0.29

Table 3. The classification matrix of the seven categories received with discriminant analysis

Category	Actual cases	Predicted category membership						
		Suae.	Aelu.	Spor.	Salv.	Tria.	Cres.	Pros.
<i>Suaeda fruticosa</i>	22	11	3	2	2	2	1	1
		50%	14%	9%	9%	9%	4%	4%
<i>Aeluropus lagopoides</i>	16	3	10	2	0	1	0	0
		19%	62%	12%	0%	6%	0%	0%
<i>Sporobolus marginatus</i>	9	2	1	5	0	0	1	0
		22%	11%	56%	0%	0%	11%	0%
<i>Trianthema triquetra</i>	8	2	1	0	0	4	1	0
		25%	12%	0%	0%	50%	12%	0%
<i>Cressa cretica</i>	7	1	0	1	1	1	3	0
		14%	0%	14%	14%	14%	42%	0%
<i>Prosopis juliflora</i>	7	1	0	0	1	0	0	6
		14%	0%	0%	14%	0%	0%	86%

Note: Per cent of "grouped" cases correctly classified is 56%.

Suae. = *Suaeda fruticosa*,

Aelu. = *Aeluropus lagopoides*,

Spor. = *Sporobolus marginatus*,

Salv. = *Salvadora persica*,

Tria. = *Trianthema triquetra*,

Cres. = *Salvadora persica*,

Pros. = *Prosopis juliflora*.

The discriminant analysis showed that in the case of seven category system, the match of the observed vegetation and those predicted on the basis of the soil properties was 56% (Table 3). When the number of categories were reduced from 7 to 4 by combining *Suaeda fruticosa* with *Salvadora persica*, *Sporobolus marginatus* with *Prosopis juliflora* and *Creassa cretica* with *Trianthema triquetra*, the prediction level increased from 56 to 70% (Table 4).

From the classification matrix, it is possible to infer the homogeneity of the vegetation categories in terms of the predictability by the soil data. In the cases of *Suaeda fruticosa*, *Aeluropus lagopoides*, *Trianthema triquetra* vegetative categories, most of the

misclassifications fall into other category, which indicates that most of the soil properties of these vegetations do not differ much. The chemical properties of the salt affected soil studied can substantially help in classification of vegetation categories.

Table 4. Classification matrix of the four categories received with discriminant analysis

Category	Actual cases	Predicted category membership			
		Suae.	Aclu.	Spor.	Cres.
<i>Suaeda fruticosa</i>	31	25 81%	3 9%	2 13%	13%
<i>Aeluropus lagopoides</i>	16	4 25%	10 62%	1 6%	1 6%
<i>Sporobolus marginatus</i>	16	2 12%	3 19%	10 62%	1 6%
<i>Cressa cretica</i>	15	2 13%	2 13%	1 7%	10 66%

Note: Per cent of "grouped" cases classified is 70%.

Suae. = *Suaeda fruticosa*

Aclu. = *Aeluropus lagopoides*

Spor. = *Sporobolus marginatus*

Cres. = *Cressa cretica*

The relationship between soil variables

Factor analysis was used to find the interrelationship between different soil variables. The status of correlation matrix showed that there existed a strong correlation between pH and Ca+Ma concentration which was slightly reduced in 20-30 cm soil depth. A positive correlation was also recorded between Ec and Na content. To determine the contribution of different factors towards total variability, principal component analysis has been carried out which indicate that first three components (pHs, ECe and OC%) contributed 85.8% of the total variance in 0-10 cm layer. Out of these pHs constitutes the maximum variance (40.0%) which went upto 48% in 10-20 cm layer (Table 5).

Table 5. Eigen values of the correlation matrix

Chemical constituent	Eigen value	Per cent of individual element	Per cent cumulative
0-10 cm sample			
pHs	3.20	40.0	40.0
ECe2.38	2.38	29.8	69.8
OC	1.28	16.0	85.8
$\text{HCO}_3^- + \text{CO}_3^{-2}$	0.78	9.8	95.6
CaCO_3	0.26	3.3	98.9
Ca+Mg	0.01	0.1	99.0
Na	0.00	0.0	99.0
10-20 cm sample			
pHs	3.84	48.0	48.0
ECe	2.22	27.8	75.8
OC	1.12	14.0	89.8
$\text{HCO}_3^- + \text{CO}_3^-$	0.77	9.6	99.4
CaCO_3	0.29	0.2	99.6
Ca+Mg	0.01	0.1	99.7
Na	0.01	0.1	99.8
20-30 cm sample			
pHs	3.22	40.2	40.2
ECe	2.38	29.8	70.0
OC	1.26	15.7	85.7
$\text{HCO}_3^- + \text{CO}_3^{-2}$	0.79	9.9	95.6
CaCO_3	0.27	3.4	99.0
Ca+ Mg	0.08	1.0	100.0
Na	0.00	0.0	100.0

CONCLUSION

Salt affected soils of western Rajasthan were dominated by vegetation categories of *Suaeda fruticosa*, *Aeluropus lagpoides* and *Prosopis juliflora*. Soils were calcareous, low in organic matter and had a high concentration of electrolytes dominated by Na and Ca+Mg. The linear combination of the soil variables calculated by discriminant analysis correctly classified the vegetation for half of the points. Soil properties such as pHs, ECe, Na, Ca+Mg which can be measured relatively inexpensively can be used to predict vegetation of a given area successfully.

REFERENCES

- Jackson, M.L. (1973). *Soil Chemical analysis*. New Delhi : Hall of India Private Limited.
- Marshall, D. (1987). *Statistics for Geoscientists*. Oxford, United Kingdom : Pergamon Press.
- Toth, T., & Kertesz, M. (1995). *Arid Soil Research and Rehabilitation*., 10,1.
- Toth, T.S., Matsumoto, R.M., & Yin, N. (1995). *Soil Science*. 160,219
- Toth, T., & Rajkai, K. (1994). *Soil Science*. 157,253.
- Waisel, Y. (1972). *Biology of Halophytes*. New York : Academic Press.

HYBRID VIGOR IN CROSSES OF IR58025A WITH NEPALESE RICE CULTIVARS

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ABSTRACT

The magnitude and direction of hybrid vigor is essential for its commercial application. Heterobeltiosis and standard heterosis were studied in crosses of each of three rice (Oryza sativa L.) cultivars ('Kanchan', 'Sabitri', and 'Chaite-6') with 'IR58025A', a wild aborted male sterile line. These crosses showed marked variations in the expression of heterobeltiosis and standard heterosis for straw yield, plant height, Harvest Index (HI), grain number, and panicle number. Grain yield, HI, 1000-grain wt, and days to flowering manifested highly significant heterobeltiosis and/or standard heterosis in all the three crosses. With appropriate choice of parental lines, it is possible to develop F₁ rice hybrid possessing distinct yield superiority over the best-inbred lines.

Key words: CMS line, Heterobeltiosis, Rice, Standard heterosis.

INTRODUCTION

Researchers are doing extensive study for exploitation of hybrid vigor following the release of hybrid rice for commercial cultivation in China. Many hybrids demonstrate a phenomenon called heterosis, which can be described as the tendency of offspring of genetically diverse parents to perform better than their parents in one or more agronomic traits. Davis and Rutger, 1976 and Virmani et al., 1981 reviewed heterosis on various agronomic traits of rice. Virmani et al., 1981 reported a significant positive mid and high parent heterosis for yield ranging from 1.9 to 369% in rice. Standard heterosis ranging from 16 to 63% was reported by Rutger and Shinjyo, 1980 and from 29 to 45% by Yuan et al., 1994. Virmani et al., 1982 observed 54 and 34% heterosis for better parent and standard heterosis, respectively. Significant positive mid parent, high parent and standard heterosis have been observed for one or more of yield components in a number of crosses (Carnahan et al., 1972; Mohanty & Mohapatra, 1973; Mallick et al., 1978; Virmani et al., 1982; Nijaguna & Mahadevappa, 1983;

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Luat et al., 1985). Most crosses showing significant standard heterosis for yield were found to be possessing heterosis for more than one component (Maurya & Sing, 1978; Virmani et al., 1982). Results obtained in China and at IRRI indicated that heterotic F_1 combinations usually show an increased sink size through an increase in spikelet panicle⁻¹, spikelet fertility percentage, and 1000-grain weight (Virmani & Edwards, 1983).

Emasculation is a major constraint in rice heterosis breeding but the use of male sterile line increases the chance of identifying more heterotic hybrids. In addition, parents should be locally adopted and should perform well in hybrid combination. Hence, a male sterile line was used for the estimates of heterobeltiosis and standard heterosis for several characters.

MATERIALS AND METHODS

This experiment was conducted in screen house and in experiment farm at the Institute of Agriculture and Animal Sciences (IAAS), Rampur, Nepal during the dry and wet seasons of 1998. IAAS is located at 84° 29' E and 27° 37' N, and 224 masl. Three improved cultivars: Kanchan, Sabitri and Chaite-6, and a wild aborted Cytoplasmic-genetic Male Sterile (CMS) line: IR58025A were used in this study. The improved cultivars were obtained from National Rice Research Program (NRRP), Hardinath and CMS line from International Rice Research Institute (IRRI), Los Banos, the Philippines. F_1 seeds were produced using approach method (Erickson, 1970) in the screen house.

Field layout and analytical procedures: Field experiment, consisting of three F_1 's, three pollen parents, a CMS line, and one local check, 'Masuli' was conducted to estimate the heterobeltiosis and standard heterosis. Seedlings were raised in trays of 30 × 20cm size filled with soil and farmyard manure in the ratio of 2:1. Pre-germinated seeds were seeded in 10 cm apart from solid seeded rows of 30 cm long in each tray. Irrigation and weeding in nursery were done as necessary.

The field was laid out in a Randomized Complete Block Design (RCBD) with three replications. The pollen parent was planted beside their F_1 and CMS line planted after the pollen parent. The check variety, Masuli was planted in six replications for getting more accurate data. Field was fertilized at the rate of 120N: 60P: 60K kg ha⁻¹. Half of the nitrogenous fertilizer was applied as a basal dose and half was top-dressed after one month of transplanting. Twenty-one days old seedlings were transplanted in the field in four rows in each plot with 10 hills per row at spacing of 20 cm × 20 cm. Single seedling was planted per hill. Field was weeded twice at one-month interval after transplanting. Roguing was carried out at both vegetative and flowering stage.

All other standard agronomical practices were followed.

Following characters from the middle two rows of each plot were recorded according to Anonymous, 1980.

- Days to heading: number of days from seeding to the day 5% plants showed panicle exertion.
- Days to flowering: number of days from seeding to the day 50% plants showed panicle exertion.
- Plant height: from the ground to the tip of the main panicle at maturity.
- Panicle number plant⁻¹: average from 20 hills plot⁻¹ at maturity.
- Number of filled grains panicle⁻¹: average number from five panicles plot⁻¹.
- 1000-grain weight: recorded from randomly collected seeds from seed lot of each plot.
- Grain yield: weight of clean and dry grains (g m⁻²).
- Biological yield: weight of total biomass including grains after harvesting and drying (g m⁻²).
- Harvest index: ratio of grain yield to biological yield.
- Panicle length: average from five panicles plot⁻¹, measured from panicle base to tip.
- Straw yield: biological yield minus grain yield (g m⁻²).
- Spikelet fertility: number of seed set divided by total spikelet.

Grain and straw yield, and 1000-grain weight were adjusted at 14% moisture as suggested by Gomez, 1972. F₁ hybrid performance was evaluated on the basis of the estimates of heterobeltiosis (Fonseca & Patterson, 1968) and standard heterosis (Virmani et al., 1982). Heterosis is expressed as percent increase of the F₁ hybrids above the better parent and check cultivar.

The analysis of the variance was performed following Gomez and Gomez, 1984. The interaction of blocks by entries was used to test the significance of the mean square for entries. The F test was used to test the significance of mean squares. Means values of the characters of test entries were compared using the Least Significant Difference (LSD) test. Anon, 1986 software was used to analyze the data.

RESULTS AND DISCUSSION

Highly significant positive heterobeltiosis and standard heterosis for yield were noticed in IR58025A/ Kanchan and IR58025A/ Sabitri (Table 1). Only one hybrid showed negative standard heterosis of 3.15% but, the value was statistically non significant. Hybrids showed superiority over inbred line in most of the traits.

There were no significant heterobeltiosis and standard heterosis for tiller number, but hybrids showed higher tillering capacity than check cultivar. Increase in tiller number has earlier been observed by Singh et al., 1980 and Anandhakumar and Sree Rangasamy, 1986. Virmani et al., 1981, 1982 and Jennings, 1967 reported the negative heterosis for tiller number in the hybrids. Maximum positive heterobeltiosis for plant height was expressed by the hybrid, IR58025A/Kanchan and the lowest standard heterosis by the IR58025A/Chaite-6. The results are similar to those obtained by Singh et al. (1980) and Anandakumar and Sree Rangasamy, 1986. Heterobeltiosis of straw yield was maximum in IR58025A/Chaite-6 followed by IR58025A/Sabitri. Mallick et al., 1978 reported a negative heterosis for plant height, a component of straw yield.

One hybrid had significantly higher HI than better parent and the check. Two other hybrids showed significantly negative heterobeltiosis and standard heterosis. HI is a measure of the partitioning of the dry matter production in terms of panicle weight and total plant weight. Improvement of varieties for high yield resulted mainly in the improvement of HI. Yoshida, 1972 observed the close association of HI and yielding potential of rice varieties. Spikelets increased significantly in those hybrids having higher HI. Grain weight also showed the factors of increasing the HI in hybrids. This may be due to increase in sink capacity. It was indicated that, plant shortness is associated with higher HI. The results thus, suggest that one can expect to develop heterotic hybrids from the parents (CMS and restorers) possessing semi-dwarf plant height, medium maturity, high HI. There were no positive significant heterobeltiosis and standard heterosis for spikelet fertility percentage. Insignificant positive or negative heterosis for this trait was reported by Virmani et al. (1981).

Table 1. Heterosis for different characters in three crosses of rice

Character	IR58025A/Kanchan		IR58025A/Sabitri		IR58025A/Chaite-6	
	Heterosis % over		Heterosis % over		Heterosis % over	
	Check cultivar	Better parent	Check cultivar	Better parent	Check cultivar	Better parent
Grain yield (g m^{-2})	67.92**	55.64*	144.62**	37.29**	-3.15	-42.5**
1000-grain wt (g)	25.70*	3.41	34.57**	0.35	23.81**	-3.24
Panicle no. plant ⁻¹	7.32	0.00	4.83	-6.52	12.14	-9.82
Spikelet no. panicle ⁻¹	16.66	14.06	17.16	36.17*	13.14	38.71*
Grain no. panicle ⁻¹	-6.29	5.53	17.44	33.15**	-22.69*	-7.21
Panicle length (cm)	12.03	9.88	19.17**	9.47	18.61**	15.34*
Spikelet fertility (%)	-19.67**	-7.48	0.23	-2.22	-31.70**	-33.41**
Harvest index (%)	59.36**	19.22	63.46**	25.26**	0.37	-43.35**
Plant height (cm)	19.37	39.53**	-7.80	-0.32	-8.38	10.45

(Table 1 continued)

Character	IR58025A/Kanchan		IR58025A/Sabitri		IR58025A/Chaite-6	
	Heterosis % over		Heterosis % over		Heterosis % over	
	Check cultivar	Better parent	Check cultivar	Better parent	Check cultivar	Better parent
Straw yield (g m^{-2})	-22.93	20.43	8.18	-10.21	-6.24	43.2*
Biological yield (g m^{-2})	-15.71	30.55*	19.71**	9.28*	-22.81	1.50
Days to flowering	-13.78**	2.28	-7.38**	-6.48**	-17.63**	3.63*
Days to maturity	-12.08*	0.00	-0.96	0.00	-17.39**	0.29

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

For days to flowering, negative heterosis is usually desirable, because this will cause to increase the productivity per day per unit area. All hybrids had negative standard heterosis for days to flowering. The early flowering tendency of the hybrids has also been reported by (Khaleque et al., 1977, Mallick et al., 1978; Virmani et al., 1981, 1982).

It appeared that heterosis in yield may be either due to significantly high HI or significantly high other yield components e.g., tiller number, spikelet fertility, 1000-grain weight. Grafius, 1959 suggested that there would be no separate gene system for yield per se and that the yield is an end product of the multiplication interaction between the yield components. This was supported by the present investigation where none showed heterosis for yield alone. In two crosses, the heterotic effect in yield was along with heterosis for panicles number, 1000-grain weight, spikelet number panicle⁻¹ and panicle length thus.

CONCLUSION

It is obvious that heterosis for yield is the result of interaction of simultaneous increase in the expression of yield components. Among the yield component highest heterosis effect was for grain weight followed by grain panicle⁻¹ and panicle length. Swaminathan et al. (1972) suggested that, heterobeltiosis of 20 to 50% over better parent could offset the cost of hybrid seed. Thus, the crosses showing more than 20% of heterobeltiosis viz., IR58025A/Kanchan, IR58025A/Sabitri may be useful for hybrid rice production. F₁ rice hybrids are useful not only for their high grain yield per cropping season but also for their higher productivity brought about by their earlier maturity. With appropriate choice of parental lines it appears possible to develop F₁ rice hybrid possessing distinct yield advantage over the best-inbred lines.

REFERENCES

- Anonymous. (1980). *Standard evaluation system for rice: International rice testing program*. The Philippines : IRRI.
- Anonymous. (1986). *MATAT: A microcomputers program for the design, management and analysis of agronomic research experiments*. East Lansing : Michigan State Univ.
- Carnahan, H.L., Erickson, J.R., Tseng, S.T., & Rutger, J.N. (1972). Outlook for hybrid rice in USA. In *Rice breeding* (pp.603-607). Los Banos : IRRI.
- Davis, M.D., & Rutger, J.N. (1976). Yield of F_1 , F_2 and F_3 hybrids of rice (*Oryza sativa* L.). *Euphytica*, 25, 587-595.
- Erickson, J.R. (1970). Approach crossing of rice. *Crop Sci.*, 10, 610-611.
- Fonseca, S., & F.L. Patterson. (1968). Hybrid Vigor in a seven-parent diallel cross in common winter wheat. *Crop Sci.*, 8, 85-88.
- Gomez, K.A. (1972). *Techniques for field experiments with rice*. Los Banos, the Philippines : IRRI.
- Gomez, K.A., & Gomez, A.A. (1984). *Statistical procedures for agricultural research* (2nd Ed.). New York : John Wiley and Sons.
- Grafius, J. (1959). Heterosis in barley. *Agronomy Journal*, 51, 551-554.
- Jennings, P.R. (1967). Rice heterosis at different growth stages in a tropical environment. *International Rice Commission Newsletter*, 16 (2), 24-26.
- Khaleque, M.A., Jorder, O.I., & Eunus, A.M. (1977). Heterosis and combining ability in a diallel cross of rice (*Oryza sativa* L.). *Bangladesh Journal of Agriculture Science*, 4 (2), 137-145.
- Luat, N.V., Bong, B.B., & Chandra Moahan, J. (1985). Evaluation of F_1 hybrids in the cuu Long Delta, Vietnam. *International Rice Research Newsletter*, 10 (3), 19.
- Mallick, E.H., Ghosh, H.N., & Bairage, P. (1978). Heterosis in indica rice. *Indian Journal of Agriculture Science*, 48, 384-386.
- Maurya, D.M., & Singh, D.P. (1978). Heterosis in rice. *Indian Journal of Genetics and Plant Breeding*, 38, 71-76.
- Mohanty, H.K., & Mohapatra, K.C. (1973). Diallel analysis of yield and its components in rice. *Indian Journal of Genetics and Plant Breeding*, 33, 264-270.
- Nijaguna, G., & Mahadevappa, M. (1983). Heterosis in intervarietal hybrids of rice. *Oryza*, 20, 159-161.
- Rutger, J.N., & Shinjyo, C. (1980). Male sterility in rice and its potential use in breeding. In *innovative approaches to rice breeding* (pp.53-66). Manila : IRRI.
- Singh, S.P., Singh, R.R., Singh, R.P., & Singh, R.V. (1980). Heterosis in rice. *Oryza*, 17, 109-113.
- Swaminathan, M.S., Siddiq, E. A., & Sharma, S.D. (1972). Outlook for hybrid rice in India. In *Rice Breeding* (pp.609-613). Los Banos, the Philippines : IRRI.
- Virmani, S.S., & Edwards, I.B. (1983). Current status and future prospects for breeding hybrid rice and wheat. *Advances in Agronomy*, 36, 145-214.
- Virmani, S.S. Aquino, R.C., & Khush, G.S. (1982). Heterosis breeding in rice (*Oryza sativa* L). *Theoretical and Applied Genetics*. 63, 373-380.
- Virmani, S.S., Chaudhary, R.C., & Khush, G.S. (1981). Current outlook on hybrid rice. *Oryza*, 18, 67-84.
- Yoshida, S., Cock, J.H., & Parao, F.T. (1972). Physiological aspects of high yields. In *Rice Breeding* (pp.455-469). Los Banos : IRRI.
- Yuan, L.P., Yang, Z.Y., & Yang, J.B. (1994). Hybrid rice in China. In Virmani, S.S. (Ed.) *Hybrid rice technology: New development and future prospects* (pp.143-147). The Philippines : IRRI.

DEVELOPMENT OF A NEW HIGH YIELDING MUNGBEAN VARIETY "AEM 96" THROUGH INDUCED MUTATIONS

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ABSTRACT

Dry dormant seed of an indigenous mungbean variety, 6601 was irradiated with gamma rays with the dose range of 100-400 Gy from CO 60 source at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan for raising M₁ generation. In M₂ generation vigorous selection practised for high seed yield, earliness and synchronous in maturity, determinate plant growth habit and resistant to insect pests and diseases. Two hundred mutants bearing these desired attributes were selected. Among them 23% confirmed for their traits in later generations. Eight of them were promoted to the zonal trials after testing in the station yield trials. The mutant line AEM 32-20 was selected from the material treated with 200 Gy gamma rays. In eight years station yield trials (1987-1994), mutant line AEM 32-20 produced significantly higher seed yield of 27 and 38% during spring and kharif seasons respectively as compared to check variety NM 20-21. The consolidated results of zonal trials, conducted at 13 locations during two consecutive spring and two consecutive kharif seasons (1987-1989), indicated the superiority of AEM 32-20 by producing 37% higher seed yield as compared to check variety NM 20-21. In national trials (1991-1992) the mutant line AEM 32-20 produced 29 and 11% more yield as compared to standard checks in spring and kharif seasons respectively. The increase over control (zero nitrogen) was maximum in case of mungbean (25.83%) followed by combined system (12.78%) and cotton alone (8.56%) under mungbean+cotton cropping system.

Key words : Induced mutations, Mungbean, Mutant line.

INTRODUCTION

Mungbean (*Vigna radiata* L. wilczek) can play an important role as a source of good quality protein(24%) in our cereal based diet (Rachie and Robert, 1974). As a short duration

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and widely adaptable kharif pulse crop, it can fit in different crop rotations. Mungbean occupies an important place in our intensive cropping system (Malik et. al., 1986, Sarwar & Rajput, 1999). The crop is particularly important in rainfed areas owing to its low water requirements, negligible inputs and ability to restore soil fertility through symbiotic nitrogen fixation.

In Pakistan, mungbean is grown in an area of 2,02,700 ha with an annual production of 94800 tons having an average seed yield of 468-Kg ha⁻¹ (MOFA, 2000). Pakistan ranks seventh in average seed yield which is very low. The low seed yield may be due to non-availability of pure seed of improved varieties along with low inputs and poor management practices (Sarwar et al., 1993). The yield per unit area may be increased substantially through the evolution of high yielding genotypes, bearing a good combination of all yield components. Keeping this in view mungbean improvement programme was initiated at Nuclear Institute of Agriculture (NIA), Tandojam to evolve genotypes with altered plant type having high pod bearing, early and uniform maturity, determinate plant growth habit and resistance to different diseases. The methodology and performance of AEM96 in different yield trials is discussed in this paper.

MATERIALS AND METHODS

Dry dormant seeds (12% moisture content) of an indigenous mungbean variety 6601 were irradiated with gamma rays doses ranging from 100-400Gy from CO 60 at NIAB, Faisalabad for raising M₁ generation. In M₂ generation, vigorous selection was practiced for high seed yield, earliness and synchrony in maturity, determinate plant growth habit and resistance to insect pest and diseases. Two hundred mutants bearing these desired attributes were selected. Among them 23% confirmed for their traits in later generations. The mutant line AEM32-20 was selected from 200Gy treatment and was further studied in station yield trials (1987-1994) at NIA farm, Tandojam during the spring as well as summer seasons along with the check variety, NM20-21 which showed better and stable yield performance in the province of Sindh (Rajput et al., 1986). Zonal trials of AEM32-20 along with NM 20-21 were conducted during the next two years in both the seasons (1987-1989) in different mungbean growing areas of Sindh at 11 locations including Hyderabad, Sanghar, Umerkot, Mirpurkhas, Nawabshah and Badin Districts. The mutant line AEM32-20 remained under evaluation in National Uniform Yield Trials during two consecutive years (1991-1992) in both spring and summer seasons.

The Station trials, Zonal trials and National trials were conducted in Randomized Complete Block Designs (RCBD) in four repeats in standard plot size (7.2 m²). AEM 32-20 was intercropped with cotton at different nitrogen (N) levels and effect of nitrogen levels in sole crop and combined was worked out. The seed yield data were collected in different trials and subjected to analysis of variance (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

The performance of AEM32-20 in different yield trials is discussed as under.

Station Yield Trials

Mutant AEM32-20 remained under evaluation at NIA experimental farm for eight years (1987-1994) in station yield trials, during Spring as well as Kharif seasons. The results of these trials (Table 1) indicated that the mutant line out yielded check variety significantly. The overall performance of AEM32-20 indicated that it produced 27.12% higher yield than the check variety during the eight consecutive spring seasons. The highest yield potential was noted during spring 1993 (1890 kg/ha). The fluctuation in yield was due to different environmental conditions during the growth and reproductive period of the crop. However, in all the eight years the check variety also showed comparable fluctuation and produced lowest seed yield in all the cases. Mutant AEM32-20 gave better yield performance during kharif season as compared to spring season (Table 2). During consecutive eight kharif seasons, AEM32-20 showed 38% higher yield by producing 1429 kg/ha as compared to 1035 kg/ha of check variety NM20-21. In this way the mutant line, on average produced 38% higher yield as compared to check variety NM20-21.

Table 1. Performance of the mutant AEM 32-20 in station yield trial during spring season from 1987-1994

Genotypes	Grain yield (kg/ha)								Mean	Percent increase over check
	1987	1988	1989	1990	1991	1992	1993	1994		
AEM32-20	1051	760	990	773	1208	1337	1890	890	1112	27.12
NM 20-21	1011	656	847	609	1041	1104	1038	694	875	-
LSD 5%	107	-	86	151	117	219	251	-	118	-
1%	-	-	117	-	-	402	247	-	-	-

Table 2. Performance of the mutant AEM 32-20 in station yield trial during kharif season from 1987-1994

Genotypes	Grain yield (kg/ha)								Mean	Percent increase over check
	1987	1988	1989	1990	1991	1992	1993	1994		
AEM32-20	1461	1300	1498	1198	2062	1522	2010	383	1429	38.05
NM 20-21	1247	744	922	652	1427	1414	1611	265	1035	-
LSD 5%	386	-	205	213	219	339	189	-	29	-
1%	390	-	-	288	401	-	262	-	39	-

Zonal Trials

Zonal trials of AEM32-20 along with the check variety NM20-21 were conducted in different growing areas of the Sindh province. The consolidated results (Table 3) of these trials conducted during two consecutive spring and two consecutive kharif seasons are presented in Table 4. In all the locations, the mutant line AEM32-20 produced significantly higher seed yield as compared to check variety NM20-21. The mutant line also maintained its improved attributes like early and uniform maturity and determinate plant growth habit in all the zones. Maximum seed yield potential was achieved during kharif 1988 (1300 kg/ha) followed by kharif 1987 (1269 kg/ha), spring 1988 (825 kg/ha) and spring 1989 (720 kg/ha). These results indicated that this mutant line can be successfully grown in both the seasons. On the other hand, the impure seed being grown by the growers of Sindh bear fruit only in spring season and acquire continuous vegetative growth pattern during kharif season and produce negligible grain yield.

Table 3. Performance of the mutant AEM32-20 in the zonal trial in Sindh Province

Genotypes	Grain yield kg/ha				Avg. of two years	Percent increase over check
	Kharif 1987 Avg. of 4 locations	Spring 1988 Avg. of 5 locations	Kharif 1988 one location	Spring 1989 Avg. of 3 locations		
AEM 32-20	1269 A	825 BC	1300 A	720 ABC	1029 B	37
NM 20-21	972 B	727 C	741 CD	562 CD	751 E	-

On overall basis of mean performance, the mutant line AEM32-20 produced 37% higher seed yield by producing significantly highest seed yield of 1029 kg/ha as compared to 751 kg/ha of check variety NM20-21.

National uniform yield trials

The mutant line AEM32-20 was evaluated under the National Uniform Yield Trial during four consecutive years in both the seasons. The results of each season is shown below:

Spring Season

In National Uniform Yield Trial, conducted in Sindh province during spring 1991 (Table 4), the mutant line AEM32-20 produced maximum seed yield (1280 kg/ha). As compared to this the check variety, NM121-25 produced 903 kg of seed/ha. During spring 1992 AEM32-20 produced significantly highest seed yield (929 kg/ha) as compared to check variety NM121-25 (813 kg/ha). On average, during the two consecutive spring seasons AEM32-20

produced 1104.5 kg/ha seed yield as compared to 858 kg/ha of check variety NM121-25. The mutant line produced 28.72% higher seed yield than check NM121-25.

Table 4. Performance of the mutant line AEM 32-20 in Sindh Province in Mungbean

Genotype	National Uniform Yield Trials (Seed yield Kg ha ⁻¹)					Mean	Yield (%) 121-25	Diversity NM 51
	Spring 1991	Spring 1992	Mean	Kharif 1991	Kharif 1992			
AEM 32/20	1280	929	1104.5	1492	1329	1258	25.29	12.92
NM51	-	729	-	1341	1272	1114	-	-
Check								
NM121-25	903	813	858	1296	-	1004	-	-
Check								

Kharif Season

During the kharif 1991, AEM32-20 produced the highest seed yield (1492 kg/ha) compared to the check variety producing 1296kg/ha. During the kharif 1992 AEM32-20 again ranked first by producing 1329 kg/ha seed yield as compared to 1272 kg/ha of check variety NM 51.

During the two seasons, on average, the mutant line AEM 32-20 produced the highest seed yield (1258 kg/ha). As compared to this, the check varieties NM 121-25 and NM 51 produced 1004 and 1114 kg/ha seed yield, respectively. The mutant line AEM 32-20 produced 25.29% and 12.92% higher seed yield than NM 121-25 and NM 51 respectively during four consecutive seasons.

Performance of AEM 32-20 in National Uniform Yield Trials during Kharif on Pakistan basis

During kharif 1991, National Uniform Yield Trials were conducted at 11 locations. On overall average basis (Table 5) the mutant line AEM 32-20 produced higher seed yield (889.5 kg/ha) compared to the check variety NM51 (857-kg/ha). During kharif 1992, AEM32-20 produced higher seed yield (797 kg/ha) than check variety NM51 (761 kg/ha). On overall average basis (Table 5) of two years at 19 locations, AEM32-20 produced 4.2% increase in seed yield (843 kg/ha) than NM51 (809 kg/ha).

Table 5. Consolidated results of mungbean national uniform yield trials kharif 1991 and kharif 1992

Genotype	Seed Yield(Kg/ha)		Overall average	% increase over check
	Kharif 1991 (mean of 11 locations)	Kharif 1992 (mean of 8 locations)		
AEM 32- 20	889	797	843	4.20
NM 51 (standard check)	857	761	809	-

Mung + Cotton inter cropping system

Mungbean mutant AEM32-20 was intercropped with cotton at different N levels. A progressive yield increase (Table 6) was observed with the increasing dose of nitrogen (N) fertilizer in all the cropping systems. At 180 kg/ha of N dose, there was progressive increase in mungbean while a minor decrease was observed in case of cotton alone and cotton + mungbean. The increase over control was maximum in case of mungbean (25.83%) followed by combined system (12.78%) and cotton alone (8.56%).

Table 6. Performance of AEM 32-20 in different intercropping systems and nitrogen (N) levels

	Grain yield (kg/ha)				Mean	LER
	Fertilizer levels (Kg / ha)					
Cropping system	0	60	120	180		
Cotton	3036	3308	3443	3396	3296	-
Mungbean	360	443	502	506	453	-
Cotton + Mungbean	3417	3796	4270	3932	3854	1.17
% increase over control (zero N)						
Cotton	8.9	13.40	11.85	8.56		
Mungbean	23.05	39.44	40.55	25.83		
Combined	11.09	24.96	15.07	12.78		

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Quality attributes

The Seed colour and seed size of mutant variety AEM32-20 is superior to check varieties. Its seed has shiny colour and larger seed size (3.99g/100 seed) as compared to local check C-23 (3.26g/100 seed). AEM32-20 has also high protein content (25%) as compared to check (24.78%) and parent (24.02%) varieties. It produced 4.08% higher protein as compared to parent variety 6601.

Reaction to diseases

In Sindh, where mungbean is grown during spring season, the crop normally escapes from Yellow Mosaic Virus and *Cercospora* leaf spot diseases. Thus very moderate reaction was noted on AEM32-20. The behaviour of AEM32-20 was more tolerant to diseases as compared to check varieties.

Salient features of AEM32-20

Plant type

Mutant AEM32-20 plant is short stature with erect, compact and determinate growth habit. This kind of plant type not only facilitates the light infiltration in a more uniform way throughout the plant canopy for better photosynthetic activity but also makes the agricultural operations such as interculture, pesticide spray, harvesting etc. easier (Malik *et al.*, 1988). The mutant bear higher number of pods, produce seed of uniform size, gives higher seed yield and the crop can be harvested in a single operation.

The mutant AEM32-20 does not lodge like the local variety C-23 due to its inherent short stature and determinate plant growth habit. The top fruit bearing habit of the mutant also makes it amenable to mechanized harvesting.

Early and uniform flowering and maturity

The flowering and pod maturity in local cultivars continue for long due to their indeterminate plant growth habit i.e. after anthesis the growth in the vegetative and reproductive organs continue simultaneously. The lack of synchrony in flowering and pod maturity necessitates 2-3 hand pickings to obtain maximum yield which is economically not feasible. The flowering and maturity in the mutant on the other hand is markedly uniform. The mutant AEM32-20 flowers early by a margin of 9 days and matures 12-15 days earlier than the local check C-23.

The crop duration of mutant AEM32-20 ranged from 60-66 days compared to 78 days taken by the local cultivar C-23 and 75 days taken by the parent variety 6601. The early and uniform maturity makes this mutant suitable for intercropping with cotton, sugarcane and

vegetables and also growing them in fruit gardens as a companion crop both in spring and summer crop seasons. (Sarwar & Rajput, 1999).

CONCLUSION

The mutant AEM 32-20 has been released as a commercial variety for the Sindh Province, Pakistan in view of its better performance in the Sindh area. Mungbean variety "AEM96" is the outcome of this breeding strategy, achieved by employing nuclear techniques.

REFERENCES

- Ministry of Food and Agriculture (MOFA), Govt. of Pakistan (2000). *Agricultural statistics of Pakistan*. Pakistan : Author
- Malik, I. A., Ali, Y., & Sarwar, G. (1988). Improvement of mungbean *Vigna radiata* (L.) (Wilezerk) and blackgram (*Vigna mungo* (L.) Hepper) in yield, plant type and resistance to diseases through induced mutations, Improvement of grain legumes production using induced mutations. *In Proceeding of a workshop* (pp. 293-317). Vienna : IAEA.
- Malik, I.A., Sarwar, G., & Ali, Y. (1986). Growing mungbean as a catch crop using early maturing and high yielding mutant varieties. *Mut. Breeding Newsletter*, 28, 14-16.
- Rachie, K.O., & Roberts, L.M. (1994). Grain legumes of low land tropic. *Adv. Agron.*, 26, 1-118.
- Rajput, M.A., Sarwar, G., & Tahir, K.H. (1986). Stability for grain yield in mungbean mutants. *Bangladesh J. Nuclear Agri.*, 2, 58-59.
- Sarwar G., & Rajput, M.A. (1999). Role of nuclear techniques in the development of new high yielding mungbean varieties. In the *International Symposium a New Genetical Approaches to Crop improvement* (pp. 37-46). Tandojam, Pakistan.
- Sarwar, G., Rajput, M.A., & Memon, K.S. (1993). Performance of mungbean mutant under Farming System Research (FSR) Programme in Pakistan. *Mutation Breeding Newsletter*, 40, 10-11.
- Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedure of statistics*. New York : Mc Graw Hill Book Company Inc.

INHERITANCE AND LINKAGE AMONG MORPHOLOGICAL MARKERS IN DIVERSE HYBRIDS OF *Vigna mungo* L.

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ABSTRACT

Eleven parents (BG 9010, BG 9024, BG 9025, BG 9102, BG 9104, BG 9105, BG 9106, MM 5-60, MM 33-40, Pk-45923 & Mash 1) from diverse origin were used to study inheritance of morphological qualitative traits like, pubescence, seed coat colour, presence of spot on the seed and pod colour in blackgram (Vigna mungo). All four qualitative traits revealed monogenic inheritance, (3:1) ratio. Hairiness was dominant over non-hairiness; brown seed coat colour dominant over green seed coat colour. Presence of spots on seed coat was dominant to absence of spots and black pods were dominant over brown pods. Seven hybrids revealed strong linkage between spots on seed coat and pod colour in the present research material and hence these were suggested to be used for preliminary gene mapping in blackgram. Green seed coat colour produced higher seed weight in the segregating populations. Transgressive was segregasson observed especially in hybrid, BG 9025/MM 33-40 in which extra bold seeded plants were selected from F₃ population. From this hybrid, early maturing single plants with high seed weight were expected. It is suggested to establish the constancy of detected QTLs, and to locate exact position in the genome.

Key words: Blackgram, Mash, Mono-genic, Qualitative inheritance, QTL.

INTRODUCTION

Polymorphic monogenic traits were some of the earliest genetic markers employed in scientific investigations and they may still be optimal for genetic, breeding and plant germplasm management. Although morphological markers are limited in nature but their assays neither require sophisticated equipments nor complicated procedures. Monogenic or oligogenic

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morphological markers are generally simple, rapid and inexpensive to score. Until recently, scientific plant classification was based exclusively on morphological traits (Stuessy, 1990), some of which may serve as genetic markers suitable for plant germplasm management (Gottlieb, 1984, Hilu, 1984, Stanton *et al.*, 1994). The association of QTL with easily identifiable markers could permit the rapid and precise identification and transfer of QTL into superior crop cultivars (Tanksley, 1983). The amount of information provided by marker based approach would depend on the type and number of markers, and their linkage relationship (Singh *et al.*, 1991; Singh, D.P. & Singh, B.B., 1992).

Limited genetic information is available on blackgram although, it is a desirable food legume for tropic and sub-tropics. The reason for little genetic work is mainly due to lack of diverse parents with conspicuous morphological markers and difficulties in crossing the parents form reports are available on inheritance of qualitative traits (Sen & Jana, 1963; Ramaiah & Samolo, 1992; Rao *et al.*, 1989). One of the uses of morphological markers is to detect QTLs for markers assisted breeding programme. The linkage studies for biochemical and morphological markers have been conducted by Kazan *et al.*, 1993 in chickpea; Zamir and Tadmor, 1984 and Muehlbauer *et al.*, 1989 in lentil; Weeden and Marx (1984, 1987) in pea and Koenig and Gepts (1989) in *Phaseolus*. They observed distorted ratios i.e., deviation from normal assortment (9:3:3:1) and considered it might be due to linkage for some alleles. The present studies were planned to investigate inheritance of qualitative markers, their validity in determining seed weight and linkage if any for utilization in breeding programme.

MATERIALS AND METHODS

From a broad based blackgram germplasm, 11 diverse parents were selected (Table 1) and crossed under green-house conditions during spring seasons of 1994, 1995 and 1996. Thirteen crosses involving 11 parents (BG 9010, BG 9024, BG 9025, BG 9102, BG 9104, BG 9105, BG 9106, MM 5-60, MM 33-40, Pk-45923 and Mash 1) were conducted for inheritance study of simply inherited traits. Out of these parents, MM 5-60, MM 33-40 and Pk-45923 were of exotic origin. Mash 1 was approved variety and others were advance breeding lines selected for high yield potential in the breeding programme at National Agricultural Research Centre, Islamabad, Pakistan.

Table 1. Morphological descriptors of parents used in hybridization of blackgram

Genotype	Source	Plant pubescence	Seed colour	Spots on seed testa	Pod colour
BG 9010	Pakistan	Pubescent	Brown	Present	Black
BG 9024	Pakistan	Pubescent	Brown	Present	Black
BG 9025	Pakistan	Pubescent	Brown	Present	Black
BG 9102	Pakistan	Pubescent	Brown	Present	Black
BG 9104	Pakistan	Glabrous	Brown	Present	Black
BG 9105	Pakistan	Pubescent	Brown	Present	Black
BG 9106	Pakistan	Pubescent	Brown	Present	Black
MM 5-60	AVRDC	Pubescent	Brown	Absent	Brown
MM 33-40	AVRDC	Pubescent	Green	Absent	Brown
Pk-45923	Korea	Glabrous	Brown	Present	Black
Mash 1	Pakistan	Glabrous	Brown	Present	Black

Half of the seeds obtained from F_1 crosses were planted in green-house to have maximum recombinants in F_2 population during 1997. Plants were allowed to grow in an insect free green-house at 30-35°C temperature. The F_1 , F_2 and parents of these crosses were grown during summer 1998. Three hybrids, viz., Mash 1/MM 33-40, BG 9025/MM 33-40 and BG 9010/MM 33-40 were advanced for F_3 generation during 1999 adopting Single Seed Descent (SSD) method of breeding and data for 100-seed weight was recorded in 40 plants sampled at random and relationship between two generations was investigated for seed weight. Data for plant pubescence were recorded at the flowering stage in five hybrids. Data on seed colour were recorded when the seeds were fully matured in eight crosses. The spots on seed coat were recorded after harvesting individual plants at maturity for all the thirteen crosses because one of the parents in all crosses used was either green seeded or brown seeded without spots on seed coat. Pod colour was recorded in seven hybrids after harvesting individual plants. Data thus recorded were analyzed with the help of chi-square (χ^2) to test hypothesis concerning the frequency distribution of one or more populations. In this study, we used χ^2 for a fixed ratio hypothesis using data from F_2 segregating population of each cross as described by Gomez & Gomez (1984).

Nine hybrids were investigated for the analysis of linkage among genetic markers in F_2 generation using the computer programme "LINKAGE 1" of Suiter et al., 1983. Three hybrids were used for association of morphological markers with seed weight from F_2 segregating generation using "t" statistics. Association of qualitative markers with genes affecting the variation of seed weight was determined by dividing seed weight into two groups on the basis of dominance or recessiveness of mono-genic locus. Group mean for quantitative characters were calculated, and *t-test* was applied to compute the probabilities that two group means were equal, using computer software "SPSS" and "Microsoft Excel.

RESULTS

The genotypes used in the present study were true breeding for traits mentioned in the Table 1, and these were self pollinated for 2 years prior to hybridization. The allelic notion for plant pubescence was assigned as *HH* (dominant Homozygous Hairy); *Hh* (Heterozygous Hairy) and *hh* (Homozygous recessive non-hairy). The F_1 plants were all having hairs for each hybrid either female parent was taken pubescent or glabrous, suggesting *hh* allele recessive to *HH*, *Hh* types. The F_2 segregation for all the crosses showed 3:1 ratio which fit for goodness by χ^2 method which indicated monogenic inheritance for this character (Table 2). The observation on seed coat colour was taken at maturity because recording it in immature seeds may be misleading. The allelic notion was given as *CC* (homozygous brown); *Cc* (heterozygous brown) and *cc* (recessive green). The F_1 plants were all having brown seed coat colour with slightly diffused black spots for each hybrid, either female parent was kept brown or green, suggesting the dominance of brown seed coat in nature, whereas green being recessive. The F_2 population segregated in a 3:1 ratio for all the crosses except BG 9025/MM 33-40, in which χ^2 did not fit well for 3:1 ratio.

Table 2. Segregation for 4 qualitative traits in the F₂ population in blackgram

<i>Plant pubescence</i>	Observed		Expected ratio	χ^2	P at 5%
	<i>HH, Hh</i>	<i>hh</i>			
MM33-40/BG 9104	62	20	3:1	0.016	0.90
Mash 1/MM 33-40	45	16	3:1	0.049	0.82
Pk-45923/MM 33-40	274	93	3:1	0.022	0.88
Mash 1/MM 5-60	169	57	3:1	0.006	0.94
BG 9104/MM 33-40	81	26	3:1	0.028	0.87
Seed coat colour	<i>CC, Cc</i>	<i>cc</i>			
MM33-40/BG 9104	60	22	3:1	0.146	0.70
Mash 1/MM 33-40	45	16	3:1	0.051	0.82
Pk-45923/MM 33-40	285	82	3:1	1.381	0.24
BG 9106/MM 33-40	105	32	3:1	0.197	0.66
BG 9104/MM 33-40	86	21	3:1	1.648	0.20
BG 9010/MM 33-40	107	34	3:1	0.060	0.81
BG 9025/MM 33-40	90	42	3:1	3.270	0.07
MM 33-40/BG 9105	200	67	3:1	0.005	0.91
Spots on seed coat	<i>SS, Ss</i>	<i>ss</i>			
Mash 1/MM 33-40	49	12	3:1	0.923	0.34
Pk-45923/MM 33-40	284	83	3:1	1.113	0.29
BG 9106/MM 33-40	99	38	3:1	0.547	0.46
BG 9104/MM 33-40	78	29	3:1	0.252	0.62
MM 33-40/BG 9104	62	20	3:1	0.016	0.90
BG 9010/MM 33-40	107	34	3:1	0.590	0.80
BG 9025/MM 33-40	101	31	3:1	0.161	0.69
MM 33-40/BG 9105	201	67	3:1	0.000	1.00
Mash 1/MM 5-60	175	51	3:1	0.714	0.40
BG 9105/MM 5-60	130	44	3:1	0.008	0.93
BG 9102/MM 5-60	106	41	3:1	0.655	0.42
BG 9025/MM 5-60	16	7	3:1	0.362	0.55
MM 33-40/9024	218	74	3:1	0.020	0.89
Pod colour	<i>BB, Bb</i>	<i>bb</i>			
Pk-45923/MM 33-40	280	87	3:1	0.508	0.49
BG 9106/MM 33-40	107	30	3:1	0.703	0.40
BG 9104/MM 33-40	85	22	3:1	1.125	0.29
MM 33-40/BG 9104	62	20	3:1	0.016	0.90
MM 33-40/BG 9105	205	63	3:1	0.318	0.57
Mash 1/MM 5-60	180	46	3:1	2.602	0.11
MM 33-40/9024	207	85	3:1	2.630	0.10

The spots on seed coat can be seen in fully matured seeds, whereas in immature seeds these spots are not developed and difficult to observe. Observations on spots were taken at maturity and allelic forms were assigned as *SS* (homozygous spots present); *Ss* (heterozygous spots present) and *ss* (recessive spots absent). Two exotic parents, MM 5-60 and MM 33-40 used in hybridization programme were without spots on seed coat, whereas all others were having spots. All the F_1 plants were observed with spots for each hybrid either female parent was kept spotted or un-spotted which indicated the dominant nature of this character, whereas the un-spotted nature was recessive. The F_2 population segregated in a ratio of 3:1 for all the crosses which fit for goodness by χ^2 method with slight variation in probability. This 3:1 ratio revealed the presence of monogenic gene action for phenotypic expression on seed coat of blackgram. Two types of pod colour were observed, i.e., black and brown, these were assigned allelic notion *BB*, (homozygous black); *Bb* (heterozygous black) and *bb* (recessive brown). All the F_1 plants were observed with black pod colour for each hybrid which revealed the presence of dominance for black pod colour, whereas brown colour being recessive in blackgram. The F_2 population segregated in a 3:1 ratio for all the crosses which fit for goodness by χ^2 method with slight variation in probability.

Linkage analysis: Inheritance of qualitative characters revealed single gene dominance involved for pubescence, seed colour, spots and pod colour. Further, analysis of linkage among these characters was carried out and the results regarding linked loci are presented in the Table 3. The joint segregation of independent assortment revealed that out of nine hybrids, 7 exhibited linkage for various character pairs. Hairiness was weakly linked with seed colour in one hybrid (Pk-45923/MM 33-40) whereas, in other hybrids, no linkage was observed for this character pair. In this hybrid, out of 367 observed plants, 119 were recombinants and 248 were parental types which slightly deviate from the normal 9:3:3:1 ratio of independent assortment.

Table 3. Joint segregation for 4 morphological marker loci in F_2 population of blackgram

Hybrid	Loci	Number of plants/observations				χ^2	P	<i>r</i>
		-/-	-/+	+/-	+/+			
MM 33-40/BG 9104	<i>HH:CC</i>	4	16	18	44	0.6284	0.43	0.43±0.09
	<i>HH:SS</i>	5	15	15	47	0.0053	0.94	0.49±0.08
	<i>HH:BB</i>	4	16	16	46	0.2765	0.60	0.45±0.09
	<i>CC:SS</i>	7	15	13	47	0.8996	0.34	0.43±0.09
	<i>CC:BB</i>	8	14	12	48	2.3374	0.13	0.39±0.09
	<i>SS:BB</i>	17	3	3	59	52.6918	0.00	0.08±0.11
BG 9104/MM 33-40	<i>HH:CC</i>	4	22	17	64	0.3917	0.53	0.45±0.08
	<i>HH:SS</i>	6	20	23	58	0.2817	0.60	0.46±0.08
	<i>HH:BB</i>	4	22	18	63	0.5634	0.45	0.44±0.08
	<i>CC:SS</i>	9	12	20	66	3.2823	0.07	0.38±0.08
	<i>CC:BB</i>	10	11	12	74	11.7120	0.00	0.27±0.09
	<i>SS:BB</i>	20	9	2	76	57.0676	0.00	0.11±0.09
BG 9106/MM 33-40	<i>HH:CC</i>	12	33	20	72	0.4099	0.52	0.46±0.66

Table 3 (Continued)

Hybrid	Loci	Number of plants/observations				χ^2	P	r
		-/-	-/+	+/-	+/+			
Pk-45923/MM 33-40	HH:SS	12	33	26	66	0.0383	0.84	0.50±0.06
	HH:BB	9	36	21	71	0.1411	0.71	0.47±0.06
	CC:SS	11	21	27	78	0.9178	0.34	0.44±0.07
	CC:BB	7	25	23	82	0.0000	0.99	0.50±0.06
	SS:BB	23	15	7	92	45.8797	0.00	0.18±0.08
	HH:CC	28	65	54	220	4.3277	0.04	0.42±0.04
	HH:SS	18	75	65	209	0.7569	0.38	0.46±0.04
	HH:BB	15	78	52	222	0.3777	0.53	0.47±0.04
	CC:SS	24	58	59	226	2.6701	0.10	0.43±0.04
	CC:BB	19	63	48	237	1.7090	0.19	0.44±0.04
Mash 1/MM 33-40	SS:BB	53	30	14	270	149.44	0.00	0.14±0.05
	HH:CC	3	12	13	33	0.3989	0.53	0.44±0.10
	HH:SS	4	11	11	35	0.0463	0.83	0.47±0.10
	HH:BB	3	12	12	34	0.2260	0.63	0.45±0.11
	CC:SS	5	11	10	35	0.5188	0.47	0.44±0.10
	CC:BB	6	10	9	36	1.9493	0.16	0.38±0.11
Mash 1/MM 5-60	SS:BB	13	2	2	44	41.3359	0.00	0.06±0.13
	HH:SS	10	47	41	128	1.1003	0.29	0.44±0.05
	HH:BB	6	51	40	129	4.5413	0.03	0.37±0.06
MM 33-40/BG 9105	SS:BB	30	21	16	159	60.1259	0.00	0.19±0.06
	CC:SS	10	38	57	163	0.5414	0.46	0.46±0.05
	CC:BB	12	36	51	169	0.0724	0.79	0.48±0.05
BG 9010/MM 33-40	SS:BB	52	15	11	190	145.4304	0.00	0.10±0.06
	CC:SS	12	22	21	86	3.5332	0.06	0.39±0.07
BG 9025/MM 33-40	CC:SS	11	31	20	70	0.2509	0.62	0.47±0.07

-/- and +/+ are homozygous recessive and homozygous dominant, whereas -/+ and +/- are heterozygous dominant. HH- denotes hairiness; CC- seed colour brown; SS- the spots present on seed coat and BB- black pod colour.

Weak linkage between hairiness and pod colour was observed in the hybrid Mash 1/MM 5-60. The deviation from 9:3:3:1 ratio in this hybrid was observed in low magnitude where 91 recombinants out of 226 plants were observed. The hybrid BG 9104/MM 33-40 exhibited medium linkage between seed colour and pod colour. In this hybrid, out of 107 plants observed in F₂, twenty three plants were recombinants and 84 were parental types. Seven hybrids, viz., MM 33-40/BG 9105, Mash 1/MM 5-60, BG 9106/MM 33-40, BG 9104/MM 33-40, MM 33-40/BG 9104, Pk-45923/MM 33-40 and Mash 1/MM 33-40 revealed strong linkage between spots on seed coat and pod colour in the present research material.

Morphological Markers for QTL detection: The association of qualitative markers with 100-seed weight was studied in 3 crosses and results are presented in the Table 4. All the three hybrids exhibited significant relationship between seed colour and seed weight, whereas other markers did not exhibit any significance in detecting seed weight in blackgram. It is evident from the data that green seed coat colour produced higher seed weight in the segregating populations and the difference was observed significant. In the hybrid, BG 9025/MM 33-40, green seeded ranged from 4.83 to 6.67 g per 100 seeds, whereas brown seeded were from 3.96 to 6.21 g. In general green seeded were higher in weight (Fig. 1). The hybrid BG 9010/MM 33-40 ranged from 4.18 to 6.81 g for green seeded and from 4.28 to 6.08 g for brown seeds. The hybrid, Mash 1/MM 33-40 ranged from 4.30 to 5.59 g per 100 seeds for green seeds and from 4.09 to 5.06 g for brown seeds. Similar trend was observed in F_3 generation (Fig. 2). On individual plant basis, transgressive segregants were observed in all the hybrids especially in BG 9025/MM 33-40 in which extra bold seeded plants were selected from F_3 population.

Table 4. Detection for seed weight using morphological markers in F_2 generation of blackgram

Plant Trait	Allele	Frequency	Mean $\pm$ SD	Difference $\pm$ SE
<i>Mash 1/MM-33-40</i>				
Hairiness	<i>H-</i>	45	4.42 $\pm$ 0.54	0.01 $\pm$ 0.17ns
	<i>Hh</i>	16	4.43 $\pm$ 0.59	
Seed colour	<i>C-</i>	45	4.29 $\pm$ 0.56	0.72 $\pm$ 0.12**
	<i>Cc</i>	16	5.01 $\pm$ 0.46	
Spots	<i>S-</i>	49	4.39 $\pm$ 0.54	0.18 $\pm$ 0.19ns
	<i>Ss</i>	12	4.57 $\pm$ 0.57	
<i>BG 9025/MM-33-40</i>				
Seed colour	<i>C-</i>	92	4.88 $\pm$ 0.66	0.86 $\pm$ 0.10**
	<i>Cc</i>	42	5.74 $\pm$ 0.61	
Spots	<i>S-</i>	101	5.40 $\pm$ 0.66	0.04 $\pm$ 0.11ns
	<i>Ss</i>	31	5.37 $\pm$ 0.64	
<i>BG 9010/MM-33-40</i>				
Seed colour	<i>C-</i>	107	4.97 $\pm$ 0.62	0.30 $\pm$ 0.11**
	<i>Cc</i>	34	5.27 $\pm$ 0.52	
Spots	<i>S-</i>	107	5.03 $\pm$ 0.57	0.00 $\pm$ 0.13ns
	<i>Ss</i>	34	5.03 $\pm$ 0.67	

** - significant at 1% level.

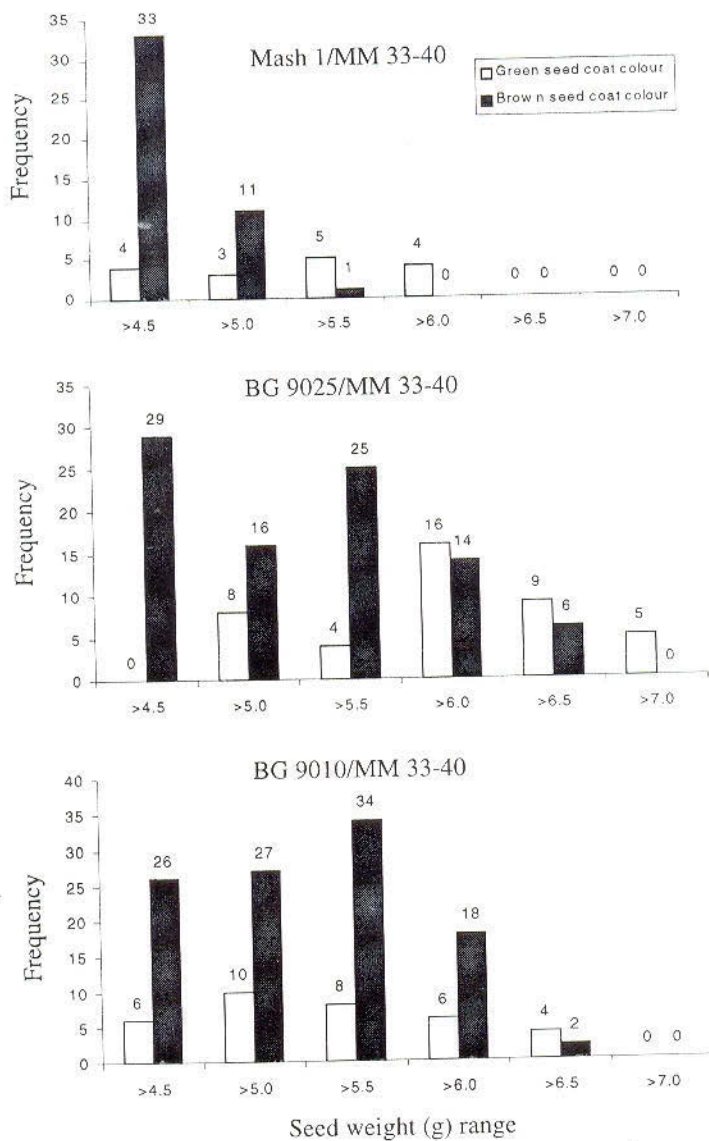


Fig. 1:- Frequency distribution for 100-seed weight in F^2 populations of 3 hybrids of blackgram

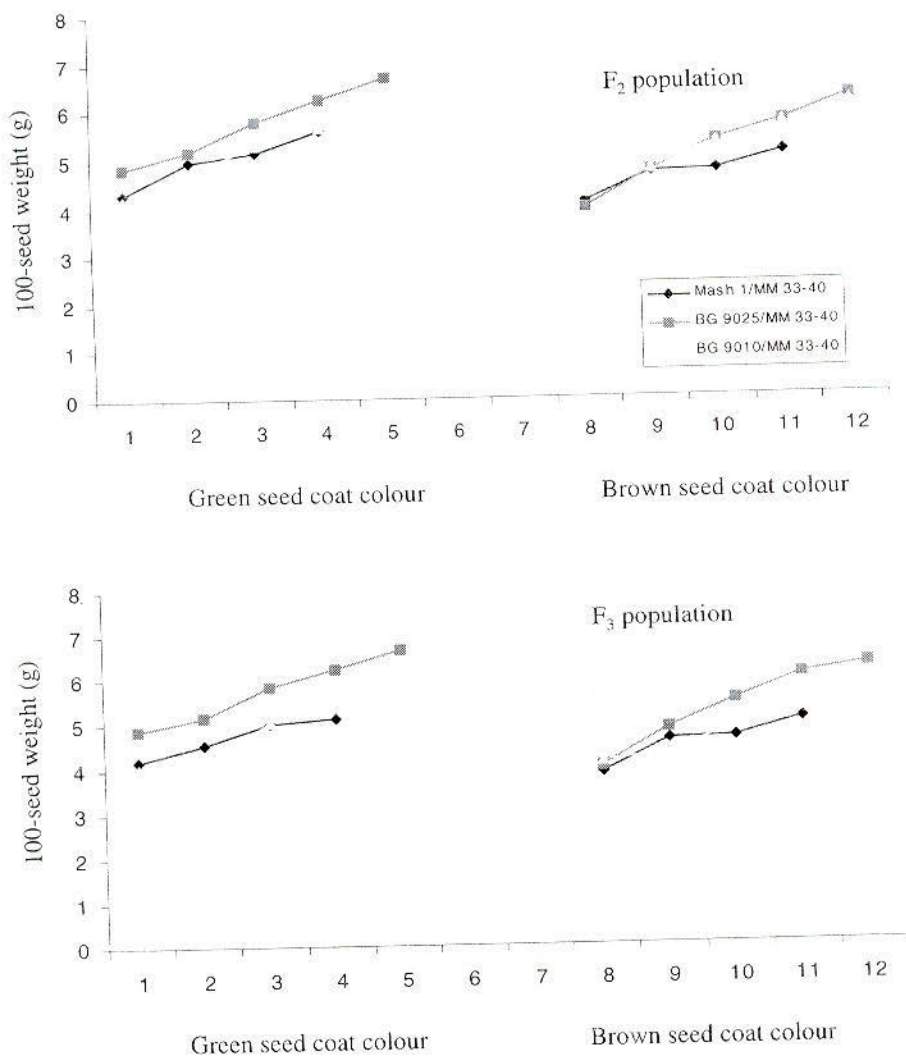


Fig. 2:- Classification of 100-seed weight (g) based on seed coat colour in 3 crosses of blackgram

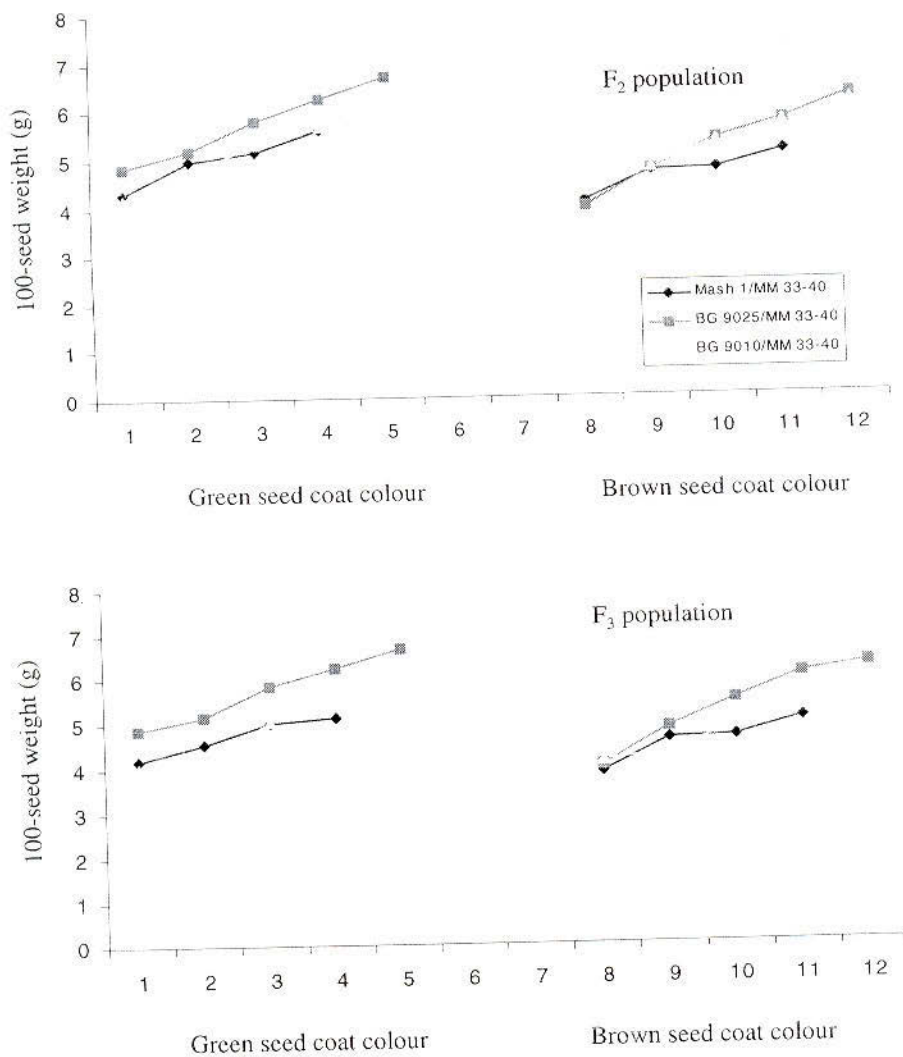


Fig. 2:- Classification of 100-seed weight (g) based on seed coat colour in 3 crosses of blackgram

DISCUSSION

In the present study, all the qualitative characters revealed monogenic segregation in 3:1 ratio for most of the hybrids. Hairiness was dominant over non-hairiness or glabrous; brown seed coat colour was dominant to green; presence of spots on seed was observed dominant over absences of spots and black pod colour dominant to brown pod colour. Monogenic inheritance for testa colour in groundnut has been reported by Senapati and Roy (1990). Monogenic markers are useful in estimating the rate of out crossing in predominantly self pollinated crops. They also help in identification of F_1 hybrids in the breeding programme. Heterozygous are not possible to detect in case of complete dominance gene factors for morphological markers, therefore, the segregating ratios fit well in 3:1 chi-square fitness. Sen and Jana (1963) studied inheritance of pod colour and found black colour dominant over brown colour in blackgram, whereas Pathak and Singh (1983) observed 3:1 ratio for blackish to brown colour in green gram.

Joint segregation of character pairs revealed normal distribution of independent assortment (9:3:3:1) for most of the character pairs but some distorted segregation for some crosses and character pair was also observed. All the character pairs segregated in a normal independent assortment except for *SS* vs *BB* in all the hybrids which was strongly linked in all cases. Deviation from normal assortment might be due to linkage for some alleles, and this type of distorted ratios have been observed by Kazan *et al.*, 1993 in chickpea; Zamir and Tadmor, 1984; Muehlbauer *et al.*, 1989 in lentil; Weeden and Marx 1984, 1987 in pea and Koenig and Gepts, 1989 in *Phaseolus* for morphological markers inheritance. Hairiness was weakly linked with seed colour in one hybrid (Pk-45923/MM 33-40), whereas in other hybrids, no linkage was observed for this character pair, which might be due to different genes involved for one of the loci. Hairiness and/or seed colour might be at different loci in various parents used for hybridization. Similar case may be for weak linkage between hairiness and pod colour in the hybrid "Mash 1/MM 5-60". As linkage between spots on seed coat and pod colour was observed in all the hybrids involved, therefore, it may be concluded that the genes for these characters might be from same origin. The linkage of blackgram proposed in this study contains 4 morphological loci. Morphological markers are limited in plants especially, blackgram because limited genetic work has been conducted on this crop. Five morphological loci have been reported by Kazan *et al.*, 1993 in chickpea. The identified linkage of *SS* VS *BB* is suggested to be used for initial mapping of blackgram genome. The arrangements proposed were based on linkage observed between genetically diverse cultivated blackgram in the present study. The usefulness of the mapped marker loci should be realized when loci affecting QTLs including diseases and other economically important genes are added to the linkage group. The use of closely linked markers should facilitate breeding by giving a unique identity by tagging the genes of economic importance and by providing a mean of selection in the absence of nurseries and screening procedures that can be costly and time consuming.

It is suggested to utilize diverse parents for both qualitative and quantitative traits for planning experiments for inheritance and mapping. Analysis for QTL detection confirmed the

association of seed coat colour and seed weight. Since the end product of improvement in self pollinated crops is pure-line, therefore transgressive segregants for seed weight along with high yield potential were selected from F_3 populations to develop superior germplasm, because performance of a particular cross for seed weight could be adequately predicted (Kunta et al., 1997, Ghafoor, 2000). In the cross "BG 9025/MM 33-40" single plants with early maturity and high seed weight might be selected because, BG 9025 is a short duration high yielding cultivar having low seed weight, whereas second parents is a bold seeded, late in maturity and low yielding. Tahir and Muehlbauer (1995) in a study on lentils reported linkage of 3 isozyme markers out of 10 for seed weight and suggested this marker for mapping. In present study, the initial results are encouraging for locating factors that influence the expression of seed weight. However, the conclusions are specific to the populations examined, and the environments under which the measurements were recorded. Further research is needed to establish the constancy of detected QTLs, and to locate their exact position in the blackgram genome. Further, enhancement of markers (morphological, protein and DNA) is suggested to have a precise understanding of linkage groups in blackgram.

REFERENCES

- Ghafoor, A., Ahmad, Z., Afzal, M., & Qureshi, A.S. (2000). Influence of genetic diversity and combining ability in determining hybrid vigour in *Vigna mungo* L. Hepper. *J. Genet. & Breed.*, 54, 125-131.
- Gomez, K.A., & Gomez, A.A. (1984). *Chi-square test: statistical procedure for agricultural research*, (2nd Ed.) : In International Rice Research Institute Book, John Wiley & Sons, pp: 458-478.
- Gottlieb, L.D. (1984). Genetics and morphological evolution in plants. *Am. Nat.*, 123, 681-709.
- Hilu, K. (1984). The role of single gene mutations in the evolution of flowering plants. *Evol. Biol.*, 16, 97-128.
- Kazan, K., Muehlbauer, F.J., Weeden, N.F., & Ladizinsky, G. (1993). Inheritance and linkage relationship of morphological and isozyme loci in chickpea (*Cicer arietinum* L.). *Theor. Appl. Genet.*, 86, 417-426.
- Koenig, R., & Gepts, P. (1989). Segregation and linkage of genes for seed proteins, isozymes and morphological traits in common bean (*Phaseolus vulgaris*). *J. Hered.*, 80, 455-459.
- Kunta, T., Edwards, L.H., & Keim, R. (1997). Heterosis, inbreeding depression, and combining ability in soybeans [*Glycine max* (L.) Merr.]. *SABRAO*, 29 (1), 21-32.
- Muehlbauer, F.J., Weeden, N.F., & Hoffman, D.L. (1989). Inheritance and linkage relationship of morphological and isozyme loci in lentil (*Lens Miller*). *J. Hered.*, 80, 293-303.
- Pathak, G.N., & Singh, B. (1983). Inheritance studies in green gram. *Indian J. Genet. Pl. Breed.*, 3, 215-218.
- Ramaiah, D.K., & Samolo, B.N. (1992). Inheritance of pod colour in blackgram. *Indian J. pulses Res.*, 5(1), 74-75.
- Rao, Y.K., Sreerangasamy, S.R., Muralidharan, V., & Chandrababuy, R. (1989). Inheritance of multifoliate leaf in urdbean. *Legume Research*, 12 (2), 166-168.

- Senapati, B.K., & Roy, K. (1990). Genetics of colour in groundnut (*Arachis hypogaea* L.). *Legume Research*, 13 (4), 188-190.
- Sen, N.K., & Jana, M.K. (1963). Genetics of blackgram. *Genetica*, 34, 56-57.
- Singh, D.P., & Singh, B.B. (1992). Inheritance of morphological characters in chickpea (*Cicer arietinum* L.). *Indian J. Genet.*, 52 (1), 55-57.
- Singh, S.P., Gutierrez, J.A., Molina, A., Urrea, C., & Geots, P. (1991). Genetic diversity in cultivated common bean: II. Marker-Based Analyses of morphological and agronomic traits. *Crop Sci.*, 31 (1), 23-29.
- Stanton, M.A., Steward, J.M., Percival, A.E., & Wendel, J.F. (1994). Morphological diversity and relationships in the A-genome cottons, *Gossypium arboreum* and *Gossypium herbaceum*. *Crop Sci.*, 34, 519-527.
- Stuessy, T. (1990). *Plant taxonomy*. New York : Columbia Univ. Press.
- Suiter, K.A., Wendel, J.F., & Case, J.S. (1983). LINKAGE 1: A PASCAL computer program for detection and analyses of genetic linkage. *J. Hered.*, 74, 203-204.
- Tanksley, S.D. (1983). Molecular markers in plant breeding. *Plant Mol. Biol. Rep.*, 1, 3-8.
- Tahir, M., & Muehlbauer, F.J. (1995). Association of quantitative trait loci with isozyme markers in lentil (*Lens culinaris* L.). *J. Genet. & Breed.*, 49, 145-150.
- Weeden, N.F., & Marx, G.A. (1984). Chromosomal locations of twelve isozyme loci in *Pisum sativum*. *J. Hered.*, 75, 365-370.
- Weeden, N.F., & Marx, G.A. (1987). Further genetic analyses and linkage relationship of Isozyme loci in pea: confirmation of the diploid nature of the genome. *J. Hered.*, 78, 153-159.
- Zamir, D., & Tadmor, Y. (1984). Unequal segregation of nuclear genes in plants. *Bot. Gaz.*, 147, 355-358.

SUSCEPTIBILITY OF MILLED RICE GENOTYPES TO ANGOUMOIS GRAIN MOTH *Sitotroga cerealella* (Oliv.) (*Lepidoptera: Gelechiidae*)

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ABSTRACT

Fifteen milled rice genotypes were screened for resistance to Angoumois grain moth, *Sitotroga cerealella* (Oliv.) under laboratory conditions ($27 \pm 2^{\circ}\text{C}$ and $60 \pm 5\%$ R.H.). Samples of each cultivar were infested with 50 one-day-old eggs for two generations (70 days). After the expiry of experimental period, adult progeny was counted and weight loss to infested samples was determined. The results revealed that moth progeny produced was significantly low (31.00) with minimum weight loss (4.99%) in NIAB-Rice-1 followed by DM15-14-96, DM 20-3-91 and Super Basmati, indicating resistance to *S. cerealella*. Highest number of moths emerged in rice genotype EF35-2-98 (105.33) inflicting maximum weight loss (12.61%) followed by NIAB-IRRI-9, Basmati 385 and Basmati Pak. The correlation coefficient between moth progeny produced and weight loss in rice genotypes caused by *S. cerealella* larvae was positive and highly significant ($r = 0.961$). The resistance of genotypes during postharvest storage should be given due consideration in rice breeding programmes.

Key words : Milled rice genotypes, Susceptibility, Angoumois grain moth.

INTRODUCTION

After wheat, rice is the main cereal crop of Pakistan. It is a major source of foreign exchange earning item in agricultural sector. During 2000-2001, 2.07 million tonnes of rice worth 428.7 million US \$ was exported (Personal communication, Export Promotion Bureau of Pakistan). Rice is prone to many insect pests during postharvest storage. Angoumois grain moth and lesser grain borer have been reported in substantial numbers in rice fields as well as in rice storages (Cogburn & Vick, 1981; Cogburn et al., 1984). However, rice varieties responded differentially for

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resistance to the attack of various insect species (Cogburn, 1974). Resistance in rough rice to Angoumois grain moth was positively correlated with the intact hull (Cohen & Russell, 1970). Russell and Cogburn (1977) screened about 1000 rice varieties from USDA world collection for resistance to Angoumois grain moth. They suggested that more than one mechanisms were operating against the insects. The moths developed more slowly on resistant varieties than on susceptible ones. Cogburn et al. (1983) concluded that intact hull was an unreliable base of resistance because its effectiveness varied with species of insects. Thus the present study was initiated with a view to selective rice genotypes resistant to Angoumois grain moth during storage.

MATERIALS AND METHODS

The studies were carried out at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad during 2001. Fifteen milled rice genotypes (IR6, NIAB-Rice-1, NIAB-IRRI-9, Basmati 370, BC-L-68, EF 25-14-98, EF30-1-97A, EF30-1-97B, EF35-2-98, DM15-14-96, DM20-3-91, DM25-11-95, Basmati 385, Super Basmati and Basmati Pak) supplied by Mutation Breeding Division of NIAB, Faisalabad were screened for resistance to Angoumois grain moth, *Sitotroga cerealella* (Oliv.) under laboratory conditions at $27 \pm 2^{\circ}\text{C}$ and $60 \pm 5\%$ R.H. Rice samples were cleaned and preconditioned at 5°C for two weeks. Four samples (30 g each) of each rice genotype were kept in 150 g capacity glass jars covered with finely perforated tin lids. One-day-old eggs of *S. cerealella* were collected from stock culture maintained for Angoumois grain moth. The eggs (50/replicate) were placed in 3 replicates of each rice genotype while fourth replicate was kept as untreated control. After completion of 2 generations (i.e. 70 days), the total adults produced including the moth carcasses were counted. Each sample was sieved through a 12-mesh screen above a 60-mesh screen. All rice and insect fragments that remained on the 60 mesh were collected and returned to the sample, but the dust that passed through was discarded.

The samples were reweighed to determine weight loss. Weight loss was determined by subtracting the value of infested rice from that of the controls. Five g from each sample were dried in a forced-draft oven at 60°C till constant weight. The moisture content (wet basis) was calculated from the weight loss. The data recorded on moth population development in rice genotypes and percent weight loss caused by feeding of *S. cerealella* larvae were subjected to analysis of variance and means were compared using Duncan's multiple range test at 5% level of significance. Coefficient of correlation (r) and regression (b) between *S. cerealella* moth produced and grain weight loss (%) in rice genotypes were determined and regression line was drawn.

RESULTS AND DISCUSSION

The resistance of milled rice genotypes to Angoumois grain moth, *Sitotroga cerealella* (Oliv.) was evaluated on the basis of moth population produced and weight loss in infested rice samples. The results revealed (Table I) that moth population produced was significantly low (31.00) with minimum grain weight loss (4.99%) on NIAB-Rice-1 followed by DM15-14-96, DM20-3-91, Super Basmati and EF30-1-97A. Contrary to that rice genotype EF35-2-98 was preferred for feeding

by the developing larvae and hence the highest moth population (105.33) emerged inflicting maximum weight loss (12.61%) followed by NIAB-IRRI-9, Basmati 385, Basmati Pak, DM 25-11-95 and BC-L 68. Correlation coefficient between adult progeny produced and weight loss in rice genotypes by feeding of the insect larvae was positive and highly significant ($r = 0.961$). The regression (fig. 1) of grain weight loss (Y) on moth progeny produced (x) in rice genotypes was:

$$Y = 0.43 + 0.121 X$$

This indicates that low moth population development would certainly cause low weight loss (%) and hence reflect resistance in rice.

This study clearly showed that milled rice genotypes varied significantly for resistance to *S. cerealella* larvae. Low moth progeny was produced on NIAB-Rice 1, DM 15-14-96, DM 20-3-91, Super Basmati and EF 30-1-97A and hence less weight loss was affected. However, no single cultivar demonstrated complete resistance to the insect. Genotype EF 35-2-98, NIAB-IRRI-9, Basmati 385, Basmati Pak, DM 25-11-95 and BC-L68 harboured large number of moth progeny, consequently more weight loss occurred to rice. McGaughey (1970) also found differential reproduction by four insect species on different varieties of milled rice.

Resistance in rice to storage insect has been attributed to various physico-chemical characteristics of rice grains. Cogburn (1974) reported that intact hulls of rough rice totally excluded rice weevils from feeding or oviposition and neonate *Rhyzopertha dominica* larvae suffered about 90% mortality in intact-hull rough rice. However, about 29% *S. cerealella* moths succeeded to complete development in rice with intact hulls. Hull morphology was thus considered an unreliable base of resistance as the effectiveness varied with species of insects (Cogburn et al., 1983a). Ressel and Cogburn (1977) concluded that more than one mechanisms were operating against the insects and that the moths developed more slowly on resistant varieties than on susceptible ones. Serratos et al. (1987) mentioned that resistance in maize populations to maize weevil, *Sitophilus zeamais* was contributed by the anti-feedant effect of phenolic compounds. The maize grain weight loss due to *Prostephanus truncatus* (Horn) and *S. zeamais* was found to be negatively correlated to total phenolics in the grain (Ranason et al., 1992).

Yashizawa et al., (1970) reported free phenols, lipid-phenols and sugar phenols in rice bran. Phenols have also been reported in volatiles of milled rice (Yajima et al., 1978) and rice bran (Fuujimaki et al., 1977). Phenolic acids content in rice, therefore, may impart some resistance to storage insects (Shibuya, 1984). It is recommended that phenols of different rice genotypes should be studied and correlated with their tolerance/resistance to storage insects. Rapid chemical indicators/markers can greatly assist in the selection process during breeding for resistance to storage insects.

The resistant/tolerant genotypes of rice can certainly be helpful to reduce qualitative and quantitative losses by storage insects. Postharvest insect problems should be given due consideration during the evolution of new varieties. It would be more appropriate if the postharvest storage studies with special reference to insect attack are made a part of variety release proposal.

Table 1. Susceptibility of milled rice genotypes to Angoumois grain moth, *Sitotroga cerealella*

Rice genotypes	Average moth progeny produced (number)	Weight loss (%)
IR 6	58.33 GH	7.00 DEF
NIAB-Rice 1	31.00 K	4.99 H
NIAB-IRRI-9	89.33 B	12.55 A
Basmati 370	67.33 EF	8.15 BCD
BC-L-68	74.67 DE	9.59 B
EF 25-14-98	62.00 FG	7.72 CDE
EF-30-1-97(A)	48.67 IJ	6.82 DEFG
EF-30-1-97(B)	53.67 HI	6.79 DEFG
EF-35-2-98	105.33 A	12.61 A
DM 15-14-96	45.00 J	5.38 GH
DM-20-3-91	46.67 IJ	5.81 FGH
DM-25-11-95	79.00 D	9.41 B
Basmati 385	87.67 BC	12.39 A
Super Basmati	48.00 IJ	6.26 EFGH
Basmati Pak	80.67 CD	9.10 BC

Means sharing similar letters in each column are non-significant ($P < 0.05$).

REFERENCES

- Cogburn, R.R. (1974). Domestic rice varieties: Apparent resistance to rice weevil, lesser grain borer and Angoumois grain moths. *Environmental Entomology*, 3, 681-685.
- Cogburn, R.R., & Vick, K.W. (1981). Distribution of Angoumois grain moth, almond moth and Indian meal moth in rice fields and rice storages in Texas as indicated by pheromone-baited sticky traps. *Environmental Entomology*, 10, 1003-1007.
- Cogburn, R.R., Bollich, C.N., & Meola, S. (1983). Factors that affect the relative resistance of rough rice to Angoumois grain moths and lesser grain borers. *Environmental Entomology*, 12, 936-942.
- Cogburn, R.R., Burkholder, W.E., & Williams, H.J. (1984). Field tests with the aggregation pheromone of the lesser grain borer (*Coleoptera: Bostrichidae*). *Environmental Entomology*, 13, 162-166.
- Cohen, L.M., & Russell, M.P. (1970). Some effects of rice varieties on the biology of Angoumois grain moth. *Sitotroga cerealella*, *Annals of Entomological Society of America*, 63, 930-931.
- Fujimaki, T., Tsugita, T., & Kurata, T. (1977). Fractionation and identification of volatile acids and phenols in the steam distillate of rice bran. *Agricultural and Biological Chemistry*, 41, 1721-1725.

- Mcgaughey, W.H. (1970). Effect of degree of milling and rice variety on insect development in milled rice. *Journal of Economic Entomology*, 63, 375-1376.
- Ranason, J.T. et al. (1992). Role of phenolics in resistance of maize grain to the stored grain insects, *Prostephanus truncatus* (Horn) and *Sitophilus zeamais* (Motsch.). *Journal of Stored Product Research*, 28, 119-126.
- Russell, M.P., & Cogburn, R.R. (1977). World collection rice varieties: resistance to seed penetration by *Sitotroga cerealella*. *Journal of Stored Product Research*, 13, 103-106.
- Serratos, A. et al. (1987). Contribution of phenolic anti-feedants to resistance of maize populations to the maize weevil. *Sitophilus zeamais*, *Journal of Chemical Ecology*, 13, 751.
- Shibuya, N. (1984). Phenolic acids and their carbohydrate esters in rice endosperm cell walls. *Phytochemistry*, 23, 2233-2237.
- Yajima, I., Yanai, T., Nakamura, M., Sakabibara, H., & Habu, T. (1978). Volatile flavour components of cooked rice. *Agricultural and Biological Chemistry*, 42, 1229-1233.
- Yoshizawa, K., Komatsu, S., Takahashi, I., & Otsuka, K. (1970). Phenolic compounds in fermented products. 1 Origin of ferulic acid in sake. *Agricultural and Biological Chemistry*, 34, 170-180.

ZERO-TILLAGE TECHNOLOGY OF SOWING WHEAT: EFFECTS ON PREDATORS IN RICE-WHEAT CROPPING SYSTEMS

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ABSTRACT

Studies were carried out at Muridke and Mona, Punjab, Pakistan from 1999-2000 to 2001-2002 to determine the effect of zero-tillage technology of sowing wheat on the population of predators in rice-wheat cropping system. Population of predators was substantially high at both the selected sites in wheat fields sown after rice with zero-tillage (without land preparation) than in wheat fields sown conventionally after seedbed preparation. Such difference was of more magnitude in January, decreased steadily and was minimum in April. The difference in the population of predators between two wheat establishment techniques may be attributed to tillage operations. In zero-tillage, rice stubbles remain intact which provide food and shelter to predators and conserve their population after rice harvest. Population of predators in rice crop planted after zero-tillage wheat was slightly higher than rice crop planted after conventionally sown wheat. Due to zero-tillage technology population of predators was conserved in the rice-wheat cropping system.

Key words : Zero-tillage, Predators, Conservation, Rice-Wheat.

INTRODUCTION

Rice-Wheat cropping systems occupy 24 million hectare of cultivated land in the Asian Subtropics. In South Asia these systems have been practiced on about 13 million hectare (10 million in India, 1.7 million in Pakistan, 0.8 million in Bangladesh and 0.5 million hectare in Nepal). In Pakistan productivity of rice-wheat systems is low. One of the major causes of low wheat productivity in rice growing areas is its late sowing due to the late harvest of rice crop. Sowing of wheat after mid November causes reduction in grain yield by one per cent per day (Randhawa *et al.*, 1979; Hobbs *et al.*, 1988).

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Traditionally, wheat is sown by broadcasting in prepared land after the harvest of rice crop. Late maturity of rice and time taken for land preparation causes delay in wheat sowing. To solve the problem, zero-tillage technology was introduced for timely sowing, reduce cost of production and enhance wheat productivity (Aslam *et al.*, 1991/1999). In zero-tillage technology, seed is placed into untilled soil by opening a narrow slot, trench or a band of sufficient width and depth for seed coverage (Phillips, 1980). With zero-tillage seed can be sown successfully just after rice harvest without land preparation. With zero-tillage technology almost all rice stubbles remain intact, but in traditional method of sowing wheat, due to ploughing and planking most of the stubbles are destroyed. It is a big technological shift in the rice-wheat cropping system, therefore, it was imperative to determine the effect of new technology on the population of predators in the rice and wheat ecosystems.

MATERIALS AND METHODS

To determine the effect of zero-tillage technology of wheat sowing on the population of predators in rice-wheat ecosystems, two sites viz. Muridke (Sheikhupura) and Mona (Sargodha) were selected in the rice-wheat growing area of the Punjab. Five farms were selected at each site based on the adoption of zero-tillage technology and each farm consisted of two fields one with zero-tillage and the other with conventional wheat sowing. In each field, sampling was done on monthly basis to record the population of predators. The population of predators was estimated by visual counting, or hand netting depending on the behaviour of the predator species. Population of major groups of predators such as spiders, coccinellids was recorded from 5 sweep samples and 10 sweep strokes at each sampling site. Population of other predators such as *Paederus* was recorded by visual counting from 1m² at each sampling site. Five sampling sites were selected diagonally in each field. Data were tabulated into means.

RESULTS AND DISCUSSION

In rice ecosystems, predators play an important role to maintain the population/infestation of insect pests lower than economic threshold levels. There has been increased interest in the utilization of predators, for the regulation of rice insect pests (Baltazar, 1963; Gabriel, 1978; Chandra, 1978). Substantial pest suppression occurs when predators populations are conserved to attack hoppers in the field (Kenmore, 1980). It has been estimated that predators including spiders cause 95% mortality of plant hopper nymphs (IRRI, 1979). Wolf spider (*Lycosa pseudoannulata*) has high pest killing capacity and is considered one of the dominant spiders in paddy fields in many countries (Kobayashi, 1961; Kawahara *et al.*, 1969; Chu & Okuma, 1970). In Japan the predator reduced the population of leaf hopper by 9% (Kobayashi, 1961; Yasumatsu & Torii, 1968). Coccinellids are important predators of white backed plant hopper (Kamal, 1981). *Paederus fuscipes* (Rove beetle) is widely distributed. Its adults migrate to rice fields shortly after transplanting and remain among the tillers throughout the rice growing season and even in stubbles after the harvest of rice crop. It feeds on all

species and ages of leaf hoppers. Both larvae and adults are active predators having a high searching ability (Manley, 1977). More than 40 species of predators of rice pests have been recorded in Pakistan (Salim, 1981; Beg & Khan, 1982; Khan & Ahmad, 1987; Salim *et al.*, 2001). Of these, spiders rove beetle and coccinellids are important predators in rice-wheat cropping systems.

Data were recorded on the population of predators in rice and wheat crops regularly from selected fields of rice and wheat crops to determine the effect of zero-tillage technology of sowing wheat on their population in rice-wheat cropping system. Population of predators was comparatively high at Muridke throughout study period from 1999-2000 to 2001-2002 in wheat fields sown after rice with zero-tillage than in wheat fields sown conventionally after proper seedbed preparation (Table 1). Similar trend was found at Mona site (Table 2). At both sites the magnitude of difference in the population of predators between zero-tillage and conventional method of sowing wheat increased with the passage of time. Such difference was comparatively less during the first year (2000), increased in the second year (2001) and further increased in the third year, 2002 (Figure 1). The difference in the population of predators between zero-tillage and conventional method of sowing wheat may further increase in the subsequent years.

Table 1. Population of predators in wheat crop sown after rice at Muridke

Predators	2000		2001		2002	
	Z	C	Z	C	Z	C
Muridke						
Spiders	3.0	1.3	3.1	1.2	4.7	1.6
<i>Paederus</i>	2.9	1.4	3.1	1.5	4.7	1.9
Coccinellids	0.9	0.6	1.2	0.6	1.8	0.9
Total	6.7	3.3	7.5	3.3	11.2	4.3

Table 2. Population of predators in wheat crop sown after rice at Mona

Predators	2000		2001		2002	
	Z	C	Z	C	Z	C
Mona						
Spiders	3.0	1.4	3.4	1.7	4.6	1.7
<i>Paederus</i>	2.8	1.3	3.1	1.5	3.8	1.3
Coccinellids	0.9	0.4	0.7	0.4	1.3	0.6
Total	6.7	3.1	7.2	3.7	9.4	4.1

Z. Zero-tillage technology for sowing wheat.

C. Conventional method of sowing wheat after land preparation

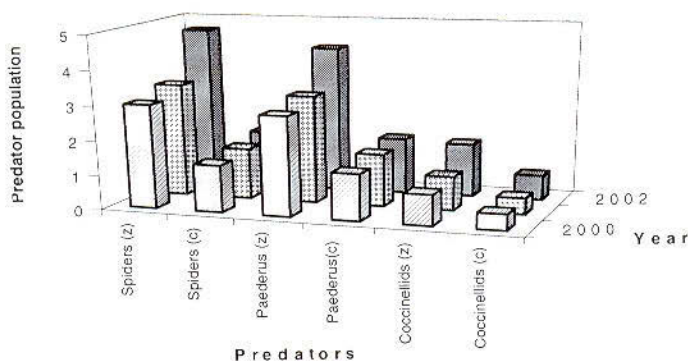


Figure 1. Mean populations of predators in wheat crop sown after rice with zero tillage and conventional tillage during different years

Difference in the population of predators between zero-tillage and conventional method of sowing wheat was of more magnitude in the month of January, decreased steadily and it was minimum in the month of April (Figure 2), due to maturity of crop and limited availability of prey. The difference in the population of predators between two wheat establishment techniques may mainly be attributed to seedbed preparation for sowing wheat. After the harvest of rice crop, due to low temperature, the predators take shelter either in the rice stubbles or in the cracks or crevices of soil, depending on their ecological behaviour. Rice stubbles provide shelter and food to predators.

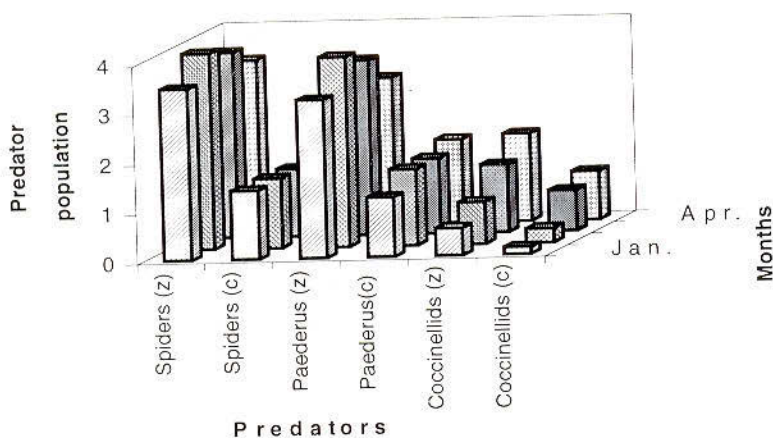


Figure 2. Mean populations of predators in wheat crop sown after rice with zero tillage and conventional tillage during different months

Morphological Markers for QTL detection: The association of qualitative markers with 100-seed weight was studied in 3 crosses and results are presented in the Table 4. All the three hybrids exhibited significant relationship between seed colour and seed weight, whereas other markers did not exhibit any significance in detecting seed weight in blackgram. It is evident from the data that green seed coat colour produced higher seed weight in the segregating populations and the difference was observed significant. In the hybrid, BG 9025/MM 33-40, green seeded ranged from 4.83 to 6.67 g per 100 seeds, whereas brown seeded were from 3.96 to 6.21 g. In general green seeded were higher in weight (Fig. 1). The hybrid BG 9010/MM 33-40 ranged from 4.18 to 6.81 g for green seeded and from 4.28 to 6.08 g for brown seeds. The hybrid, Mash 1/MM 33-40 ranged from 4.30 to 5.59 g per 100 seeds for green seeds and from 4.09 to 5.06 g for brown seeds. Similar trend was observed in F₃ generation (Fig. 2). On individual plant basis, transgressive segregants were observed in all the hybrids especially in BG 9025/MM 33-40 in which extra bold seeded plants were selected from F₃ population.

Table 4. Detection for seed weight using morphological markers in F₂ generation of blackgram

Plant Trait	Allele	Frequency	Mean±SD	Difference±SE
<i>Mash 1/MM-33-40</i>				
Hairiness	<i>H</i> -	45	4.42±0.54	0.01±0.17ns
	<i>Hh</i>	16	4.43±0.59	
Seed colour	<i>C</i> -	45	4.29±0.56	0.72±0.12**
	<i>Cc</i>	16	5.01±0.46	
Spots	<i>S</i> -	49	4.39±0.54	0.18±0.19ns
	<i>Ss</i>	12	4.57±0.57	
<i>BG 9025/MM-33-40</i>				
Seed colour	<i>C</i> -	92	4.88±0.66	0.86±0.10**
	<i>Cc</i>	42	5.74±0.61	
Spots	<i>S</i> -	101	5.40±0.66	0.04±0.11ns
	<i>Ss</i>	31	5.37±0.64	
<i>BG 9010/MM-33-40</i>				
Seed colour	<i>C</i> -	107	4.97±0.62	0.30±0.11**
	<i>Cc</i>	34	5.27±0.52	
Spots	<i>S</i> -	107	5.03±0.57	0.00±0.13ns
	<i>Ss</i>	34	5.03±0.67	

** - significant at 1% level.

Sowing of wheat with zero-tillage does not destroy stubbles, therefore, the mortality of predators was negligible. While, in the conventional method of sowing wheat, after the harvest of rice crop, land was prepared by a number of ploughings and planking. Tillage operations destroy rice stubbles and the proportion of destruction of stubbles depends on the type of tillage equipment and the number of tillage operations. One operation of rototiller plus two of cultivator and one planking caused 99% destruction of rice stubbles (Zafar & Razzaq, 1988). Rototiller destroyed rice stubbles completely and killed the hibernating stem borer larvae. With conventional cultivator tillage, rice stubbles were not completely destroyed even after several ploughings (Inayatullah *et al.*, 1989). Due to tillage operations predators both in the stubbles and soil were either killed or shifted to other fields. Low temperature, tillage operations, lack of food and non-availability of suitable habitat caused very high mortality of predators. Therefore, population of predators was higher in zero-tillage wheat fields than conventionally sown wheat fields.

It is evident from the data of Table 1 and 2 that rice stubbles conserved the population of predators after the harvest of rice crop and helped early colonization of predators in wheat fields. Synchronization of rotting of rice stubbles and onset of favourable environmental conditions forced the predators to leave the stubbles, shift on wheat plants and play their role to suppress the population of insect pests of wheat.

Population of predators in rice crop at Muridke, planted after zero-tillage wheat was comparatively high than the rice crop planted after conventional wheat crop (Table 3). Similar trend in the population of predators was found at Mona (Table 4). The magnitude of difference in the population of predators between two wheat crop establishment techniques (zero-tillage and conventional) was comparatively less in rice crop than that of wheat crop. Irrigated rice is sown or transplanted after thorough land preparation, so a large proportion of the arthropod fauna must come from outside the cropped land. It is, therefore, crucially important that key natural enemies should arrive as early in the crop colonizing pests. Early arriving predators can quickly overtake and keep population of insect pests of rice low (Way & Heong, 1994). Early arrival of predators in newly planted rice fields depends on immigration from local sources (Cook & Perfect, 1985 and 1989; Heong *et al.*, 1991). Comparatively high population in rice fields planted after zero-tillage wheat was due to comparatively high population in the adjoining fields/habitats or in the agricultural matrix as a whole. The increase in the population of predators in rice fields due to zero-tillage sowing of wheat is of great importance to enhance the activity of predators in suppressing the population/infestation of insect pests of rice.

Wheat crop sown with zero-tillage is comparatively more diverse due to the presence of stubbles than that of conventionally sown wheat. In general, diversity refers to number of species in a community. It covers variation within each species as well as the number and relative abundance of different species in space and time. Diversity within a species gives the ability to change weather and climatic conditions and to change agricultural methods. Here we are mainly concerned with the diversity in the environment. Generally diverse ecosystems are more stable. Stability describes the degree to which a system remains constant, despite normal small-scale fluctuations in the environmental variables. According to (Way & Heong, 1994) in

pest management the aim is to maintain permanent stable population, in which high peak as well as the equilibrium levels are kept below those causing economic crop loss.

Table 3. Population of predators in rice crop sown after wheat at Muridke

Predator	1999		2000		2001	
	Z	C	Z	C	Z	C
Coccinellids	2.8	1.9	1.0	0.5	1.0	0.8
Spiders	15.2	13.8	13.9	13.3	13.7	13.3
Longhorned grasshopper	2.0	1.5	2.2	1.7	2.1	1.7
<i>Ophionea</i>	1.4	0.5	4.6	3.9	4.4	3.9
Damselfly	3.0	2.5	3.1	2.5	2.9	2.5
<i>Paederus</i>	13.0	11.5	14.0	12.0	14.5	12.5
Total	37.4	31.7	38.8	33.9	38.6	34.7

Rice was manually transplanted in well-prepared and puddled soil after the harvest of wheat crop, which was sown with zero-tillage.

Table 4. Population of predators in rice crop sown after wheat at Mona

Predator	1999		2000		2001	
	Z	C	Z	C	Z	C
Coccinellids	2.0	1.5	1.0	0.8	1.5	0.5
Spiders	14.8	13.0	16.0	14.5	14.0	13.0
Longhorned grasshopper	2.5	1.5	3.0	2.0	2.0	1.5
<i>Ophionea</i>	1.0	0.5	2.5	2.0	4.5	4.0
Damselfly	2.5	2.0	3.0	2.5	3.5	2.5
<i>Paederus</i>	13.0	12.0	15.0	13.0	15.5	14.0
Total	35.8	30.5	40.5	34.8	41.0	35.5

Rice was manually transplanted in well-prepared and puddled soil after the harvest of wheat crop, which was sown with zero-tillage.

Diversity is mainly related with the degree of heterogeneity of physical environment. More heterogeneity in the habitat gives rise to more number of plant species and more number of animal species, including insect pests and their biocontrol agents. Diversity provides stability to

the ecosystem and minimizes the chances of out-breaks of pests. A diverse ecosystem contains more buffers against environmental hazards by providing needed hosts, food, shelter and overwintering sites (Price, 1975).

Decreased biodiversity increases instability and therefore, invites pest attacks (Ehrlich and Ehrlich, 1970) and increase outbreaks of pests (Elton, 1958; Pimental, 1961). Increased diversity in some agricultural systems may increase rather than decrease pest problems (Southwood & Way, 1970). It is, therefore, imperative to maintain or create such diversity which is helpful to conserve the population of predators and suppress the infestation/population of insect pests.

It has been demonstrated that in the pure stand of collards (simple plant community) several species of insect pests such as aphids, flea beetles, *Pieris rapae*, *Trichoplusia ni* reached outbreak-proportions and caused substantial losses in yield. When collards were sown under diverse environment, mixed with natural old field vegetation (diverse environment), pest outbreaks did not occur (Pimental, 1961). Studies carried out at International Institute of Biological Control, Pakistan revealed that the practice of burning sugarcane trash after harvesting was harmful because, during burning, the *pyrilla nymphs* escaped while the parasitoid, *Tetrastichus pyrillae* were killed. In fields, where the sugarcane trash was kept on the sides, the parasitoid started parasitizing pyrilla eggs in the third week of March and by June about 80% eggs were destroyed, while pyrilla flourished in the fields where trash was burnt and only 5% eggs were killed in June by the parasitoid. Studies carried out at the same institute indicated that in apple orchards the efficiency of predators for the control of codling moth was enhanced by applying farm-yard manure in the beginning of May. The manure provided very suitable habitat to the predators. During this period, full grown larvae of the pest left the fruit and entered in the soil, and predators living in the manure fed on the larvae and reduced their population drastically (Mohyuddin, Pers. Comm.).

CONCLUSION

Our studies indicate that increase in the area under zero-tillage technology will conserve the population of predators in the agricultural matrix and will be helpful to increase their population and develop stability in the rice-wheat cropping system.

REFERENCES

- Aslam, M., Ahmad, M., Hashmi, N. I., Chattha, M. Q., & Veen, M.V. (1991). *Zero-tillage wheat pilot production programme for the Punjab rice-wheat system*. Islamabad, Pakistan : PARC.
- Aslam, M., Majid, A., & Gill, M. A. (1999). Zero-tillage wheat production technology: prospects and threats. *J. Science Technology Develop.*, 18 (3), 17-23.
- Baltazar, C. R. (1963). Import and export of biological control agents in the Philippines (1850-1960). *Phil. J. Agric.*, 28 (1-2), 1-30.

- Beg, M. N., & Khan, A. G. (1982). Natural enemies of paddy pests in Pakistan. *Pak J. Agric. Res.*, 3, 84-95.
- Chandra, G. (1978). Natural enemies of rice leafhoppers and planthoppers in the Philippines. *Int. Rice Res. Newsl.*, 3 (5), 20-21.
- Chu, Y. I., & Okuma, C. (1970). Preliminary survey on the spider fauna of the paddy fields in Taiwan. *Mushi*, 44, 65-88.
- Cook, A. G., & Perfect, T. J. (1985). The influence of immigration on population development of *Nilaparvata lugens* and *Sogatella furcifera* and its interaction with immigration by predators. *Crop Protection*, 4, 423-433.
- Cook, A. G., & Perfect, T. J. (1989). The population characteristics of the brown planthopper, *Nilaparvata lugens* in the Philippines. *Ecological Entomology*, 14, 1-9.
- Ehrlich, P. R., & A. H. Ehrlich. (1970). *Populations, resources, environment*. San Francisco: Freeman.
- Elton, C. S. (1958). *The ecology of invasions by animals and plants*, London: Chapman and Hall.
- Gabriel, B. P. (1978). The natural enemies of rice insect pests. In *FAO short course on integrated pest control for irrigated rice in South and Southeast Asia*. Manila, the Philippines : Bureau of Plant Industry.
- Heong, K. L., Aquino, G. B., & Barrion, A. T. (1991). Arthropod community structures of rice ecosystems in the Philippines. *Bull. Entomol. Res.*, 81, 407-416.
- Hobbs, P. R., Mann, C. E., & Butler, L. (1988). A perspective on research needs for rice-wheat rotation. In A. R. Klott, (Ed.). *Wheat Production* (pp.197-211). Mexico : CIMMYT.
- Inayatullah, C., Ehsan-ul-Haq, Ata-ul-Mohsin, Rehman, A., & Hobbs, P. R. (1989). Management of rice stem borers and the feasibility of adopting no-tillage in wheat. Pakistan : PARC. Islamabad.
- International Rice Research Institute. (1979). *Annual report*. Los Banos, the Philippines : IRRI.
- Kamal, N. Q. (1981). *Suppression of whitebacked planthopper, Sogatella furcifera (Horvath) and rice leafhopper, Cnaphalocrocis medinalis (Guenée), populations by natural enemies*. Ph. D. Thesis, Manila, the Philippines: Gregoria Araneta University.
- Kawahara, S., Kiritani, K., Sasalea, T., Nakasuji, F., & Okuma, C. (1969). Seasonal changes in abundance and faunal composition of spiders in the paddy fields with special reference to their relation to the seasonal prevalence of the rice green leafhopper, *Nephotettix cincticeps*. *Plant Prot.*, 4, 33-44.
- Kenmore, P. E. (1980). *Ecology and outbreaks of a tropical insect pest of the green revolution, the rice brown planthopper, Nilaparvata lugens (Stal)*. Unpublished Ph. D. Thesis, Berkeley, USA, University of California.
- Khan, M. R., & Ahmad, M. (1987). *Final Technical Report 1984-87*. (Project No. Pak. 1158). Faisalabad, Pakistan : Univ. Agric.
- Kobayashi, T. (1961). The effect of insecticide applications against the rice stem borer on the leafhopper populations. (In Japanese with English summary). In *Special research reports on disease and insect forecasting* (pp. 1-126). Japan: Tokushima Agr. Expt. Sta.
- Manley, G. V. (1977). *Paederus fuscipes* (Col. Staphylinidae): a predator of rice fields in West Malaysia. *Entomophaga*, 22, 47-49.

- Philipps, S. H. (1980). No-tillage, past and present. In R. E. Phillips, G. W. Thomas & R. L. Blevins (Ed.), *No-tillage Research: research reports and reviews*, (pp. 1-6). Lexington : University of Kentucky.
- Pimental, D. (1961). Species diversity and insect population outbreaks. *Annal. Entomol. Soc. America*, 54, 76-86.
- Price, P. W. (1975). *Insect Ecology*. New York : John Wiley and Sons.
- Randhawa, A. S., Jolly, R. S., & Dhillon, S. S. (1979). Effect of seed rate and row spacing on the yield of dwarf wheat under different sowing dates. *Field Crop Abstr.*, 32 (2), 87-96.
- Salim, M. (1981). *Management of insect and weed pests of sugarcane and paddy crops in Pakistan. (Annual Technical Report)*. Islamabad, Pakistan : PARC.
- Salim, M., Masud, S. A., & Ramzan, M. (2001). Integrated insect pest management of basmati rice in Pakistan. In R. Duffy (Ed.), *Specialty rices of the world: Breeding, production and marketing* (p. 358). Rome, Italy : FAO.
- Southwood, T. R. E., & Way, M. J. (1970). Ecological background to pest management. In R. L. Rabb & F. E. Guthrie (Eds.), *Concepts of pest management* (pp. 6-28). Raleigh : North Carolina State University.
- Way, M. J., & Heong, K. L. (1994). The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice: A review. *Bull. Entomol. Res.*, 84, 567-587.
- Yasumatsu, K., & Torii, T. (1968). Impact of parasites, predators and diseases on rice pests. *Ann. Rev. Ent.*, 13, 295-324.
- Zafar, M. A., & Razzaq, A. (1988). Effect of tillage on stem borer (SB) larvae carry-over in a rice-wheat rotation. *Intl. Rice Res. Newsletter*, 13 (1), 30-31.

GLOBALIZATION CHALLENGES FOR TEA PRODUCING COUNTRIES : THE CASE OF SRI LANKA

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ABSTRACT

The current globalization phenomenon has affected the world's tea industry in a number of ways. The increased competition has primarily created a significant need for a strong base for developing competitive advantage. The objective of this paper is to show how the Sri Lankan tea industry should respond to this global challenge. Given the global challenge, shifting of emphasis from a simple commodity production to value-added tea production could prove not only be more productive but also ensure the survival of the industry. But with the acceleration of globalization, the Sri Lankan value-added tea itself will invariably be subject to acute competition. The analysis done based on the Porter's diamond framework revealed that the country requires constant efforts in order to remain competitive.

Key words : Globalization, Sri Lanka, Tea industry, Value-added tea, Competitive advantage.

INTRODUCTION

Globalization, which is a complex phenomenon that integrates trade, production and finance as well as socio-cultural behaviour has accelerated the nation-state's dependency on trade. As a result of this increased integration process, creation of wider markets, expansion of the array of tradables and the emergence of new competitors could be seen. It also enhance the global availability of raw materials through trade and accessibility of raw material sources through foreign direct investment. Hence, the globalization process has placed restrictions on the greater dependency on the factor endowments as the basis of production and competition. Basically because, the factor comparative advance is considered to be insufficient and static both in the modern global economy and in the long-term viability of a country (Hopkins &

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Lewis, 1996; Porter, 1998). Therefore, it has become necessary to create a strong base for developing competitive advantage either by using existing factor endowments or by using created advantages.

Similar to any other industry, tea has also subjected to comparable increasing pressures of globalization. Competitive pressures of multinationals, as well as the competition among tea producing countries have increased along the global integration process. This has created a continuing pressure for tea producing countries and firms to be cost competitive and innovative both at home and in foreign markets. The tea producing countries who act as commodity marketers have seriously affected by this globalization process while providing more beneficial impacts on some participants in the industry who act globally. Given this global challenge, this paper address the perspective of the Sri Lankan tea industry. The overall objective of this paper is to show how the Sri Lankan tea industry should respond to the increasing pressures of globalization and the efforts that it needs to remain competitive.

First, the paper addresses the current weaknesses associated with the tea industry, the largest net foreign exchange earning industry in Sri Lanka. Secondly, it argues the viability of a value-added tea production strategy in meeting the increased competitive pressures. In the third section, the paper discussed the constraints that the country would face in pursuing the above strategy. Finally, the present status of the industry is analyzed by using the Porter's competitiveness diamond framework and suggests the efforts that it needs to remain competitive.

Weaknesses associated with the Sri Lankan tea industry

Sri Lanka, the world's largest tea exporter has more than a century old history for its tea industry. From its initiation in the 1867, the Sri Lankan tea industry has maintained strong links with the outside world. Even though the concept of globalization was not known at that time, foreign involvement in producing tea was very high. During the time that Sri Lanka was a British colony, the British invested in tea plantations in order to take added advantages from the country in producing tea. The total quantity produced was transferred and the value-addition was carried out in the United Kingdom. At present, as an independent state Sri Lanka illustrates a liberalised economic framework and has a certain level of integration with the outside world.

Tea industry in Sri Lanka is a good example of an industry that a highly reliant on factor comparative advantages. Due to its high factor advantages vis-a-vis other tea producers, the Sri Lankan tea industry has been able to play a significant role in the world tea trade. But the country has given a very low emphasis to upgrading its factor advantages. Along with that, past national policies created further negative influences where the nationalisation concept played a significant role. Newcomers to the industry, especially Kenya, expanded their production facilities and have outperformed the majority of the factor advantages held by Sri Lanka. With that the Sri Lankan tea industry's competitiveness in the world market started to fade away. Its export market share demonstrated a significant drop after the mid-1960s. This

was due mainly to the country's high level of dependency on factor advantages. Similarly, Porter has pointed out also that a country which is highly dependent on its factor advantages can face the continual threat of losing competitive position (Porter, 1998)

At present, a majority of the factor advantages of the Sri Lankan tea industry is eroded and it produces tea at the highest cost (in 1992, cost of manufacturing tea (US\$/Kg) in Sri Lanka, India and Kenya were 1.48, 1.05 and 0.80 respectively). Its labour, land and factory productivity is weak. In 1992, Sri Lankan plantations had 2.8 labourers per ha and the intake per green leaf plucker was 14.22 kg whereas India and Kenya had 2.5 and 2.2 labours per ha respectively. The intake per green leaf plucker was 25 kg for India and 48 kg for Kenya (as cited in Fonseka, 1997). However, this situation has not improved even after the privatisation of tea plantations as the average intake per plucker remained at a lower level of 15 kg per labour day in 1996 (Central Bank of Sri Lanka, 1997). Furthermore, nearly 45 percent of the land area is cultivated with seedling tea, which resulted on a comparatively lower yield level. In Sri Lanka the national yield level was 1559 kg per ha in 1998 whereas the major competitors in the industry, India and Kenya had higher average yield levels of 2284 and 1950 kg per ha respectively in the same year (Central Bank of Sri Lanka, 1999). It can be argued that the main reason for the Sri Lankan tea industry's declining competitiveness was its high reliance on its basic factor comparative advantage and price-based competition. Furthermore, over 66 per cent of the cost of production of tea is presented by the labour cost component (Central Bank of Sri Lanka, 1999) and even its labour productivity is the lowest among the major tea producing countries (Betz, 1989). However, the added advantages of the new comers especially Kenya, increases its exportable surplus at low prices and have had a serious impact on the Sri Lankan tea industry's competitiveness. Given this scenario, the success of a price-based competition for the Sri Lankan tea industry is highly unlikely and raises the importance of adopting a better strategic focus to ensure its survival.

Value-added tea production as a viable strategy

In order to overcome the present weakness, the Sri Lankan tea industry needs productivity improvements, especially with respect to land and labour. However, these remedial measures take time both to implement and to become effective. Even if the country were to succeed in cost minimization, it would create a least cost structure in the industry and, therefore, the competition would be in terms of cost. Competition based on cost is considered to be a non-viable strategy in the long-term if it is not based on technological improvements-as any competitor can overcome the advantages (Fairbanks & Lindsay, 1997; Porter, 1998). Further, by assessing the competitive position of the Sri Lankan tea industry, Ali, Choudhury and Lister (1997) pointed out that achievement of a cost leadership strategy for Sri Lanka would be difficult due to its cost structure with highest costs and lowest productivity. Accordingly, product differentiation achieved through value addition may be the best strategy for Sri Lanka to enhance its competitiveness.

In the global tea trade Value-Added Tea (VAT) has captured a significant position because of the sophistication of tea consumption patterns. Therefore, the future demand for tea is likely to be different from that of the past and there could be more demand for convenience oriented products. Consumer preference for loose tea is on the decline, while demand for tea bags and ready-to-drink teas is on the increase. According to Kelegama *et al.* (1995) over 75 percent of the markets in the Middle East and Pakistan are for tea in packets, while tea in bags comprises over two-thirds of the consumer markets in Western and Northern America. Along with the concerns about a healthy life-style there is an increasing demand for organically produced tea. This indicates that, overall, there could be a greater demand for tea with high value-added component than for loose tea. Therefore, a greater emphasis on VAT rather than on bulk tea will provide the best opportunity for the Sri Lankan tea industry to enhance its competitiveness. It has the potential to capture a larger portion of the changing world demand and will be able to increase export earnings through high world prices. Finally, the multiplier effects will have a very beneficial impact on the plantation-base of the country. Further, it can be said that at present, the industry can base its factor comparative advantage only with respect to its natural climate and the ability to produce best quality tea. None of the other factors demonstrate an advantageous position. These remaining advantages are playing a significant role in the tea industry especially with respect to VAT. This reveals a higher possibility of pursuing a VAT production strategy in the country. Similarly, it can be argued that VAT production is one of the responses which arose due to increasing global integration -- especially in meeting changing consumer demands. Many have argued that the trade in processed goods -- rather than in agricultural commodities -- is directly related with the globalisation process (Klein and Kerr, 1995; West and Vaughan, 1995). Therefore, the VAT production strategy enables the Sri Lankan tea industry to broaden its global integration process and meeting increased global challenges. It will also be a useful strategy in gaining advantages due to the globalisation of distribution. As pointed out by Klein and Kerr (1995) globalisation of distribution creates wider opportunities for an agribusiness producer by enabling it to reach a range of consumers with varying tastes. Therefore, there is a huge potential for VAT producers to differentiate their product through flavouring and packaging in order to cater for consumers with varying tastes rather than based on a commodity-based strategy.

The additional investments made in developing VAT production and marketing will enhance the creation of competitive advantage. These created advantages such as brand names, superior product quality, design innovations, skills and the like in VAT production can guide firms as well as the country as a whole in gaining an advantage over competitors. Similarly, many researchers have argued also that investments in non-primary industry will change the comparative advantage position and the level of development of a country (Rana, 1988; Leamer, 1995; Song, 1996). Rana (1988) by specifically considering NIEs, ASEAN and South Asian countries, pointed out that comparative advantage has declined in primary and crop and animal product groups, while it has increased in the manufacturing sector. This indicates that there would be a shift in comparative advantage with the development process. Finally, this --

rather than a factor-based comparative advantage -- will create more sustainability for the tea industry in the future.

Multinational companies and the tea industry

As discussed earlier VAT production could be considered as a viable strategy in overcoming the present weaknesses of the Sri Lankan tea industry. However, with the acceleration of globalization, the Sri Lankan VAT itself will invariably be subject to acute competition, especially, from the Multi-National Companies (MNCs) who act as the leading producers of VAT.

All the MNCs who are involved in tea have extended their production activities through Foreign Direct Investment (FDI) in tea producing developing countries in order to obtain ownership, location and internationalization advantages. An UNCTAD report on areas for International Co-operation with respect to marketing and processing of tea has concluded that multinational involvement is much higher in the tea industry than in any other industry. Thus these MNCs have either full or partial ownership of plantations, and ownership relations with brokers. They have also a high level of concentration in buying at auctions, ownership of processing facilities, and dominant market shares in major market areas. Moreover, they have increased market power through diversification into other product areas, and either possess well-known brand names, and other advertising techniques, or have established retail networks (UNCTAD, 1982). According to Ali, Choudhury and Lister (1997) the processing and distribution of tea is controlled by four vertically integrated United Kingdom-based Corporations: Unilever/Brook Bond, Cadbury Schweppes, Allied Lyons and Associated British Foods, which have around four fifths of the market share in most countries. This high level of involvement of the MNCs could be considered as the main problem for the developing countries in upgrading their tea industry with respect to value-addition and marketing. Further, their multimillion-dollar promotion budgets and high competitive price cutting behaviour have greatly affected the performance of the tea industry in the developing countries.

All these pressures from MNCs have increased with intensified competition along with the globalisation process. They continually innovate in developing strong and unique competitive advantage over their rivals and has become the governing factor in competitive success. Further, firms have increased their production activities outside the domestic border mainly by being cost-efficient and obtaining factors that are favourable to competitive success. In terms of tea, the increasing involvement of MNCs in producing VAT in low-cost tea producing countries, and a high level of integration with the plantation-base are carried out mainly to achieve a low-cost position against their competitors. Further, by locating production activities abroad, firms can identify the local needs of the consumers better than their competitors can, and thereby they try to achieve a high level of competitiveness over their rivals. Moreover, the initiation of VAT production in consuming countries will enable firms to gain high tariff benefits (almost all the tea importing countries have implemented high tariff rates for VAT compared to bulk tea). Simatupang (1998) explained also that these types of

cross-border production activities through FDI contribute substantially to improving export performance, manufacturing competitiveness, product quality and labour productivity and thereby contribute to a high level of competitiveness. Therefore, along with the globalization process one of the main challenges faced by the tea producing developing countries are how to face the intensified competitive pressures by the MNCs.

Foreign involvement and the Sri Lankan tea industry

Even though at present the majority of the comparative advantages formerly held by the Sri Lankan tea industry have diminished, it still has access to advantages like quality tea, and strategic assets such as the Lion logo and Pure Ceylon tea. These are significant comparative advantages in terms of VAT production and in marketing. Possession of these advantages by the Sri Lankan tea industry, along with the free availability of low-cost and skilled labour in the country, has created a favourable environment for MNCs in undertaking FDI. MNCs play a significant role in the Sri Lankan context, and the same applies to the other tea producing countries. These cross-border production activities of MNCs are performed in order to achieve a competitive edge in the global tea trade, especially with respect to VAT. In the past, all the MNCs purchased their semi-processed commodity from Sri Lanka and had it shipped to a different country for its final processing and packaging, from where it was transported all over the world for retail activities. But at present, almost all the subsidiaries of MNCs are directly involved in VAT production within the country in addition to shipping it as a commodity for further value-addition.

In this process, Unilevers and Finlays are playing a significant role. Both have invested heavily in instant tea processing plants, and are the only instant tea producers in the country. Further, not only has finlays extended their activities to producing tea but also they are one of the leading producers of speciality tea in Sri Lanka. In terms of the Sri Lankan-owned firms, M.J.F. Group (*Dilmah* brand) is the only firm that competes directly with multinational brands and it is very evident in Australia. *Dilmah* is gaining brand popularity, and competes directly with Unilevers in the mass market through a differentiation strategy. Further, *Dilmah* has extended its production operations to Poland in catering for the European Economic Union region is commendable. Although *Dilmah* plays a significant role in the VAT industry segment in Sri Lanka by capturing more benefits from globalisation of the industry, others have not yet ventured for possible advantages. This is a common fact with all the other tea producing developing countries as well.

Further, the role played by the overseas intermediaries in the VAT production of Sri Lanka could be considered as another significant foreign involvement. Similarly to MNCs this has been enhanced by the increasing globalisation of the tea industry. In Sri Lanka, a major portion of the VAT production is produced under brand names of the overseas intermediaries. Currently, around 40 per cent of the tea exports are branded -- of which only 15 per cent or less goes out under Sri Lankan-owned brands. This demonstrates the prominence of overseas intermediaries in VAT production. Similarly to MNCs, the presence of overseas intermediaries

is greatly encouraged by the comparative advantages held by the Sri Lankan tea industry. Whether a VAT production contract is established or not is determined largely by the added advantages gained by the overseas intermediaries. In this process, some of the overseas intermediaries are driven mainly by low-priced VAT, whereas some are driven by the quality of tea and other strategic assets such as Lion logo and Pure Ceylon Tea. Unlike the subsidiaries of MNCs, the overseas intermediaries are playing a role in VAT production only, hence this has a direct impact in enhancing VAT production. Even though this increases the overall VAT production, it will not lead to the development of consumer loyalty for Sri Lankan VAT products. Therefore, more emphasis needs to be given to strengthening VAT production under Sri Lankan-owned brand names.

Sri Lankan response in meeting this global challenge

In the global tea trade, Sri Lanka plays a significant role as an exporter. However, the country has demonstrated a declining competitiveness compared to that of other major tea producers. It could be argued that the main reason for the Sri Lankan tea industry's declining competitiveness is its high level of reliance on its basic factor comparative advantages and price-based competition. But, this factor comparative advantage has not provided any sustenance for competitiveness of the Sri Lankan tea industry. Because the added advantages of the newcomers, especially Kenya, which increased its exportable surplus at low prices have adversely affected the Sri Lankan tea industry. Given this scenario, the success of price-based competition for the Sri Lankan tea industry is highly unlikely. Therefore, as explained earlier, there is an increased viability of a non-price-based competition achieved through value-addition to tea. However, the acceleration of globalization has created a severe challenge for Sri Lanka in pursuing this strategy. This has created the necessity of developing specific and unique advantages to remain competitive in the global tea trade. Given this need, this study assesses the present position of the Sri Lankan VAT industry segment by using the Porter's diamond framework and the efforts that it needs to remain competitive.

Competitiveness diamond of the VAT industry segment

The main attributes that influence the overall competitiveness of the VAT industry segment of Sri Lanka was assessed by using the Porter's diamond framework. Each factor that influences positively (+) and negatively (-) are illustrated in Figure 1. The development of a competitiveness diamond for the Sri Lankan VAT industry segment is important in determining the advantages and weaknesses of the cluster that direct the firms in achieving competitive advantage. Since the Sri Lanka VAT industry segment is strongly linked with the plantation-base, it is vital to relate the diamonds of the plantation-base and the VAT industry segment. This is of the utmost importance as the country has many restrictions on tea imports. Thus there will be a direct, strong link with the demand conditions of the plantation-base and the factor conditions of the VAT industry segment. Therefore, it can be argued that there should be a

double diamond framework in explaining the VAT industry segment of Sri Lanka, because the enhancement of the competitiveness of one industry segment is conditional upon the enhancement of the competitiveness of the other industry segment. That is, the achievement of competitiveness by the VAT industry segment is largely conditional upon the competitiveness of the plantation-base. Therefore, the present weaker competitiveness of the plantation-base of the Sri Lanka tea industry cannot be overlooked in the process of enhancing the competitiveness of the VAT industry segment.

The factor conditions reveal that it has moderate advantages in directing the overall VAT industry segment in achieving competitiveness. But, except for the created advantages like the Lion logo and Pure Ceylon tea, all the other favourable factors represent basic factor advantages. These basic factor advantages will not be strong advantages as imports and FDI can overcome the factor disadvantages of competitors. This has been the sole reason for the United Kingdom-based MNCs in increasing their FDI in tea producing countries. Even though the VAT industry segment is linked with the plantation-base, it seriously needs productivity and cost improvement strategies to enhance its performance. Further, the Tea Research Institute (TRI), which has contributed significantly in developing VAT products, needs to develop strong links with VAT producers. It was the pioneering research institute that invented processes for obtaining instant tea direct from green leaf (The Tea Research Institute of Ceylon, 1967). Similarly it has developed a liquid tea concentrate which is available for commercial exploitation. This clearly reveals that the TRI could play a significant role in enhancing competitiveness by developing proprietary technology and by focusing on market oriented research. But at present its research is highly focused on the plantation-base and is not market-oriented. On the whole, the factor conditions raise the need to strengthen the advanced factors by developing more focused education infrastructure, and research and technology advancement programmes, along with strengthening its basic factor advantages.

Based on the present situation, it can be said that all other three factors that influence the competitiveness of the VAT industry segment are not favourable -- unlike the factor conditions. The presence of related and supporting industries within the country is very weak. Neither the required machinery, filter paper, packing materials, flavours, ink, threads nor the aluminium wire that are important for VAT production are produced locally. The most widely used tea bagging machines, *Constanta* and *Ima* are imported from Germany and Italy. Similarly, more than 90 per cent of the local packing material demand is met by imports from Indonesia, Sweden, Norway, and India. The designing and printing industry is not sophisticated. Even though the shipping industry has shown a greater liberalisation compared to that of the other South Asian countries, firms are largely dependent on foreign cargo services for shipment of their VAT products overseas. All these factors significantly contribute to less favourable related and supporting industries of the VAT industry segment of the country.

Even though, Sri Lanka exports nearly 40 per cent of its tea as VAT a greater portion is produced under private brands. Competitive price cutting behaviour among the VAT producers in obtaining an opportunity to produce VAT under private brands has become one of the serious weaknesses in the country. It decreases the quality and the price of tea offered and

thereby it negatively influences the overall tea industry. Further the limited promotional budgets of the firms has become one of the main barriers in developing brand marketing strength. Even though the Tea Promotion Bureau extends financial assistance in promoting

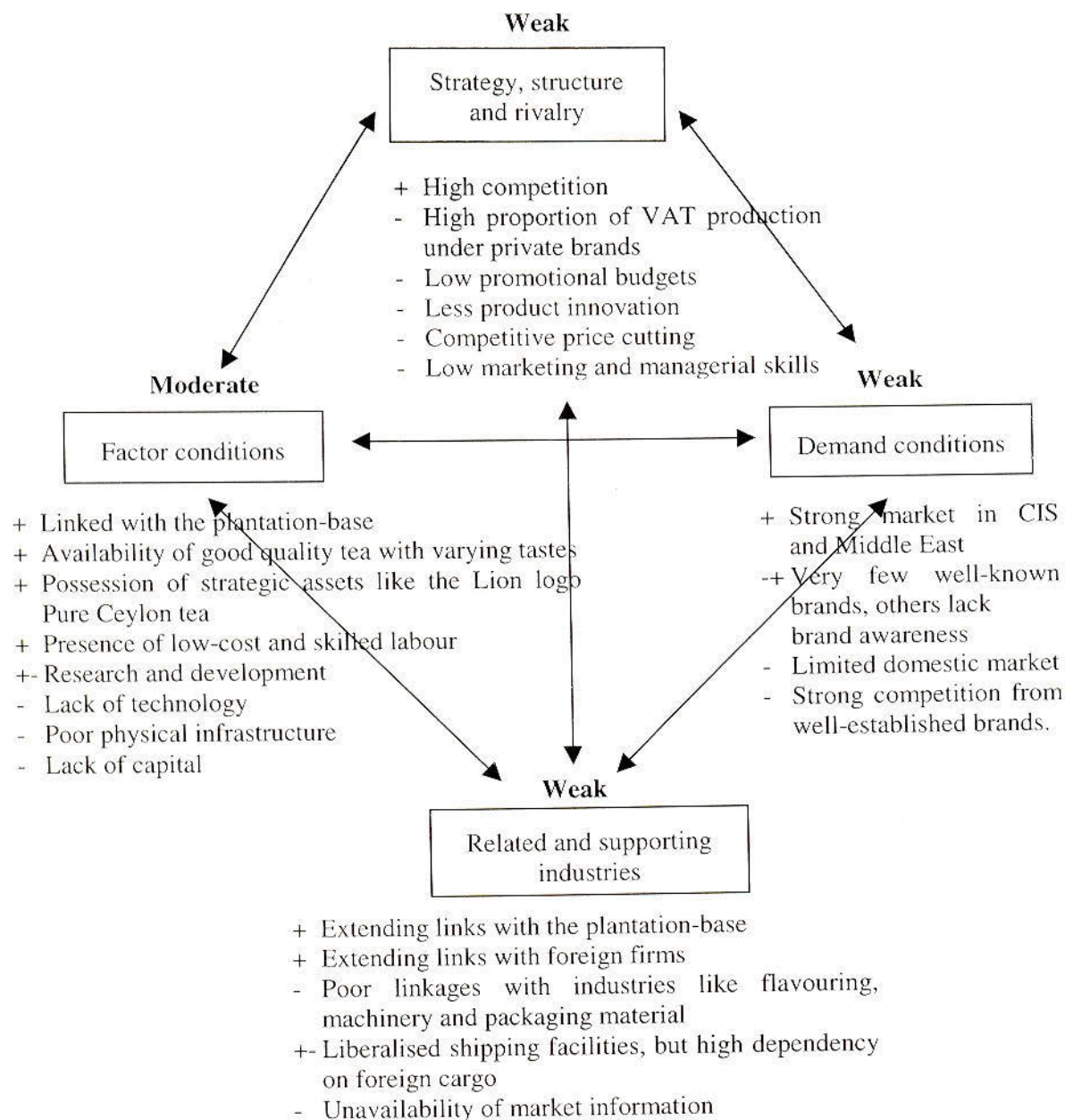


Fig. 1. Sri Lankan value-added tea industry segment: Competitiveness diamond

(+ denotes favourable and - denotes unfavourable factors)

VAT, the present budgetary allocation is inadequate. In 1999, approximately Rs. 39 million was allocated to brand promotion linked to the Lion Logo, covering only 10 brands in 10 different markets. In the same year, a total budget of approximately Rs. 40 million was allocated for uni-national promotion campaigns including trade fair participation (Sri Lanka Tea Board, 2000). However, while this seems considerable in terms of Sri Lankan standards, it is negligible in terms of the multimillion dollar promotional budgets of MNCs (Kelegama *et al.*, 1995; Tea Promotion Bureau, 1998). Further at present, Sri Lanka can be ranked as the world's third largest tea bag producer next to the United Kingdom and Germany. This higher competition within Sri Lanka has created a favourable environment for firms in developing stronger competitive advantages. Therefore, it can be pointed out that in general, the VAT industry segment's strategy, structure and rivalry are less favourable in directing the overall VAT industry segment in achieving competitiveness.

As discussed previously, the role of MNCs in VAT production greatly influences the demand conditions of the Sri Lanka VAT. Moreover, the domestic market for tea in Sri Lanka is very weak and it exports more than 90 per cent of its production. According to the annual bulletin of statistics of the International Tea Committee, during the period 1996-1998 Sri Lanka per capita consumption of tea was only 1.29 Kg per year -- whereas the highest per capita consumption of 3.23 Kg per year was recorded in Ireland (ITC, 1999). Even this lower level of per capita consumption is not well specialised and the demand is primarily for loose tea. Therefore, in general it can be pointed out that the demand conditions and strategy, structure and rivalry are less favourable in strengthening the competitive advantage of the Sri Lankan VAT industry segment.

The other two indirect factors, government and chance, also have not played favourable roles in the VAT industry segment. As pointed out by Porter's stages of development of national competitive advantage, it can be argued that Sri Lankan VAT industry segment is in the factor-driven stage where the government has a significant role to play. The government can function as an actor and a decision-maker in improving the level of competitiveness by implementing better strategies at the government and at industry level. However, although the government could play a significant role in strengthening competitiveness, it can be argued that, in the Sri Lankan context, the role of the government is relatively weak. Chance has exercised positive influences through drought in a number of major tea producing countries, whereas the Russian currency crisis has had a serious negative influence. Therefore, on the whole it can be pointed out that the determinants of the Sri Lankan VAT industry segment's competitive advantage are less favourable. Given this scenario, it is very important to build specific advantages with respect to all four attributes in order to enhance VAT production in the future. Specifically, more emphasis needs to be given to developing factors that are weak. Further, as pointed out by Porter (1998) it is important to upgrade and innovate all the present advantages in order to sustain the competitive advantage.

Similarly to Sri Lanka, all the other major tea producing countries will also initiate their VAT production in order to capture more benefits in the future. Among them, Indian's intended entry into VAT production could be significant. A report prepared by Duff and Phelps Credit Rating (DCR) has recommended that the Indian tea industry should reposition its tea by changing the product form, packaging, delivery system and promotional policies to meet the challenges under the World Trade Organisation regime (Venugopal, 2000). Even though India has a declining exportable surplus of tea, it has a well-developed industry with respect to machinery, packing material and other necessary sources that are important in enhancing VAT production. Therefore, Sri Lanka needs to develop strong and unique bases of competitive advantage in meeting the competitive threats. Prior identification of present advantages and weaknesses will ensure greater potential in strengthening the competitiveness of the Sri Lanka tea industry in the future, especially by preparing it in competing against other major players in the global tea industry.

CONCLUSION AND POLICY IMPLICATIONS

Countries are increasingly involved in VAT production as one of the responses, which arose due to increasing global integration -- especially in meeting changing consumer demands. Therefore, it can be expected that all the tea-producing countries will expand their VAT production in order to be competitive in the global market. But with respect to VAT, MNCs will continue to play a significant role in the global tea trade. All these will create a continuing stimulus to the Sri Lankan VAT producing firms to be cost competitive and innovative in achieving competitiveness in global trade. In the process of enhancing the performance of VAT production, Sri Lanka -- while utilising its comparative advantages to the maximum -- should look for the development of more sustainable competitive advantages. The strongest competitive advantage for Sri Lanka may be the development of Sri Lankan brand image in the minds of the consumers. In this regard, the small VAT - producing firms of Sri Lanka are far behind the promotional budgetary requirements compared to MNCs. Therefore, government support at the initial stages of brand promotion is mandatory. Further, government support should be extended in strengthening the overall competitiveness of the Sri Lankan VAT industry segment. However, the continued increasing performance of VAT production will depend on continuous innovation and upgrading of the competitive advantages that are created.

The role of the government could be considered to be important in the process of enhancing the competitiveness of the entire tea industry. However, the lack of a long-term strategic plan of the country is serious -- and leads to ad hoc policy decisions. This instability of policy decisions adversely influences the investment decisions of the VAT producers. Hence, it is essential to develop a strong and stable strategic plan to address how the national level strategies are targeted to meet the increasing competitive pressures and thereby to achieve competitive success. From their knowledge of the underlying policy directions, firms will then be able to anticipate future policy changes. Extended support by the government could be significant in their shifting from a factor-driven to an investment-driven stage of development.

Such support could be extended in terms of skill enhancement, provision of market information, provision of promotional assistance and the like.

With a few exceptions, almost all the VAT producers were small and medium-scaled and had a serious lack of financial strength in promoting VAT products under their own brand name. In this context, government could play a considerable role in assisting VAT producers to increase their brand awareness. Further, the strategies at the national level should also be targeted at encouraging investments in related and supporting industries in Sri Lanka through Board of Investment assistance. The creation of such favourable environment will pave the way for more new investments and it would ultimately strengthen the competitiveness of the VAT industry segment.

NOTES

1. Comparative advantage is an added advantage of a country vis-a-vis other countries. Traditionally, the comparative advantage phenomenon was referred to as a country's advantages in terms of basic factors. This is known as the factor comparative advantage and is associated with the added advantages of a country with respect to factors of production such as land, labour, natural resources and capital vis-a-vis other countries.
2. The tea industry is a collection of tea plantations and firms that are involved in activities related to tea. But both these segments illustrate great differences in terms of the nature of inputs utilized and output. Therefore, in this study, a collection of all firms involved in VAT production was referred to as the VAT industry segment.
3. Michael Porter, the competitive advantage theorist, showed that a nation could develop competitive advantage through four broad attributes (Porter, 1998). These four attributes, factor conditions, demand conditions, related and supporting industries and structure, strategy and rivalry are considered to be important in creating, sustaining and promoting a competitive environment. Basically, he considered an industry cluster to be competitive if all of these four factors are favourable. In addition, he identified government and chance as indirect factors that affect all of these.

REFERENCES

- Ali, R., Choudhury, Y.A., & Lister, D.W. (1997). *Sri Lanka's tea industry: succeeding in the global market*. Washington, DC: The International Bank for Reconstruction and Development.
- Betz, J. (1989). Tea policy in Sri Lanka. *Marga*, 10, 48-71.
- Central Bank of Sri Lanka (1997). *Annual report*. Colombo: Author.
- Tea Promotion Bureau (1998). *Sri Lankan tea industry*. Sri Lanka: Author.

- Fairbanks, M., & Lindsay, S. (1997). *Plowing the sea: Nurturing the hidden sources of growth in the developing world*. Massachusetts : Harvard Business School Press.
- Fonseka, A.T. (1997). Strategic approach to marketing of Sri Lankan tea. *Sri Lankan Journal of Management*, 2 (2), 155-183.
- Hopkins, S., & Lewis, P.E.T. (1996). Competitiveness in Australian agriculture: a review. *Review of marketing and agricultural economics*, 64 (3), 309-317.
- International Tea Committee (1999). *Annual bulletin of statistics*. London: International Tea Committee.
- Kelegama, J.B., Gunaratne, N.W.H.D., Samaraweera, D.S.A., & Abeygunawardana, S.K. (1995). *Report of the presidential commission on the tea industry and trade*. Colombo: Government Publication Bureau.
- Klein, K.K., & Kerr, W.A. (1995). The globalization of agriculture: a view from the farm gate. *Canadian Journal of Agricultural Economics*, 43 (4), 5551-563.
- Leamer, E.E. (1995). *The heckscher-ohlin model in theory and practice*. Princeton studies in international finance, (No. 77). New Jersey : Dept. of Economics, Princeton University.
- Porter, M.E. (1998). *The competitive advantage of nations: With a new introduction (2nd Ed.)*. London : Macmillan Press Ltd.
- Rana, P.B. (1998). *Shifting revealed comparative advantage: Experiences of Asian and Pacific developing countries*, (Economics office report series, Report No. 42). Manila : Asian Development Bank.
- Simatupang, B. (1998). Association of the South East Asian Nations (ASEAN) Free Trade Area (AFTA): The changing environment and incentives in A.E.F. Jilberto & A. Mommen, (Eds.) *Regionalisation and globalisation in the modern world economy: Perspectives on the third world and transitional economies*, (pp. 307-328). London : Routledge.
- Song, L. (1996). *Changing global comparative advantage: Experience from Asia and the Pacific*. Australia : Addison Wesley Longman.
- Sri Lanka Tea Board (2000). *Annual report 1999*. Colombo : Author
- The Tea Research Institute of Ceylon (1967). A century of Ceylon tea 1867-1967. *The Tea Quarterly*, 38 (2), 90.
- United Nations Conference on Trade and Development (UNCTAD) (1982). *The marketing and processing of tea: Areas for international cooperation*. New York : United Nations Secretariat.
- Venugopal, D. (2000). Nilgiri tea in crisis: Causes consequences and possible solutions. Retrieved October 11, 2000 from <http://www.badaga.org>
- West D., & Vaughan, O. (1995). Globalization and the food and beverage processing industry. *Canadian Journal of Agricultural Economics*, 43 (4), 565-578.

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