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A COMPARATIVE STUDY ON THE QUALITY OF YOGHURT PREPARED FROM COW, BUFFALO AND GOAT MILK

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ABSTRACT

The present experiment was conducted to assess the quality of dahi (yoghurt) prepared from cow, goat and buffalo milk. Milk samples were collected from Bangladesh Agricultural University, Dairy Farm; Senbari and Gobiddochar, Mymensingh. Three types of dahi samples were analyzed during the experiment. The parameters used to monitor the quality of dahi samples were physical (smell and taste; body and consistency; color and texture), chemical (protein, fat, total solids, ash, acidity and pH) and microbiological (gram positive rods and cocci, total viable count, coliform and mould count). From the result of all parameters it was concluded that dahi prepared from cow milk is superior than dahi prepared from buffalo or goat milk. Considering all parameters from the nutritional point of view it was concluded that dahi made from buffalo and goat milk is also good and finally, it was suggested that dahi from cow, buffalo and goat milk is of equal value so long it is prepared maintaining strict hygienic conditions.

Key words: Dahi; Quality; Yoghurt; Milk

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INTRODUCTION

The main sources of milk in the world are cows. Buffaloes are the second largest source of milk supply in the world. In India, nearly half of the milk processed by the organized dairies comes from buffaloes.

Buffalo milk fat has less cholesterol and more tocopherol, which is a natural antioxidant. Buffalo milk is richer in calcium and phosphorus and lower in sodium and potassium than cow's milk. Goat milk is also richer in calcium, phosphorus & chlorine. Goat milk fat globules are smaller in size compare to cow & buffalo milk; that is why it is easily digestible especially for children & old man (Husain; 1987).

Milk is very nutritious and perhaps an indispensable food for human being. But in this era of industrialization, food habit of common people is changing. They prefer healthier, delicious foods to fresh raw foods. Hence, milk is converted to various milk products. Dahi or yoghurt is one of them. Dahi/Yoghurt is a popular fermented milk product known for its typical flavour, characteristic semi-solid consistency and high nutritive and therapeutic value. With the advent of health foods, there is a considerable increase in the popularity of yoghurt in all parts of the world. Of the milk production in India, about 7% is converted to dahi (Chakraborty, 1998), in Pakistan, 4% is converted to dahi (Cakraborty, 1998) and about 4% of the total milk produced in Bangladesh is used for the preparation of dahi (Mustafa, 1997).

Difference between Yoghurt and Dahi

Although yoghurt and dahi are cultured or fermented dairy products still there are little differences between those. Yoghurt is prepared by using the starter organisms *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in a proportion of 1:1, whereas dahi is prepared by using mixed culture of *Streptococcus lactis*, *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, *Streptococcus citrophilus*, *Lactobacillus plantarum* etc.

Types of dahi/ yoghurt

I. Sweet or Misti dahi/ Yoghurt: Sweet dahi is generally prepared from mixed culture of *Str. lactis*, *Str. thermophilus* and *Str. citrophilus*. Sugar was added at the rate of 8 to 10% during preparation.

II. Sour dahi/ Yoghurt: Sour dahi is made by seeding milk with a combination of *S. thermophilus* and *L. bulgaricus*.

III. Flavored dahi/ Yoghurt:

In modern fermented milks, especially yoghurt flavor is derived from fruit and other additives are added (Varnam and Sutherland, 1994).

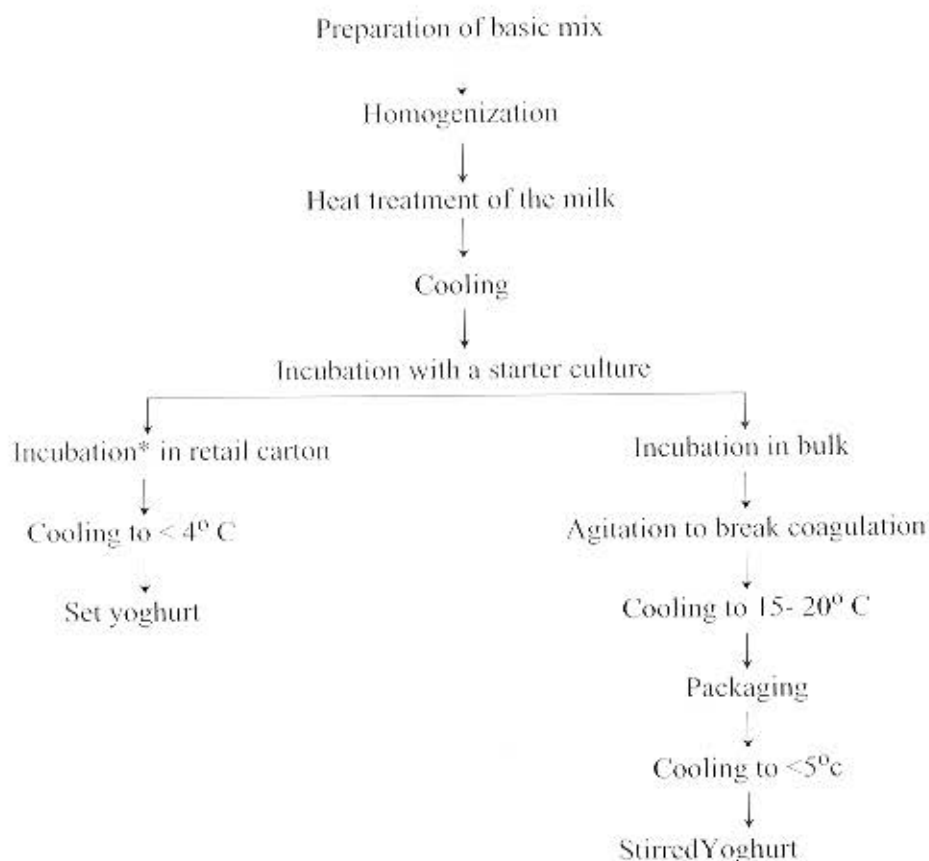
Composition of dahi:

Composition of plain dahi prepared from whole milk and skimmed milk is represented below:

Product	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Lactic Acid(%)	Ash (%)	Ca (%)	P (%)
Dahi (whole milk)	85-88	5-8	3.2-3.4	4.6-5.2	0.5-1.1	0.70-0.75	0.12-0.14	0.09-0.11
Dahi (skimmed milk)	90-91	0.05-0.10	3.3-3.5	4.7-5.30	0.5-1.0	0.70-0.75	0.12-0.14	0.09-0.11

Source: Laxminarayana et al. (1952)

A flow diagram for yoghurt making as per Robinson (1985) is show below:



(*Source and/or fruit (fruit flavors) can be added at this point)

Dahi is very nutritious dairy product. It has been demonstrated that fermented milk product like dahi is somewhat easily digestible than normal milk. Its demand is increasing day by day for its multipurpose health benefits such as improves intestinal health, which preventing constipation, diarrhoea and dysentery and also prevent gastrointestinal infections. It is based on the assumption that acid fermenting bacteria and lactose of milk are able to create conditions in the intestinal tract, which are unfavorable for the growth of putrefactive bacteria, and thereby prevents the formation of gas and a condition known as 'auto-intoxication'. It is also effective in lowering blood cholesterol, reduces coronary heart disease, breast and ovarian cancer (Munzur *et al.*, 2004). Immunity level also increased by dahi consumption (Kaic and Antonic, 1996). Dahi, especially misti dahi, is one of the most popular fermented milk products in Bangladesh. The typical Bangladeshi consumers always prefer dahi with sweetmeat.

Although it is very nutritious and popular food, the products available in the market lack quality and uniformity. That is why; a desirable standard for the manufacture of dahi should be established to maintain consumer's health.

Some research works have been done in different countries on the quality of dahi (yoghurt) prepared from cow and buffalo milk. But very limited works have been done on the quality of dahi made from goat milk. Hence, an attempt was made to judge the quality of dahi (yoghurt) prepared from cow, buffalo and goat milk. This experiment is carrying significance because in this country people have no idea about this type of fermented food product.

This food product can bring significant change in our national health. Moreover, the availability of data on cow, buffalo and goat milk dahi (yogurt) is scanty, so this experiment is very important for practical point of view. Therefore, the present study was undertaken to prepare acceptable quality of dahi (yoghurt) using different sources of milk to monitor the physical, chemical and microbiological quality of dahi (yoghurt) and also to compare the quality of dahi prepared from cow, buffalo and goat milk.

MATERIALS AND METHODS

Site and Period of Experiment

The experiment was conducted at the Dairy Technology and Microbiology Laboratory

of the Department of Dairy Science and Department of Animal Nutrition, Bangladesh Agricultural University, Mymensingh during the period from July to August 1999.

Collection of Milk Sample

Cow milk was collected from Bangladesh Agricultural University (BAU) Dairy Farm. Buffalo milk was collected from Senbari, Mymensingh and Goat milk was collected from Gobiddochar, Mymensingh.

Preparation of different types of dahi

After collecting the whole milk, dahi was prepared in the laboratory. At first milk was boiled up to boiling temperature. At the time of boiling sugar at the rate of 8 percent was added to the whole milk and continued boiling until the volume was reduced to 20 - 25%. Boiled milk was then cooled down to near 42°C and inoculated with 2 to 3 percent starter cultures collected from Dairy Science Laboratory.

After inoculation, warm milk was poured into plastic cups and kept at an incubation temperature of 37°C until complete coagulation. After complete coagulation (8-10 hours) titratable acidity percentage of the curd was measured. In this way three types of dahi (Cow, buffalo & goat) were prepared. The samples were then stored in a refrigerator at about 4°C for further analysis.

Analysis of dahi samples

After preparation of all types (cow, buffalo & goat) of dahi different physical, chemical and microbiological tests were conducted to investigate the quality of dahi samples.

Physical test

A panel of six experienced judges assessed different types of organoleptic parameters such as smell & taste, body & consistency, color & texture separately. The scorecard used for judging the sample is given in Table 1.

Table 1. Score card for judging dahi samples

Tests	Maximum points
Smell and Taste	50
Flavor	
Rancid	
Cooked	
Acid	
Bitter	
Flat	
Sharp sour	
Mouldy	
Body and consistency	30
Thick	
Thin	
Syneresis	
Gas	
Crack	
Color and texture	20
Light	
Deep	
Chuckled	
Greenish	
Soft and loose coagulum	
Gassy coagulum	
Lumpy-gritty	

Chemical analysis

To investigate the nutritional status of dahi following tests were conducted. These were acidity (%), fat (%), total solids (%), Protein (%), ash (%) and P^H . Total solids content of the different types of dahi were determined according to AOAC (1982). Fat percent was determined by Babcock method using the procedure described by Aggarwala and Sharma (1961). Acidity was determined by titrating with N/10 sodium hydroxide solution using the procedure of Aggarwala and Sharma (1961). Protein was determined by kjekdahal procedure (AOAC, 1982). Specific gravity test was performed by using Quevenne Lactometer, according to the method described by Aggarwala and Sharma (1961). P^H was measured with the help of P^H meter-215 (Ciba Corning Diagnostics Ltd. Sudhury, Suffolk, England Co 106 x D).

Micobiological tests

Different types of microbiological tests like, gram-positive cocci (%), gram-positive rods (%), total viable count/ml, coliform count/ml and mould count/ml were performed to know the microbiological status of the products. For determination of gram-positive cocci and gram-positive rods in dahi samples grams staining procedure was followed and for total viable count, standard plate count was done according to the method described in the "Standard method for the Examination of Dairy products", (American Public Health Association, 1967).

Data Analysis

Data obtained from collected and prepared samples were analyzed statistically using Complete Randomized Design (CRD) with one factor in MSTAT programme. The differences among sample means were compared by calculating Least Significant Difference (LSD) value (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Initial quality of Milk

It is mentioned earlier that milk samples were initially analyzed before preparation of dahi for getting idea about the quality of milk used in this experiment (Table 2). Acidity was 0.153 ± 0.004 , 0.188 ± 0.013 and 0.151 ± 0.008 percent in cow, buffalo and goat milk respectively. Acidity was higher in case of buffalo milk than cows and goat milk. Average specific gravity was 1.0295 ± 0.0012 , 1.0290 ± 0.0018 and 1.0299 ± 0.0020 in cow, buffalo and goat milk respectively. The average percentage of milk fat was 4.18 ± 0.26 , 7.83 ± 0.67 and 3.68 ± 0.46 in cow, buffalo and goat milk respectively. The fat percentage was higher in buffalo milk than cow and goat milk. The average percentage of milk protein was 3.71 ± 0.26 , 4.25 ± 0.37 and 3.33 ± 0.31 in cow, buffalo and goat milk respectively. The percentage of mean total solids contents was 12.16 ± 0.18 , 16.86 ± 0.99 and 11.83 ± 0.34 in cow, buffalo and goat milk respectively. It is to be noted that protein and total solids percentage was also higher in buffalo milk compared to cows and goat milk samples (Table 2).

Table 2. Initial Quality of milk Sample

SL. No.	Name of Samples	Acidity (%)	Specific Gravity	Fat (%)	Protein (%)	Total Solids (%)
1	Cow milk	0.153 $\pm$ 0.004	1.0295 $\pm$ 0.0012	4.18 $\pm$ 0.26	3.71 $\pm$ 0.26	12.16 $\pm$ 0.18
2	Buffalo milk	0.188 $\pm$ 0.013	1.0290 $\pm$ 0.0018	7.83 $\pm$ 0.67	4.25 $\pm$ 0.37	16.86 $\pm$ 0.99
3	Goat milk	0.151 $\pm$ 0.008	1.0299 $\pm$ 0.0020	3.68 $\pm$ 0.46	3.33 $\pm$ 0.31	11.83 $\pm$ 0.34

Quality of different dahi Samples

a) Smell & taste

Smell & taste score was the highest in case of dahi prepared from cow milk (45.50 ± 1.29) and the lowest for the dahi (38.75 ± 2.22) that prepared from goat milk (Table 3). The variation in smell and taste score of different dahi samples could be attributed due to different types of milk used in the present study. The result agrees with the findings of Duitschaever (1978) who reported that in his study 32% consumers gave preference for goat milk yoghurt and 68% preferred cow milk yoghurt.

b. Body and consistency

The mean value of body and consistency score for dahi prepared from cow, buffalo and goat milk were 25.00 ± 3.56 , 28.00 ± 2.16 and 23.75 ± 2.63 respectively (Table 3). Statistical analysis showed that there was no significant difference between the body and consistency score of different types of dahi samples. It was the highest in case buffalo milk (28.00 ± 2.16) and the lowest for goat milk (23.75 ± 2.63). Duitschaever (1978) reported that goat milk yoghurt was less viscous and less firm than that was made from cows milk. Venkateshaiah *et al.* (1996) reported that higher levels of fat and SNF in cow & buffalo milk improved the body and consistency score of cow and buffalo milk yoghurt. Bozanic *et al.* (1998) reported that yoghurt samples prepared from goat milk had a softer consistency and lower viscosity than those prepared from cow milk. The variation in body and consistency score of different dahi samples could be attributed due to differences in total solids in milk samples.

c. Colour and texture

The mean value of colour and texture score of dahi prepared from cow, buffalo and goat milk were 17.0 ± 1.83 , 15.5 ± 1.29 and 14.5 ± 1.29 respectively (Table 3). Statistical analysis showed that there was no significant difference between the colour and texture score of different types of dahi samples. Colour and texture score of cow milk dahi was

higher than other type of dahi samples that might be due to golden yellowish colour of cow milk. Total solids and fat content of milk samples had positive effects on colour and texture of dahi samples. Goat milk had lower content of fat and total solids; hence the colour and texture score was the lowest in goat milk dahi than other dahi samples. The result of the present study agrees with the findings of Pette and Lolkema (1950) who reported that if the total solids content of milk samples is low than the texture of dahi will be low.

Table 3. Average organoleptic taste of different Dahi samples

SL. No.	Name of Samples	Smell & taste score	Body and consistency	Color and texture	Overall
1	Cow milk	45.50 $\pm$ 1.29	25.00 $\pm$ 3.56	17.00 $\pm$ 1.83	87.50 $\pm$ 4.51
2	Buffalo milk	40.50 $\pm$ 2.52	28.00 $\pm$ 2.16	15.50 $\pm$ 1.29	84.00 $\pm$ 4.24
3	Goat mil k	38.75 $\pm$ 2.22	23.75 $\pm$ 2.63	14.50 $\pm$ 1.29	77.00 $\pm$ 4.24

Chemical parameters

Acidity (%)

The average percentage of acidity in the samples prepared from cow, buffalo and goat milk were 0.82 ± 0.04 , 0.74 ± 0.06 and 0.93 ± 0.03 respectively (Table 4). Statistical analysis showed that there were significant differences ($p < 0.001$) between the mean acidity values of different types of Dahi samples. Acidity was the highest for dahi made from goat milk (0.93 ± 0.03) whereas the value was the lowest for dahi made from buffalo milk (0.74 ± 0.06). Similar types of acidity were reported by some researchers (Laxminarayana et al. 1952) 0.81 to 2.45%, (Ray and Srinivasan, 1972) $0.84 \pm$ to 1.16%, (Ghosh and Rajorhia, 1987) 0.73 to 0.9% and (Sarkar et al., 1996) 0.36 to 1.22% respectively for cows milk dahi. The results also agree the reports of Cardoso et al (1991) who found 1% acidity in buffalo milk. Wide variation in the titratable acidity could be attributed due to different types of milk (Kharmbatta and Dastur, 1950; Reddy et al. (1987) & different buffering action of protein, citrates, lactase & phosphates etc (Jenness and Patton, 1959).

Fat %

The percentage of mean fat content of cow, buffalo and goat milk dahi were 5.82 ± 0.35 , 10.85 ± 0.86 and 5.16 ± 0.65 respectively (Table 4). Statistical analysis showed that fat content of different dahi samples differ significantly ($p < 0.001$). Maximum fat percent

was seen in buffalo milk dahi and the lowest in goat milk dahi. Akin *et al.* (1995) reported from an experiment that cow milk yoghurt contained 3.9% fat. In another experiment Manojit (1998) found that fat content of buffalo milk dahi was 8.08%.

Total solids (%)

The percentage of total solids content of cow, buffalo and goat milk dahi were 29.99 ± 1.64 , 40.73 ± 2.77 and 27.89 ± 1.27 respectively (Table 4). There was significant difference ($p < 0.001$) between the total solid content of different types of dahi samples. Average total solids content was the highest (40.73%) in buffalo milk dahi and the lowest in goat milk dahi (27.89%). Ali (1998) found that fresh cow milk yoghurt contained 29.06% total solids, which is similar to our experimental result. From another experiment Chakraborty (1998) observed that total solids content of buffalo dahi was 30.67%, which supports our experimental results.

Table 4. Chemical parameters of Dahi samples

SL. No.	Name of Samples	Acidity (%)	Fat (%)	Protein (%)	Total solids (%)	Ash (%)	pH
1	Dahi from Cow milk	0.82 ± 0.04	5.82 ± 0.35	4.58 ± 0.34	29.99 ± 1.64	0.809 ± 0.04	4.88 ± 0.20
2	Dahi from Buffalo milk	0.74 ± 0.06	10.85 ± 0.86	5.13 ± 0.17	40.73 ± 2.77	0.980 ± 0.06	5.01 ± 0.48
3	Dahi from Goat milk	0.93 ± 0.03	5.16 ± 0.65	4.00 ± 0.36	27.89 ± 1.27	0.784 ± 0.06	4.25 ± 0.06

Protein (%)

The average protein percentage of dahi prepared from cow, buffalo and goat milk were 4.58 ± 0.34 , 5.13 ± 0.17 and 4.00 ± 0.36 respectively (Table 4). Statistical analysis showed that there was significant difference ($p < 0.01$) within the protein content of different types of dahi samples. Maximum protein percent was seen in buffalo milk dahi (5.33) and the lowest in goat milk dahi (3.50). In case of cow milk dahi the result agreed with the findings of Chakraborty (1998) and Ali (1998) whom found that cow milk dahi contained 4.22 and 4.44% protein respectively. In case of buffalo milk dahi the result agreed with the findings of Chakraborty (1998) who found that percentage of protein of buffalo milk dahi was 5.1. In case of goat milk dahi the result agreed with the findings of El-Samragy and Samragy (1988) whom found that average percentage of protein of goat milk dahi was 3.80.

Ash (%)

The ash content of cow, buffalo and goat milk dahi was 0.809 ± 0.04 , 0.980 ± 0.06 and 0.784 ± 0.06 respectively (Table 4). Significance differences ($p < 0.01$) were found among those mean values. Maximum ash content was seen in buffalo milk dahi (1.017) and the lowest in goat milk dahi. In case of cow milk dahi the result agreed with the findings of Rahman (1998) who reported that cow milk dahi contained 0.825 ± 0.06 percent ash. In case of goat milk the result agreed with the work of El- Samragy and Samragy (1988) whom found that ash content of goat milk dahi were 0.818 ± 0.01 .

pH

The pH values of different dahi samples for cow, buffalo and goat milk dahi were 4.88 ± 0.20 , 5.01 ± 0.48 and 4.25 ± 0.06 respectively (Table 4). Statistical analysis showed that there was significant difference ($p < 0.01$) within the pH value of different dahi samples. In our experiment acidity of goat milk dahi was higher than cow and buffalo milk dahi that might be due to lower pH of goat milk than cow and buffalo milk. In case of cow milk dahi the result agreed with the findings of Rahman (1998) who found that average pH value of cow milk dahi were 4.47 ± 0.45 .

Microbiological parameters**Gram-positive cocci (%)**

The percentage of gram-positive cocci of cow, buffalo and goat milk dahi were 64.14 ± 4.33 , 67.85 ± 3.65 and 62.17 ± 5.78 respectively (Table 5). There was no significant difference between the values of different types of dahi samples. The highest value was found in case of buffalo milk & the lowest in goat milk dahi. The result agreed with the findings of Chakraborty (1998) who found that the percentage of gram-positive cocci of cow milk dahi was 66.00. Proper ratio of rods and cocci are generally important for preparing cultured dairy product to ensure better quality (Davis et al., 1971 and Driessen *et al.*, 1982).

Gram-positive Rods (%)

The average percentage of gram-positive rods in cow, buffalo and goat milk dahi were 35.86 ± 4.33 , 32.15 ± 3.65 and 37.83 ± 5.78 respectively (Table 5). There was no significant difference between the values of different types of dahi samples. Highest value was found in case of cow milk & the lowest in goat milk dahi. Our result agreed with the findings of Hasan (1970) who found that the gram-positive rods of cows milk dahi were

about 26%. The result agreed with the findings of Chakraborty (1998) who found that the percentage of gram-positive rods of cow milk dahi was 36.00.

Total viable count

The average total viable count per ml of dahi samples made from cow, buffalo and goat milk were 5.9 ± 0.03 , 6.0 ± 0.05 and 5.9 ± 0.05 (Log value) respectively (Table 5). Statistical analysis showed that significant differences ($p < 0.05$) were existed among the different dahi samples. Average the highest total viable count was recorded from buffalo milk dahi (6.0 ± 0.05) and the lowest from goat milk dahi (5.9 ± 0.05). The present investigation partially supported by the result of Adeyl (1998), who found that the total viable count per ml of laboratory made misti dahi samples were within the range of 6.2 to 6.3 (log value).

Table 5. Microbiological count in different Dahi samples (per/ml)

SL. No.	Name of Samples	Gram positive cocci (%)	Gram positive rod (%)	Total viable count (Log value)	Coliform count (Log value)	Mould count (Log value)
1	Dahi from Cow milk	64.14 ± 4.33	35.86 ± 4.33	5.88 ± 0.03	1.75 ± 1.20	1.445 ± 1.07
2	Dahi from Buffalo milk	67.85 ± 3.65	32.15 ± 3.65	6.00 ± 0.05	2.70 ± 0.21	1.889 ± 0.59
3	Dahi from Goat milk	62.17 ± 5.78	37.83 ± 5.78	5.86 ± 0.05	1.00 ± 1.15	2.064 ± 0.44

Coliform count

The average coliform count per ml of cow, buffalo and goat milk dahi were 1.75 ± 1.20 , 2.70 ± 0.21 and 1.00 ± 1.15 (log value) respectively (Table 5). The highest coliform count per ml was found in buffalo milk dahi (2.70 ± 0.21) and the lowest for goat milk dahi (1.00 ± 1.15). Statistically significant differences were found in respect of coliform count per ml of different dahi samples. Ghose and Rajorhia (1987) and Sarker *et al.* (1996) who found that coliform count per ml of laboratory made dahi was (440.660 ± 114.020), log value (2.64 ± 2.05) for cow milk dahi. The presences of coliform organisms in dahi samples indicate that contamination during its production and handling.

Mould and yeast count

Microscopic examination showed that average mould content per ml of cow, buffalo and goat milk dahi were 1.445 ± 1.07 , 1.889 ± 0.59 and 2.064 ± 0.44 (log value) respectively (Table 5). The highest mould count per ml was (2.064 ± 0.44) found in goat milk dahi and the lowest in cow milk dahi (1.445 ± 1.07). No significant differences were found among the different dahi samples.

No yeast was found in our experiment. It indicates that the quality of dahi made from cow, buffalo and goat milk were good.

CONCLUSION

Judging from the results of all parameters (physical, chemical and microbiological) it could be advocated that dahi made from cow milk was the best among the dahi made from cow, buffalo and goat milk. However, the second and third position was adorned by dahi made from buffalo and goat milk respectively. Although buffalo milk dahi and goat milk dahi ranked second and third positions respectively, their nutrient contents were excellent.

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AN ECONOMIC STUDY ON GOAT DISEASES IN SOME SELECTED AREAS OF BANGLADESH

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ABSTRACT

This study was an attempt to analyze the prevalence of goat diseases and financial loss incurred therein. For this purpose, a total of 250 goat raising farms were investigated. Results showed that infection in goat, treatment of diseased goat and mortality of goat differed significantly ($p < 0.01$) with areas. The goats were mostly infected by Peste des Petits Ruminants (PPR), Goat pox, Bloat/Tympany, Parasitic diseases, Haemorrhagic Septicemia (H.S) and Malnutrition. The morbidity and mortality of goats were found 24% and 11%, respectively. The highest mortality (86%) was due to Peste des Petits Ruminants (PPR). Treatment cost per diseased goat was Tk. 46. Financial loss due to death of goat per affected farm and all farms were Tk. 881 and Tk. 338, respectively. Extrapolating 11% mortality on 12.92 million goat population, the annual financial loss was calculated to Tk. 870 million.

Key Words : Peste des petits Ruminants (PPR), Mortality financial loss.

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INTRODUCTION

Goat plays an important role by producing meat, milk and skins in the national economy of Bangladesh. The share of goat meat and milk to the total production of ruminant meat and milk is 23% and 4.2%, respectively (Razzaque, 2002). The contribution of goats to the national economy is worth Tk 500 crores per year (MOFL, 2002). It is to be mentioned here that during the late eighties and early nineties goat population increased at the rate of 3% and 7.89% per annum, which was faster than that of other species of livestock (Alam, 1995). But the goat production decreased by 5.42% in 1996 (BBS, 1999) compared to 1983-1984. This decrease in goat production was due to the death of goats by various diseases, especially due to PPR epidemic in 1993-94. A study conducted in Mymensingh district in 1981 on 100 households showed that 84 goats were attacked by some diseases and 76% of the diseased goats died and most of them were below 6 months of age. The mortality rate of goats was calculated at 10.7% and loss due to death of goats was estimated to Tk. 64 per farm (Jabbar and Green, 1983). Another study conducted in Patuakhali district showed that out of 57 goats 13 goats were attacked by various diseases and 6 goats died causing 46% mortality (Hossain *et al.*, 1996). The loss due to death of goats was estimated at Tk. 2100. So, for increasing goat production control and preventive measures of goat diseases are very important. Moreover, recently government launched a national programme on increasing goat production for reducing poverty. Therefore, to achieve the national objective successfully, this study was undertaken with the following objectives:

- i. To know the prevalence of diseases and goat mortality by area,
- ii. To estimate the financial loss due to goat diseases (death loss and treatment loss) area and
- iii. To identify the nature of treatment and extent of veterinary services received by the goat raising farmers in those areas.

MATERIALS AND METHODS

For this study, 5 districts namely, Bogra, Comilla, Dinajpur, Jessore and Mymensingh were selected. A survey was conducted on 250 goat-raising farm households taking 50 from each of the selected districts. Five villages from each of the

selected district were selected considering concentration of goat population. Data were collected randomly from 10 goat raising households from each of the selected villages. Total number of goats reared by the selected households was 1264 with an average of 5.06 per household. Data for the year 2001 were collected using pre-designed and pre-tested survey schedule by a single visit. A second visit was made to some households for collecting missing information. The survey was conducted during January 2002 to April 2002. Microsoft spreadsheet was used to analyze data. Chi-square test was carried out for better precision of data to determine the prevalence of goat diseases and goat mortality.

RESULTS AND DISCUSSION

Socio-economic characteristics of goat raising farmers

Socio-economic characteristics of goat raising farmers are presented in Table 1. The average size of landholdings per farm was 1.17 acres varying from 0.52 acres in Bogra to 1.90 acres in Dinajpur. The distribution of land is skewed irrespective of locations. The average size of family per household was 5.51, which seemed to be slightly higher than the national average of 4.8 per household (Population Census, 2001). The average family members per household were 4.78, 6.30, 5.08, 5.64 and 5.72 for Bogra, Comilla, Dinajpur, Jessore and Mymensingh, respectively. Occupation of heads of households were agriculture (52%), followed by business (16%), service (14%), day-labourers (14%) and rickshaw/van pulling (4%).

Table-1. Size of holdings and ownership of goat

Areas	No. of farms	Land holdings (hectare)	Average No. of goat/farm	No. of family members	Main occupation (percentage)				
					Agriculture	Service	Business	Day labourers	Rickshaw/ Van pullar
Bogra	50	0.52±0.08	5.32±0.05	4.78±0.25	46.00	4.00	10.00	34.00	6.00
Comilla	50	0.84±0.09	5.52±0.03	6.30±0.30	82.00	4.00	12.00	2.00	-
Dinajpur	50	1.90±0.23	5.16±0.04	5.08±0.29	34.00	26.00	38.00	2.00	-
Jessore	50	1.69±0.22	5.82±0.07	5.64±0.30	66.00	20.00	10.00	2.00	2.00
Mymensingh	50	0.90±0.21	3.46±0.04	5.72±0.38	32.00	14.00	12.00	30.00	12.00
All areas	250	1.17±0.09	5.06±0.01	5.51±0.14	52.00	13.60	16.40	14.00	4.00

Distribution of goat by area and age

The age composition of goat-herd is shown in Table 2. From the age group distribution of goat herd it can be observed that for all the areas proportion of kids of 1 day to six months of age was the highest (37.26%) followed by productive age group of 1 year to 2 years (34.10%), growing age of 6 months to 1 year (15.51%), adult goats of 2 years to 3 years (11.87%) and goats of above 3 years old (1.27%). It was found that goats in the age of 1 day to 6 months, 6 months to 1 year, 2 years to 3 years and above 3 years differed significantly ($\chi^2=46.01$, $p<0.01$; $\chi^2=31.73$, $p<0.01$; $\chi^2=27.95$; $p<0.01$ and $\chi^2=15.54$; $p<0.01$, respectively) with areas. No significant difference was observed for the goats of productive age group of 1 year to 2 years ($\chi^2=2.14$; $p>0.05$) with areas. The average number of goat per farm was 5.06. The distribution of goats was found more or less similar in all the areas.

Table 2. Distribution of goat by area and age

Areas	1 day-6 months	Above 6 months - 1 year	Above 1 year-2 years	Above 2 year -3 years	Above 3 years	Total	Average no. of goat of goat per farm
Bogra	126 (47.37)	23 (8.65)	101 (37.97)	16 (6.02)	0 (0.00)	266 (21.04)	5.32 $\pm$ 0.05
Comilla	128 (46.38)	23 (8.33)	90 (32.61)	26 (9.42)	9 (3.26)	276 (21.84)	5.52 $\pm$ 0.03
Dinajpur	83 (32.17)	50 (19.38)	89 (34.50)	36 (13.95)	0 (0.00)	258 (20.41)	5.16 $\pm$ 0.04
Jessore	70 (24.05)	63 (21.65)	97 (33.33)	57 (19.59)	4 (1.37)	291 (23.02)	5.82 $\pm$ 0.07
Mymensingh	64 (36.99)	37 (21.39)	54 (31.21)	15 (8.67)	3 (1.73)	173 (13.69)	3.46 $\pm$ 0.04
All area	471 (37.26)	196 (15.51)	431 (34.10)	150 (11.87)	16 (1.27)	1264 (100)	5.06 $\pm$ 0.01
χ^2 values*	46.01	31.73	2.14	27.95	15.54		
Significance	$p < 0.01$	$p < 0.01$	$p > 0.05$	$p < 0.01$	$p < 0.01$		

Figures in parentheses are the percentages to respective area total.

* χ^2 was estimated from absolute numbers and not from percentages

Prevalence of goat diseases by areas

Sixty-two per cent of the sample households reported the occurrence of diseases in their goat-herd (Table-3). Percentage of households with diseased goats were 66, 70, 82, 64 and 28 in Bogra, Comilla, Dinajpur, Jessore and Mymensingh, respectively. Farms reported occurrence of diseases in their goat-herd differ significantly ($\chi^2=34.80$; $p<0.01$) with areas. The overall prevalence of goat diseases was found 24%. Prevalence of goat diseases was the highest in Jessore (39.86%) followed by Dinajpur (27.91%), Comilla (20.65%), Bogra (17.67%) and was Mymensingh (8.09%). It was found that infection in goat differed significantly ($\chi^2=73.38$; $p<0.01$) with areas. Of the infected goats about 84% were treated. Treatment of diseased goats was the highest in Mymensingh (92.86%) followed by Dinajpur (91.67%), Jessore (91.38%), Bogra (70.21%) and Comilla (68.42%). Chi-square values showed that the treatment of diseased goat differed significantly ($\chi^2=24.77$; $p<0.01$) with areas. A total of 140 goats died in different diseases. Fatality rate was found the highest in Mymensingh (85.71%), followed by Bogra (51.06%), Comilla (47.37%), Dinajpur (43.06%) and Jessore (39.66%) and it differed significantly ($\chi^2=11.55$; $p<0.01$) with areas. The overall mortality rate of goat was 11%. It was 9.02%, 9.78%, 12.02%, 15.81% and 6.94% for Bogra, Comilla, Dinajpur, Jessore and Mymensingh, respectively. Chi-square value showed that the area had significant effect ($\chi^2=11.46$; $p<0.01$) on mortality of goat (Table-3).

Table 3. Prevalence of diseases in different study areas

Areas	Number of goat reared	Farms reported diseases of goat	No. of goat infected	Number of infected goat treated	Fatality rate	Mortality of goat (%)
Bogra	266 (21.04)	33 (66)	47 (17.67)	33 (70.21)	24 (51.06)	9.02
Comilla	276 (21.84)	35 (70)	57 (20.65)	39 (68.42)	27 (47.37)	9.78
Dinajpur	258 (20.41)	41 (82)	72 (27.91)	66 (91.67)	31 (43.06)	12.02
Jessore	291 (23.02)	32 (64)	116 (39.86)	106 (91.38)	46 (39.66)	15.81
Mymensingh	173 (13.69)	14 (28)	14 (8.09)	13 (92.86)	12 (85.71)	6.94
All area	1264 (100)	155 (62)	306 (24.21)	257 (83.99)	140 (45.75)	11.08
χ^2 values*	-	34.80	73.38	24.77	11.55	11.46
Significance	-	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$

Figures in parentheses are the percentages to the respective area total.

* χ^2 was estimated from absolute numbers and not from percentages

Prevalence of diseases by age of goat

Prevalence of diseases by age of goat is presented in Table 4. The table shows that morbidity was 15%, 45%, 25%, 23% and 31% for goats of 1 day-6 months, 6 months-1 year, 1 year-2 years, 2 years-3 years and above 3 years of age, respectively with an average of 24% for all groups. Results showed that *morbidity* differed significantly ($\chi^2=68.81$; $p<0.01$ with age group. The overall fatality rate was 45.75%. Fatality rate was found the highest for kids under 6 months of age (100%) followed by goats of above 3 years (60%) and goats of 1-2 years of age (18.52%). Fatality rate of goat differed significantly ($\chi^2=118.52$; $p<0.01$) with age of goats. Kid *morbidity* is more or less same with that reported by Jabber *et al.* (1983) and Honhold (2001). The goat mortality varied from 5% to 19 % across the age group and overall goat mortality was 11%. This result is also similar to Jabber *et al.* (1983). Mortality of goat differed significantly ($\chi^2=34.65$; $p<0.01$) with age of goats. The age group proportional mortality rate (AGPMR) showed that goat mortality decreased with the increase in age. The AGPMR was the highest (50%) for kids of 1 day - 6 months old followed by growing age (24%) of 6 months-1 year old, (14%) for 1-2 years, (9%) for 2-3 years and (2%) in older age group of above 3 years. Honhold (2001) observed similar trend in his study.

Table 4. Prevalence of diseases by age of goat

Age group	Total no. of goats	Morbidity	Fatality rate	Mortality	AGPMR* %
0-6 months	471 (37.26)	70 (14.86)	70 (100)	70 (14.86)	50.00
Above 6 months-1 year	196 (15.51)	88 (44.90)	34 (38.64)	34 (17.35)	24.29
Above 1 year-2 years	431 (34.09)	108 (25.06)	20 (18.52)	20 (4.64)	14.28
Above 2 year-3 years	150 (11.88)	35 (23.33)	13 (37.14)	13 (8.67)	9.29
Above 3 years	16 (1.26)	5 (31.25)	3 (60.00)	3 (18.75)	2.14
All groups	1264 (100)	306 (24.21)	140 (45.75)	140 (11.08)	100
χ^2 values*		68.81	118.52	34.65	
Significance		$p<0.01$	$p<0.01$	$p<0.01$	

Figures in parentheses are the percentages to the respective age total.

* AGPMR: Age group proportional mortality rate, i.e., death specific age group in a year per total deaths in the same year, expressed per 100 (Jabbar and Green, 1983).

** χ^2 was estimated from absolute numbers and not from percentages

Death of goat by area and age

Death of goat by area and age is shown in Table 5. It can be seen from the table that death of goat decreased with the increase in age. Death of goat was the highest (50%) for 1 day-6 months old goat followed by 6 months-1 year (24.29%), 1 year -2 years (14.29%), 2 years -3 years (9.29%) and above 3 years old goat (2.14%). It was found that death of goat differed significantly ($\chi^2 = 22.11$; $p < 0.01$, $\chi^2 = 16.78$; $p < 0.01$) with areas for 1 day-6 months and 6 months - 1 year old goats but no significant effect was observed for death of goats for 1 year -2 years, 2 years -3 years and above 3 years old goat ($\chi^2 = 3.78$, $P > 0.05$; $\chi^2 = 5.97$, $P > 0.05$; $\chi^2 = 2.84$, $P > 0.05$) with areas.

Table 5. Death of goats by area and age

Areas	1 day-6months	Above 6 months-1year	Above 1 year-2years	Above 2 year-3 years	Above 3 years.	Total
Bogra	16 (66.67)	4 (16.67)	3 (12.50)	1 (4.17)	0 (0.00)	24 (100)
Comilla	20 (74.07)	2 (7.41)	2 (7.41)	2 (7.41)	1 (3.70)	27 (100)
Dinajpur	18 (58.06)	8 (25.81)	3 (9.68)	2 (6.45)	0 (0.00)	31 (100)
Jessore	14 (30.43)	12 (26.09)	10 (21.74)	8 (17.39)	2 (4.35)	46 (100)
Mymensingh	2 (16.67)	8 (66.67)	2 (16.67)	0 (0.00)	0 (0.00)	12 (100)
All area	70 (50.00)	34 (24.29)	20 (14.29)	13 (9.29)	3 (2.14)	140 (100)
χ^2 values*	22.11	16.78	3.78	5.97	2.84	
Significance	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P > 0.05$	$P > 0.05$	

Figures in parentheses are the percentages to the respective area total

* χ^2 was estimated from absolute numbers and not from percentages

Severity of diseases

Prevalence of various diseases are the major constraints to goat production. Diseases cause death to goats or reduce productivity, which reduce the income of the goat raisers in one way or other. The major goat diseases reported by the farmers were Peste des Petits Ruminants (PPR), malnutrition, parasitic diseases, goat pox, bloat/tympany and Haemorrhagic Septicemia (H.S). It revealed from Table 6 that Peste des Petits Ruminants (PPR) caused the highest mortality (86%) followed by malnutrition (9%), parasitic diseases (2%), goat pox (1%), bloat/tympany (1%) and H. S. (1%). It revealed that the highest goat mortality was due to PPR which badly affected goat raisers particularly, small and landless farmers who reared about 85% of goats. Mortality of goat by various diseases did not differ significantly with areas.

Table 6. Disease-wise mortality rate of goat by area

Areas	No. of goat died	Mortality of goat (%)					
		PPR	Malnutrition	Parasitic Disease	Goat Pox	Bloat/Tympany	H. S.
Bogra	24 (17.14)	18 (75.00)	4 (16.67)	2 (8.33)	- (0.00)	- (0.00)	- (0.00)
Comilla	27 (19.29)	22 (81.48)	4 (14.81)	- (0.00)	1 (3.70)	- (0.00)	- (0.00)
Dinajpur	31 (22.14)	25 (80.65)	4 (12.90)	1 (3.23)	1 (3.23)	- (0.00)	- (0.00)
Jessore	46 (32.86)	45 (97.83)	- (0.00)	- (0.00)	- (0.00)	- (0.00)	1 (2.17)
Mymensingh	12 (8.57)	10 (83.33)	- (0.00)	- (0.00)	- (0.00)	2 (16.67)	- (0.00)
All farms	140 (100)	120 (85.71)	12 (8.57)	3 (2.14)	2 (1.43)	2 (1.43)	1 (0.71)
χ^2 values*		8.81	8.94	6.16	2.72	1.86	1.97
Significance		p>0.05	p>0.05	p>0.05	p>0.05	p>0.05	

Figures in parentheses are the percentages to the respective area total

* χ^2 was estimated from absolute numbers and not from percentages

Cost of treatment of diseased goat

During the survey period, a total of 360 goats were attacked by various diseases. Of the diseased goats, 84% were treated. The average cost of treatment per goat was Tk. 46.30. Of the total cost, 85% and 15% were incurred for medicine and fees, respectively. The cost of treatment was found the highest in Mymensingh (Tk. 63.00) followed by Jessore (Tk. 61.16), Dinajpur (36.36), Comilla (30.92) and Bogra (30.61) (Table 7). No farms reported to vaccinate their goats against any diseases during the survey period in any area.

Financial loss due to mortality of goat

The average loss per farm due to mortality of goats in the reference year was estimated to Tk. 338 (Table 8). In estimating loss due to goat mortality, only direct financial loss has been calculated. This loss was the highest for farms in Jessore (Tk. 716) followed by Dinajpur (Tk. 368), Comilla (Tk. 243), Bogra (Tk. 201) and Mymensingh (Tk. 164). The average unit price of goat died was estimated to Tk. 604. Average loss to the affected farms was Tk. 881. This loss was Tk. 479, Tk. 528, Tk. 736 and Tk. 2106 for Bogra, Comilla, Dinajpur, Jessore and Mymensingh, respectively. Based on goat mortality of 11%, the calculated loss due to death of goats stood at Tk. 870 million per year. For the long run the losses would be manifolds.

Table 7. Cost of treatment of diseased goat

Areas	Number of goat infected	Number of infected goat treated	Cost of treatment per goat		
			Medicine	Fee	Total
Bogra	47 (15.36)	33 (12.84)	24.70	5.91	30.61
Comilla	57 (18.63)	39 (15.18)	24.51	6.41	30.92
Dinajpur	72 (23.53)	66 (25.68)	25.38	10.98	36.36
Jessore	116 (37.91)	106 (41.25)	55.95	5.21	61.16
Mymensingh	14 (4.58)	13 (5.06)	63.00	0.00	63.00
All farms	306 (100)	257 (100)	39.40	6.90	46.30

Figures in parentheses are the percentages to the respective area total

Table 8. Financial loss due to mortality of goats

Areas	No. of affected farms	Number of goat died	Total loss (Tk.)*	Price/unit of dead goat **	Loss/ affected farms***	Loss for all farms****
Bogra	21	24	10050.00	418.75	478.57	201.00
Comilla	23	27	12150.00	450.00	528.26	243.00
Dinajpur	25	31	18400.00	593.55	736.00	368.00
Jessore	17	46	35814.00	778.57	2106.71	716.28
Mymensingh	10	12	8186.00	682.14	818.60	163.72
All farms	96	140	84600.00	604.29	881.25	338.40

It was calculated by estimating the value of goats died in each area.

** It was calculated by estimating the total value of goat died dividing by number of goat died in each area.

*** It was calculated by estimating the total value of goat died dividing by number of affected farms in each area.

**** It includes loss due to death of goat for both affected and non-affected farms in each area.

Availability of veterinary services

The farmers were asked about the veterinary services available to them. It revealed from Table 9 that 79% of the farmers had access to veterinary facilities. Of the veterinary facilities, farms in Dinajpur had the highest access (90%) followed by Jessore (80%), Mymensingh (78%), Comilla (74%) and Bogra (72%). The access was found higher in areas near to the veterinary hospitals and lower in the distant villages.

Table 9. Facilities of veterinary services

Areas	Access to veterinary hospital (% of respondents)
Bogra	72
Comilla	74
Dinajpur	90
Jessore	80
Mymensingh	78
All farms	78.8

Types of veterinary services

The types of veterinary services received by the farmers were analyzed and presented in Table 10. It was found that 51% of the farmers received prescription only, 29% goat raisers received treatment with medicine and about 20% reported that doctors/veterinary field staffs were available on call.

Table 10. Types of veterinary services

Veterinary services	Percentage of respondents					All area
	Bogra	Comilla	Dinajpur	Jessore	Mymensingh	
Only prescription	55.56	54.05	48.89	45.00	53.85	51.27
Treatment with medicine	33.33	24.32	28.89	25.00	33.33	28.93
Doctors/Veterinary field staff available on call	11.11	21.62	22.22	30.00	12.82	19.80

CONCLUSION

Goat is vulnerable to various diseases, which badly affect the economy of farmers who rear goats. Among the goat diseases, Peste des Petits Ruminants (PPR) was found the most fatal and a great menace to goat production. But mortality by various diseases did not differ significantly with areas. In 51% cases veterinary facilities were limited with prescription only. Therefore, veterinary facilities need to be enhanced and disease control measures should be strengthened for profitable goat production.

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MULTILOCATION YIELD TRIAL OF AMERICAN COTTON (*Gossypium hirsutum*)

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ABSTRACT

Performances of one advanced line encoded SR-05 with three other existing Cotton Development Board(CDB) varieties namely CB-1, CB-5 and CB-9 were investigated at four SDB research stations of Rangpur, Gazipur, Dinajpur and Jessore during 2004-2005. Significant variations among the line and varieties were observed for number of vegetative branches per plant, node number of first fruiting branches, days to first flowering, days to first boll split and seed cotton/boll weight. But plant count at harvest, primary fruiting branches, secondary fruiting branches, number of bolls per plant, plant height at harvest and seed cotton yield did not show any significant difference. There was a significant difference among the locations for seed cotton yield. SR-05 produced the highest seed cotton yield (3t/ha) at Sadarpur farm, Dinajpur; the second highest was produced at Sreepur farm, Gazipur (2334 kg/ha) and the lowest at Mahiganj farm, Rangpur (1463 kg/ha). This line also produced the highest seed cotton/ boll (5.7g), and CB-5 the lowest (4.9g). The tested line SR-05 showed 0.53% more seed cotton yield than the best check CB-9. In case of lint production SR-05 showed 3.34% more lint than CB-9. Superior performance of SR-05 was mainly due to its higher yield of seed cotton /boll.

Key words : Advanced line, Existing variety, Location, Seed cotton / boll, GOT, Seed index.

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INTRODUCTION

Cotton is a very sensitive crop. Its yield performance is influenced by many genetic and environmental factors. Yield variation in cotton was observed from variety to variety, location to location and with variety x location interactions. To develop high yielding cotton variety, Sreepur cotton farm developed 7 cotton strains from crosses under variety development programme since 1993 and SR-05 is one of them. This advance line was primarily evaluated in 2003-2004 through preliminary evaluation trial in 4 locations of Cotton Development Board (CDB) research farm at Rangpur, Gazipur, Dinajpur and Jessore. The potential advanced line SR-05 was obtained from the performance of preliminary yield trial.

High yield and quality are obtained by the optimum combination of boll weight and boll number (Tan, C. S. 1993). The fundamental way to realize the target of high yield and good quality was to regulate the time of flowering and boll position to coincide with the optimum period under the local climatic and ecological conditions. Boll size, boll wt. and fibre properties were positively correlated with flowering date and boll retention (Fan, Z. J. et al., 1989). Thomson, et al., (1987) showed that, under the light spray regime, against *Heliothis*, genotypes with the okra leaf and / or nectariless mutant genes had higher yields than the normal, while genotypes with glabrous leaf and / or frego bract had lower yields than the normal. Okra leaf, a deeply divided and reduced leaf form, enhances earliness, reduces boll rot and provides resistance to boll weevil (Jones, 1982).

So, the study of Advance Yield Trial (AYT) was aimed to test the yield and quality performance of that advanced line by comparing the agronomic and ginning characteristics with the existing CDB varieties as control.

MATERIALS AND METHODS

The experiment was laid out at each of the four CDB farms, i.e., Rangpur, Gazipur, Dinajpur and Jessore. One advance line (SR-05) and three existing varieties (CB-1, CB-9 and CB-5) were included in the study. Seed sowing started from mid July to last week of July in different locations. Experiment in all locations was done in Randomized Complete Block Design (RCBD) with four replications. The unit plot size was 10m x 5.4m (6 rows). Data were recorded from the middle four rows (10m x 3.6m) from every unit plot in order to avoid border effects. The plant spacing was 90 cm between the lines and 60 cm between the plants. Three or four seeds were sown per hill during planting, but after final thinning one seedling per hill was allowed to grows. If a stand was missing, two plants were left at once to the adjacent stands. Green manuring and decomposed cowdung were applied before final land preparation. All chemical fertilizer

such as TSP, MP, Gypsum, Borax and Urea were applied at the rate of 175, 125, 100, 10 and 50 respectively during final land preparation as basal dose. Urea applied at 3 times as side dressing with 3, 6 and 9 weeks after planting @ 50 kg/ha and also 50 kg/ha MP applied at 2nd side dressing.

Ten plants were chosen at random from each plot to observe number of vegetative branches, number of primary fruiting branches, number of secondary fruiting branches, node number, of first fruiting branches (N.F.B.), plant height at harvest and average weight of seed cotton / boll. Days to first flower and days to first boll split were recorded when 50% plants bore an flower and open boll, respectively. Recommended agronomic practices were followed during the period of trial. Analysis of variance was performed for all characters according to Zaman, et al., (1982).

RESULTS AND DISCUSSION

Mean performances of the line and varieties for agronomic characteristics are presented in Table 1. Seed cotton yield of different lines and varieties in different locations are given in Table 2, where as average seed and lint characteristics of tested line and varieties are given in Table 3.

Significant variations among the lines and varieties for number of vegetative branches per plant, node number of first fruiting branches (N.F.B), days to first flowering, days to first boll split, and single boll weight were observed. But some characters such as plant count at harvest, primary fruiting branches, secondary fruiting branches, number of bolls per plant, plant height at harvest and seed cotton yield did not show any significant difference.

In case of number of vegetative branches per plant, SR-05 showed the highest number (3.09) and CB-1 showed the lowest (2.24). In case of node number of first fruiting branches per plant, CB-5 the highest number (6.99) and CB-1 the lowest number (5.93).

In case of days to first flowering, SR-05 showed earliness for flowering (47days) and CB-5 was found late 55days (Table 1). On the other hand, in case of days to first boll split, CB-1 and SR-05 showed earliness in boll split 111 and 112days, respectively and CB-5 was found late (123 days)

In case of average weight of seed cotton/ boll SR-05 produced the highest (5.7g) and CB-5 produced the lowest (4.9g). The highest average weight of seed cotton/ boll (5.7g) enhanced the highest seed cotton yield (Table 1), which was in agreement with that of Fan, et al.,1989.

Plant height at harvest were not significant for varieties in this trial (Table 1). The shortest plant was found in CB-9 (103cm) and the tallest plant was found in CB-9 (110cm).

Table 1. Mean performances of the varieties / line for different agronomic characteristics of AYT

Variety /line	Plant count at harvest /36m ²	No. of vegetative branches plant	No. of primary fruiting branch plant	No. of secondary fruiting branches plant	N.F.B.	Days to 1 st flower	Days to 1 st boll split	No. of bolls/ plant	Average weight of seed cotton/ boll (g)	Plant height at harvest (cm)	Seed cotton yield	
											(Kg/ha)	As% of CB-9
SR-05	74	3.09	15.25	24.05	6.13	47	112	24.60	5.7	106	2108.18	100.53
CB-1	74	2.24	16.08	17.79	5.93	50	111	26.19	5.1	110	2105.01	100.38
CB-9	74	2.84	15.48	19.48	6.40	51	122	26.67	5.3	103	2097.02	100.00
CB-5	72	2.90	16.05	17.72	6.99	55	123	24.06	4.9	105	1829.76	87.26
CV (%)	3.30	13.41	8.20	42.92	5.36	3.55	5.08	15.95	4.88	5.49	15.47	-
LSD at 5 %	NS	0.59	NS	NS	0.55	2.87	9.51	NS	0.41	NS	NS	-

* NS – Not Significant

Yield of seed cotton did not show any significant difference for varieties, line (Table 1). The mean performance of seed cotton yield showed that SR-05 produced 0.53% yield more than the control variety CB-9, where CB-5 produced the lowest (Table 1). SR-05 was found superior for seed cotton yield. But different locations showed a great significant difference for seed cotton yield (Table 2). In Sadarpur farm, Dinajpur, SR-05 produced the highest seed cotton yield (3000 kg/ha); the second highest was produced at Sreepur farm, Gazipur (2334 kg/ha), the third position was for Jagadishpur farm, Jessore (1635.37 kg/ha) and the lowest was produced at Mahiganj farm, Rangpur (1463.33 kg/ha). Heavy shower during September hampered the plant growth at Sreepur farm, Gazipur. In case of Rangpur and Jagadishpur farm, October disaster affected the yield of seed cotton due to dropping of lower bolls.

In case of ginning outturn (G.O.T), the highest was found in CB-5 (41.08%), Whereas second highest was from in CB-1 (39.21%). The lowest was found in CB-9 (33.95%). The line SR-05 produced the second lowest (34.90%) (Table 3).

But in case of lint yield, the highest yield of lint was found in CB-1 (825.37kg/ha). The lowest yield of lint was found in CB-9 (711.94kg/ha). The line SR-05 produced 3.34% more lint than the check varieties CB-9.

In case of seed index, the highest seed index was found in CB-9 (11.99g). The lowest seed index was found in CB-5 (9.40g). The second highest was produced in SR-05 (10.53g) (Table 3).

In case of lint index, the highest lint index was found in CB-5 (6.32). The lowest lint index was found in CB-9 (5.71) (Table 3). Highest seed index was produced from the lowest lint index (Table 3).

CB-5 and CB-9 were pubescent and SR-05 and CB-1 were glabrous. Only SR-05 showed okra leaf having frego bract among the four genotypes.

Table 2. Seed cotton yield (kg/ha) of different varieties /lines in different locations

Variety / line	Locations				Mean Yield (kg/ha)
	Rangpur	Sreepur	Sadarpur	Jagadishpur	
SR-05	1463.33	2334.02	3000.00	1635.37	2108.18
CB-1	1861.11	2222.85	2691.67	1644.39	2105.01
CB-9	1788.14	2662.47	2394.44	1543.02	2097.02
CB-5	1774.30	2344.08	1719.44	1481.20	1829.76
C.V. (%)	-	21.08	17.19	21.08	-
L.S.D. (.05)	-	602.69	674.24	602.69	-

CONCLUSION

The line SR-05 showed the highest seed cotton yield (2108.18 kg/ha) as well as average weight of seed cotton/ boll (5.7g). Though seed cotton yield could not show any significant difference among the varieties, but seed cotton yield showed significant differences for locations. Though the tested line SR-05 did not give 10% more yield than CB-9 but to its okra leaf, frego bract, high yield potentiality, further investigation is needed.

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Table 3. Average lint yield and lint characteristics of different varieties / lines of AYT

Variety / line	Lint yield		GOT (%)	Seed Index (g)	Lint Index
	(kg / ha)	As % of CB-9			
SR-05	735.75	103.34	34.90	10.53	5.73
CB-1	825.37	115.93	39.21	9.46	5.85
CB-9	711.94	100.00	33.95	11.99	5.71
CB-5	751.67	105.58	41.08	9.40	6.32

ASSESSMENT OF RESISTANCE IN *Aphis Gossypii* TO PYRETHROIDS

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ABSTRACT

A study was carried out in the Integrated Approach to Crop Research (IACR)- Rothamsted, Harpenden, Hertfordshire, England during June, 2001 to October, 2001 to assess the resistance of Aphis gossypii to Pyrethroids. Two clones of A. gossypii (clone 171B of UK origin and clone Adana of Turkey origin) reared and treated with Cypermethrin, Bifenthrin, Fenfluthrin, Deltamethrin, NRDC 196, BTG502 and RH63421. Pyrethroids were applied twice in both topical application method and leaf dip method. Pyrethroids, BTG 502 and RH 63421 were confirmed as having high level of resistant to strain (Turkey Adana) and susceptible to strain (171B). It was clear that topical application gave more reproducible results with higher confidence limits than the leaf-dip method.

Key words : Resistance, *Aphis gossypii*, Pyrethroids.

INTRODUCTION

The aphid is an extremely adaptable insect and under favourable conditions, can reproduce and build-up high population densities extremely fast. Under favourable field conditions, mid-season aphid numbers have been observed to double in about every 6-8 days. Wingless adult females produce young without mating and, therefore, develop large populations often rapidly. However, populations have also been reduce observed to quickly when high populations of beneficial insects were present during the early and late season.

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Insecticide resistance is the ability of an insect to survive a rate of insecticide that other individuals in the population cannot survive. This characteristic is inherited and the survivors pass the gene(s) for resistance to the next generation.

Insecticide resistance is one of the greatest challenges, facing applied entomologists today, because of ever widening circle of cross-resistance and multiple-resistance among insect pests, diminishing number of effective commercial insecticides and exponentially-increasing costs of developing new pesticides (Metcalf, 1989).

It is difficult to imagine the cessation of the development of resistance, because resistance is acknowledged as one of the evolutionary products of pesticide application. However, it is possible to reduce the rate of development of resistance or to control resistant insect pests if insecticides are utilised ideally.

Resistance in *Aphis gossypii* to Pyrethroids

The cotton aphid, *Aphis gossypii* (Glover), is a world-wide pest on field and greenhouse crops, especially on cotton and cucurbitaceae. Their diversity, species-specific effects on crops and ability to develop resistance make them important to agriculture. Several authors have reported that the overproduction and enhanced activity of esterases such as acetylcholinesterase (AChE) and mixed function oxidase (mfo) have attributed to the resistance in cotton aphid (Moore *et al.*, 1996 and Delorme *et al.* 1997).

The biochemical assays and synergistic studies showed that pyrethroid resistance was due to increase in esterase activity, differences in pyrethroid metabolism by susceptible and resistant aphid strains.

Through biochemical assays, pyrethroid resistance was attributed to increased metabolism due enhanced mfo (Delorme *et al.*, 1997) or esterase activity (Zheng *et al.*, 1988).

However, failure to demonstrate differences in pyrethroid metabolism by susceptible and resistant aphid strains studied at Rothamsted suggests an alternative mechanism, probably target-site insensitivity due to modifications of voltagegated sodium channels, as the primary cause of pyrethroid resistance in many populations.

Thus the present study was undertaken to assess the resistance of *Aphis gossypii* to Pyrethroids.

MATERIALS AND METHODS

The accurate way to assess the resistance is through bio-assays. The topical application and leaf-dipping method were used in assessing resistance levels in the laboratory.

Insects

Two clones of *Aphis gossypii* Glover (Homoptera: Aphididae) cultures were maintained without insecticide selection as anholocyclic clones derived from a single female in the original field samples.

Clone 171B was collected in 1981 from untreated weed hosts in the UK (Furk et al. 1990). It has been maintained at Rothamsted as a reference clone exhibiting baseline susceptibility to insecticides and without any selection pressure since 18 July, 1990.

The resistant strain Adana was received from Sibel Velioglu, Turkey in January 2001 in IACR, Rothamsted and maintained under selection pressure (Table 1).

Table 1. Origin and resistance mechanisms associated with the *Aphis gossypii* clones used in this study

Clone	Origin	Host plant	Amino acid at <i>kdr</i> site	Amino acid at super- <i>kdr</i> site	Homozygote/Heterozygote
171B	UK	Pumpkin	Leu	Met	Homozygote
Adana	Turkey	Pumpkin	Leu	Leu	Homozygote

The insecticides used in the study are presented in the Table 2.

Table 2. List of insecticides used in the experiment (Tomlin, 2000)

Insecticides	Common name	IUPAC name	Molecular formula	Molecular weight
Cypermethrin	Cypermethrin (BSI, E-ISO, ANSI,BAN)	(RS)-cyano-3-phenoxybenzyl (1RS,3RS; 1RS, 3SR)-3-(2,2dichlorovinyl)-2dimethyl=cyclopropanecarboxylate.	$C_{22}H_{19}Cl_2NO_3$	416.3
Bifenthrin	Bifenthrin (BSI, ANSI, draft E-ISO).	2-methylbiphenyl-3-ylmethyl (z)-(1RS,3RS)-3-(2-chloro-3,3, 3-trifluoroprop-1-enyl)-2, 2-dimethylcyclopropanecarboxylate	$C_{25}H_{22}ClF_3O_2$	422.9

Fenfluthrin	Fenfluthrin	3-(2,2-dichloro-vinyl)-2,2-dimethyl-cyclopropanecarboxylic acid pentafluorophenylmethyl ester	$C_{15}H_{11}Cl_2F_5O_2$	389.15
Deltamethrin	Deltamethrin BSI, draft E ISO)	(S)- -cyano-3-phenoxybenzyl (1R,3R)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropanecarboxylate	$C_{21}H_{19}Br_2NO_3$	505.2
NRDC 196	NRDC 196	3-(2,2-dibromo-vinyl)-2,2-dimethyl-cyclopropanecarboxylic acid cyano-[3-(methoxyimino-methyl)-phenyl]-methyl ester	$C_{18}H_{15}Br_2N_2O_4$	470.16
BTG 502	BTG 502	N{(1,2-dimethyl propyl)-6 (bromo2-naphthyl)hexa2(E)4(E)-dienamide	$C_{21}H_{25}BrNO$	-
RH63421	RH63421	3-(4-Chlorophenyl)-4-methyl-4-(4-fluoromethyl-phenylcarbamoyl)-4,5-dihydro-3H-pyrazole-4-carboxylic acid methyl ester	$C_{20}H_{17}ClF_2N_4$	-

Aphid rearing

Aphids were reared routinely at a constant temperature of 20°C in the Laboratory in plastic boxes containing leaves excised from pumpkin (*Cucurbita pepo*). A number of measures were taken to prevent cross-contamination between clones. In addition to the isolation of the clones in different rooms, no two cultures were supplied with fresh plants on the same day. All plant materials removed from cages was bagged, deep-frozen and then incinerated. All glasshouse work was carried out prior to culture work, and the glasshouse was not re-entered till the next day. The regular treatment of the resistant clones with insecticides and the inability of the clones to switch host plants was helpful to reduce the potential for contamination.

Bioassays

Both susceptible (171B) and resistant (adana) strains were exposed to pyrethroids and other related compounds in several separate types of bioassays.

Topical application method

Adult apterous males and females were transferred to newly excised pumpkin leaflets which was placed on moistened agar bed in a small plastic box.

Pumpkin leaf discs (35-mm diameter) were placed upside down on an agar bed (25 mm in depth) in disposable plastic containers (30 mm high). Apterous adults (10 per container, and 3 replicates per concentration) were then placed onto the leaf surface and confined by applying a ring of fluon to the exposed lip of the container.

The aphids were individually dosed to the dorsum by 0.25ml droplets of test solution in acetone using a microapplication (Needham & Devonshire, 1973). Compounds tested included, cypermethrin, bifenthrin 9166C, bifenthrin 9167, fenfluthrin, deltamethrin, NRDC196, BTG502 (N-alkylamide) and RH63421. The acetone was also used as a control. Containers are stored upright, in a Constant Environment (C.E.) facility at 20°C under continuous room lighting. Mortality was assessed at 24 hrs intervals from the time of dosing. Adults failing to exhibit repetitive (i.e., nonreflex) movement of more than one leg (after gentle prodding if necessary) were scored as dead.

Leaf dip method

Pumpkin leaf discs (35 mm diameter) dipped in aqueous solutions of insecticide (containing 0.01% agram surfactant) were placed upside down on an agar bed (25 mm in depth) in disposable plastic containers (30 mm high) and allowed to air-dry. Apterous adults (10 per container; 3 batches per concentration) were then placed onto the treated leaf surface and confined by applying a ring of fluon to the exposed lip of the container. Leaf discs dipped in water plus agram were used as controls.

Bioassay containers were stored upright, in a Constant Environment (C.E.) facility at 20°C under continuous room lighting. Mortality was assessed for 24 hrs intervals after initial exposure to insecticide deposits.

Analysis

Results for at least two independent bioassays with insecticides were pooled and subjected to probit analysis using the POLO computer program (LeOra Software, Berkeley, CA).

For comparison of results, the Resistance Factor (RF) was calculated for each compound as follows:

$$\begin{aligned} \text{Resistance factor} &= \frac{\text{LD}_{50} (\mu\text{g per aphid}) \text{ of resistant strain}}{\text{LD}_{50} (\mu\text{g per aphid}) \text{ of susceptible strain}} \\ \% \text{Mortality} &= \frac{\text{Sum of mortality in three replicates} \times 100}{\text{Total number tested per concentration}} \end{aligned}$$

RESULTS AND DISCUSSION

Two bioassay methods for assessing resistance in two strains of *Aphis gossypii* to pyrethroids were examined. Results for one compound (cypermethrin) are given in Table-3 and for several pyrethroids are showed in Table 4.

Table 3. Response of two aphid clones to insecticides in leaf dip bioassay (based on 48-hrs mortality assessments)

Insecticide	171B	Adana	RF
	LD ₅₀	LD ₅₀	
Cypermethrin	0.913	29.615	32
	(0.035 -2.512)	(12.819 -182.148)	

Table 4. Response of two aphid clones to insecticides in topical application bioassays

Insecticide		171B	Adana	RF
Pyrethroids	Replicate	LD 50	LD 50	
Cypermethrin	1	0.518	149.065	288
		(0.130 -1.181)	(80.382 -205.697)	
	2	1.21	288.38	238
		(0.582 -2.150)	(231.824 -350.821)	
	1	0.635	166.922	262
		(0.155 -1.485)	(96.117 -226.703)	
	1	0.453	142.526	314
		(0.127 -0.977)	(78.813 -194.499)	
Bifenthrin 9166 C	1	1.179	315.300	267
Bifenthrin 9167		(0.526 -2.193)	(243.625 -392.736)	
	1	1.393	168.269	120
		(0.629 -2.507)	(98.884 -227.471)	
Fenfluthrin	1	0.127	130.998	1031
Deltamethrin		(0.004 -0.466)	(48.013 -199.985)	
NRDC 196				
BTG 502	1	1.227	318.421	259
		(0.550 -2.298)	(256.889 -389.724)	
RH63421	1	0.853	315.844	370
		(0.367 -1.604)	(244.907 -391.746)	

*171B= susceptible clone, Adana= resistant clone.

Response of aphid clones to pyrethroids and other related compounds were determined by carrying out in vivo & contact bioassays. To compare the level of resistance, Resistance Factors (RFs) were determined by $(LD_{50} \text{ resistant strain}) / (LD_{50} \text{ susceptible strain})$. The susceptible strain was 171B and the resistant strain was adana. To determine the resistance, two clones of aphids were exposed to pyrethroids, BTG 502 and RH63421 compounds.

From this study it is found that homozygote strain, adana showed a level of high resistance to pyrethroids, BTG 502 and RH63421 in topical application method after exposure at 129.6 ppm, 216 ppm, 360 ppm, 600 ppm and 1000 ppm respectively. Susceptible strain 171B was also exposed to the same compounds in topical application method at 0.156 ppm, 0.625 ppm, 2.5 ppm, 10 ppm and 40 ppm respectively. In leaf dip bioassay method two clones were exposed to only cypermethrin at 1.00 ppm, 4.00 ppm, 16.00 ppm and 64.00 ppm respectively.

Table 4 shows that the susceptible clone, 171B was killed at low doses of the insecticides tested. The resistant strain, adana possessed a high level of resistance to NRDC 196 (RF= 1031) and a weaker resistance to the deltamethrin (RF= 120). Resistance Factors for insecticides ranged from 120 to 1031. Moderate (RF=238) resistance was also found in cypermethrin. Only a small significant difference was seen between the susceptible and resistant strains for bifenthrin 9166 C and fenfluthrin.

So from the results it is clear that there was a variation in resistance factors to pyrethroids in two clones of *A. gossypii*. This may be due to the increased level of detoxifying enzymes, (e.g. esterases) produced by adana, that modifies the pyrethroids to inactive metabolites. Esterase modifications in resistant strains of *A. gossypii* have been noted by several authors (O'Brien et al., 1992) and have been claimed to be responsible for resistance.

In topical application method, the resistance was shown to pyrethroids in adana strain was due to the mutation at super-*kdr* site. Super *kdr* mutation contributed to resistance.

In leaf dip bioassay the resistance factor for cypermethrin (Table 3) was found to be 32. The resistance factor appeared to be different for cypermethrin compared with topical application. In leaf dip bioassay there were some variables (e.g. dose transfer from leaf to aphids) that affected the experiment.

Variation was shown by the aphids in response to test compounds between adana and 171B may be due to various causes, both intrinsic and extrinsic. Intrinsic factors may include size, sex and age.

In this study the effects of pyrethroids upon both adana and 171B were briefly observed and became clear that the use of topical application provided a more consistent assay.

**Summary of bioassay results for aphid clones treated with cypermethrin
(Topical application, replicate-1)**

Aphid strain	Super - <i>kdr</i> *	LD ₅₀ ng AI per aphid	95% CI	Slope	RF
171B	S/S	0.518	0.130 -1.181	0.691	1.00
Adana	Skdr/Skdr	149.065	80.382 -205.697	1.994	288

* Knockdown resistance status. Strains lacking of the sodium channel mutation are designated kds and those with the mutation as *kdr*. The *kds/kds* are homozygotes, while *kdr/kds* are heterozygotes.

- Effective dose to give 50% dead or with irreversible symptoms of poisoning.
AI = active ingredient.
- ◆ 95% confidence interval.
- ♣ Resistance Factor = (LD₅₀ of adana)/(LD₅₀ of 171B).

**Summary of bioassay results for aphid clones treated with cypermethrin.
(Topical application, replicate-2)**

Aphid strain	Super - <i>kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	1.209	0.582 -2.150	1.068	1.00
Adana	Skdr/Skdr	288.381	231.824 -350.821	2.702	238

**Summary of bioassay results for aphid clones treated with bifenthrin 9166 C
(Topical application)**

Aphid strain	Super - <i>kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	0.635	0.155 -1.485	0.583	1.00
Adana	Skdr/Skdr	166.922	96.117 -226.703	1.994	262

**Summary of bioassay results for aphid clones treated with bifenthrin 9167
(Topical application)**

Aphid strain	Super <i>r-kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	0.453	0.127 -0.977	0.688	1.00
Adana	Skdr/Skdr	142.526	78.813 -194.499	2.144	314

**Summary of bioassay results for aphid clones treated with fenfluthrin.
(Topical application)**

Aphid strain	Super <i>-kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	1.179	0.526 -2.193	0.976	1.00
Adana	Skdr/Skdr	315	243.625 -392.736	2.670	267

**Summary of bioassay results for aphid clones treated with deltamethrin.
(Topical application)**

Aphid strain	Super <i>-kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	1.393	0.629 -2.507	1.125	1.00
Adana	Skdr/Skdr	168.269	98.884 -227.471	2.018	120

**Summary of bioassay results for aphid clones treated with NRDC 196.
(Topical application)**

Aphid strain	Super <i>-kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	0.127	0.004 -0.466	0.539	1.00
Adana	Skdr/Skdr	130.998	48.013 -199.985	1.622	1031

**Summary of bioassay results for aphid clones treated with BTG 502.
(Topical application)**

Aphid strain	Super <i>-kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	1.227	0.550 -2.298	0.937	1.00
Adana	Skdr/Skdr	318.421	256.889 -389.724	2.629	259

**Summary of bioassay results for aphid clones treated with RH 63421.
(Topical application)**

Aphid strain	Super - <i>kdr</i>	LD ₅₀	95% CI	Slope	RF
171B	S/S	0.853	0.367 -1.604	0.910	1.00
Adana	Skdr/Skdr	315.844	244.907 -391.746	2.769	370

**Summary of bioassay results for aphid clones treated with cypermethrin.
(Leaf dip bioassay)**

Aphid strain	Super - <i>kdr</i>	LD ₅₀	95% CI	Slop	RF
171B	S/S	0.913	0.035 -2.512	0.785	1.00
Adana	Skdr/Skdr	29.615	12.819 -182.148	0.664	32

The following observations can be made from this study:

1. Both the susceptible and resistant strains of *A. gossypii* tested in this research exhibited high levels of resistance (i.e. high RF values) and RFs for all the compounds tested were within a narrow range. Thus no relationship between structure and RFs could be observed. This was in contrast to observations with other studies with super-*kdr* insect species where significant differences were observed (Khambay et al., 1994).
2. The two compounds BTG502 and RH63421, representing two distinct chemical classes (alkylamide and dihydropyrazole, respectively), were also highly resisted by the resistant strain of *A. gossypii* (adana) tested in this study.

But this is an unexpected result because both those compounds are known to exhibit negative cross-resistance to insects that are resistant to pyrethroids. So possible explanation may be based on the fact that the resistant strain of *A. gossypii* used here contains two resistance mechanisms, site-insensitivity and metabolism.

3. From the above comparison it is clear that topical application method gave more producible results with higher confidence limit than the leaf dip method. It can, therefore, be concluded that pyrethroid resistance in adana is an autosomally inherited, largely recessive trait.

No decrease in the degree of resistance of adana to pyrethroids was observed from previous work by Xiaowen, 2001(unpublished) in the laboratory at Rothamsted, implying a high level of homozygosity for the resistance gene(s) in this strain.

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COST EFFICIENCY IN WHEAT FARMS OF BANGLADESH: AN ANALYSIS OF DEA BASED ON FARM SIZE

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ABSTRACT

This study pertains to a region of Khulna Division, a southwestern part of Bangladesh. Cost efficiency of wheat farms in a rural area of Bangladesh was estimated through Data Envelopment Analysis (DEA) of farm level data for the year 2002. The overall mean cost efficiency scores of the sample farms were 0.546 meaning that the cost efficiency of the sample farms was 45% below what can be achieved. Computed efficiency scores were subsequently regressed on explanatory variables using a Tobit analysis, to help identify inefficiency related factors. Nine explanatory variables were identified as being related to efficiency. Finally, how inefficient farm becomes an efficient was estimated in this study and it was found that 34.29% of the TSP fertilizer was being over used at the farm level of Bangladesh, which is the highest misallocation in the study area. To this end, a constant return to scale and input orientation model has been applied to a sample of 150 wheat farms.

Key words : Cost efficiency, DEA, Input-orientation model, Tobit analysis, Wheat farms

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INTRODUCTION

Agriculture is the dominant sector of the Bangladesh economy. Growth and stability of Bangladesh depends largely on the growth of agriculture. It is the main occupation of the people employing 62 percent of the labor force. This sector directly contributes around 24 percent to the Gross Domestic Product and above 68 percent of the total population directly or indirectly depends on agriculture. Many of them are engaged in agriculture cum business. About 70% of the land of the study area is devoted to agriculture directly or indirectly (BBS, 2003). The prime concern for development efforts in Bangladesh rests upon agricultural development.

Agricultural productivity growth needs to be fostered, through either technological development or an increase in production efficiency to remain competitive. On the one hand, the government has carried out a set of appropriate policy reforms, which helped attain major technological development in agricultural sectors. On the other hand, the implementation of protectionist measures to ensure self-sufficiency in strategic products might generate considerable cost inefficiencies.

Within the past few years, Bangladesh reached self-sufficiency in its main cereal, rice. Its success is largely a story of close cooperation between the government of Bangladesh and its people with the help of foreign aid agencies, international research institutes, and indigenous NGOs (Non Government Organizations). Wheat production climbed from 0.11 million metric ton in 1974 to 1.9 million metric tons in 2002. Cereal prices are low and stable, and production continues to increase. The economy is also showing rapid diversification, particularly in the livestock and poultry sectors (Alam, 1999).

Wheat farms are good examples of how the Bangladesh government has introduced several policy reforms to increase the supply of wheat product and ensure self-sufficiency. However, given the persistent and substantial variations in wheat farms profitability, it may be assumed that efficiency gains shall be furthered. To this end, measuring farms efficiency is important as this could be the first logical step in a process that leads to substantial resources savings.

The focus of this study is to explain the influence of the overall economic performance of wheat farmers in Bangladesh. The study differs from many previous

studies into the estimation and explanation of cost efficiency by including variables that relate to both personal aspects and aspects of the decision-making process of the farmer.

The objectives of this research are twofold. In first place, we investigated the possibility of improving wheat farm overall cost efficiency and provided empirical evidence applying DEA to a sample of 150 farms respondents in the region of Khulna Division in Bangladesh. Secondly, we resorted to Tobit analysis to assess the effects of several explanatory variables, i.e. farmers' age, farm size, family size, education, wheat price, soil quality, boro rice price, non-farm income, and weeding on efficiency of wheat growers in Bangladesh.

The Data

The analysis was based on the primary data collected through a comprehensive field survey. A sample of 150 farms was chosen. The survey was conducted to the agricultural year 2002. Secondary data were also collected from the Bangladesh Bureau of Statistics (BBS) for the period 1972 to 2002. In addition, Journals, Reports, Official Records, documents of Fourth Five Year Plan, and Ministry of Planning of Bangladesh were the sources of secondary data. Excel and SPSS program composed the data and finally it was analyzed by DEA-Solver, e.g. Efficiency Measurement Systems (EMS).

The analysis in this study was based on a wheat yield and inputs production systems. For the measurement of cost efficiency the inputs prices/costs were used: i. human labour; ii. bullock labour; iii. power tiller cost; iv. seed; v. urea; vi. Triple Super Phosphate (TSP); vii. Muriate of Potash (MP); viii. Farm Yard Manure (FYM); ix. irrigation cost; x. pesticides cost; and xi. working capital.

Farmers took part in the survey on a voluntary basis, receiving no payment for supplying the information. Farmers who took part in the survey received a detailed analysis of data for the cost efficiency performance of their wheat production. Physical and financial information was collected from the farmer during farm visits conducted by the researcher himself. These visits were conducted over the period when the crop was being sown, harvested and marketed. During these visits the researcher, in conjunction with the co-operating farmer, recorded data on outputs and inputs down to the gross margin level only for the year 2002.

Output data were recorded by the quantity of grain sold, tones produced of each quantity per farm and price obtained. For practical reasons, the amount of data collected on individual inputs varied from farm to farm. For seed, both the quantity used and price per ton was collected. Similar information was collected on fertilizer usage with the quantity applied further broken down into its constituent parts (the amount of nitrogen, phosphates and potassium). However, only the cost of crop protection materials (which are defined as applications of herbicides, fungicides, and insecticides) was collected. Since labour and machinery data (both being measured in terms of the hours of each that were applied to the wheat crop) were only available for 2002 we assumed that per ha utilization of these inputs remain fixed over the period.

Table1 gives a broad description of the information of wheat farms by different categories of farms. Yield was calculated by dividing the total kg produced per farm by the area. The cost of seeds was used to capture differences in quality of purchased and farm-saved seed (family supplied seed as fixed cost and purchased seed as variable cost). The number of farms included in the panel data set varies slightly from year to year because a small number of farmers in the set did not grow wheat in every year considered.

Due to resource limitations, a random rather than purposive sample process was used. A sample of 150 farmers was identified as the maximum feasible sample given resource and time constraints. By using the cluster analysis, the sample was collected from 10 districts, one Thana² in each district, three villages were selected from each Thana and five farmers were selected in each village. In each Thana, we selected three villages, one of which was to be located near the largest town, the second one located in the far from town and the third one to be located in a remote area of the Thana. The farms were treated as a homogeneous for several reasons. Firstly, all the farms were in an area where technical and agronomic practices were all most same. Secondly, they were in reasonable proximity to each other. Thirdly, all of them faced same natural market conditions and infrastructure. Finally, all the sample farms had broadly similar types of soil.

During the collection of data farms were not classified, in order to avoid the bias. After collecting the primary data, all 150 farms were classified into farm size groups. For the convenience, wheat farms were classified into the following category: i) small farms;

²A Thana is the smallest administrative unit in Bangladesh above the village level.

having land 0.01 ha to 1.00 ha, ii) medium farms: those having 1.01 ha to 3.00 ha land and iii) large farms: those possessing land 3.01 ha and above. The survey schedule was designed to collect information in local units. The survey was administrated using acres and decimals (100 decimals = 1 acre) because these are the units familiar to Bangladeshi farmers and extension agents. Some farmers also responded using bigha, a traditional unit equivalent to 33.3 decimals. However, local units were converted later into standard units, for example all area units in this study have been converted to ha (1 ha = 2.47 acres) and price in Taka per maund converted to Taka per kg (1 maund = 37.32 kg).

Study Area

The area of the present study is Khulna Division in Bangladesh. It occupies a fertile plain area of 29.45 million ha (26.94% are cultivated area and 12.15% are irrigated area of the total area). The land is suitable for production of rice, wheat, jute, tobacco and winter crops. The temperature in this area varies from 7.9°C to 31.1°C. The average monthly rainfall is about 177.93 mm with the lowest in mid December to mid January and the highest in June and July.

Models Specification

There are a number of multiple-input multiple-output production units to be evaluated, which are taken as Decision Management Units (DMUs). Each DMU consume varying amounts of inputs to produce different level of wheat production. DEA uses the set of production units in the sample to construct an efficiency frontier consisting of all possible linear combination of efficient production units. The efficiency frontier represents applicable techniques since it reflects the practices implemented by existing production units. It also represents efficient techniques since it is exclusively defined in terms of the techniques used by efficient production units.

Different methods were used by a number of researchers (e.g. Farrell, 1957; Cooper, et. al., 2000; Asby, 1998; Sampath, 1979; Charnes et al., 1978, Manos and Psychoudakis, 1997; Psychoudakis and Dimitriadou, 1999; Menzelxhiu-Cepani and Manos, 1995; Battese and Coelli, T.J., 1995; Tadesse and krishnamoorthy, 1999; Anderson, et al., 2002; Lachaal, Chaltour and Thabet, 2002; Backshoodch and Thomson, 2002; Fukuyaman and Weber 2002) in order to measure the efficiency of various enterprises or regions in different sectors of economy. Among them the uses of simple indexes of efficiency (e.g.

economic, profit, return to capital, etc.), the use of production functions and linear programming models are included.

The framework for the DEA procedure was initiated by Farrell (1957) and reformulated as a mathematical programming problem by Charnes *et al.*, (1978). Given a number of producing units, which are Decision Management Units (DMUs), the DEA producer constructs an efficiency frontier from the sample of producing units. The efficiency frontier reflects the practices of existing efficient units. Producing units that are not on the frontier are said to be inefficient. The proposed measure of efficiency of any DMU is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity. The DEA model for a specific DMU is formulated as a non-linear fractional programming problem.

Since the pioneering work of Farrell (1957), two competing paradigms on frontier estimation have been developed in the literature. The first one relies upon econometric techniques to estimate a frontier function and estimate primal and dual efficiency scores of the estimated frontier. The second one applies non-parametric mathematical programming techniques to construct a transformation frontier and compute primal and dual efficiency of the frontier.

Non-parametric frontier analysis, known as DEA, over comes some of the critical points of the statistical frontier approach. In particular, there is a need for restrictive assumptions about the functional form of the frontier or the distributional form of inefficiency. Instead of fitting a regression surface into the data center, DEA lays a piecewise linear surface on the top of the observations.

In this paper, we used DEA to investigate cost efficiency in sample wheat growers of Bangladesh. Also, all data were assumed to be positive and weight choices were also restricted to positive values. We conducted DEA assuming Constant Returns-to-Scale (CRS). In this study, we also used input-orientated model that aims to minimizing inputs while producing at least the given output levels.

Cost efficiency

Cost efficiency is the product of technical and allocative efficiency. If a DMU is fully efficient (0 = 100) in both the technical and allocative, then DMU is cost efficient.

Otherwise, DMU is inefficient. If DMU has the full efficient in technical (allocative) score but low efficient in allocative (technical) score, then it is not cost efficient farms. Alternatively, we can evaluate the cost efficiency of each DMU as follows:

The objective function:

$$\text{Min } \sum_{i=1}^m c_{i0} x_i \quad (1)$$

Subject to:

$$x_i \geq \sum_{j=1}^n x_{ij} \lambda_j \quad (i = 1, \dots, m) \quad (2)$$

$$y_{r0} \geq \sum_{j=1}^n y_{rj} \lambda_j \quad (r = 1, \dots, s) \quad (3)$$

$$1 \geq \sum_{j=1}^n \lambda_j \geq U \quad (4)$$

$$\lambda_j \geq 0 \quad \forall j$$

where, c_{i0} = the unit cost of the input i of DMU₀ which may vary from one DMU₀ to another.

m = the number of inputs

s = the number of outputs

x_{ij} = amount of input i in j unit, $i = 1, 2, \dots, m$

y_{rj} = amount of output r in j unit, $r = 1, 2, \dots, s$

This model allows substitutions in inputs. Based on an optimal solution (x^*, λ^*) of the above LP, the cost efficiency of DMU₀ is defined as:

$$(5) \quad E_c = \frac{c_0 x^*}{c_0 x_0}$$

Tobit analysis

In some works, production efficiency has been linked with a number of socioeconomic variables. The relationship between economic efficiency and education has been extensively investigated in agriculture (Bravo-Ureta and Rieger, 1991; Kumbahar et al., 1989; Lockheed et al., 1981).

The production efficiency may also be related to the farm size. Large farms are often considered more efficient than small farms due to economic advantages concerning the organization and economic knowledge. Empirical evidence, provided by several studies on the relationship between efficiency and the farm size, has also been taken into account (Aly et al., 1987; Garcia et al., 1982; Byrnes et al. 1987). Another variable, which seems

to be related to efficiency, is the farmer's age. Old farmers are often assumed to have had more time to learn and become more experienced in managing their farms and thus, they are thought to be more efficient.

The main conclusion that can be drawn is the lack of substantial evidence of the relationship between efficiency and these variables and hence, more empirical research is still needed. In this analysis, several variables are identified as potential determinants of cost efficiency. These variables reflect the farmers' age, farm size, family size, education, wheat price, soil quality, boro rice price, non-farm income and weeding. To this end, the efficiency scores obtained are regressed on these farm attributes using the following linear Tobit model. We used Tobit analysis due to dependent variable, cost efficiency, is a censored variable, having an upper limit of one (Lockheed *et al.*, 1981).

$$\text{Eff} = \alpha_0 + \alpha_1 \text{AG} + \alpha_2 \text{FS} + \alpha_3 \text{FaS} + \alpha_4 \text{ED} + \alpha_5 \text{SQ} + \alpha_6 \text{WP} + \alpha_7 \text{BP} + \alpha_8 \text{NFI} + \alpha_9 \text{WD} + \varepsilon \quad (6)$$

Where:

Eff is the efficiency of wheat farms,

AG is the age of the farmers in years,

FS is the farm size in ha,

FaS is the family size in number,

ED is the education of the farmers dummy variables = 1 if high school completed, = 0 otherwise,

SQ is the soil quality dummy variables = 1 if good quality, = 0 otherwise,

WP is the wheat price in Taka per kg reported by the farmers,

BP is the average boro retail price in Taka per kg collected from BBS, 2003,

NFI is the non farm income dummy variables = 1 if yes, = 0 otherwise,

WD is the weeding dummy variable = 1 if yes, = 0 otherwise,

ε is the error term.

Economic Results

Table 1 presents the input-output coefficients per ha yield of the farms. From the results we observed that the medium farms produced higher yield (2386.55 kg/ha) of wheat than small and large farms. The national average yield of wheat was 1956.71 kg/ha during 1972-2002, which is lower than yields of our sample farms. Although in the year 2002, the national average yield of wheat was 2578.17 kg/ha, which is higher than Yields of our sample farms.

Table 1. Summary statistics of wheat farms in sample households of Bangladesh

Items	Farm size			Overall
	Small (0.01-1.00 ha)	Medium (1.01-3.00 ha)	Large (3.01 + ha)	
1. Farm size (ha)	0.62	2.04	4.68	1.91
2. Family size (no.)	5.19	3.82	2.66	4.24
3. Wheat sown area (ha)	0.06	0.14	0.24	0.12
4. Wheat share in total crop sown area (%)	10	6.86	5.13	6.28
5. Age (years)	32.52	30.20	37.97	32.99
6. Yield (kg/ha)	2300.33	2386.55	2279.13	2321.67
7. Wheat price (Tk/kg)	7.90	8.36	9.05	8.29
8. Fertilizer use:				
a. Urea fertilizer (kg/ha)	192.09	193.84	197.70	193.81
b. TSP fertilizer (Kg/ha)	81.67	88.23	86.29	84.62
c. MP fertilizer (kg/ha)	50.32	52.35	48.54	50.55
d. Farmyard manure (ton/ha)	8.88	10.81	10.11	9.72
9. Human labour (man-days/ha)	46.35	45.40	44.36	45.64
10. Bullock labour (pair days/ha)	27.15	28.18	29.48	27.95
11. Seed (kg/ha)	152.95	154.09	155.44	153.89
12. Number of observation	73	45	32	150

Table 2 shows that the medium farms had higher gross margin (9602.73 Tk/ha) than small and large farms. However, the medium farms had expended more variable cost than small and large farms. On the other hand, fixed cost was low in medium farms as compared to small and large farms. In this study, Benefit Cost-Ratio (BCR) was analysed and BCRs over variable cost were found to be 1.77, 1.86 and 1.75 for small, medium and large farms, respectively. This means that if small, medium and large farms' invest Taka 100.00 for wheat production then they would get a return of Taka 177.00, 186.00 and 175.00, respectively. Therefore, the investment return per ha from the wheat production for medium farms is the highest than small and large farms. Medium farms had also higher gross return (21412.13 Tk./ha) than small (19312.67 Tk./ha) and large (20442.57

Table 2. Variable cost, fixed cost and return of wheat production by farm size in Bangladesh

Items		Farm size			Overall
		Small	Medium	Large	
1.	Grain yield (kg/ha)	2272.68	2403.82	2368.40	2272.68
2.	Gross return (Tk/ha)	19312.67	21412.13	20442.57	17933.70
3.	Variable cost (Taka/ha):	11349.35	11809.40	13292.99	11265.31
a.	Human labour:	1253.09	1690.83	1560.90	1253.09
b.	Land mortgage/rented	655.43	977.13	808.15	655.43
c.	Hired bullock labour	923.59	1099.80	1373.57	923.59
d.	Tractor/power tiller ^a	677.46	676.29	914.90	677.46
e.	Seed purchased	731.31	531.98	713.21	731.31
f.	Fertilizer:	1156.01	1169.99	1184.57	1156.01
i.	Urea	730.72	789.39	767.97	730.72
ii.	TSP	396.22	413.94	383.03	396.22
iii.	MP	272.98	166.26	407.01	272.98
iv.	Others	2894.62	2943.74	2904.34	2894.62
g.	Irrigation:	2894.62	2943.74	2904.34	2894.62
i.	Fuel	1128.71	1136.20	1120.84	1128.71
ii.	Machine charge	1765.91	1807.55	1783.49	1765.91
h.	Pesticide	441.48	476.10	568.78	441.48
i.	Working capital	10096.17	10282.43	11544.75	10132.91
j.	Interest on operating capital (@ 5%)	504.81	514.12	577.24	506.65
k.	Miscellaneous (@ 3.5%)	725.69	398.13	1185.42	639.81
4.	Fixed cost (Taka/ha):	6649.92	5914.72	6072.85	6649.92
a.	Land tax	41.47	38.15	35.66	41.47
b.	Family human labour	997.49	822.35	1170.51	997.49
c.	Family bullock labour ^b	794.30	994.09	940.61	794.30
d.	Seed (family supplied)	1180.62	1313.31	1178.02	1180.62
e.	Farm manure (family applied)	391.10	297.57	255.05	391.10

Table 2 (Continued)

f. Depreciation and repairing of machinery and buildings	2131,14	1320,14	1206,92	2131,14
g. Interest on land improvement	684,07	724,99	871,40	684,07
h. Interest on fixed capital (@ 3.5%)	204,84	204,10	209,32	204,84
i. Miscellaneous (@ 3.5%)	224,88	200,01	205,36	224,88
5. Total cost (Tk/ha)	17999,26	17724,12	19365,84	17915,22
6. Gross margins (Taka/ha)	7963,32	9602,73	7149,58	6668,39
7. Profit (Tk/ha)	1313,41	3688,01	1076,73	18,47
8. Benefit-cost ratio over variable cost	1,77	1,86	1,65	1,66
9. Benefit-cost ratio over fixed cost	3,53	3,78	3,59	3,29
10. Benefit-cost ration over total cost	1,10	1,22	1,08	1,03

Note : a. Tractor and power tiller is being used for both land preparation and carrying purpose.

b. Bullock labour cost per pair-day is included man works.

c. One Euro is equal to 71.571 (Taka as on 30.04.2003)

Cost efficiency

Using the linear programming method outlined above, non-parametric analysis of cost efficiency was performed for wheat production farms in Bangladesh. The data were solved by EMS program and each farm size was separated. The cost efficiency score for the small, medium, large and overall farms in the sample as well as the number of farms are reported in Table 3. Given the large variability in the computed measures, efficiency scores are clustered into five groups such as 0.00-0.70, 0.71-0.80, 0.81-0.90, 0.91-0.99, and 1.00 (efficient).

The second and third group displays more decent mean efficiency scores between 0.71 and 0.80 and 0.81-0.90, respectively. This means that farms of these groups can decrease their inputs by as much as 25% and 15%, respectively, producing the same level of production more efficiently. The results also indicate a wide variation in the levels of efficiency between the farms. The result shows the mean and standard deviation for output and inputs for the years 2002 for this sample.

The cost efficiency scores reflect the need for adjustments in relative factor input levels. In small farms, the result shows that 57 farms (78.08%) achieved a cost efficiency

score of 0.70 or less when compared to the most efficient farms. While 8 farms (10.96%), and 3 farms (4.11%) and 1 farm (1.37%) were able to achieve cost efficiency score between 0.71 and 0.80, 0.81 and 0.90, and 0.91 and 0.99, respectively and the rest 4 farms (5.48%) achieved an efficiency level 1.00. The result shows that average cost efficiency of the small farms was 0.566. This means that the small farms can decrease their production inputs by as much as 45% producing the same output more efficiently.

Table 3. Cost efficiency in wheat growers of Bangladesh by farm size using input orientation model

Efficiency index	Farm size			Overall
	Small	Medium	Large	
0.00-0.70	57 (78.08)	8 (17.78)	5 (15.63)	121 (80.67)
0.71-0.80	8 (10.96)	11 (24.44)	4 (12.50)	12 (8.00)
0.81-0.90	3 (4.11)	12 (26.67)	7 (21.88)	7 (4.67)
0.91-0.99	1 (1.37)	4 (8.89)	7 (21.88)	2 (1.33)
Efficient (1.00)	4 (5.48)	10 (22.22)	9 (28.13)	8 (5.33)
Mean	0.566	0.807	0.841	0.546
Standard deviation	0.153	0.144	0.135	0.179

Figures in parentheses are percentages to the total

Twenty two percent of the medium farms were found to be cost efficient, in directing that the second maximum cost efficiency was achieve by them. This also means that the medium farms organized there inputs and produced wheat using the existing technology efficiently. Therefore, no increase in the outputs can be achieved by reorganizing the same bundle of inputs or the decrease in the inputs will result decrease in the output. The reaming 88% of the medium farms achieved efficiency score below maximum ($? < 1$) with the given technology. These farms can reorganize their inputs and the composition of output in order to become efficient.

Similarly, 9 large farms (28.13%) was achieved cost efficiency score of 1.00, which are the most efficient farms. However, remaining 33 farms (71.87%) were not able to achieve cost efficiency in the rural area of Bangladesh. The meaning of these results is clear. In each case, the evaluation is effected from a point on the efficient frontier and a mean value like 0.546 for overall farms means that it is 46% inefficient.

The Study shows that there is little variation in yields and input application rates. Despite this fact parameter estimates for the stochastic frontier and cost inefficiency effects model show that systematic cost inefficiency effects exist and that these are, in part, explained by the variables included in the model.

Table 3 shows the standard deviations of the estimates that again support the picture of considerable variation between farms and hence considerable scope for increasing farm efficiency in the study area. While there was wide spread inefficiency scores in all types of farms, small, medium and large exhibited a relatively better performance in terms of various efficiency measures.

Tobit analysis

To identify factors associated with cost inefficiencies, the Tobit regression defined in equation (6) was estimated and results are represented in Table 4. The estimated model has good explanatory power. As for the apparent unimportance of wheat prices could indicate that the decision to grow wheat was driven by non-price factors (since many households grow wheat primarily for home consumption, their production decisions are relatively insensitive to change in market condition). An alternative explanation is that the amount of variability present in these cross sectional price data is insufficient to establish a clear relationship between economic efficiency and wheat price.

The likelihood that a rural household grows wheat was hypothesized to be positively and statistically associated with agroclimatic factors that favour wheat production, particularly in soil quality. In addition, since the area planted to boro rice is apparently limited by resource constraints, the likelihood that a household grows wheat was hypothesized to increase with farm size, since farmers with large landholdings frequently will not be able to plant their entire farm to boro rice. Finally, Table 4 shows that the cost efficiency of wheat farms were negatively associated with changes in boro prices.

The soil quality associated with soil salinity and waterlogging has a direct effect on the cost efficiency of wheat production through the impact it has on the timing of critical production practices and the overall response of outputs to inputs. The farmers, in order to check the salinity problem, commonly carry out a variety of additional farm operations such as deep ploughing, several ploughing, leveling fields, raising bunds, dividing plots into smaller plots, collecting rain water in fields, and scrapping the top soil layer to remove salts. Carrying out these extra operations not only requires extra factor inputs but

also requires additional time on the part of the farmer. This extra time requirement disturbs the schedule of farm operations for land preparation, sowing, irrigation, and the application of fertilizer and pesticides, thereby affecting farm cost efficiency. The timing of application is often more important than the total level of input use in production systems like those examined, unfortunately is not included in this study. Nevertheless, the adoption of the salinity management measures on affected lands probably resulted in higher efficiency levels than where the operations did not make any effort to deal with the problem. In this study, it was found that about 47 per cent of the total respondents made efforts to reclaim affected lands and these efforts were most common in small farms.

Table 4. Tobit analysis testing inefficiency and factors associated to it for a sample of wheat farms in Bangladesh

Variables	Estimated coefficient	t-value
1. Constant	-23.652 (33.47)	-0.707
2. Age (AG)	0.368* (0.147)	2.503
3. Farm size (FS)	0.872 (1.36)	-0.640
4. Family size (FaS)	0.335*** (1.21)	1.76
5. Education (ED)	4.022*** (3.24)	-1.543
6. Wheat price (WP)	7.811** (4.01)	2.49
7. Soil quality (SQ)	1.546 (3.17)	0.487
8. Boro price (BP)	-0.198 (0.827)	0.240
9. Non farm income (NFI)	-1.151 (3.22)	-0.358
10. Weeding (WD)	1.705 (3.17)	0.538

Notes : Figures in parentheses are standard error

* Significant at 10% level, ** Significant at 5% level & *** Significant at 1% level.

Farm size shows a positive relationship with cost efficiency suggesting that efficiency would improve with increase in farm size. In the Bangladeshi context, it has been observed that if the farm size is increased the cost efficiency would be increased. This means that small farms are less efficient than medium and large farms.

Of the human capital variables (education and age), which are the positive and statistically significant estimates may appear counter intuitive, it is consistent with the findings of a previous study based on a simple probit estimate from earlier data. Rosenzweig (1982) postulates that education can affect new technology adoption in different ways. On the one hand, it can encourage adoption by lowering learning costs. On the other hand, it may discourage adoption since education provides more profitable off-farm employment opportunities and new technologies that may reduce the ability of farm operators to substitute their time cultivation. The estimated coefficient farm age is positive, suggesting as we have assumed, that farmers close to retirement are more motivated and are therefore more efficient than middle-aged farmers'.

Family size was statistically insignificant too; however, it becomes significant at the 10% level (not reported here). With the exception of planting and harvesting periods in which all family members contribute to operations, adult males undertake routine labouring. But in the planting and harvesting periods, there is an acute shortage of labour (Metzel and Ateng, 1993), and every spare hand, including children, is pressed into farm work. This phenomenon is even more acute in wheat cultivation, where crop management is generally more labour intensive. In this regard, a larger family size is more conducive to wheat production, and this observation is reflected in estimate presented in Table 4.

Suggested resource reorganizations

The efficient reference set for each farm is available but not reported since it is of practical use to the managers of the farm only. The resulting information allows the construction of a hypothetical wheat farm for each inefficient run, while the comparison between them indicates which inputs are being overused and output of wheat are being under produced, suggesting by how much each input levels need to be adjusted. Table 5 presents the required adjustment of the mean sample farm. The required adjustments of over utilized inputs are more important than the required adjustment of the output. Thus, it suggests that the main source of cost inefficiency is misallocation of resources.

From the result give in table5 we observe that 34.29% of the TSP fertilizer was being over used at the farm levels, which is the highest misallocation followed by MP fertilizer (32.42%), pesticides cost (31.15%), working capital (25.61%), irrigation cost (20.11%), FYM (19.55%), bullock labour, urea fertilizer, power tiller cost, seed, and human labour.

Table 5. The required reorganization in the variable inputs of the overall wheat farms in Bangladesh

Inputs	Existing	Adjustment	Reorganized	Change (%)
1. Human labour (man-days/ha)	45,64	2	43,64	4,38
2. Bullock labour (pair-days/ha)	27,95	2,13	25,82	7,62
3. Power tiller cost (Tk./ha)	677,46	47,52	629,94	7,01
4. Seed (kg/ha)	153,89	7,8	146,09	5,07
5. Urea (kg/ha)	193,81	13,02	180,79	6,72
6. TSP (kg/ha)	84,62	29,02	55,6	34,29
7. MP (kg/ha)	50,55	16,39	34,16	32,42
8. FYM (ton/ha)	9,72	1,9	7,82	19,55
9. Irrigation cost (Tk./ha)	2894,62	582,01	2312,61	20,11
10. Pesticides cost (Tk./ha)	441,48	137,51	303,97	31,15
11. Working capital (Tk./ha)	10132,91	2595,1	7537,81	25,61

CONCLUSION

Cost inefficiency in the wheat farms of Bangladesh has been estimated and the variation in cost inefficiency explained using explanatory variables. The results indicate that the majority of wheat farmers in Bangladesh operate below maximum technically feasible yield levels and that there is potential to improve cost efficiency. Moreover, increasing farm size and seeking information are also associated with higher levels of efficiency. The information-seeking variable was not included in this research to examine the influence of aspects of the managerial decision-making process.

The results presented both reinforce findings from previous studies that examine the issue of cost efficiency and also highlight some of the factors that affect cost efficiency. Perhaps most contemporary interest is that those farmers who consider maintaining the

environment as an important objective achieve higher levels of cost efficiency. The results of this study therefore suggest that the medium farms were the most efficient farms lead to an improvement in cost efficiency.

Finally, the question to of how to make the inefficient farms efficient, i.e. how to move them up to efficient frontier. Inefficient farms used excess amount of inputs on wheat farms in the study areas. By reducing the excess amount of inputs in one hand and by raising yield per ha on the other, their efficiency level can be improved. Thus farmers can be benefited technically and the rural economy as well as the country will be developed if farmers can follow the suggested allocative principle.

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GENETIC STRUCTURE OF THE INDIGENOUS CHICKENS OF BHUTAN

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ABSTRACT

The indigenous chickens of Bhutan today make up approximately 95% of the total rural chicken population. They have nutritional, cultural and traditional roles, and have been invaluable resource for the livelihood of the Bhutanese farmers. This study aims to trace the origin and assess the genetic relationships of indigenous chickens of Bhutan. To achieve this, mitochondrial DNA (mtDNA) was used because of its maternal inheritance, haploidy, and rapid rate of evolution. The entire mtDNA displacement loop (D-loop) region of eight different Bhutanese indigenous chicken lines was amplified with polymerase chain reaction. The amplified DNAs were purified, cloned, and sequenced. The partial D-loop sequences (500 bp) of four jungle fowls reported in the GeneBank were retrieved together with entire D-loop sequences of five other domestic chickens. Both partial (500 bp) and entire (1232 bp) D-loop sequences were analysed using various phylogenetic methods. A dendrogram constructed from partial D-loop sequences using Neighbour-Joining (NJ) method suggest that indigenous chickens of Bhutan have originated from Red Jungle Fowl in spite of their close geographical location with Indian Grey Jungle Fowl. The analysis of entire D-loop sequences using NJ, Fitch, and Maximum Likelihood methods suggest matrilineal mtDNA sequence variation and genetic diversity among Bhutanese chickens. These findings are useful as a pre-requisite database for conservation and promotion of indigenous chicken resources in Bhutan.

Key Words : Mitochondrial DNA, D-loop, DNA sequences, Bhutan, indigenous chickens, phylogenetic, genetic diversity, conservation.

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INTRODUCTION

Bhutan has chicken population of about 230,723 birds, of which 95% of the total flocks are indigenous chickens (Nidup, 2003; Nidup, 2005a; Nidup, 2005b). Chicken existed in Bhutanese villages from time immemorial withstanding changes and the test of time. The main input is the feed from household refuse and grain by-products. They are generally scavengers within the households and village boundaries and represent one of the important assets of the farming communities. Indigenous chickens have nutritional, cultural and traditional roles, and have been invaluable resources for the livelihood of the rural Bhutanese farmers (Nidup, 2005a; Nidup, 2005b).

Animal resources are necessary for food and environmental and social-economic stability of the country. The conservation and utilization of animal and poultry resources in developed countries are different from developing world. In developed countries only breeds with high economic values and their hybrids are raised in great numbers. On the other hand, the developing countries are very rich in breed resources but they have inadequate conservation and indiscriminating importation of foreign breeds (Wu, 2001), which have caused the deterioration in quality and reduction in number of the native breeds. In both cases, a worldwide crisis of genetic resources resulting from depletion of animal and poultry gene pools is impending. It was estimated that 40% of all breeds of domestic livestock and fowl have been lost since 1970 (Alderson, 1989; Wu, 2001). The FAO in 1995 estimated the loss of three breeds every two weeks worldwide (Wu, 2001). Although, these two situations are not quite the same, it is a grave concern. The Royal Government of Bhutan is fully aware of the importance of biodiversity resources in the country and equally concerned of the depleting genetic resources in the world.

Although reference is often made about rich biodiversity in Bhutan, it has not yet been determined surely how varied is the national's biodiversity. It has, therefore, rightly been emphasized to accord priority to completing a full inventory of the nation's biodiversity resource base". Working towards this vision and realising the value and importance of indigenous chickens, the preliminary Bhutanese chicken diversity study by Nidup *et al.* (2002) at the Natural Resources Training Institute (NRTI) of the Royal University of Bhutan had for the first time unveiled the nation's rich domestic chicken biodiversity resources in the country. Based on certain phenotypic characteristics

(plumage, frizzling, naked neck, body confirmation etc.), more than thirteen lines of indigenous chickens were identified (Nidup et al., 2002; Nidup, 2003; Nidup 2005).

This study is a continuation of on-going indigenous chicken study (phenotypic and genotypic) at NRTI. The main aim of this study was:

- To trace the origin of Bhutanese indigenous chickens
- To map the diversity of indigenous chickens with the help of mitochondrial DNA sequences.
- To generate pre-requisite molecular genetic database, that would be invaluable for conservation and promotion of indigenous chicken resources in Bhutan.
- To compare Bhutanese chickens with other domestic chickens around the world.

In the past, the approach to genetic analysis of origin and diversity of native chicken breeds were based on cytogenetic and morphological studies (Cheng et al., 1996; Li et al., 1996; Liu and Cheng, 1997; Ma and Lu, 1993). Today, the molecular biology techniques, particularly the DNA sequences analysis, are becoming very popular for assessing phylogenetic relationships among various animal groups. By comparing DNA sequences data, one can derive evolutionary relationships, levels of variability and geographical sub-structuring within and between groups of animals.

The DNA of mitochondria (Figure 1) is extranuclear genetic material and has been widely used for phylogenetic studies for several reasons.

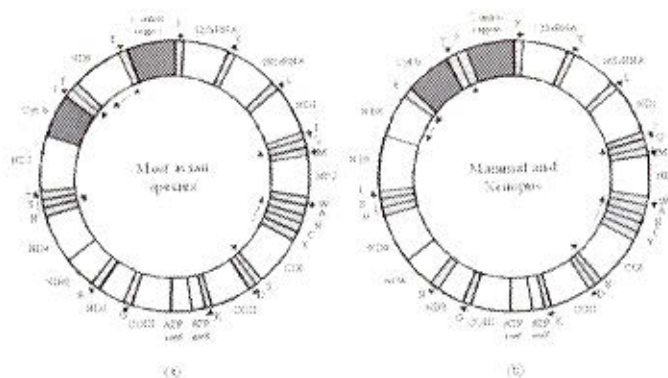


Figure 1: Mitochondrial genomes of birds (a), mammals & *Xenopus* (b). tRNA genes are identified by their 1-amino acid codes (T = tRNA^{Thr}; P = tRNA^{Pro}; tRNA^{Glu}). Outer circle represents the Heavy (H) strand and the inner circle the Light (L) strand. Polarity of the transcription and the transcribed strand is shown with the arrowheads. When no arrowhead is marked the gene is transcribed from the H-Strand with clockwise polarity. (Source: Redrawn by Kvist, 2000, from Desjardins & Morais, 1990).

Firstly, mtDNA evolves mainly via single base pair substitutions (Kvist, 2000) with only infrequent major sequence rearrangements (Wolstenholme, 1992). Secondly, the rate of mtDNA evolution appears to be 10 times faster than nuclear DNA (Brown *et al.*, 1979; Hartl & Clark, 1997; Kvist, 2000). Different regions of the mitochondrial genome evolve at different rates (Saccone *et al.*, 1991) and this allows suitable regions to be chosen for the question under study. For instance, sequence analysis of vertebrate mtDNA has revealed that the control region or the D-loop (Figure 2) is the most rapidly evolving part of the genome (Desjardins & Morais, 1990; Wenink, *et al.*, 1993).

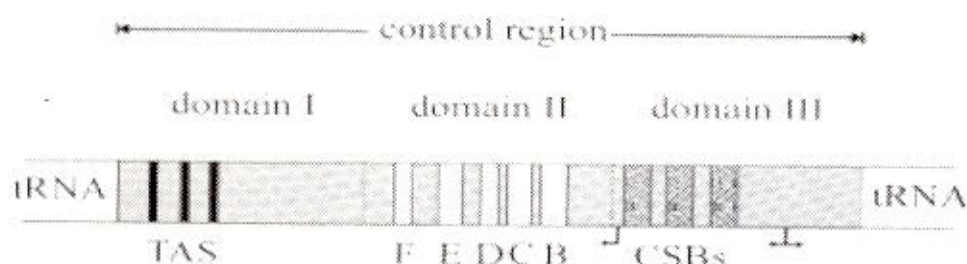


Figure 2: General structure of the vertebrate mitochondrial control region. The D-loop region in chicken is slightly larger (1227 bp) than the corresponding sequence found in human (1122 bp), cow (910 bp) mouse (879 bp), or rat (889) but shorter than *X. laevis*, which has 2134 bp (Morais & Desjardins, 1990). As illustrated, the whole of the D-loop region is divided into three domains, domain II, III, and I. Arrows indicate location of the H-strand replication origin and the bi-directional promoter for L- and H-strand transcription. TAS, termination association sequences; F through B, conserved sequence boxes in the central domain; CSBs, conserved sequence blocks. (Source: Ruokonen & Kvist, 2002).

Thirdly, mtDNA is haploid, non-recombining (Avice, 1994), and maternally inherited. From 87 gophers studied, 23 distinct types of mtDNA were identified (Hartl & Clark, 1997). Each of these types represented a maternal mtDNA lineage, distinct from other lineages. In other words, it can be inferred that the animals that share similar mtDNA type must have a female ancestor in common. All these features make mtDNA a useful and one of the most frequently used markers in molecular systematics (Sorenson *et al.*, 1999; Kvist, 2000) for determining relationships among individuals within and among closely related species. The mtDNA is particularly useful in inferring phylogenetic relationship between closely related species within the same family or even within the

same species (Hartl & Clark, 1997). The D-loop sequences in particular have been used to establish intraspecific and interspecific relationships, determine maternal contributions, and trace the origin of modern and ancient animals.

MATERIALS AND METHODS

Animal Resources and Experimental sites

The blood from eight different lines of indigenous chickens (Seim, Frizzle, LocalX, Nab Yubjha, Barred yubjha, Naked Neck, Kauray, Native White) with five replicates in each line was sampled from different areas of Tsirang and Lobesa valleys. The former was the main study area as it harboured most lines of chickens found in Bhutan. DNA extraction was done at the Regional Veterinary Epidemiology Centre (RVEC), Serbithang, Bhutan. The molecular biology techniques such as PCR, Cloning, and generating DNA sequences were carried out at the Centre for Advanced Technologies in Animal Genetics and Reproduction (Reprogen), Faculty of Veterinary Science, University of Sydney, Australia.

Preparation of DNA and Polymerase Chain Reaction (PCR) Amplification of mtDNA D-loop

The QIAamp DNA Mini Kit and QIAamp DNA Blood Mini Kit supplied by Qiagen (Australia) were used to isolate DNA from chicken whole blood. The Qiagen protocol was used with some modification in order to suit nucleated erythrocytes of chicken blood.

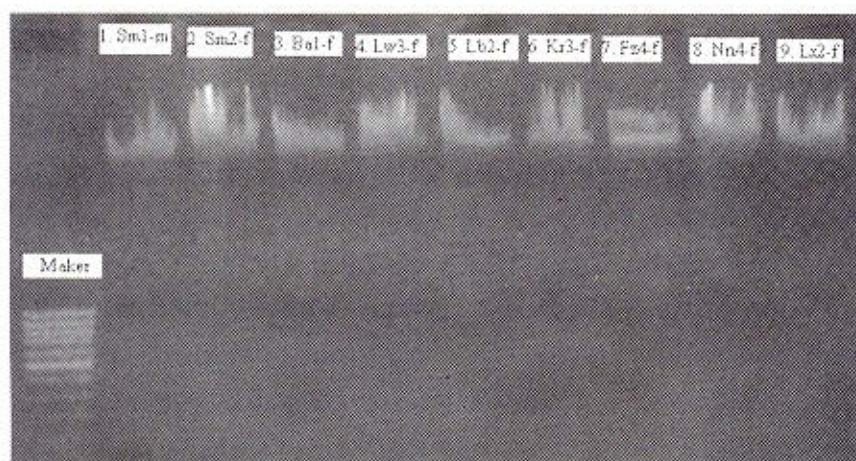


Figure 3 : Genomic DNA concentration determined by electrophoretic ethidium bromide fluorescent method. The DNAs are from nine different Bhutanese indigenous chickens.

The concentration of DNA can be estimated by comparing with a standard series of dilutions, since the amount of the fluorescence corresponds to the amount of DNA (Sambrook *et al.*, 1989).

The D-loop region was amplified by PCR in two pieces as illustrated in Figure 4. The primer combination of 16719 FP1 (5'GGTTAGACCCCAAGGACTAC3') and 550 RP1 (5'GTGCCTGACCGAGGAACCAAGTG3') were used to amplify the first 550 bp of the D-loop, and the combination 436 FP2 (5'CCTCACGAGAGATCAGCAAAC3') and 1279 RP2 (5'GTACCATCTTGGCATCTTCAGTG 3') were used for amplification of the rest of the sequences. In this primer design, the D-loop region starts at position one which is equal to position 16776 and ends at position 1227 of the first published sequence of the entire chicken mtDNA (Desjardins & Morais, 1990).

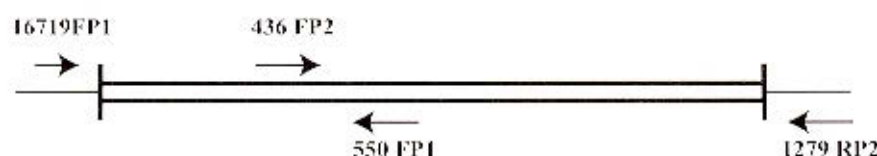
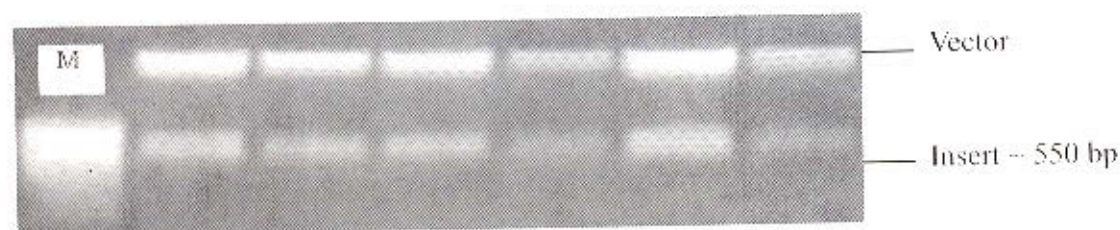


Figure 4: D-loop mitochondria of chicken. This is found to be more than 1.2 kb, and this figure illustrate how the fragment was amplified for cloning and sequencing. Note two pairs of primers (indicated by red and green arrow respectively) used for this purpose.

For the first set of primer (16719 FP1 & 550 RP1), the PCR was performed in 25 μ l reaction volumes, each containing 200 ng DNA template, 0.2 unit of *Taq* polymerase (prepared in the laboratory), 0.2 *Tli* DNA polymerase, 1 μ l dNTP (mM), 1.5 μ l $MgCl_2$ (25 mM), 2.5 μ l 10 buffer (100mM Tris.Cl, 15mM $MgCl_2$, 500mM KCl, pH 8.3), and 13.6 μ l distilled sterile water. The mixture was placed in 0.2 μ l PCR tubes with 2 drops of paraffin oil. The reaction profile included 5 minutes denaturation step at 95°C followed by 40 cycles, each consisting of 40 sec denaturation at 94°C, 2 min annealing at 55°C, 40 sec of extension at 72°C, and then a final 20 min extension step at 72°C. Similar procedures were followed for the second set of primer pair (436 FP2 and 1279 RP2) except the concentration of $MgCl_2$ was increased to 2.0 μ l and the annealing temperature to 58°C.

Cloning the PCR Products

The PCR products were gel-purified using a JETquick spin column kit (GeneWork, Australia) and cloned using TOPO TA Cloning® kits according to the manufacturer's instructions (Invitrogen, San Diego, CA USA). After identifying clones with the correct insert, high quality plasmid DNA was purified using Ultra Clean™ Mini Plasmid Prep Kit™ (MO BIO Laboratories, Inc.). The *Eco* RI restriction enzyme digestion (5 ml Plasmid & insert, 2.0 ml 10 x buffer, 0.2 ml Acetylated BSA (10 g/ml), 1.0 ml *Eco* RI restriction enzyme, and 11.8 ml Distilled H₂O) was carried out to evaluate the efficiency and yield of plasmid DNA recovery. Figure 5 illustrates the digestion products for one of the primer pairs.



5: *Eco* RI restriction digestion verifying correct inserts of Bhutanese chicken clones

DNA Sequencing

DNA sequencing reactions were carried out using a SequiTherm EXCEL™ II DNA Sequencing kit-LC (Epicentre Technologies, Inc.). The PCR reactions were 95°C initial denaturation followed by 30 cycles each with 30 sec further denaturation at 95°C, 56°C annealing for 15 sec and 1 min extension step at 70°C. The products were loaded on 4% polyacrylamide gel installed in the Li-Cor sequencer (Model 4200, Li-Cor Inc.), which is excellent for long sequence reads. After running the sequencing gel for 12 hours, the sequence data were analysed with Base ImageIR™ software (version 4.1, Li-Cor Inc.).

The raw sequence data generated was blasted against GenBank using BLASTN 2.0.14 (Altschul et al., 1997), BioManager by ANGIS. DNA sequence alignment program, Sequencher™ (Gene Code Corporation, Ann Arbor, MI), was used to align sequences. The correctness of raw sequence was determined by using both forward and reverse raw strands as reference of each other and counter-checked with three GenBank sequences (WLH, Plymouth Rock, Thai Bantam) as further references. Ambiguous base appearing in the sequence was verified using raw sequence chromatogram. This way the entire D-loop region with 1232 bp was aligned.

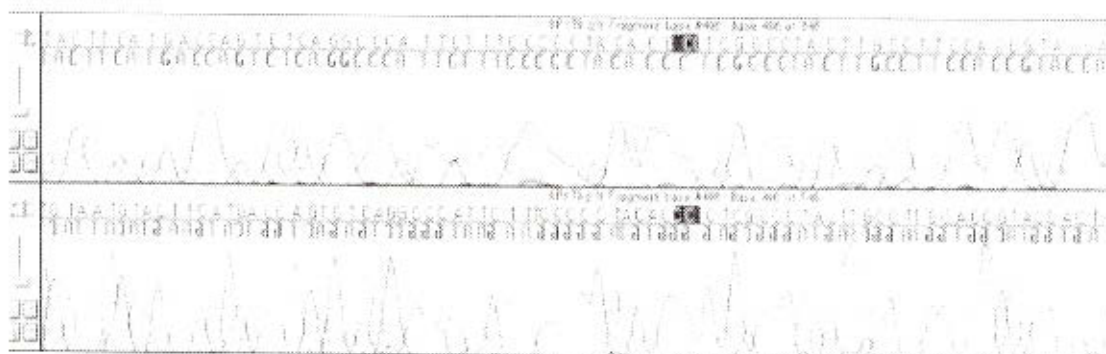


Figure 6: DNA Sequence chromatogram from sample 6 (Kauray)

Analysis Based On Partial D-Loop Sequences

Neighbour Joining (NJ) Method

The NJ genetic distance method analysis was used to trace the maternal ancestor of the Bhutanese indigenous chickens. The same method was also used by Niu *et al.*, (2002) to analyse the origin and genetic diversity of Chinese native chickens breeds. To do this, partial D-loop sequences for each of the jungle fowl species, one Japanese *Gallus domesticus* (*Nagoya Dori*), Thai Bantam, an Indonesian Ayam Kokok Balenggek, and two commercial breeds (Plymouth rock and WLH), were retrieved from the GenBank, and their partial sequences (~500 bp) were aligned against the equivalent D-loop sequences of eight Bhutanese indigenous chicken lines.

Analysis Based on Entire D-Loop Sequences

Neighbour Joining Analysis

This analysis was done to investigate the genetic diversity of Bhutanese chickens in relation to other selected breeds and the wild ancestor. The entire d-loop sequences from Bhutanese chickens and other selected breeds were analysed using the NJ distance method implemented within the PAUP program.

Maximum Likelihood (ML) Analysis

The ML analysis on the complete D-loop sequences was performed to verify the output generated by NJ method. ML estimates phylogenies from nucleotide sequences. ML model takes account of following assumptions:

- ❖ Each site in the sequence evolves independently.

- ❖ Different lineages evolve independently.
- ❖ Each site undergoes substitution rate at an expected specified rate.

Fitch Method Analysis

The FITCH phylogenetic program (Felsenstein, 1989) was used because it estimates phylogenies from distance matrix data under the "additive tree model" according to which the distances are expected to equal the sums of branch lengths between the species. The program uses the Fitch-Margoliash criterion and some related least squares criteria and does not assume an evolutionary clock. It generally produces similar results to the NJ method (Felsenstein, 1989).

RESULTS AND DISCUSSION

Origin of the Bhutanese Indigenous Chickens

The genus *Gallus* is composed of four wild species, *Gallus gallus* (Red Jungle Fowl), *Gallus sonneratii* (Grey Jungle Fowl), *Gallus lafayettei* (Ceylon Jungle Fowl) and *Gallus varius*.

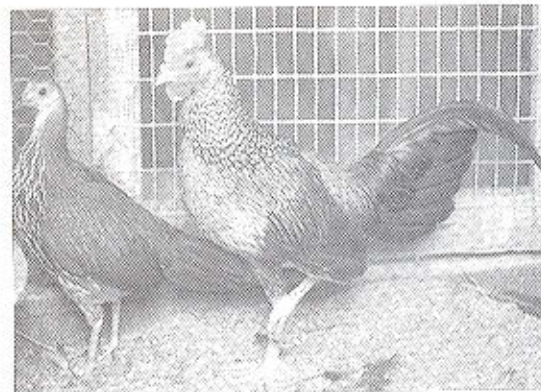


Figure 7 : Left- Red Jungle Fowl or *Gallus gallus* (Source: Wong, 2001); Right- Grey Jungle Fowl or *Gallus sonneratii* (Source: Robbins, 2002)

The red jungle fowl (Figure 7) inhabits South East Asia including northeast India covering Bhutan and Nepal and some parts of Tibet and China. The grey jungle fowl (Figure 7) is found only in India (Stevens, 1991) while *Gallus Lafayettei*, the Ceylon jungle fowl (Figure 8), originally inhabited in Sri Lanka. The green jungle fowl also called Javan jungle fowl (Figure 8) is a native of Java Island in Indonesia.

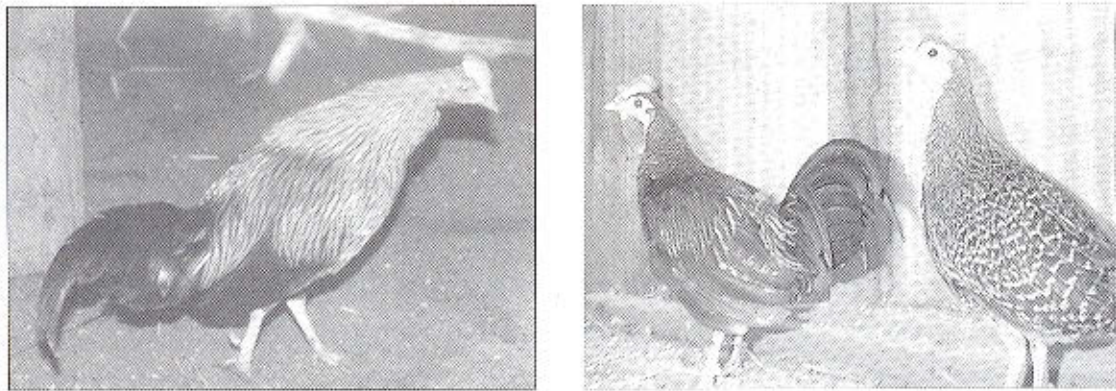


Figure 8 : Left- Ceylon Jungle Fowl or *Gallus lafayetiei* ; Right- Green Jungle Fowl or *Gallus varius*. (Source: Robbins, 2002).

The NJ method analysis of partial D-loop sequences from thirteen domestic chickens and four jungle fowls showed that three of the four jungle fowls are very distinct from domestic chicken sequences. The Red Jungle Fowl or *Gallus gallus* mitochondrial D-loop sequence was found to be most similar to the domestic chickens, which is in accordance with history of chicken domestication (Akishinonomiya *et al.*, 1994).

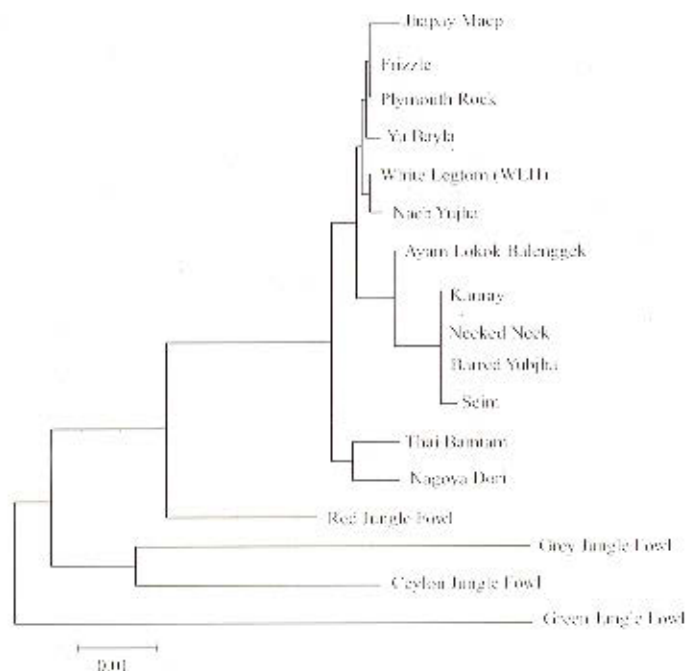


Figure 9 : NJ tree of the fowl species on the basis of partial (500 bp) D-loop sequences. This was constructed using PHYLIP Package provided by ANGIS

Despite the close geographical location of Grey Jungle Fowl (*Gallus sonnerati*) of India to Bhutan, this study supports the origin of Bhutanese indigenous chickens (Figure 10) from Red Jungle Fowl.



Figure 10 : Jhapay Maep or red rooster (Left); Barred Yubjha (Centre); Indigenous white hen or Yubjha Kab (Right). (Source: Nidup, 2003)

Figure 9 indicates clustering of Bhutanese indigenous chickens with other domestic chickens sequences and more closely to Red Jungle Fowl than other three species of jungle fowls. This study also further reinforces the conclusion that the Red Jungle Fowl is the matrilineal ancestor of present day domestic chickens, and is in consistent with the findings by Akishinomomiya et al., (1994), Akishinomomiya et al., (1996), and Niu et al., (2002).

Genetic Relationship of Bhutanese Chickens

The analysis of mtDNA D-loop sequences from eight chicken lines indigenous to Bhutan showed twenty-six polymorphic sites (See Table 1), representing 0.02% of the total DNA sequence analyzed (1232 bp). There were no deletion in the sequences and all the twenty-six variable positions were single nucleotide substitutions.

As in mammalian mitochondrial evolution (Vigilant et al., 1991; Kim et al., 1999), the D-loop region of the Bhutanese chickens indicates strong transitional bias or in other words, transitional substitutions are found to occur more frequently than transversions. These variations or substitutions indicate reasonably high diversity among Bhutanese chickens.

The entire mtDNA sequences of Bhutanese indigenous chicken lines, red jungle fowl, and other domestic chickens sequences retrieved from the Genbank were analysed using Kimura genetic distance method. The genetic distances between each of these chickens and the red jungle fowl are given in Table 2.

The NJ phylogenetic consensus tree (Figure 11) generated using entire mtDNA sequences groups Bhutanese indigenous chicken lines into two main clusters. In the first clade, the Bhutanese indigenous chicken *Nab Yubjha* appears to be closely related to two commercial breeds (WLH and Plymouth Rock) and three other Bhutanese chickens (*Jhapay Maep*, Frizzle and *Yu Bayla*).

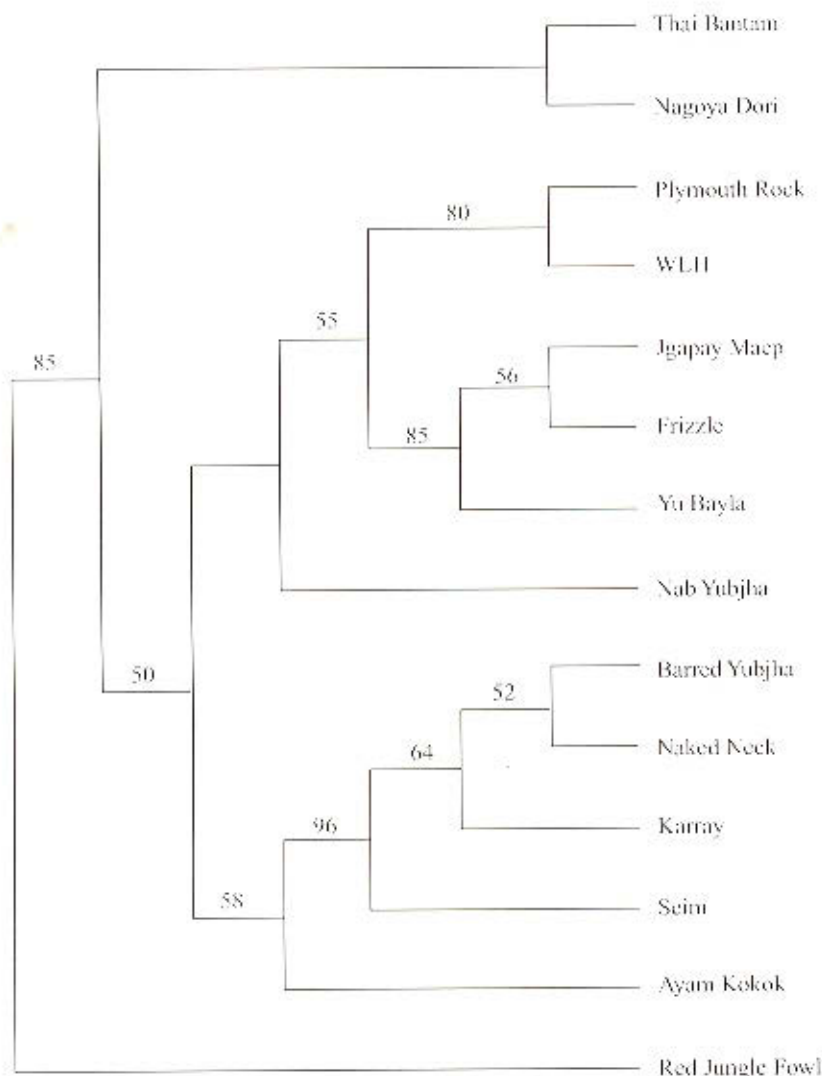


Figure 11 : Neighbour-Joining tree with bootstrap support values (50-96%) generated using PAUP program (Version 4.0b4a).

It is possible that WLH and Plymouth Rock could have been developed from chicken with similar mtDNA sequences to that of Naeb Yubjha, which is without doubt one of the most common indigenous chicken lines (second to Seim) found in Bhutan. Alternatively, it is possible that the widespread crossbreeding programs (Nidup et al., 2005) attempted in Bhutan have introduced mitochondrial sequences from exotic birds into the indigenous Bhutanese chicken populations. Thus, the mtDNA of three Bhutanese indigenous chickens (Jhapay Maep, Frizzle and Yu Bayla) could be derived from exotics similar to WLH and Plymouth Rock. Yu Bayla, an improved breed was expected to associate closely with the two exotic commercial breeds since its mtDNA, should come from its exotic female parent (BV 380 Strains = Bayla). Given the small sample (only one each of WLH and Plymouth Rock), the clustering of the Yu Bayla sequence is consistent with this scenario.

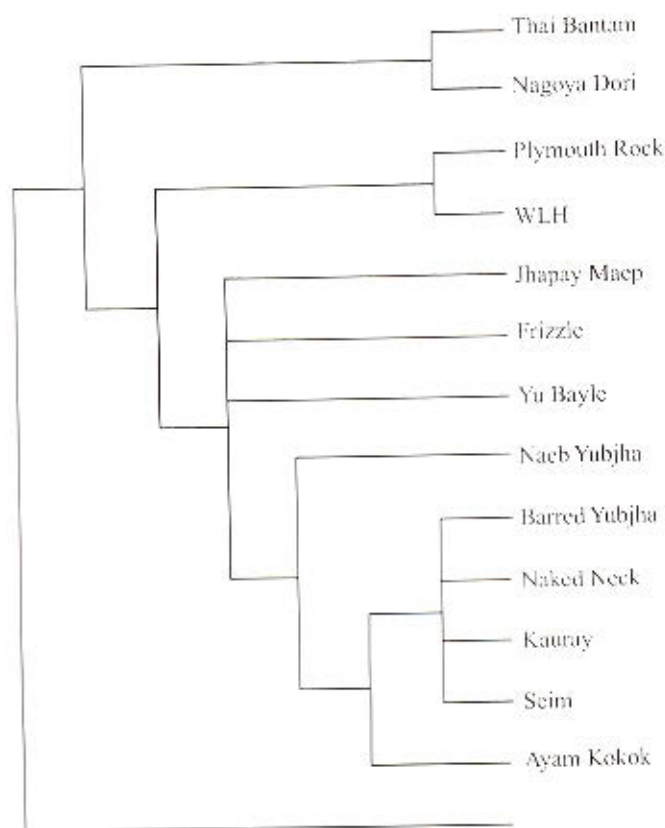


Figure 12: Maximum Likelihood tree constructed from entire d-loop sequences using PAUP program.

In the second clade, the Bhutanese mitochondria sequences cluster with Indonesian Ayam Kokok Balenggek, perhaps indicative of genetic exchanges between Indonesia and Bhutan. This is surprising given that Bhutan and Indonesia are geographically widely separated. This wide geographical separation of two countries divided by sea and other Asian countries suggests that mtDNA D-loop sequences of Ayam Kokok Balenggek would not have been directly introduced into Bhutan but would have come via indirect routes. This would be another interesting area of research. An encouraging finding in this clade was that mtDNA sequences of *Kauray*, Naked Neck, and *Barred Yubjha* clustered closely and it appears that all these three chicken lines may be derived from *Seim*, the most common indigenous chicken found in Bhutan.

However, the analysis of ML in Figure 12 does not fully support this interpretation. Although the ML dendrogram is reasonably similar to NJ tree (Figure 11), the commercial breeds (WLH and Plymouth Rock) do not cluster in a clade with the four indigenous breeds (*Naeb Yubjha*, Frizzle, *Jhapy Maep*, *Yu Bayla*).

Further sampling of exotic and indigenous sequences is required for a more definitive interpretation.

These patterns of clustering among Bhutanese chickens were reaffirmed when only the sequences from Bhutanese chickens and red jungle fowl (out-group) were considered for evaluation by Fitch-Margoliash genetic distance method.

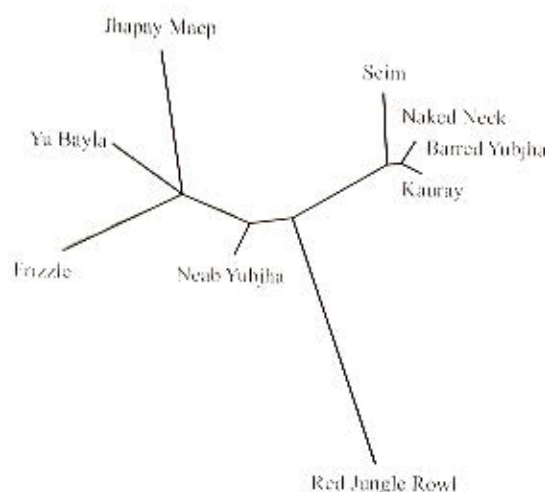


Figure 13 : A phylogenetic consensus tree generated using the Fitch-Margoliash method to assess the genetic diversity within the Bhutanese chickens with Red Jungle Fowl taken as out-group.

The output from Fitch-Margoliash (Figure 13) compared quite closely with dendrogram generated by NJ method (Figure 11) and with similar pattern to ML tree (Figure 12) thereby further validating the result.

Geographical Correlations

There is no consistent pattern of clustering within trees and close geographical locations. For instance, in the first cluster, Barred Yubjha and Kauray were from Tsholingkhori and Naked Neck from Mandegang, both in Tsirang district, while Seim was sampled from Lobesa in Thimphu district. In the second cluster, Frizzle and Jhapay Maep were from Tsholingkhori and Daje respectively with both villages located in Tsirang region, while Naeb Yubjha in the same cluster comes from Lobesa in Thimphu region. Clearly, there has been plenty of opportunity for mitochondrial sequences to disperse within Bhutan.

One might expect that those birds from the same district would cluster closely in dendrogram but this is not always the case here. It might also have been expected that mtDNA of Jhapay Maep (rooster) and Seim (hen) be almost identical, since Nidup et al. (2002) categorised them as one breed. However, mtDNA sequences do not correlate with geographical distribution or even breed.

CONCLUSION

The indigenous chickens comprise 95% of the total rural chicken population in Bhutan. The analysis of mtDNA sequences suggest that Bhutanese chickens are genetically diverse and like all other domestic chickens originated from red jungle fowl.

Recommendations

❖ In this study, sampling was limited to only two regions of Bhutan i.e. Lobesa and Tsirang. Bhutan can be divided into four regions namely eastern, western, central and southern regions. Sampling from these areas may provide an ultimate idea on chicken biodiversity resources in the country.

❖ Mitochondria DNA by itself may not be the most useful molecular marker when used for determining genetic diversity. Therefore, use of microsatellite genotyping should be considered for further study. Microsatellites have been proposed as the best markers

for evaluating the genetic diversities of domestic animals because of their abundant, even distribution in the genome, high polymorphism and ease of genotyping. The food and agriculture organization's MODAD Program has recommended a set of microsatellite loci for evaluating the genetic diversities of chickens as a part of the global strategy for the management of farm animal genetic resources (Wimmers *et al.*, 2000; FAO, 2004).

❖ Participation of local people and use of locally available resources are the two main pillars of sustainability of any development initiative. It is unequivocal by stated that local chickens will have to be used as a basal germplasm in breeding programmes for sustainable chicken production in Bhutan.

For this reason, further research on genetics, production parameters, breeding and management in local chickens to improve productivity will have to be carried out. This will enable the formulation and implementation of sustainable poultry development programmes.

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MILK YIELD OF MITHUN CROSS AND SIRI CATTLE ON BHUTANESE FARMS

TAMANG,¹ NB AND PERKINS, JM²

ABSTRACT

*Cattle is important to Bhutanese agrarian economy as it plays a important role in providing draught power, manure, meat, milk and milk products to farm families. Over many years, Bhutanese farmers have been crossing Mithun (*Bos frontalis*) bulls with Siri (*Bos indicus*) cows to improve the performance of crossbred progenies for their milk yield, fat percent, size and power. But there is very little published information available to support the claim high performance of these progenies. In view of this, a study was undertaken to measure the milk yield of Mithun x Siri cross-bred (Mithun cross) and Siri cattle, as reared in typical Bhutanese farming systems.*

*Milk yields were measured at fourteen different farms, both morning and evening for one day per month in April and May 2004. A total of 101 cows were sampled in April, of which 43 were Jatsham (Mithun:Siri, 50:50), 20 were Yangkum (Mithun:Siri, 25:75) and 26 were Siri (>96% Siri). In May only 73 percent of same animals (33 Jatsham, 19 Siri and 13 Yangkum) could be re-sampled. However another 12 cattle (three Jatsham, six Yangkum and three Siri) were included which had not been measured in the first month. Average milk yield of Jatsham was the highest in April at 2.08 l/day $\pm$ 0.09, Yangkum averaged 1.8 l/day $\pm$ 0.10, followed by Siri with 1.52 l/day $\pm$ 0.13 and yields were similar in May 2004. These averages do not include the free self consumed amount of milk by calves. The fat percent and corresponding butter and cheese yields were higher in Jatsham milk. These cattle do not have the genetic potential for high milk yields but the combination of higher milk fat percent, adaptability to local conditions and good disease resistance has made Jatsham a highly prized cross-breed within Bhutan's village grazing systems for many years. However, with the development of urban centres and improvement of market accessibility for liquid milk, farmers in peri urban areas who opt dairying as a major farming activity is likely to switch over to *Bos taurus* based herds.*

Key Words : *Jatsham (Mithun: Siri, 50: 50), Yangkum (Mithun: Siri,25: 75) Siri (>96% pure Siri), Milk yield, Village grazing systems.*

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INTRODUCTION

Cattle have long been a central component of many Bhutanese farming systems. They are used for the production of milk, the most of which is converted to butter or cheese for consumption and trade; draught power, income and a storage of wealth. Most of the country's 320,000 (MoA, 2000) cattle are *Bos indicus* types, a Siri breed known locally as *Thrabam* but there is also a strong interest in the Mithun (*Bos frontalis*).

For over a century, and probably longer, farmers in Bhutan have been crossing Mithun bulls with Siri cows (Roder et al., 2001). Their purpose in crossing is to improve the performance of crossbred progenies in relation to milk yield, fat percent, size and power.

The first filial generation (F_1) male, called *Jatsha*, is sterile while the equivalent female, *Jatsham*, is fertile. To deal with the problem of male infertility, the *Jatsham* are back-crossed with Siri bulls for the next three to four generations. This usually results in three or four generations of cross-breeds present in village communities.

Many farmers are highly enthusiastic breeders, with very detailed knowledge of their animals' pedigrees. They firmly believe that the *Jatsham* crosses yield more milk which has higher fat levels than Siri cattle, and Mithun cross-breeds command higher prices. In order to keep pace with the demand for Mithun, animal scientists at Government research centres in Bhutan are obliged to pursue a national cattle breeding strategy based on the utilisation of Mithun, both as a means of boosting fat content in milk and draught power and conserving the Mithun gene pool.

At present, there is relatively little data available to support the claims of higher productivity or justify an expanded Mithun cross-breeding strategy. The arguments supporting the strategy often rely on anecdotal evidence and published information is scarce. Some performance recording has been made for Siri cattle maintained on government farms but there is a lack of data about milk yields recorded on village farms, plus limited general information on Siri and Mithun-cross cattle husbandry in Bhutan (Burgois Leuthi, 1999). Pure Mithun cows yield very little amount of milk. Yadav and Verma (1996) reported yields of 0.41 l/day from sample of one Mithun cow; Giasuddin *et al.*, (2003) reported milk yield to be even lower, about 0.30 l/day on an average for three Mithun cows. Staff at Mithun breeding farms in Bhutan suggested milk yields would not exceed 0.5 l/day (C. Dendup and AB. Bhujel, *pers. comm.*, Regional Mithun Breeding Farm, Chukha, Bhutan).

In view of the lack of data in Bhutan and the strong interest in a Mithun-based breeding strategy, this study was undertaken to provide initial data for testing the general hypothesis:

Mithun cross cattle (especially *Jatsham*) managed under typical Bhutanese farms have higher milk yields than Siri cattle.

MATERIALS AND METHODS

The study area

The study area was in Bongo *geog* (smallest administrative unit) in the Chukha District of Bhutan. Bongo comprises 15 widely scattered villages of which three were selected for study: Gedu Trashigang, Chasilakha and Junja. The villages lie within the humid subtropical zone and share similar physical and social environments. They comprise a total of 89 households, with relatively high populations of Mithun cross and Siri cattle. Most farmers are agro-pastoralists, depending on livestock, cropping and collecting forest products. Much of the production is for home consumption but farm families are also actively involved in local trade, particularly milk products such as cheese and butter. Land is cultivated at lower altitudes, with the cattle typically herded in nearby broadleaf forests.

Sampling of animals

Farmers willing to participate voluntarily were selected in three strata: eight small herds (1-5 milking cows), four medium herds (6-10 cows) and two large herds (greater than 10 cows). Selection of individual cattle in the farms was based on breeding history and phenotypic characteristics. Coat colour and horning pattern of animals were also noted for each individual animal, as additional aids to identification. Records were prepared for a total sample of 101 animals. In April 43 *Jatsham*, 20 *Yangkum* and 26 Siri were recorded. It was proposed that milk yield for same individual animals were to be undertaken on two occasions in two consecutive months. But during May 2004 only 73 percent of same animals (33 *Jatsham*, 19 Siri and 13 *Yangkum*) could be re-sampled as most herds have migrated to higher altitudes far away from the road head and could not be traced; some animals had been sold to new owner. However, in order not to compromise with the sample size, another 12 cattle (three *Jatsham*, six *Yangkum* and three Siri) were included which had not been measured in the first month.

Recording of milk yield

Several researchers recommend that monthly milk yield recording is adequate for individual selection of cows and recording once every two months is usually sufficient for progeny testing (Chamberlain, 1989; Arbenz and Tshering, 2000). Therefore, measurement of milk yield for individual animals was undertaken on a monthly basis for two consecutive months. Milk yield was measured both morning and evening, using a graduated measuring cylinder.

Milk samples for estimating fat percent were collected at random from six different farms. All milk obtained in a day from the selected farms was fermented and churned to estimate butter and cheese yield, and weighed with a spring balance.

RESULTS AND DISCUSSION

Average daily milk yield

As noted, there was widespread suckling of calves at the village farms. Calves suckled mostly two or three quarters, thus total yield must comprise two components:

- ❖ Consumption milk or milk off take
- ❖ Calf allowance or calf off take

Daily consumption of milk collected by herder was measured and the amount of milk consumed by the calves (calf allowance) was estimated. The milk yield recorded on the sampled farms refers only to consumption milk or milk off take.



Fig. 1 Jatsham and Siri cows being suckled by calves at the village farms

Average consumption milk yield (litres per day) for *Jatsham* (Mithun:Siri 50:50) in April 2004 was the highest at 2.08 ± 0.09 , *Yangkum* (Mithun:Siri 25:75) was second highest, 1.8 ± 0.10 , followed by Siri (Siri >96) at 1.52 ± 0.13 . Average milk yield per day in the second round of recordings showed almost no change for *Jatsham* at $2.02 \pm 0.0.13$ l/day while slight increases were recorded for *Yangkum* and Siri, 1.93 ± 0.27 l/day and 1.59 ± 0.17 l/day respectively (Table 1).

During the first recording period in April, the milk yields of *Jatsham* were higher than those of *Yangkum* but analysis of variance revealed no statistically significant difference; similarly there was no significant difference between yields of *Yangkum* and Siri. However, *Jatsham* crosses had a significantly higher milk yield than Siri ($p < 0.001$). There were no significant differences ($p = 0.176$ or $p > 0.05$) in milk yields between all three cattle types in May 2004.

Table 1. Average milk yields in first and second recording rounds

Cattle types	Number	April 2004		Number	May 2004	
		Average milk yield (l/day)	SEM		Average milk yield (l/day)	SEM
<i>Jatsham</i>	43	2.08 ^a	0.09	36	2.02 ^a	0.13
<i>Yangkum</i>	20	1.80 ^{ab}	0.10	19	1.93 ^a	0.27
Siri	26	1.52 ^b	0.13	22	1.59 ^a	0.17
p-value		0.001			0.176	

^{a, b} values with different superscript within a column are statistically different

Cattle are typically milked twice each day. Milk yields from the morning milking were found to be significantly higher than those recorded in the evening, for all cattle types ($p < 0.05$), (Table 2).

Table 2. Milk yields in morning and evening milkings

Cattle types	Average milk yields (litres)		
	Morning	Evening	Total daily
<i>Jatsham</i>	1.16	0.89	2.08
<i>Yangkum</i>	0.99	0.81	1.80
Siri	0.86	0.65	1.52

The results from this present study are slightly lower than the daily yields of 2.2 ± 0.25 litres for *Jatsham* and 1.9 ± 0.24 for *Yangkum* reported earlier by Phanchung and Roden (1996). The data for their study were collected in villages of *Lobesa geog* Thimphu district, using structured questionnaires for a sample of five *Jatsham* and four *Yangkum* cattle respectively. Milk yields for Siri cattle were slightly higher than 1.47 l/day reported for Siri in western Bhutan but lower than the 1.8 l/day for Siri cattle on a Government farm, as reported by Arbenz and Tshering (2000).

Estimated total milk yield and calf allowance

It has been mentioned earlier that the milk yield recorded on the sampled farms refers only to consumption milk or milk off take by farmers and did not include the milk intake by calves. To estimate total milk production, the milk intake by the calves was calculated using a simple model. The assumptions are that calves are permitted to suckle before milking for the purpose of encouraging let-down; all quarters are healthy; milk production from each quarter is almost equal. Calves were permitted to resume suckling after milking was completed by the farm family.

The number of quarters milked for each cow was recorded. If two quarters were milked and two left for the calf to suckle, total milk yield was estimated as double the production measured from two quarters. If three quarters were milked, total yield was calculated as measured yield multiplied by $4/3$. If all quarters were milked, no correction factor was used. These correction factors were applied independently to morning and evening milking if necessary, as some farmers did vary the number of quarters milked on a cow during the day. The sum of morning and evening milking was considered to represent total daily milk yield.

The average total daily milk yield (after correction) for *Jatsham* was 3.6 l/day of which calf allowance (corrected yield minus milk off-take) averaged 1.53 l/day, for *Yangkum* 3.0 l/day of which calf allowance was 1.2 l/day and Siri 2.48 l/day and calf allowance 0.96 l/day.

The conventional wisdom among Bhutanese farmers is not to milk cows for three to month, allowing calves to suckle freely and gain a healthy start. After a that calves are subjected to restricted suckling; typically two quarters are milked if the calves are less than five months of age because herders cannot provide appropriate replacement feeds.

By about six months of age, calves are considered mature and able to graze and manage their own feed; one quarter is left available to suckle until lactation ceases.

There do appear to be some opportunities to encourage earlier weaning but, again, resource constraints are quickly apparent. Milk replacements are not widely available and earlier weaning would require significant changes in time allocation of labour and management. Most subsistence-centred farmers are reluctant to make these changes as the marginal benefits are relatively small and could well be outweighed by marginal costs.

Milk fat percentage

Average milk fat percent was the highest in *Jatsham* milk, at 8.5%, with *Yangkum* at 7.2% and *Siri* 4.9%. Milk fat percent of *Jatsham* recorded in this study was very similar to the results from Hickman and Tenzing (1982) who reported it to be 8.6% but slightly higher than Phanchung and Tshewang (2002) who reported fat percent at 8.1%. Milk fat from the *Yangkum* was slightly higher than the 6.7 % and 6.4% reported by these authors while the result for *Siri* was a little lower in this study. Samples taken from animals at different stages of lactation could have varied in fat content. High fat percent in *Jatsham* followed by *Yangkum* is directly related to the higher level of Mithun inheritance. Pure Mithun has very high fat percent 10.6% (Hickman and Tenzing, 1982) and the successive reduction in fat content of back-crosses compared to F_1 can be attributed to the reduction of Mithun inheritance in successive generations.

Cheese and butter yield

Cheese and butter yields are extremely important to the farm family. Fluid milk is rarely consumed fresh and distances to market usually do not permit sale of fresh milk. It is invariably converted into butter and cheese on the farm, both for home consumption and sale. Softer cheeses, called *datshi*, are usually produced from cattle. Estimates made from on-farm churning and production at selected farms showed that both butter and cheese yields per litre of *Jatsham* milk are higher than those from *Yangkum* and *Siri* (Table 3). For interest, the yields from Jersey-cross cattle have also been included. These are lower (g/kg) than other samples taken during the study, probably a result of lower fat proportions in the Jersey-cross cattle. Higher milk volume from the Jersey-cross cattle would more than compensate for the lower yields of milk-based products.

Table 3. Butter and cheese yields per litre of milk at farm level

Cattle types	Butter yield	Cheese yield
	Grammes per litre of milk	
<i>Jatsham</i>	83	186
<i>Yangkum</i>	63	131
<i>Siri</i>	56	121
<i>Jersey cross</i>	45	109

CONCLUSION

The main aim of this study was to provide a reasonably accurate measurement of the milk yields of Mithun-Siri crossbreds and Siri cattle in village farms, plus to estimate fat percent and butter and cheese yields. This objective was achieved: the study provides estimates from the largest sample, thus far, of village cattle surveyed for milking performance in Bhutan.

The results largely followed expectation. Neither the Siri (*Bos indicus*) nor Mithun (*Bos frontalis*) are specialist dairy animals. The variation in genotypes of cattle in the sample were reflected by differences in production performance: highest output in term of milk volume, fat content, butter and cheese yield in the milk came from *Jatsham* (Mithun:Siri 50:50), intermediate from *Yangkum* (Mithun: Siri 25:75) and lowest from Siri (Siri >96%).

The study confirmed that Mithun-Siri cross-bred cattle have higher milk and fat yields than pure Siri. However, the milk yields are substantially lower than those obtained from specialist *Bos taurus* dairy breeds and crosses which suggests that the Mithun:Siri cross is unsuitable for development as a specialized dairy animal. These yield levels, together with the infertility of F_1 males (and low fertility of F_2 males), throw into question the pursuit of Mithun-based breeding strategies as a possible component of future dairy industries in Bhutan.

As is common elsewhere in the world, the development of a dairy industry in Bhutan is very much dependent upon market access. The main growth in demand for liquid milk and products is likely to be in urban areas. Transport is a key component of servicing this

market. Bhutan's mountainous terrain and relatively few, narrow roads will mean that only farming communities which are close to urban areas will become suppliers to the liquid milk market. A farmer who is interested in becoming a regular commercial milk supplier is likely to shift to a *Bos taurus* based herd and introduce substantial changes to feeding and management practices. This is already occurring; herders in the vicinity of Gedu town are increasingly rearing Jersey-cross cattle which are better fed and housed. Their access to a ready market for fluid milk seems to be a driving force in restructuring the herd, with farmers opting for exotic-cross cows.

In addition, many herders have started crossing their *Jatsham* with Jersey bulls to produce progeny called Jersey *Yanglum* because the older generations are beginning to realize that younger people may not cope with traditional cattle rearing practices and are adjusting to current needs. To overcome drudgery, some herders with large herds envision scaling down current herd sizes, to maintain a manageable number of high-yielding Jersey cross cows.

In summary, it is forecast that traditional cattle breeding strategies may not continue long near urban milk markets. However, most Bhutanese rural families live some distance from urban communities. For these people, the tradition of Mithun-cross cattle will continue because of real benefits obtained from combinations of milk yield, draught work, adaptation, hardiness, market value and other significant factors. The information provides an opportunity for agencies to shift the focus of their current work to programs which will directly concentrate on the genetic conservation and effective utilization of Siri and Mithun cattle, meeting herders' very strong demands for Mithun bulls and semen.

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CLUSTER ANALYSIS BASED ON MORPHOLOGICAL AND TUBER TRAITS IN POTATO GERMPLASM (*Solanum tuberosum* spp. *tuberosum*)

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ABSTRACT

The present study was aimed to characterize the potato germplasm (*Solanum tuberosum* sub-species *tuberosum*) based on genetic divergence for morphological and tuber traits and their further distribution into well characterized clusters. One hundred and sixty (160) accessions of germplasm from 14 different countries were evaluated for foliage traits comprising shoot height, number of shoots, number of leaves, number of nodes, internode length, foliage weight and tuber characters viz., tuber number, tuber weight and average tuber number. The field evaluation was done in augmented Complete Block Design. Two characters namely foliage weight and average tuber weight exhibited high coefficient of variability. Eight eigen vectors based on principal component analysis, accounted for 96.55 per cent of total variation. Following the non-hierarchical Euclidean cluster analysis all the 160 accession were grouped into six clusters with variable number of genotypes. The maximum genetic distance was between cluster IV and V and minimum was between I and V. The cluster IV with maximum intra-cluster distances and the highest mean values for desirable agronomic traits was hence identified for selecting superior genotypes. Genetic diversity was not related to geographic diversity. On the basis of genetic divergence and mean performance of yield and other traits, six genetically diverse and agronomically superior accessions, namely, Andinita, Dejima, SR. 1, P-6, P-7 and POOS.16 were selected. Each of these genotypes was either superior or comparable to the controls for important traits and thus, may be involved in multiple crossing programme to recover useful segregates. Character association studies showed that selection of parents with high average tuber weight coupled with optimum foliage weight would result in progenies of high yield potential.

Key words : Germplasm, *Solanum tuberosum*, classification
divergence, cluster analysis.

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INTRODUCTION

Worldwide, potato is the fourth most important food crop after wheat, rice and maize. It possess wide ranges of adaptation and climatic flexibility. There is a serious concern for global food security especially that of developing countries for increasing food demand for rapidly expanding population. Potato, having high production potential per unit area and time, and with high nutritive value, is the best answer to sustain burgeoning population and ward off malnutrition and hunger. One of tuber bearing species, *Solanum tuberosum* sub-species *tuberosum* has been exploited world wide for commercial cultivation. Simmonds (1962) pointed to the narrow genetic base of the most of the cultivated potato varieties resulting from a very limited number of breeding clones which may be inter-related through common ancestors (Hougas and Ross, 1956). The progress made in the improvement of *tuberosum* could therefore, be largely attributed to a low level of diversity.

Collection, conservation and evaluation of germplasm to identify diverse genetic donors, which can serve as parents to realize maximum heterosis is an inevitable requirement for any crop improvement programme. Moreover, quite often in a germplasm collection, many of the accessions may be duplicates and to find unique types, it is necessary to characterize the germplasm. The ordination techniques like principal component analysis followed by cluster analysis was found to be useful tool for getting multi correlated variables into another set of uncorrelated variables which can be utilized for classification of genotypes into homogenous groups (Spark, 1973 and Dillon and Goldstein, 1984). The genotypes from diverse clusters can be earmarked for different objectives. In the present study, the germplasm from different countries, were taken up with specific objectives (i) to preliminary evaluate the variability in the germplasm, (ii) to perform natural classification in the germplasm accessions for their characterization based on non-hierarchical Edclidean cluster analysis.

MATERIALS AND METHODS

Germplasm material

The material comprised of 160 potato germplasm accessions (*Solanum tuberosum* spp. *tuberosum*) along with three Indian varieties viz., Kufri Chandramukhi, Kufri Ashoka and Kufri Badshah. The accessions selected for study were highly diverse geographically. These have been collected from 14 different countries (Table 1) and being maintained vegetatively under field conditions.

Table 1: Source of Tuberosum germplasm used in this trial

Country	No. of accessions	Country	No. of accessions
Australia	3	The Netherlands	3
Bangladesh	3	New Zealand	2
Bulgaria	1	Peru	92
Canada	19	Poland	2
Germany	18	Sweden	2
India	7	United Kingdom	4
Nepal	2	United States	2

Total 160 accessions from 14 countries

Characters recorded

The germplasm material was evaluated under short day conditions during autumn season from October to January with decreasing day length (11.5-9.75 hr), and temperature min. 5-18°C, maximum 17-33°C at Central Potato Research Station, Jalandhar located in the North - Western Indo Gangetic plains at the longitude of 75°E, latitude of 30°N and 237 m from mean sea level. The trial was laid in 1999-2000, in eight blocks each with 20 test genotypes and three popular varieties (Kufri Chandramukhi, Kufri Ashoka and Kufri Badshah) as intermittent checks. Twelve plants in a single row planted at inter and intra-row distances of 60 cm and 20 cm, respectively, represented each genotype. Recommended agronomic practices were followed. Foliage characters were recorded at 70 days of crop maturity on five competitive plants (i.e., the best growing plants) per plot and tuber traits on a plot basis at 75 days of harvest (crop was dehaulmed at 75 days after planting and 30 days are given for tuber skin curing before

harvest). The characters studied were number of main stem per plant (total number of primary shoots directly emerging from the soil); plant height (height of the main shoot from the base of the plant to the top of the apical meristem in cm); number of nodes per plant (on the main shoot only); internode length (cm); number of leaves per plant, leaflet index (ratio: leaflet length/leaflet width of fourth leaflet); total foliage weight at full growth (gm), tuber yield per plant (gm), tuber number per plant, average tuber weight (gm) and harvest index (ratio: tuber yield/total biomass, multiplied by 1000). Adjusted mean values and estimates of error mean were calculated (Federer and Raghavarao, 1975). Correlation co-efficients of tuber yield with other characters were estimated using adjusted mean values.

Analytical procedures

Adjusted mean values were also used for principal component analysis to transform the inter dependent variables into a set of independent variables (Mardia, 1971; Hotelling, 1933). Principal component scores were used to compute Euclidean distances based on non-hierarchical cluster analysis (Beale, 1969; Spark, 1973) through computer software SPAR 1 (IASRI, New Delhi).

RESULTS AND DISCUSSION

Preliminary evaluation and character associations

The objective of this study was to determine the magnitude of variability among the germplasm collection using the criterion of similarity or dissimilarity based on aggregate effect of a number of agronomically important characters and to identify genetically diverse and agronomically desirable genotypes for exploitation in a breeding programme. The range, means, variances, co-efficient of variability and correlation coefficient of tuber yield with other characters are given in Table 2. Leaflet index exhibited the lowest co-efficient of variability followed by harvest index while the variability was moderate for plant height, number of nodes, internode length, number of shots per plant, number of leaves per plant, yield per plant and average tuber number. The presence of reasonably high variability for the most of characters indicated that there is a ample scope of exploiting the germplasm collection accessions. Character association study revealed that yield per plant was highly correlated to foliage weight ($r=0.49^{**}$). This suggests that choosing parental material for attempting crosses on the basis of foliage weight and

average tuber weight may produce useful transgressive segregants. Supporting the present observation on significant and positive association between tuber yield and average tuber weight, Gopal (1999a) also observed significant correlation coefficient between tuber yield and average weight in potato on character association study under diverse climatic conditions. Biomass in potato has shown close association with tuber yield but Harvest Index (HI) has no bearing on tuber yield of potato under short day conditions, where its value was very high. Singh (1996) reported that under short day conditions of Indo-Gangetic plains, the main determinant of yield was the capacity to synthesize more biomass rather than its partitioning towards tuber (HI).

Table 2. Estimates of variability parameters for 11 quantitative characters in potato

Cluster number	Mean	Variance	C.V. %	Range	Correlation coefficient (r) with tuber yield
Tuber yield/plant (gm)	271.78	89.58	34.8	64-526	-
Plant height (cm)	51.1	251.86	31.06	21.8-104.0	0.243*
No. of nodes/stem	13.7	10.08	24.28	7.4-22.0	0.279**
Internode length (cm)	3.82	1.25	29.32	1.03-6.12	0.178*
No. of shoots/plant	3.58	1.63	35.75	1.0-7.0	0.168*
No. of leaves/plant	52.48	371.72	36.74	25.2-102.2	0.104
Leaflet index	1.54	0.028	11.04	0.09-2.69	0.047
Foliage weight (gm)	137.9	43.93	48.06	40.0-340.0	0.495**
Harvest index (%)	77.72	78.17	11.45	46.37 - 95.75	0.282**
Av. tuber weight (gm)	39.46	332.69	46.22	11.3 - 101.15	0.663**
Av. tuber number	7.31	6.81	35.73	3.5-19.5	0.183*

Principal component analysis

Correlation matrix was used to transform all the metric traits into a single index of similarity in the form of principal components which yielded 11 eigen vectors and eigen roots. Only eight eigen vectors were used for further analysis as these accounted for 96.55 per cent of the variation. The per cent variation explained by these roots was 22.53, 21.71, 14.98, 9.88, 8.81, 7.72, 6.44, 4.46, 1.81, 1.09 and 0.58, respectively. The

first component was a measure of plant height and foliage weight; the second component of average tuber weight and the third component was the measure of number of leaves as the coefficients associated with these traits have the largest magnitude. Similarly, the yield/plant (gm) was presented by fourth component; number of leaves as the coefficients associated with these traits have the largest magnitude. Similarly, the yield/plant (gm) was presented by fourth component; number of nodes by fifth component, harvest index and inter node length by sixth component, leaflet index by seventh component and number of shoots/plant and average tuber number by eighth component.

Non-hierarchical Euclidean cluster analysis

Cluster analysis based on these eight principal components grouped 160 accessions into six well-characterized groups (I-VI). The average intra-cluster distance between the members of cluster IV was maximum followed in descending order by the clusters V, VI, II, I and III, ranging from 2.234-3.172 (Table 3). The minimum inter-cluster distance was observed between I and V (2.454), while the maximum inter-cluster distance was between IV and V (4.749) followed by inter-cluster distance between II and III (4.574) (Table 3). The accessions were distributed as 37 in cluster I, 28 in II, 24 in III, 19 in IV, 28 in V and 24 in VI. The accessions from different countries were grouped together in same cluster as well as from one country were scattered in all the clusters, suggesting thereby that there was no parallelism between genetic and geographical diversity. Cluster wise mean values for each character under study are given in Table 4. The accessions in cluster IV had the highest mean values for important characters viz., plant height (75.8 cm), internode length (5.73 cm), number of leaves per plant (72.09), foliage weight (219 g) and tuber yield per plant (360.44 g). Intra-cluster distance was also the highest in this group (Table 3).

Table 3. Estimates of average intra and inter cluster distances based on non-hierarchical Euclidean cluster analysis in potato

Cluster number	I	II	III	IV	V	VI
I	2.329	2.909	3.068	4.09	2.454	3.274
II		2.574	4.574	4.402	4.239	3.69
III			2.234	3.391	2.586	3.598
IV				3.172	4.749	3.445
V					2.767	3.526
VI						2.628

Diagonal (bold face) values are average intra-cluster distances, and underlined values are the highest (4.749) and the lowest (2.454) inter-cluster distances

Table 4. Average performance of different clusters for morphological and tuber traits in potato

Cluster number	Mean of variables										
	Plant height (cm)	Nodes per plant	Internode length (cm)	No. of shoots/plant	Number of leaves	Leaflet index	Foliage weight /plant	Harvest index (%)	Average tuber weight	Average tuber number	Tuber yield/plant
I	45.39	12.86	3.6	2.78	36.43	1.54	113.51	79.96	38.95	6.36	244.7
II	61.93	18.01	3.5	3.15	60.13	1.55	105.71	73.42	24.67	6.03	144.3
III	45.71	13.67	3.67	3.3	47.74	1.52	185.89	73.69	49.52	6.65	313.1
IV	75.8	13.46	5.73	3.82	72.09	1.52	219.16	84.21	71.01	5.35	360.4
V	38.13	12.9	2.99	3.81	42.56	1.62	90.71	72.25	28.18	7.85	208.3
VI	48.23	11.83	4.11	5.14	69.09	1.49	156.67	76.58	28.54	10.85	281.4

Characterization of different clusters for adaptability parameters i.e., Tuber Yield per plant (TY), Average Tuber Weight (ATW) and Average Tuber Number (ATN) also revealed that cluster IV had the highest TY 360.44 g; ATW 53.48 g and ATN 7.33. Three high yielding elite accessions were selected from this group. The accessions, which were better than controls in respect to tuber traits, were identified from other clusters also. In all, six accessions were selected; one from cluster I (Andinita); one from cluster III (POOS. 16), three from cluster IV (P-7, SR.1 and Dejima) and one from cluster VI (P-6). All these accessions were originated from Peru. Description of their tuber characters in comparison to controls is given in Table 5.

Table 5. Tuber traits of selected germplasm accessions in comparison to control varieties in potato

Germplasm	Doners name	Sources of germplasm	Tuber yield/plant (g)	Average tuber weight (g)	Average tuber number
CP 2297	P-6	Peru	412.29	77.34	5.33
CP 2298	P-7	Peru	436.98	61.46	7.11
CP 2378	POOS.6	Peru	427.53	48.31	8.85
CP 3125	SR.1	Peru	483.01	62.97	7.67
CP 3195	ANDINITA	Peru	462.16	64.34	6.25
CP 3200	DEJIMA	Peru	462.92	65.21	7.11
Controls					
Kufri Pukharaj	Indian variety		451.21	58.97	7.65
Kufri Ash oka	Indian variety		427.79	58.58	7.74
Kufri Chandramukhi	Indian variety		373.25	47.78	7.86
CD (0.05)			54.5	18.48	3.42

The grouping of 160 accessions into statistically well characterized six different clusters indicated considerable diversity in the germplasm. The observation on no association between genetic and geographical diversity, due to grouping of genotypes originated from one country into different clusters in present investigation were in general agreement with results obtained by Birhaman and Kaul, 1991. Inter and intra cluster distances which provided index of genetic diversity among and within the clusters, revealed that intra cluster distances were of lower magnitude as compared to inter cluster distances. The similar trend has been reported by workers (Gaur et al., 1978 and Gopal, 1999) supporting the heterogeneous and homogenous nature between and

within groups, respectively. It suggested that genotypes of same cluster had little divergence from each other. Therefore the hybridization among the accessions of genetically similar cluster is not desirable. The crosses between the genotypes from clusters having high inter cluster distances would give putative transgressive segregates with high genetic potential. The maximum average intra-cluster distance between members of cluster IV suggested that the genotypes in this cluster were relatively more diverse than those in other clusters. Furthermore, this cluster contained minimum number of genotypes (19) and had the highest mean values for the most of the morphological and tuber traits. Therefore, the cluster IV was deemed 'good' for selecting genetically diverse and superior genotypes with high genetic yield potential. The use of genetic distances between parents in predicting progeny means, heterosis and specific combining ability for tuber yield in potato is well documented (Gopal and Minocha, 1997). The six divergent accessions found superior to 160 germplasms were proposed in potato crossing programme to recover segregates with high genetic yield potential.

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ENHANCING RICE-WHEAT CROPPING SYSTEM PRODUCTIVITY AND FARMERS PROFITABILITY THROUGH EFFICIENT CULTURAL AND WATER MANAGEMENT PRACTICES

B.S. KALRA¹ AND A.K. SINGH²

ABSTRACT

A study was carried out in district Bulandshahr, Western Uttar Pradesh, India, in seasons of Kharif (July - October) 2001 and Rabi (November - April) 2001-02 to study the impact of different water supply situations on rice-wheat cropping systems. The data revealed extreme variability in the most of the parameters related to crop production and output. In this situation some farmers obtained very high yield levels and an attempt was made to demonstrate the attainable potential of the region by adopting the cultural practices and input use pattern of the most efficient farmers. A linear programming model was used and five most efficient plans were worked out. In case of Paddy, Plan I suggested an income of Rs. 30268/ha which is 77.6 per cent higher than that in the average Plan, which gave an income of Rs. 170333/ha. In rest of the plans also an income of Rs. 26918/ha, 24965/ha, 23592/ha and Rs. 22212 was obtained which was nearly 58 per cent, 46.5 per cent, 38.5 per cent and 30.4 per cent higher, respectively in comparison to Existing Average Plan. In case of wheat, Plan I suggests an income of Rs. 28531/ha which was 68.8 per cent higher, than that in the Existing Average Plan, which gave an income of Rs. 16907. In rest of the plans also an income of Rs. 226534/ha, 24480/ha, 23793/ha and 23489 was obtained which was 56.9 per cent, 44.8 per cent, 40.7 per cent and 39.0 per cent higher, respectively, in comparison to Existing Average Plan. Thus, it was demonstrated that the better management practices are the voids that need to be filled in to realize full potential output. The financial constraints are not the reasons for low productivity as the monetary expenditure of the farmers under Efficient Plans is not much higher than the farmers under Existing Average Plans.

Key words : Cropping system, variability, cultural practices, optimization, profitability and efficient plans.

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INTRODUCTION

In India, the intra-regional variability in production in two major crops of paddy and wheat is both a bane and a boon. There are large variations in the input practices and the output levels among farms in different regions and the regional level analysis generally ignores the inter-farm variations within a region (Mythili and Shanmugam, 2000). There is extreme variability in the most of the parameters related to crop production even at a village level. The various socio-economic characteristics of the farmer, like the financial and social status, entrepreneurial ability, agricultural literacy, crop management skills and favorable or unfavorable externalities play a dominant role in crop production (Singh, 1992; Kalirajan and Shand, 1994). Since Indian agricultural scenario is dominated by very large number of small farm holdings, such variability is the order of the day rather than the exception. In such situations, the regional production and productivity is very low. However, some farmers in any given region do achieve very high levels of productivity and expose the attainable potential of agricultural production in the region. This hidden potential is a major source of additional agricultural supplies to feed the burgeoning population. A study was undertaken with a view to assess the performance of paddy-wheat rotation in Bulandshahr district of western Uttar Pradesh and to demonstrate the gap between actual yield and the potential yield attributable mainly to cultural practices including water management followed by the farmers.

MATERIALS AND METHODS

Study Area

Bulandshahr district is a part of the Indo-Gangetic plains in the doab of the Ganga and Yamuna rivers. The district lies between 28° 0' to 28° 45'N and 77° 15' to 78° 30' E. The climate of the district is subtropical type and the average annual rainfall in the district is 669.8 mm. The irrigation is supplied from both groundwater and surface water (canals and tubewells) but the ground water irrigation constitutes about 79 per cent of total irrigated area. The main crops grown in the area are maize, jowar and paddy during kharif season and wheat, pulses and oilseeds during rabi season. The area has dominant rice-wheat cropping system and abundant supply of surface and ground water. The study was carried out in rice growing season of *Kharif* (July - October) 2001 and wheat growing season of *Rabi* (November - April) 2001-02.

Sampling frame

Farm units were selected in the area consisted of villages of Bilsuri, Pilkhanwari, Sahpani and Ismailpur in Secunderabad tehsil of Bulandshahr district. Three groups of farmers consisting of 28 farmers each were purposely selected to represent the three sources of irrigation namely, canal, tubewell and diesel pumps. However, keeping in view the fragmented holdings with different sources of irrigation and the different varieties of the paddy grown in each fragment, the contiguous fragments were post-stratified on the basis of source of irrigation and the variety of the crop grown. Thus, on 144 fragment units was collected, out of which 66 were canal irrigated, 44 electric tubewell irrigated and 33 were diesel engine irrigated fragments. In case of wheat crop no varietal distinction was made and the fragments were stratified on the basis of sources of irrigation only. Information on 124 fragment units was collected, out of which 43 were canal irrigated, 56 electric tubewell irrigated and 26 were diesel engine irrigated fragments.

Data Collection

Data were collected through personal interviews with the farmers and with help of specially structured and pre-tested questionnaire. Records of the cultural practices and input use were maintained by visiting each selected farmer, at least, once in a month during the crop-growing season. The data collected from primary sources were related to the cultivation practices, crop inputs and expenditure, crop output and income. Special caution was exercised while collecting the information on number of irrigations and the depth of water applied in paddy fields. Very frequent irrigations and large variations in irrigation practices in wet fields make the task of measurement of water very difficult. However, farmers were able to give their estimates of depth of water applied on the basis of their experience taking into consideration issues like flow of water, timing and height of field bunds to hold water etc. In case of wheat crop, water applications were measured in 20 per cent of wheat fields with the help of integrating type low head water meters on selected farm units. The cost of tubewell water was worked out on the basis of information supplied by the farmers on monthly electricity rentals, average duration of electricity availability and the crop area irrigated. Similarly, the cost of diesel engine water was calculated on the basis of diesel consumption and the area irrigated. The canal water charges are fixed on the basis of crop and its area irrigated.

The varieties of paddy grown in the selected area are: Coarse grain: Pant 12, Sita, Sharbati, Saket 4, Fine grain: Pusa Basmati 1 (PB-1), Pakistani. In case of wheat crop, no distinction was made between different varieties grown as there was no difference in the prices received by the farmers on this account.

Cultivation, Cultural Practices and Yield

Paddy

Land Preparation

The information on land preparation practices in paddy cultivation is given in Table 1. Generally, land was prepared by ploughing land three times by the tractor driven cultivator followed by two harrow ploughings. Thus, the farmers carry out approximately total five ploughings. The maximum number of ploughings in PB-1, among all the categories was 10 and the minimum 3. Similarly for coarse varieties, the farmers also ploughed land five times with maximum number being 8 and minimum 3.

Land was puddled, mostly, by tractor driven puddlers. The maximum two puddlings are affected in all the categories. Many farmers, especially the canal farmers do not puddle the land and the average number of puddling in the case of canal farms was the minimum. Thus, the average value of puddling in this region was 1.2 in PB-1 fields and 0.9 in coarse varieties fields.

The variation in land preparation practices was reflected in very high values of coefficient of variation. In case of PB-1 variety among all the sources of irrigation, average coefficient of variation is 31.1 per cent and in case of coarse varieties, it was 28.6 per cent.

Fertilizer use

The application of fertilizers in paddy crops is shown in Table 2a and 2b. In PB-1, on an average, among all the categories, 161.6 kg/ha nitrogen is applied with maximum being 268.5 kg/ha and minimum 72.2 kg/ha. The average usage of P_2O_5 and zinc sulphate, among all the categories, is 28.9 kg/ha and 6.7 kg/ha, respectively. Similarly, in case of coarse varieties on an average among all the categories, 180.0 kg/ha nitrogen is applied with a maximum of 320.6 kg/ha and minimum 70.4 kg/ha. The average usage of P_2O_5 and Zinc sulphate among all the categories was 23.4 kg/ha and 5.1 kg/ha, respectively.

There is a large variation in the use of these nutrients. In case of usage of nitrogen, in PB-1 variety among all the sources of irrigation, average coefficient of variation is 31.6 per cent and in case of coarse varieties, it is 30.5 per cent. Since all the farmers don't apply DAP and zinc sulphate in their fields, there is large dispersion of values of its usage. In case of phosphorus (P_2O_5), in PB-1 variety, among all the sources of irrigation, average coefficient of variation is 119.6 per cent and in case of coarse varieties, it is 139.4 per cent. Similarly, in case of zinc sulphate, in PB-1 variety, among all the sources of irrigation, average coefficient of variation is 142.3 per cent and in case of coarse varieties, it is 148 per cent.

Irrigation

The irrigation water use in the area is shown in Table 3. In PB-1, among all the categories, on an average, farmers applied 10.5 irrigations to the crop in whole of the season with corresponding 107.5 cm depth of water. Canal farmers, on an average, applied less number of irrigations (8.8) due to the fact that many fields in the area were prone to water logging and required very less irrigation. The electricity tubewell farmers, on an average, applied 12.6 irrigations and the diesel engine farmers applied 10.3 irrigations. The corresponding depth of water applied in categories of canal, electric tubewell and diesel engine farmers was 90.6 cm, 133.6 cm, and 98.5 cm, respectively.

In coarse varieties of paddy, among all the categories, on an average, farmers applied 10.7 irrigations in whole of the season. The average depth, among all the categories was 111.6 cm. The canal, electricity tubewell and diesel engine farmers applied on an average 10.4, 12.2 and 9.8 irrigations, respectively. The corresponding average depth of water applied was 115.80 cm, 124.1 cm and 91.7 cm, respectively. It is seen that in this case also electricity tubewell farmers applied the maximum number of irrigations and the maximum amount of water to their fields.

There is large variation in the use of irrigation water also among the farmers. In case of PB-1 variety, among all the sources of irrigation, average coefficient of variation in number of irrigations and depth of watering was 36.3 per cent and 40.1 percent, respectively. In case of coarse varieties, it was 35.5 per cent and 34.1 per cent respectively.

Yield

The crop yield in different categories of farms is shown in Table 4. In PB-1, among all the categories, the average yield was 32.1 q/ha. The canal farmers obtained the highest yield (35.7 q/ha) followed closely by electric tubewell farmers (29.7 q/ha) and diesel engine farmers (28.4 q/ha).

In coarse varieties, among all the categories, the average yield was 51.2 q/ha. The diesel engine farmers obtained the highest yield (55.0 q/ha) followed by canal farmers (51.7 q/ha) and electric tubewell farmers (45.8 q/ha).

There is relatively less variation in yield as compared to variation in input use. In case of PB-1 variety, among all the sources of irrigation, average coefficient of variation in Yield 25.3 per cent. In case of coarse varieties, it was 25.1 per cent.

Wheat

Land Preparation

The information on land preparation practices in wheat cultivation is given in Table. 5 In general, land is prepared by ploughing it three times by the tractor driven cultivator followed by two harrow ploughings. The maximum number of ploughings among all the categories was 10 and the minimum 3. The average number of ploughings in case of canal, electric tubewell and diesel engine farmers was 4.7, 5.9 and 5.9, respectively. Thus, the average number of ploughings in wheat fields in this region was 5.5. The canal farmers ploughed the land less than the electricity and diesel farmers.

The variation in land preparation practices is reflected in very high values of coefficient of variation. Among all the categories, average coefficient of variation in ploughing was 30.7 per cent.

Fertilizer use

The application of fertilizers in wheat crop is shown in Table 6. In case of nitrogen, canal, electric tubewell and diesel engine farmers supply, on an average, 145.7kg/ha, 153.0 kg/ha and 152.0 kg/ha, respectively. Among all the categories, on an average, 150.3 kg/ha nitrogen was applied with maximum being 394 kg/ha and minimum 52 kg/ha. In case of phosphorus (P_2O_5), on an average, canal, electric tubewell and diesel engine farmers supply 69.2kg/ha, 73.0 kg/ha and 75.0 kg/ha, respectively. Among all the

categories, on an average 72.6 kg/ha phosphorus (P_2O_5), is applied with the maximum being 127.0 kg/ha and minimum zero kg/ha. In case of zinc sulphate, on an average, canal, electric tubewell and diesel engine farmers supply 0.8kg/ha, 0.9 kg/ha and 1.7 kg/ha, respectively. Among all the categories, on an average 2.2 kg/ha zinc sulphate is applied with the maximum being 29.4 kg/ha and minimum zero kg/ha.

There is large variation in the use of these nutrients among the farmers. In case of usage of nitrogen and phosphorus (P_2O_5), among all the sources of irrigation, average coefficient of variation is 35.0 per cent and 38.18 per cent. Since all the farmers don't apply zinc sulphate in their fields, there is large dispersion of values of its usage, which is 285.7 per cent.

Irrigation

The irrigation water use in wheat crop is shown in Table 7. Canal farmers, on an average, applied 5.1 numbers of irrigations. The electricity tubewell farmers and the diesel engine farmers, on an average, applied 5.1 and 5.3 irrigations, respectively. The corresponding depth of water applied in categories of canal, electric tubewell and diesel engine farmers was 26.6 cm, 25.9 cm and 24.9 cm, respectively. Among all the categories, on an average, farmers applied 5.1 irrigations and 25.9 cm water depth in whole of the season.

There is large variation in the use of irrigation water also among the farmers. Among all the sources of irrigation, average coefficient of variation in number of irrigations and depth of watering was 15.1 per cent and 43.5 per cent, respectively.

Yield

The crop yield in different categories of farms is shown in Table 8. The diesel farmers obtained the highest yield (48.7q/ha) followed by electric tubewell farmers (45.5 q/ha) and canal farmers (41.0q/ha). Among all the categories, the average yield was 44.6 q/ha with maximum 66.7 q/ha and minimum 25.40q/ha. Among all the sources of irrigation, average coefficient of variation in yield was 29.4 per cent.

Optimizing the Total Returns From Irrigated Agriculture

Optimization problem was formulated with the objective to maximize total value of output from paddy and wheat crops. The linear programming model was used to find out

maximum returns by adopting the most profitable cultural practices and input use of efficient farmers in each category. No change in cropping pattern and resource use was contemplated and this objective was achieved by selecting the crop processes with alternative input use already practiced by farmers in the various situations in the region. All the crop processes with yield levels higher than the average level in their category were included in the model. An attempt was made to work out five most profitable plans. Eliminating the best crop process in the best plan and subsequently finding the next best plan and so forth achieved this objective.

The Model

The following linear programming model was framed to arrive at the optimal solutions:

$$\text{Maximize } E(z) = \sum_{j=1}^n c_j x_j - \sum_{d=1}^n w_d i_d - y$$

Subject to

$$\sum_{j=1}^n a_{kj} x_j \geq b_k$$

for all x_j, i_d and $y \geq 0$, where $E(z)$ is expected return of the plan or solution; c_j , return of activity j ; x_j , level of activity j ; a_{kj} , technical requirement of activity j for resource k ; b_k , level of resource or constraint k ; w_d , unit cost of purchase activity and i_d , level of purchase activity; y , level of water requirement activity.

The objective function of this model was to maximize the net returns (gross returns minus all the items of cost A_1 , viz., cost of fertilizer, farm yard manure, surface water as well as ground water, seed, seed treatment, hired human labour, hired bullock labour, hired tractor and machinery, fuel and electricity, insecticides, other plant protection measures, fodder, concentrates, etc., other maintenance costs of bullock labour etc.), subject to the physical resource supplies. It included per hectare returns of various crop activities and the costs of purchasing activities pertaining to inputs used and the operational measures. The output coefficients of crop activities (c_j values) were calculated by multiplying yield with its price and the output coefficients of purchasing activities were the unit costs of the respective inputs.

Real activities included crop activities and purchasing input activities for all the inputs, including various farm operations and one water availability activity. The crop activities comprised of crop processes of different crop varieties under identified irrigation situations, viz canal, electric tubewells and diesel engines. Since the objective of the model is to find out the crop production potential of the area by selecting crop processes already practiced by some farmers in the area, purchase activities on all inputs and water supply were included in the model to ascertain availability of these inputs. Thus, the purchasing activities of inputs and various farm operations were having input co-efficient of -1 in the corresponding constraint row. The land constraints were the existing maximum area under each crop and the varieties under different sources of irrigation in the given cropping pattern.

RESULTS AND DISCUSSION

The Existing Average Plan and five best plans of the most efficient farmers in each category, in case of both paddy and wheat, were obtained from the model. As stated earlier, eliminating the best crop process in the best plan and subsequently finding the next best plan and so forth achieved this objective. Associated input use and the expenditure on various farm operations were also obtained.

Paddy

The existing average plan and five best plans of most efficient farmers in each category, in case of paddy is given in Table 9a. Associated input use and the expenditure on various farm operations is given in Table 9b.

Existing Average Plan

In the Average Plan farmers obtained net income of Rs. 17033 per hectare and involved an expenditure of Rs. 11446 (\$1=Rs.46.4). Thus, the net income expenditure ratio worked out to be 1.49. The inputs utilization of farmers involved use of 162.7 kg/ha nitrogen, 28.5 kg/ha phosphorus (P_2O_5), and 6.0 kg/ha zinc sulphate. In all, Rs. 2146 worth of fertilizer was used.

The cost of irrigation provided was calculated by adding up the payments made by the farmers for all the irrigations from various sources. Farmers paid Rs.991/ha and applied an average depth of 118.2 cm of water. They also paid Rs.2974, Rs.1615, Rs.948

and Rs.288 towards plowing, transplanting, interculture and plant protection measures, respectively. Rs.2485 were paid towards threshing expenses.

Plans of Efficient Farmers

Plan I suggested an income of Rs.30268/ha when the practices of best farmer in each category are followed in whole of the area under paddy crop. This income is 77.6 per cent higher than that in the Average Plan. In rest of the plans also an income of Rs.26918/ha, 24965/ha, 23592/ha and Rs.22212 was obtained which is nearly 58 per cent, 46.5 per cent, 38.5 per cent and 30.4 per cent higher in comparison to Existing Average Plan. The total expenditure involved in the first five best plans was Rs.10139, Rs.9022, Rs.10530, Rs.10424 and Rs.10443, respectively. The efficient farmers spent less money than the farmers under Existing Average Plan and obtained higher yield and income. Thus, the net income-expenditure ratio in case of five most Efficient Farmers Plan works out to be 2.99, 2.98, 2.37, 2.26 and 2.13, respectively, in comparison to 1.49 under Existing Average Plan. The input use pattern and farm operation pattern also conform to the expenditure pattern of the farmers.

Wheat

The existing average plan and the five best plans of most efficient farmers in each category, in case of wheat are given in Table 10a. Associated input use and the expenditure on various farm operations is given in Table 10b.

Existing Average Plan

In the Existing Average Plan, wheat farmers obtained net income of Rs.16907 per hectare and involved an expenditure of Rs.12809. Thus, the net income expenditure ratio worked out to be 1.3. The input utilization of farmers involved use of 151.1 kg/ha nitrogen, 69.6 kg/ha phosphorus (P_2O_5), and 0.2 kg/ha zinc sulphate. In all, Rs.2533 worth of fertilizer was used.

The cost of irrigation provided was calculated by adding up the payments made by the farmers for all the irrigations from various sources. Farmers paid Rs.769 /ha and applied an average depth of 26 cm of water. They also paid Rs.2480/ha, Rs.32/ha, Rs.2910 and Rs.2333 towards ploughing, interculture, harvesting and threshing expenses.

Efficient Farmers Plans

Plan I suggests an income of Rs.28531/ha when the practices of the best farmer in each category are followed in whole of the area under wheat crop. This income is 68.8 per cent higher than that in the Existing Average Plan. In rest of the plans also an income of Rs.26534/ha, 24480/ha, 23793/ha and 23489 was obtained which is nearly 56.9 per cent, 44.8 per cent, 40.7 per cent and 38.9 per cent higher in comparison to Existing Average Plan. The efficient farmers spent marginally higher or less money than the farmers under Existing Average Plan and obtained higher yield and income. Thus the net income-expenditure ratio in case of the five most Efficient Farmers Plan worked out to be 1.93, 1.78, 1.99, 2.0 and 1.78, respectively, in comparison to 1.3 under Existing Average Plan.. The input use pattern and farm operation pattern also conform to the expenditure pattern of the farmers.

CONCLUSION

The efficient plans demonstrated the potential of agriculture in already agriculturally developed area and also the gap, which is to be bridged by providing infrastructure services like technical expertise in crop protection and crop production. Availability of physical resources like good quality seed, timely irrigation from canals and electric tubewells, right doses of fertilizers and knowledge and availability of plant protection measures etc. are the voids which need to be filled in to bring about second green revolution. However, the financial constraints are not the reasons for low productivity as the monetary expenditure of the farmers under Existing Average Plan is the most of the times higher than those under Efficient Plans.

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GENETICAL ANALYSIS FOR OXALIC ACID IN TOMATO (*Lycopersicon esculentum* Mill.) UNDER PROTECTED ENVIRONMENT AT 1500 M ALTITUDE

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ABSTRACT

A study was conducted on a 12 x 12 diallel set of tomato excluding reciprocals to find out the extent of combining ability, heterosis and nature of gene action for oxalic acid content. Significant differences among genotypes were obtained for the trait. Significant desirable negative heterosis (-60.36, -9.52 and -56.32%) was found over the mid, the top parent and commercial control, respectively. The magnitudes of variance due to general as well as specific combining ability were highly significant indicating the importance of both additive and non-additive gene action. However degree of dominance revealed the prevalence of non-additive gene effect. The Cross-combinations Mechin x Hawaii-7998, Hawaii-7998 x Manni Thoibe and Mechin x Manni Thoibe were found to be the best specific combiners. Predominance of non-additive gene action played a greater role in the inheritance of oxalic acid in tomato under hill conditions. Higher percentage of heretability (narrow sense) was found for this trait.

Key words : *Lycopersicon esculentum*, combining ability, heterosis, and poly house environment.

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INTRODUCTION

Oxalic acid content in tomato fruits influence tomato quality. Tomato contains an undesirable bio-molecule oxalic acid, which renders the dietary calcium unavailable to the body by forming soluble calcium oxalates. Up to 50 % of urinary oxalates may be derived from dietary oxalates on a low calcium diet (Samy *et al.*, 1960). Since human beings consume significant volumes of tomato, it is desirable to have the knowledge about this compound and the inheritance pattern of this trait. Oxalic acid can be brought down by development of low oxalic acid cultivars that would help minimize the adverse effects on human health. There is tremendous scope for growing tomato in off-season under protected environments and at present it becomes a major cash crop of hill farmers in India. Significant genetic improvement work had not been done under hill environments on this crop. There is an ample scope of improvement and exploitation of hybrid vigour for development of quality cultivars. The present investigation is aimed at studying the responses of diallel sets of genotypes under polyhouse environments for selecting desirable parents and parental combinations, which are likely to produce superior hybrids having excellent qualities on the basis of combining ability, genetic parameters and heterosis for commercial exploitation in hilly areas. Further, the study would be helpful to generate breeding materials for improvement of this trait for utilization in the future breeding programme.

MATERIALS AND METHODS

A set of 12x12 diallel cross of tomato without reciprocals along with their parents viz; Azad T-2 (1), Machin (2), DARL-64 (3), Hawaii-7998 (4), EC 386032 (5), EC 386037 (6), BL-342 (7), Sel-7 (8), EC386019 (9), EC386023 (10), Mani Thoiba (11), Mani Leima (12) and the commercial control ARTH-3 were evaluated in a randomized block design with three replications, at Defence Agricultural Research Laboratory, Pithoragarh in India at an altitude of 1500m above sea level in mid hill conditions of central Himalayas under protected condition during 2001-2003. Recommended packages of practices were adopted during the cropping period. Red ripened fruits were collected at random in each replication and estimation was done by enzymatic calorimetric method using grain sorghum leaf oxalate oxidase (Satyapal and Pundir, 1993). The optical density of samples colour was read in UV spectrophotometer at 490-560nm.

RESULTS AND DISCUSSIONS

The Analysis of Variance for combining ability (Table 1) showed existence of significant variation for oxalic acid content, indicating a wide range of variability among the genotypes. Highly significant variation due to general combining ability (gca) as well as specific combining ability (sca) indicated the importance of additive as well as non-additive type of gene action in inheritance of the character. The highest significantly desirable negative gca effect (Table 2) for oxalic acid was recorded in Main Leima (-0.47) followed by DARL-64 (-0.33) and Sel-7 (-0.33). Only five parents expressed negative general combining ability effects. These parents can be used in hybrid breeding programme for accumulation of favorable genes.

Table 1. Analysis of variance for Combining ability

Source	DF	Oxalic acid (mg/100g)
Gca	11	2.14**
Sca	66	1.04**
Error	154	0.03
Component of Variance		
σ^2_{2gca}		0.09
σ^2_{2sca}		1.04
Component ratio		
σ^2_g / σ^2_s		0.09
Predictability ratio		0.15
**, Significant at P=0.01		

Table 2. Combining ability and per se performance for oxalic acid parents

Parents	GCA	Per se performance
Azad T-2	0.78	6.70
Mechin	0.42	5.80
DARL-64	-0.37**	2.63
Hawaii-7998	0.35	4.63
EC- 386032	0.23	2.10
EC- 386037	-0.01	4.90
BL-342	-0.16**	4.90
Sel-7	-0.33**	3.27
EC-386019	-0.20**	3.97
EC-386023	-0.10**	4.17
Manni Thoibe	0.17	6.20
Mannileima	-0.47	2.57
SE (gi)	0.014	-
SE (gi-gj)	0.021	-

**, Significant at P=0.01

The top three cross combinations selected on the basis of sca effect (Table 3) also showed lower per se performance in desirable direction involving low x low gca parents. An appreciable amount of negative heterosis expressed by low x low crosses. The highest negative sca effect was observed in the cross Mechin x Hawaii -7998 (-1.66) followed by Hawaii-7998 x Mani Thoibe (-1.51) and Mechin x Mani Thoibe (-1.48).

Table 3. Top three crosses selected on the basis of specific combining ability effect

Crosses	<i>Per se</i> performance	Sca effect	General combining ability effect
Mechin x Hawaii -7998	2.60	-1.66**	L x L
Hawaii -7998 x Manni Thoibe	1.90	-1.51**	L x L
Mechin x Manni Thoibe	2.60	-1.48**	L x L

** , Significant at $P=0.01$

Range, mean values and heterosis percentage for oxalic acid (Table 4) indicated that the parents varied in oxalic acid content ranging from 2.10 to 6.70 with mean values of 4.32 mg/100g. Oxalic acid content in F_1 s varied from 1.90 to 5.80 with mean of 3.34 mg/100g. Lower mean values were recorded in F_1 s. Significant negative and the highest heterosis over mid parent was expressed by the cross BL-342 x Sel-7 (-60.36%).

However crosses showing minimum amount of oxalic acid content were EC 386032 x Sel-7 and DARL-64 x Mani Leima (1.90 mg/100g) which had also the highest negative heterosis (-9.52 and -56.32%) over top parent and commercial control, respectively. It was observed that most of the crosses derived from parents having high amounts of oxalic acid (high x high) showed significant or negative heterosis, however F_1 s involving parents of low x low, mid x mid and mid x high expressed a higher percentage of non- significant positive heterosis. Williams and Gilbert (1960) also found that positive heterosis was generally absent in tomato for all characters where parents with a high level of expression were involved and was frequent in hybrids of poorer genotypes. Bhatt *et al.*, (1998) found this type of trends in diallel analysis for ascorbic acid content in tomato.

The components of variance and component ratio for oxalic acid (Table 5) were studied under polyhouse environment. Significance of D, H_1 and H_2 indicated that both additive and non-additive variances were important in the manifestation of oxalic acid but relative magnitude of non-additive variance was higher than additive variance. Significant 'F' value (3.36) indicated more dominant genes in the parents for this important processing trait. Existence of over dominance (1.53) was observed. The $H_2/4H_1$ (0.16) had asymmetrical distribution of dominant and recessive genes among the parents. The KD/KR ratio (3.00) indicated that more number of dominant genes controlled oxalic acid. The fraction h_2/H_2 (0.94) predicted that one group of genes controlled the degree of dominance for this important trait.

Table 4. Range, mean values of parents, F₁ hybrids and heterosis (percentage of oxalic acid)

Particulars	Range and mean values
Parents	2.10-6.70 (4.32)
F ₁ s	1.90-5.80 (3.34)
Range of heterosis % over	
MP	-1.10 to -60.36
TP	-4.76 to -9.52
CC	-1.84 to -56.32
Top F₁ with their 6 x 8, 3 x 12 (1.90)	
Mean value	
Top F₁s with their heterosis % over	
MP	7x11 (-60.36)
TP	6x8 (-9.52)
CC	3x12 (-56.32)

MP, mid parent; TP, top parent;
CC, commercial control cultivar

Table 5. Components of genetic parameters variation and for for oxalic acid

Components/ Proportions	Oxalic acid (mg/100)g
D	2.20** ±0.30
H ₁	5.13** ±0.59
H ₂	3.38** ±0.49
F	3.36 ±0.67
E	0.00 ±0.08
H ₂ /4H ₁	1.53
(4DH ₁). 5 +F/ (4DH ₁) ...5	0.16
F (KD/KR)	
(H ₁ :D)	3.00
Heretability ns (%)	55.1

**, Significant at P=0.01

The study revealed importance of non-additive gene action both at variance and estimated component variance level suggesting that heterosis breeding would be exploited to improve the quality of tomato through low erring of oxalic acid content.

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IMPACT OF CLIMATE CHANGE AND ITS VARIABILITY ON AGRICULTURE

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ABSTRACT

Global climate is changing and it can have serious implications for our food security through its direct and indirect effects on crops, soils, livestock, fisheries, and pests. At the same time, this is an issue with several socio-economic-policy-political implications. In the developing countries including India, there has been relatively less attention paid to this topic in an integrated manner. Uncertainties and error association with the climate change models, impacts on soil and crop productivity by using crop growth models need to be minimized. The impact on agriculture has been worked out through soil fertility, soil moisture availability, soil biological health, growth and yield of various crops, insects and pests of crops. The interaction among various climatic parameters, mainly temperature, rainfall, radiation and carbon dioxide concentration has been evaluated through growth and yield of crops by using simulation models. Vulnerable regions and options to adapt agricultural production under changing climate have been identified. General Circulation Models for climate change scenarios give quite contrasting results, with poor resolution on temporal and spatial scales, so the uncertainties in climate change scenes remains. Non-availability of suitable socio-economic scenarios for contrasting agro-ecologies adds to the chance of error propagation. Extrapolation of the point results of the impacts to a larger scale may bring in more errors, if the spatial and temporal variability in the socio-economic and biophysical aspects are not included. The effectiveness of this kind of study is possible only if inter-disciplinary team of researchers work together on a common mission of climate change related studies.

Key Words : Climate Change, Climatic Variability, Soil Fertility, Soil Moisture Availability, Growth and Yield of Crops, Insects and Pests.

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INTRODUCTION

The relationship between agriculture and climate is well known. Droughts, which have frequented different parts of India through the history, have been responsible for many famines, rural poverty and migration despite development of impressive irrigation potentials. Similarly abnormal temperatures, high velocity winds and humidity during critical stages are known to significantly affect crop growth and development, pest incidences and epidemics, demand on irrigation resources and finally food production. Over the past few decades, the man-induced changes in the climate of the earth due to multifarious human activities linked to development have become the focus of scientific and social attention. These global changes are primarily due to the increased emissions from the combustion of fossil fuels and land use changes. Probability of the occurrence of extreme climatic events has increased in the recent past. The global mean annual temperatures at the end of the 20th century are almost 0.7 °C above those observed a century ago. Such global climatic changes are bound to impact agriculture through their direct and indirect effects on crops, soils, livestock, fisheries, and insects & pests. This paper deals with the extent of climate change and its variability and subsequent impact on agriculture through direct/indirect effects on soil and crop processes, insects and pests association.

Climatic Variability

Inter- and intra-seasonal climatic variability is quite large in this part of the world. The extent of variability in south-west and north-east monsoons fluctuate the crops' productivity around the trend line, which shows positive slope due to technology advancement in various agro-ecological regions. Analysis with the historic weather data sets, although indicate the rising temperature trend in most of the locations, but year to year seasonal and annual variation around trend line are quite large. Sometimes these variations are confused with the climate change.

Winter rains, in north-west India due to western disturbances, ranging upto 12 cm in the past years and received in more spells of small amounts but are very much beneficial to the rabi crops, mainly wheat of this region. Rainfed wheat is mainly dependent on this rainfall.

Understanding of the climatic variability is difficult, and most of the studies in this regard are with rains and to some extent temperature also. In our country, where most of

the agriculture is under dry land and rainfed, the variability in the climatic parameters plays an important role in deciding the crop production. The climatic variability has not been related with the crops' response, though in some cases the empirical relations have been developed, which have the limitations of being location and time specific. Linking the climatic variability with the productivity on regional scale can subsequently be linked with the climate change scenarios to work out the impact on soil, crops, water resources and environment.

Climate Change

Climate is changing naturally at its own pace, since the beginning of evolution of earth, 4 -5 billion years ago, but presently it has gained momentum due to inadvertent anthropogenic disturbances. There is increase in the atmospheric temperature due to the increased levels of carbon dioxide (CO_2) and other greenhouse gases. The CO_2 concentration was 280 ± 6 ppm between 1000 and 1750 AD, and today, this value has become 370 ppm. Methane (CH_4), one of the important greenhouse gases contributing to global warming, has increased since pre-industrial times from 0.7 to currently 1.78 ppmV and accounts for about 15% of the global warming. Methane concentration in the atmosphere is presently increasing at 3% per year against 1.2% in the late 1970s. Nitrous oxide (N_2O) with its current concentration of 310 ppbV in the atmosphere is an important greenhouse gas accounting for approximately 5% of the total greenhouse effect and also responsible for the destruction of stratospheric ozone. Atmospheric concentration of N_2O is increasing at a rate of 0.22% per year. The emission of N_2O is of serious concern because of its long atmospheric lifetime of 166 ± 16 years. Agricultural soils contribute 65% of anthropogenic N_2O emission (6.3 Tg y^{-1}).

The quantity of rainfall and its events has also become more uncertain. In certain places, climatic extremes such as droughts, floods, timing of rainfall and snowmelt have also increased. The global mean annual temperatures at the end of the 20th century are almost 0.7°C above those recorded at the end of the 19th century. Diurnal temperature range has also decreased. The 1990s were, on an average, the warmest decade of the earth since instrumental measurement of temperature started in 1860's and the 1900s the warmest century during the last 1000 years. All these changes have been ascribed primarily to the combustion of fossil fuel and land use changes.

There has been a boost of agricultural research world over in understanding the effects of climate change, carbon sequestration in biosphere and in carbon trading potential of the land. In developing countries including India, however, there has been relatively less attention paid to this topic.

In the Southeast Asian region, climatologically, India is situated in an important position. Changes to the present climate system may affect a wide variety of eco-systems and socio-economic sectors in the country with corresponding impacts on water resources, agriculture, forestry and other sectors. One of the major driving forces for global change is the rapid increase in the greenhouse gas content of the atmosphere, in which the role of India is small, but gradually rising.

Existing global climate change models, sometimes are quite contrasting, in generating the climate change scenarios for specific locations. The scenario needs to have higher spatial and temporal resolution, for subsequently working out the impact on agriculture.

Indian Agriculture

Agriculture sector represents 35 per cent of India's GNP and sustains the livelihood of nearly 75 per cent of the population. To meet the demand of ever increasing population, which has already touched the one billion mark, food grain production has increased during the post-independence era from 51 to around 206 million tonnes. This has been possible by increasing the area under cultivation, enhancing crops' yield through use of high yielding varieties and increased inputs (water, pesticide and fertilizer). The increase has mostly come in areas of adequate water availability, whereas majority of the cultivated area has large yield gap for crops. Total cultivated area has remained constant at about 140 million hectares over the past decade or so, although the area under double cropping system is increasing with the growth rate of 0.9 million hectare per year in the last two decades. Ours being a tropical and sub-tropical environment, thereby the inherent fertility of the soil is quite low and to sustain and maximize the agricultural productivity we have to apply more inputs (such as fertilizers, water and pesticides). The inputs' use efficiency is going down continuously. The chances of C-Sequestration are also remote, as the organic carbon degradation is at a faster rate.

During the recent past it has been observed that the productivity of rice-wheat cropping is going down or has become static in many of the productive districts of North-West India. The decline is primarily due to land degradation (soil structural changes, water table decline, increased sodicity and salinity). The regions having larger yield gap in the beginning are showing increase in trend of rice-wheat yields, but the yield gap is still large, which has still a scope of narrowing down by adopting suitable agronomic management options. In general, we have concentrated more on enhancing the agricultural productivity, with less emphasis on the quality aspects. If we have to compete and stay in the global markets, we have to give more emphasis on the quality and value addition to the products. The question of the quality of the grains/produce in relation to climatic variability / its change under different growing environments has not been addressed in depth in the past.

India has numerous agro-ecological systems, with diversity in crops/cropping systems, climate, agronomic/management inputs and related socio-economic aspects. Impact of climate change on agriculture needs to be worked out by linking these socio-economic and bio-physical aspects. Sometimes, the factors other than climate change/climatic variability dominate in deciding the production of an agricultural system.

Nation food production is a gamble with the South-West Monsoon. In the fifty years, there have been around 15 major droughts in the country, due to which the productivity in those years was affected. Though we have learnt lesson to deal with this situation after severe drought of 1987, where the area affected was around 49.2%, but the extent of decline in the food production was only 3%, even then this problem creates lot of social, political and cultural stability in the country.

Linking up of the future climate change scenario for evaluating the impact on various agricultural production systems of the country is for the following purposes:

- Extent of agricultural productivity decrease
- Effect on various socio-economic and biophysical aspects related with agricultural production system
- Delineation of the vulnerable regions
- Identification of suitable agronomic and resource management options for sustained agricultural production

Impact of Climate Change on Soil Health

The interaction of nitrogen, irrigation and seasonal climatic variability, particularly at low input of irrigation has several implications. Under adequate moisture supply situation, like for Punjab and Haryana, the yield benefits are obtained up to higher nitrogen application, whereas in the regions of limited to moderate water supply conditions, the increased yields are noticed till relatively lower values of nitrogen. At low levels of water availability, it is difficult to decide optimal levels of N fertilizer for maximizing yield returns in view of uncertainty of N response, which is strongly related to a good post monsoon rainfall received during crop growing period (Kalra and Aggarwal, 1996)..

The rabi and kharif seasons and annual food production show increasing trend, and the deviations around the technology trend line can be significantly related to seasonal rainfall for kharif and annual production, whereas no definite trend was noticed in case of rabi season food production, as majority of the food production in this season comes from the irrigated areas. Changes in rainfall due to global climate change may affect the surface moisture availability, which becomes important for crop stand establishment in the rainfed areas. Quality of surface and ground waters is a concern due to increased industrialization. Pressures of land use and land cover change drivers, other than the climate change and its, need to be inserted for working out the accurate estimate of the impact. We have large diversity in crops/cultivars, and thus are ready to adapt with climate change for sustained productivity by suitable choice of crops, suitable agronomic and cultural practices.

Soils dominate the cycling of many atmospheric trace gases because of the highest abundance and diversity of microbes in them. Earlier, equilibrium used to exist between the sources and sinks of GHGs, but a shift in this equilibrium has started becoming evident as a consequence of human induced activities. In order to comprehend the shift of source - sink equilibrium, one needs to understand the processes involved in generating the net flux (a function of production processes, consumption processes and gas transport) at the soil atmosphere interface.

The possible strategies for mitigating methane emission from rice cultivation can be made by altering water management, particularly promoting mid-season aeration by short-term drainage. Improving organic matter management by promoting aerobic

degradation through composting or incorporating into soil during off-season drained period is another promising technique. Organic amendments to flooded soils increase methane production and emission. However, application of fermented manure like biogas slurry reduces the emission (Debnath et al., 1996). In addition, nitrification inhibitors have been shown to inhibit methane emission. Another mitigation option may be the use of different rice cultivars as cultivars grown in similar conditions show pronounced variations in methane emission (Mitra, 2000). Combined with a package of technologies methane emission can best be reduced by (a) the practice of midseason drainage instead of continuous flooding, (b) direct crop establishment like dry seeded rice and (c) use of low C: N organic manure and biogas slurry.

Appropriate crop management practices, which lead to increase N use efficiency and yield, hold the key to reduce nitrous oxide emission. Application of nitrate ($\text{NO}_3\text{-N}$) fertilizers e.g. calcium ammonium nitrate (CAN), in crops with aerobic conditions and ammonium ($\text{NH}_4\text{-N}$) fertilizers e.g., ammonium sulphate, urea, in wetland crops also help reducing the emission (Pathak and Nedwell, 2001). Curtailing the nitrification process by the use of nitrification inhibitor may decrease nitrous oxide emission from soil. There are some plant-derived organics such as neem oil and neem cake, which can act as nitrification inhibitors. These are being experimented in fields to reduce the emission of nitrous oxide and increase the fertilizer use efficiency. Other biocidal inhibitors, such as karanja seed extract have been found to retard nitrification by 60-70% (Majumdar et al., 2001).

Microbes have emerged as the major contributor as well as consumer for GHGs as the microorganisms are the main intermediaries of C turnover in soil, due to which, they are considered as sole agents for soil humus formation, cycling of nutrients, soil tilth and structure and also perform myriad of other functions. What will happen to the soil fertility in the event of global climate change needs to be addressed through Soil Organic Matter (SOM). The assessment of soil health/quality/fertility through changes in SOM is very difficult, therefore other soil parameters are being used as proxy indicators. For example, soil microbial biomass (the living part of organic matter) due to dynamic character has been shown to quickly responds to changes and perturbations, often before the measurable changes occur in organic C and N, thereby acting as an indicator of long term changes in SOM content (Powlson and Brookes, 1987). However, the measurement

of microbial biomass (C_{mic}) alone will not serve the purpose because they are generally influenced by climatic variables. Hence, for real measurement of the impact in soil processes, one needs to consider proportion of total organic C or N (C_{org}) within the microbial biomass i.e. microbial quotient. Under the equilibrium conditions, C_{org} of agricultural soils contains 2.3 - 4% C_{mic} . Soils exhibiting a C_{mic} to C_{org} ratio higher or lower than these values appearing in the equilibrium line would be either accumulating or losing C, respectively (Anderson and Domsch, 1986). Different climatic conditions in particular precipitation/evaporation influence the equilibrium C_{mic} to C_{org} ratio (Insam, 1990) and a very high correlation was found in which 73% variation could be explained with the quadratic function, and thereby, one can predict the soil fertility in terms of accumulation or losses of C.

Under the changed scenario of atmospheric composition due to global warming, the tropical region such as India, with small organic C reserves, will show net efflux of CO_2 , because rates of soil respiration increase exponentially with temperature. Thus CO_2 effluxes from tropical system should increase markedly with small change in temperature without any increase in inputs from the aboveground communities thereby leading to rapid losses over a short period of a few decades and later on it will sustain the balance because of the shortage of substrate for decomposition as well as adaptation of microbial communities towards the climatic changes.

Differences in PLFA - fingerprint may be interpreted with respect to alterations in microbial community structure and their physiologies. In general PLFA profiles had decreasing unsaturation, greater chain length and larger number of cyclopropyl fatty acids at higher temperatures.

Soil microorganisms fulfil 2 major functions, i.e. they act as agents of nutrient element transportation as well as store carbon and mineral nutrients (mainly N, P and S) in their own living biomass, acting as a liable reservoir for plant available nutrients with a fast turnover. The most important process is the accelerated decomposition of organic matter, which releases the nutrients in short run but may reduce the fertility in the long run. Soil temperature affects the rates at which organic matter decomposes, nutrients are released and taken up, and plant metabolic processes proceed. Chemical reactions that affects soil minerals and organic matter are strongly influenced by higher soil and water temperature. Soil productivity and nutrient cycling are therefore, influenced by the

amount and activity of soil microorganisms. The doubling of CO_2 increases plant biomass production, soil water use efficiency by the plants, and C / N ratios of plants. The changes in the C/N ratios of plant residues returned to the soil have impact on soil microbial process and affect the production of trace gases NO_x and N_2O .

It is not only the agriculture which might get effect of global warming, but the human health may also get affected. Outbreaks of number of diseases, including dengue fever, bubonic plague, cholera and malaria have been linked to climate change. The climatic change has triggered the shift and expansion of the populations of vectors and hosts to different geographic regions. It can also directly affect the distribution and abundance of pathogens themselves, thereby increasing the prevalence of disease in humans, animals and plants. Changes in mosquito populations are of major concern, since mosquito borne microbial disease are responsible for large number of catastrophes in human population.

It has also been suggested that climate change could increase rates of soil erosion, further hampering food production. Increases in rainfall will accelerate the rates of soil loss, reducing farm productivity even more. A further negative consequence of accelerated erosion will be increased sedimentation in streams and reservoirs. This will shorten the life span of dams, which helps to prevent floods and provide both electricity and water for irrigation. Another way in which erosion could accelerate is through a decrease in rainfall, which could lead to dry spells and increased risk of wind erosion (Parry et al., 1999). If erosion rates go unchecked continued soil impoverishment would eventually force farmers to abandon their lands (Asian-Pacific Seminar). Thus, erosion is among the major threat to food production in a warmer climate. Other land degradation problems, such as water logging, soil salinity and sodicity development, are emerging due to rapid land use pattern and land cover changes. The impact of climate change on these aspects needs to be looked for sustaining the agricultural production.

Impact of Climate Change on Crop Productivity

Global climatic changes will affect agriculture through their direct and indirect effects on crops, soils, livestock and pests. Increase in atmospheric carbon dioxide has a fertilization effect on crops with C_3 photosynthetic pathway and thus promotes their growth and productivity. Increase in temperature, depending upon the current ambient

temperature, on the other hand, can reduce crop duration, increase crop respiration rates, alter photosynthate partitioning to economic products, effect the survival and distributions of pest populations thus developing new equilibrium between crops and pests, hasten nutrient mineralisation in soils, decrease fertilizer use efficiencies, and increase evapotranspiration. Indirectly, there may be considerable effects on land use due to snow melt, availability of irrigation, frequency and intensity of inter- and intra-seasonal droughts and floods, and availability of energy. All of these can have tremendous impact on agricultural production and hence food security of any region.

The rising temperatures and carbon dioxide and uncertainties in rainfall associated with global climatic change may have serious direct and indirect consequences on crop production and hence food security (Sinha and Swaminathan, 1991). We witnessed such an impact of climatic events on food availability in 1998 in the form of a crisis of onions, potatoes, cauliflower and tomato, which triggered some unprecedented social and political impact. This crisis has once again demonstrated how little we understand the integrated relationships of weather and agriculture and how little we have developed the backup for policy support in such unfortunate and unforeseen circumstances.

It is, therefore, important to have an assessment of the direct and indirect consequences of global warming on different crops contributing to our food security. It is also important to develop a policy response to address in future such concerns with a more mature scientific understanding and also to provide backup support for our negotiations in international conventions. Future agricultural planning, thus has to take note of the overall goal of attaining congruence in productivity, stability, sustainability, profitability and equity in Indian agriculture in the coming decades.

Realization of crop's yield is a complex interaction of several biotic and abiotic factors, and sometimes it becomes difficult to eliminate the effect of other stresses in order to study the impact of climate variability and climate change. Crop growth models are well suited for this purpose, where setting the boundary conditions are within our control. In India, where most of the cultivation is carried out under sub-optimal to limited inputs, the effects of weather parameters, changes are usually diminished by other biotic and abiotic factors.

But the huge task of extrapolating the results over a larger region may have large error if the temporal and spatial variability of various biotic and abiotic factors are not included. Wheat Growth Simulator (WTGROWS), developed at IARI, New Delhi, has been extensively tested for different agro-environments (Aggarwal and Kalra, 1994). This model has been successfully used for resource management, forecasting of wheat production in the country and climate change studies. Using WTGROWS, a strong linear decline in wheat yield was noticed with the increase in January temperature. For every degree increase in mean temperature, grain yield decreased by 428 kg/ha.

Inter-seasonal climatic variability has been characterized through growth and yield response under different production environments, which clearly indicate the use of crop model as an indicator of climatic variability/change. The effect of sowing at different dates on the yield of wheat was simulated for different locations. Places having higher potential yields of wheat had greater reduction in yield per day delay in sowing from the optimal date. A few locations (North Eastern parts) showed a small yield reduction with delayed sowing. With the temperature rise, the adjustments in the date of sowing to have the similar weather conditions can be ensured, but it can imbalance the cropping system schedule, which also is important for developing countries where intensive cultivation is practiced on small and marginal lands.

Gadgil and her group (1995, 1999a, b) used PNUTGRO model (Boote *et al.*, 1986) to determine the sowing window for rainfed groundnut. Variation in the model yield with sowing date showed that broad sowing window of 22nd June - 17th August is the optimum for minimizing the risk of failure. Lal *et al.*, (1999) projected 50% increased yield for soybean for a doubling of CO₂ in Central India. However, a 3°C rise in surface air temperature almost cancels out the positive effects of doubling of carbon dioxide concentration. Hundal and Kaur (1996) examined the climate change impact on productivity of wheat, rice, maize and groundnut crop in Punjab.

Temperature increase of 1, 2 and 3°C from present day condition, would reduce the grain yield of wheat by 8.1, 18.7 and 25.7%, rice by 5.4, 7.4 and 25.1%, maize by 10.4, 14.6 and 21.4% and seed yield in groundnut by 8.7, 23.2 and 36.2%, respectively. Lal *et al.* (1998) examined the vulnerability of wheat and rice crops in northwest India to climate change through sensitivity experiments with CERES model and found that under elevated CO₂ levels, yields of rice and wheat increased significantly (15% and 28% for a

doubling of CO₂). However, a 3°C (2°C) rise in temperature cancelled out the positive effect of elevated CO₂ on wheat (rice). The combined effect of enhanced CO₂ and imposed thermal stress on the wheat (rice) crop is 21% (4%) increase in yield for the irrigation schedule presently practiced in the region. Mandal (1998), Chatterjee (1998) and Sahoo (1999) calibrated and validated the CERES-maize, CERES-sorghum, CROPGRO and WOFOST models for the Indian environment and subsequently used them to study the impact of climate change (CO₂ levels: 350 and 700 ppm; temperature rise from 1-4°C with 1°C increment) on phenology, growth and yield of different cultivars. Chatterjee (1998) observed increase in temperature consistently decreased the yields from the present day conditions. Increase in temperature by 1 and 2°C sorghum decreased the grain yields by 7 to 12%, on an average. A further increase in temperature drastically reduced the potential yields by 18 to 24%, on an average. Mandal (1998) observed increase in temperature up to 2°C did not influence potential yield of chickpea as well as above ground biomass significantly. Pre-anthesis and total crop duration got reduced by 10 and 12 days with 2°C rise. Irrigated yield, which averaged around 58% of the potential yield, in general increased with temperature rise upto 2°C. Total crop duration got reduced only by 4 days with 2°C rise. Crop yield under rain-fed condition was much lower, but the effect of temperature rise on crop growth processes and subsequent yield were more or less similar as noticed in case of irrigated condition. The elevated CO₂ increased grain yield under potential, irrigated and rainfed conditions. Potential grain yield of pigeonpea (using WOFOST) decreased greatly over the control when the temperature was increased even by 1°C. Sahoo (1999) carried out simulation for irrigated and rainfed conditions. Rise in temperature decreased the yield both the environments. At CO₂ level of 350 ppm, grain yield decreased continuously with temperature rise till 4°C, where the yield decreased by about 30% over the present day condition. Effect of elevated carbon dioxide concentration on growth and yield of maize was established, but less pronounced when compared with crops like wheat, chickpea and mustard crop. With CERES-rice model, Saseendran *et al.* 1999 indicated that over the Kerala State, an increase in CO₂ concentration leads to yield increase due to its fertilization effect and also enhance the water use efficiency. For every one degree increment the decline in yield is about 6%. Physiological effect of ambient CO₂ at 425-ppm concentration compensated for the yield losses due to increase in temperature up to

Specific event of direct radiation reduction during January-March, 1999, in all parts of the country, did not show deviation in the crops' yields as evidenced from the records. This might be due to modifications in the coupled weather conditions, which compensated for the reduction in radiation amounts. Moreover, this specific event is very less probabilistic. The researchers till now have looked at the impacts of haze in the region's climate and agriculture in a very preliminary way. More refined work on climate modeling and development of crop models to take care of various scenarios of this emerging science is needed to get conclusive information.

Tropospheric Ozone has various effects on crops and plants. Under acute short-term effect on sensitive crops, under appropriate growth conditions, can result in visible foliar injury. Such injury on broadleaved plants consist of chlorosis, bleaching, benzing, flecking, stippling and necrosis. O₃ injure the mesophylllic chloroplast and by this reduces the photosynthesis rate. It also increases the rate of photorespiration, due to which net assimilates decreases and due to this yield also decreases. It delays the fruit setting and dry matter production.

In view of the evidence that suggests that UV-B has little adverse effect on photosynthesis or growth under field conditions, it appears that concern over increase in UV-B irradiation resulting from stratospheric O₃ depletion should focus on long-term effects probably involving the consequences of damage to nucleic acids. In contrast, increased tropospheric O₃ levels will undoubtedly have immediate adverse effects on most species.

Effect of Climate Change on Pests

The importance of climate and weather events for the distribution of insects and their population dynamics has long been recognized especially in applied studies on pest species. Climatic factors such as temperature, precipitation, humidity, wind speed and sunshine hours etc can directly influence pests by affecting their rate of development, reproduction, distribution, migration and adaptation and indirectly through host plants, natural enemies and interspecific interactions with other insects.

Implication of temperature for insect pest dynamics has always been found important as it determines the development of insect. Campbell et al (1974) defined physiological time as a measure of amount of heat required over time for an organism to complete various stages of development.

The effect of temperature on insect growth and development has been mostly studied at constant temperature in laboratory and the studies have shown that insects remain active with in temperature range from 15 to 30 - 32°C (Phadke and Ghai, 1994). Within the range of favourable temperature, an increase in temperature increases the rate of development thereby decreasing the developmental period. In case of red cotton bug at constant temperature of 20, 25 and 30°C, the average duration of life cycle was found to be 61.3, 38.3 and 37.6 days respectively while at 12.5 and 35°C the pest did not show any development (Bhatia and Kaul, 1966). It was also seen that within the favourable limits the temperature increase also showed an increasing trend in egg laying and egg hatching. In the field conditions the pest populations are studied under fluctuating temperature and other factors cannot be controlled unlike laboratory conditions.

Favorable range of temperature for the pest species in relation to prevailing temperature and increased temperature has to be taken in to consideration for assessing the impact of climate change on pest dynamics. If ambient temperature remains favourable for the pest after temperature increase, the pest incidence may be expected to rise due to increase in rate of development, which may result in completion of more number of pest generations. However pest population would be adversely affected once the ambient temperature exceeds the favourable range.

The distribution and frequency of rainfall may also effect the incidence of pests through changes in humidity levels as well as directly. Small insects such as aphids, jassids and whiteflies are washed away by heavy rains thereby reducing their incidence of crops. Aphid population on wheat and other crops was adversely affected by rainfall and sprikler irrigation (Daebeler and Hinz, 1977; Bakhettia and Sindhu, 1983; Chander, 1998).

Armyworm, *Mythimna separata* reach outbreak proportions after heavy rains and floods. Lever (1969) analysed the relationship between outbreaks of armyworm and to a lesser extent *Spodoptera mauritia* (Boisd.) and rainfall from 1938 to 1965 and observed that all but three outbreaks occurred when rainfall exceeded the average 89 cm. Heavy incidence of armyworm in Delhi during kharif 1995 could be related to higher maximum and minimum temperatures and rainfall as compared to previous years (Chander and Sharma, 1997).

Aphid infestation on barley from 1985-86 to 1999-2000 was analyzed in relation to climatic variability. The aphid population on barley exhibited a declining trend with time. The aphid population showed negative relationship with January mean minimum temperature and with February's total rainfall (Chander et al., 2003). The rise in minimum temperature and more intense rains in future might thus reduce aphid incidence on barley.

Climate and weather also influence occurrence and virulence of diseases. The monocyclic diseases such as stem rot, sheath rot and false smut are less influenced by the ambient weather conditions. Epidemics of monocyclic diseases are relatively rare in the sense of an explosive increase in their population. Likewise climate change might not have much influence on univoltine insects such as rice grasshopper, mango mealy bug etc. In contrast, the poly-cyclic diseases such as blast, brown spot, bacterial leaf blight and rice tungro virus that invade the aerial parts of the plants are subjected to constant interaction with weather. They easily attain epidemic proportions to cause heavy losses.

Interactive effect of climate change on pests and crops can be analyzed through simulation models. This Center has developed dynamics simulation model for rice stinkbug, *Leptocorisa acuta* using thermal time concept (Reji et al., 2003). It was found that up to 2°C rise in daily average temperature over 2001 weather will increase the pest population while further increase in temperature would have adverse effect on pest population.

INFOCROP model, a generic crop growth simulation model developed at our Institute, has been coupled with different pest damage mechanisms such as germination reduction, stand reduction, light stealing, assimilation rate reduction, assimilate sapping, tissue consumption and turgor reduction. The INFOCROP has been validated for stem borer, leaf folder, bacterial leaf blight and weed effects in rice, and for stem borer, leaf rust and weed damage in wheat. The validated model was then used to establish economic injury levels and also to formulate iso-loss curves for the pests, which can be used for rationalizing pesticide use on crops.

Ecological zonation of agriculturally important pests such as rice leaf folder and nematode species has been carried out by developing simple pest-weather modules based on more than 10 years data of a location. These location results were then extrapolated using GIS for delineation of pest hot spots. There is a need to make the pest- weather

modules dynamic and link them with on line weather so that shifting of the hot spots with changes in climate can be visualized.

The following scenarios can be visualized regarding impact of climate change on pest damage in agriculture.

Expansion in geographical range of insects: Any increase in temperature is bound to influence the distribution of insects. It is predicted that 1deg rise in temperature would enable species to spread 200 Km northwards or 140 Km upwards in altitude (Parry *et al.*, 1989). Minimum temperature plays important role in determining the global distribution of insect species rather than maximum temperature (Hill, 1987), hence any increase in temperature will result in a greater ability to over winter at higher latitudes ultimately causing northward extension of distribution, (EPA 1989; Hill and Dymock, 1989). Spatial distribution of crops and cropping system are also important in deciding insect pest distribution. Spatial changes of crops and cropping system for sustained productivity are imminent under climate change scenarios (Parry *et al.*, 1989). Presence of over wintering sites, soil types and moisture availability can become deciding factor for resurgence of insects under such newer areas (EPA, 1989). However known pest species if introduced to new areas may encounter marginal conditions for their survival and suitable host plants may not be available. Besides natural enemies may also enter new areas thereby aiding in biological control of the pest.

Increased risk of invasion: With increase in carbon dioxide concentration, there may be more crop canopy and more dense foliage, which will also create more humidity, thereby making microenvironment more favourable to pests. Increase in food quality i.e., increase in nitrogen content in plants under stress condition due to high temperature can result in sudden resurgence of population of pest. Moreover under stress condition the plant defensive system is lowered and they become more susceptible to pest attack (EPA, 1989).

Changes in overwintering success: With increase in temperature onset of hibernation may be delayed in autumn while it may be suspended earlier than usual thereby initiating pest activity early. Therefore period of activity of pests will be increased leading to more pest problems. On the other hand, the increase in temperature in May-June may reduce the activity of some pests in summer.

Changes in interactions between species: Rapeseed-mustard crop is infested by two aphid species, *Lipaphis erysimi* and *Myzus persicae*. It has been observed that *Lipaphis erysimi* dominates during severe winters while *Myzus persicae* is relatively more plant defensive system is lowered and they become more susceptible to pest attack (EPA,1989).

With rise in temperature, we may witness higher incidence of Such faunal shifts may also occur in other crops. On the other hand with rise in temperature, activity of some pests in Kharif may also be reduced as temperature may cross favourable limit.

Change in crop-pest synchrony: Crop-pest synchrony may be altered due to changes in climate. During Kharif we find heavy infestation of stem borer and shoot fly in maize and sorghum under north Indian conditions. However rabi maize and sorghum are not affected by these pests. In southern parts these pests are active during rabi season also. Therefore with increase in temperatures these pests may pose problem to these crops in kharif in North India.

Effect on pest control factors: After application of chemicals at least one rain free day of 18-24 hrs rain free period is essential otherwise the chemicals gets washed away (Rao and Rao,1996). Similarly wind is also strong deterrent due to drifting problems. These parameters have to be taken into consideration while studying the insect problem on regional scale.

Effect on land use patterns: With increasing urbanization and population more and more agricultural land is being put under other uses. Farmland is being used for constructing buildings and other infrastructure. This is breaking the continuity of agricultural farms with implications for pests. Pest can be mainly divided into three categories based on their mode of their appearance on the crops. Some are resident pests, which remain in the field and immediately infest the crop as it becomes available next season. Other pests come from adjoining areas, while third categories are long-range migrants. The discontinuity of farms due to changes in land use may not affect resident pests but it may affect migrant pests as they may fail to locate suitable habitats and food plants.

Socio-economic Aspects

Socio-economic linkage is relatively complex, and needs to be linked through the bio-physical modifications associated with the climate change. Land use and land cover change in our country is changing rapidly due to several driving forces. Socio-economic

aspects can be dealt in two ways, one working out the cost-benefit analysis for various climate change scenarios by using production functions and the other as generating the socio-economic scenario of future which links with the cropping system model for further impact analysis.

CONCLUSION

Climate change has emerged as the most prominent of the global environment issues, and future load of excess GHGs emission will change the climate to affect the living communities. Precision in climate change prediction with higher resolution on spatial and temporal scales is requirement for accurate assessment of the impact on various sectors. Response of crops to inter-seasonal climatic variability can aid in understanding system's response to weather parameters change, which subsequently can be linked to climate change scenarios to work out the impact.

Climate change should be linked with others bio-physical and socio-economic driving forces to work out its impact on agriculture. The chance of error propagation generally exists, while blowing up the results over larger regions, and we should be careful in specifying the boundary conditions under which the results have been obtained. Simulation models can be successfully used for agricultural impact assessment of the climate change by linking with the spatial databases of socio-economic and bio-physical inputs.

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PARASITOIDS OF INSECT PESTS OF STORED PULSES FROM NORTH EASTERN PLAIN OF INDIA

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ABSTRACT

A study was conducted during 1999-2003 in the North Eastern Agro-Ecological Zone of India on different genera and species of stored pulses available in the markets. Dinarmus vagabundus (Hymenoptera : Pteromalidae) and Uscana muckerjii (Hymenoptera : Trichogrammatidae) were the naturally occurring key parasitoid of the bruchid pests of stored pulses. Other minor parasitoids, namely Cerocephala dinoderi (Hymenoptera : Chalcidoidea : Pteromalidae) of Sitophilus sp. (Coleoptera : Curculionidae), Bracon sp. (Hymenoptera : Ichneumonioidea : Braconidae) of Coreya cephalonica (Lepidoptera: Pyralidae), Dinarmus sp. (Hymenoptera : Chalcidoidea : Pteromalidae) of Callosobruchus chinensis (Coleoptera : Bruchidae) and few other unidentified parasitoids were recorded. All the identified parasitoids were recorded for the first time from this Zone except Uscana muckerjii (Mani). Another attempt was made to explore the possibility of recording other available insect pests of stored Pulses and their parasitoids.

Key Words : Survey report, pest-parasitic complex, stored pulses, north-eastern plain of India, check-list

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INTRODUCTION

Pulses occupy 67.8 million hectares and contribute 55.2 million tonnes to the world's food basket (Chhabra, and Kooner, 1998). India is the largest pulse producing country and contributes 35% of world's area and 27% of the production (Kumar, 2000). Since pulses are cheaper than meat (animal protein), they are often referred to as "poor man's meat" in a developing country like India (Chaturvedi and Ali, 2000). India will need at least another 23 million tonnes of pulses by 2005 AD and 30 million tonnes by 2020 AD. It has been estimated by Ramzan *et al.*, (1990) that *Callosobruchus maculatus* (Coleoptera: Bruchidae) oviposited eggs on the seed coat of bengal gram (*Cicer arietinum*), black gram (*Vigna mungo*), black-eyed cowpea (*V. unguiculata*), green gram (*V. radiata*), kidney bean (*Phaseolus vulgaris*), lentil (*Lens culinaris*), moth bean (*V. aconitifolia*), pigeon pea (*Cajanus cajan*) and rice bean (*V. umbellata*). Females preferred *V. unguiculata* most and had the greatest damage in terms of holes (69%) and weight loss (35%), followed by *V. aconitifolia* (54 and 22%) and *V. radiata* (50 and 19%). Thus, a proper management in the storages is needed at national level (Asthana and Chaturvedi, 1999).

Storage facilities at the villages and assembling centers are still very poor. At farmers level the big growers store pulses in 'gola' made of bamboo and mud. The small and marginal farmers have no storage facilities. So, they are forced to sell the produce immediately after harvest. The farmers of North Eastern Plain Agro-Ecological Zone of India do not find any interest in large-scale production of pulses for not having enough space and proper storage facility. Besides, the pulses are highly susceptible to insect pest attack that causes serious damage to the seeds. Prior to exploring a safe management of pulse pests a survey is urgently needed to identify different species occurring in a region. Furthermore, an assessment of the extent of damage, distribution and abundance of pests and their parasitoids are essential prerequisites for developing control programme and bio-ecological safety of different Agro-Ecological Zones of India. Annex-1 This communication embodies a survey record of insect pests of stored pulses and their parasitoids in the north-eastern plain agro-ecological zone of India.

MATERIALS AND METHODS

An extensive survey was carried out in the area covering 15130 sq. km. of terai region of West Bengal, India (Location: 25°57'-27° North and 88°25' - 89°54' East; Altitude: 40-50 m.) and low elevations Agro-climatic hill region (Location: 20°31'-27°31' N and 87°59'-88°53' E; Altitude: >2000m.) of West Bengal to record insect pest species and their natural enemies of stored pulses during 1999 - 2003. Laboratory analyses was done at the Entomology Department of the Uttar Banga Krishi Viswavidyalaya, Cooch Behar, W.B. and Department of Zoology, North Bengal University, Siliguri, Darjeeling, W.B., India.

The insect pests of pulses (Annex 3 and 7) were collected from farmers', store houses, hats and markets of different administrative blocks, sub-divisions and districts of the zone, at a regular interval. Infested seeds were reared in the laboratory. All insect pests and their natural enemies (Annex 3 and 4) thus collected were killed with ethyl acetate vapor or chloroform. The insects were collected by hand and sometimes with the help of aspirator. These were mounted on card points with water-soluble glue or preserved in 70% alcohol or in the Kohli's solution. The specimens were identified by the Zoological Survey of India, Calcutta. The parasitoids of insect pests were identified by Prof. T.C.Narendran of Calicut University, Kerala, India and by Prof. M.Hayat of Aligarh Muslim University, India.

RESULTS AND DISCUSSION

Insect pests of stored pulses

A district wise occurrence of insect pests of stored pulses (Annex 3) and their parasitoids was recorded (Annex 4). Altogether six insect pests of stored pulses were recorded from 14 legume seeds, collected from indigenous store houses and markets. The bruchids were the most destructive pests of stored pulses. Among them *Callosobruchus chinensis* (Coleoptera : Bruchidae) was the most notorious pests of green gram, lentil, pigeon pea, black gram, cowpea, grass pea, pea and chickpea whereas *C. analis* and *C. maculatus* were the second most damaging pests. *C. analis* preferred mainly black gram, green gram, grass pea and cowpea, while *C. maculatus* preferred cowpea, green gram, black gram and grass pea. The pea beetle, *C. pisorum* was recorded only on pea. Its infestation occurred in the field and adult beetles emerged out after few months in

the storage. It could not complete its life cycle on stored peas supporting the earlier observation by Arora (1977). *Sitophilus* sp., *Tribolium* sp. and *Corcyra cephalonica* were recorded as minor pests of late stored pulses and their infestation was negligible and occasional.

Callosobruchus analis have been reported from different countries like India, (Lefroy, 1909), Pacific Islands (Archibald, 1988), Kenya (Warni, 1984), Burma (Ghosh, 1937), Germany (Zascher, 1930), South Africa (Evans, 1939), Japan (Miyake, 1939), Bangladesh (Begum *et al.*, 1984), Bulgaria (Sodomov, 1984), Australia (Whightman *et al.*, 1982) and South Rodesia (Jack, 1936) but still it is not a dominant pest of stored pulses like *C. chinensis* and *C. maculatus*. The common, almost cosmopolitan and most destructive *C. chinensis* Linn. has been reported previously by Goncalves (1939), Colderon (1958), Morimota (1939), Pruthi and Singh (1950), Raina (1970), Southgate (1982) and many others. This insect species causes damage to almost all pulses commonly cultivated in this zone except soybean, kidney bean, field pea and black gram (Annex 3). Bruchids having world-wide distribution are an interesting group, most abundant in the tropics, whose larvae develop inside seeds, most preferred hosts belonging to the family leguminosae and other 24 families of plants (Southgate, 1978). Approximately 1300 species of bruchids have been recorded, mostly attack the growing crops, but they get carried into stores in the ripe pods and seeds and some species are successfully able to continue and complete their development in the dry seeds (Hill, 1990). The excessive damage caused by *Callosobruchus* spp. in storages discourages the poor farmers from large-scale production and storage of pulses. In India, stored pulses are damaged by *C. chinensis* Linn., *C. maculatus* Fab., *C. analis* Fab., *C. affinis* Frol., *C. emerginatus* All., *C. phaseoli* Gyll., *C. albacallosus* Pic., and *C. pisorum* Linn. of which *C. chinensis* is the most serious pest in both India and many other countries.

Parasitoids of insect pests

Quite a good number of parasitoids were collected and identified. Among the natural enemies of stored pulse pests *Dinarmus vagabundus* and *Dinarmus* sp. (Hymenoptera : Pteromalidae), *Uscana mukerjii* (Hymenoptera : Trichogrammatidae), *Cerocephala dinoderi* (Hymenoptera : Pteromalidae) and *Bracon* sp. (Hymenoptera : Braconidae) were recorded. *D. vagabundus*, *Dinarmus* sp. and *U. mukerjii* were the key parasitoids of bruchid pests whereas *C. dinoderi* and *Bracon* sp. were the minor parasitoids of

Sitophilus sp. and *Corcyra cephalonica* respectively. *Dinarmus vagabundus* was recorded as an important, gregarious larval-pupal ectoparasitoid of bruchids. Furthermore, *Uscana mukerjii* was a minute, solitary and potent egg parasitoid of bruchids (Mani, 1989 and Pajni *et al.*, 1976). These two are naturally occurring key parasitoids of North Eastern Plain agro-ecological Zone (N.E.P.Z.) of India.

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Annex 1. Agro-ecological Zones of India (Arora, 1999)

Name of the Zones	Name of the States of India
Central Zone (C.Z.)	Madhya Pradesh, Maharashtra, Gujarat, parts of Rajasthan, Bundelkhand region of Uttar Pradesh
South Zone (S.Z.)	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Orissa
North East Plain Zone (N.E.P.Z)	Eastern part of Uttar Pradesh, Bihar, Jharkhand, West Bengal and parts of Assam
Northern Hill Zone (N.H.Z)	Jammu & Kashmir, Himachal Pradesh, hills of Uttar Pradesh, Sikkim, hills of North Eastern States such as Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur and Mizoram.
North West Plain Zone (N.W.P.Z)	Punjab, Haryana, Delhi and parts of Rajasthan

Annex 2. Indian, common and scientific name of stored pulses including the physical characters

Indian	Name of the pulse		Colour	Shape	Texture
	English	Scientific			
Mung or moong	Green gram or Mungbean	<i>Vigna radiata</i> Linn.	Green	Cylindrical	Glossy
Urd or Urad	Black gram	<i>V. mungo</i> Linn.	Blue green mosaic	Cylindrical	Rough
Khesari or Chatti matti	Grass pea	<i>Lathyrus sativus</i> L.	Grayish brown	Irregular	Rough
Chola or Chana	Bengal gram or chickpea	<i>Cicer aureitimum</i> L.	Brown	Oblong	Rough
Motor or motor	Pea	<i>Pisum sativum</i> L.	Cream white	Round	Rough
Krishna motor or chota motor	Field pea or small pea	<i>P. arvense</i> L.	Greenish mosaic	Round	Rough
Arhar	Red gram or pigeon pea	<i>Cajanus cajan</i> Milsp.	Brownish red	Round	Glossy
Lobia or barbati	Cowpea (black-eyed)	<i>V. catjang</i> Walp.	Cream white	Kidney	Rough
Thakri or mash kalai	Black gram	<i>V. mungo silvestries</i> L.	Amber brown	Cylindrical	Rough
Masoor	Lentil	<i>Lens esculentum</i> Moench.	Light brown mosaic	Round flat	Rough
Kulastha or kulthi kalai	Horse gram	<i>Dolichos biflorus</i> Roxb.	Light brown	Kidney flat	Glossy
Moth or biri mung	Moth bean	<i>V. aconitifolia</i> Jack.	Light brown	Cylindrical	Glossy
Rajmash or French bean	Kidney bean	<i>Phaseolus vulgaris</i> L.	Tan brown	Kidney	Glossy
Soya bean	Soy bean	<i>Glycine max</i> Merr.	Yellow	Round flat	Glossy

Annex 3. District wise distribution of the pests of stored pulses

Name of the pulses	Name of the pest species	Name of the districts			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
<i>Vigna radiata</i> Linn.	<i>C. chinensis</i> Linn.	M—++	M+++	M++	M—++
	<i>C. maculatus</i> Fabr.	M—+	M+	M—	M+
	<i>C. analis</i> Fabr.	M—+	M—+	M—	NR
	<i>Sitophilus</i> sp.	T	T	NR	T
	<i>Corcyra cephalonica</i> Staint.	T	NR	NR	NR
<i>Cicer arietinum</i> L.	<i>C. chinensis</i>	M++	M++	M+	M—
	<i>Sitophilus</i> sp.	T	T	NR	NR
	<i>Corcyra cephalonica</i>	T	NR	NR	NR
<i>V. mungo mungo</i> L.	<i>C. analis</i>	M+++	M—++	M+	NR
	<i>C. chinensis</i>	M++	M++	M+	M—
<i>V. mungo silvestries</i> L.	<i>C. analis</i>	M—++	M—++	M+	NA
	<i>C. chinensis</i>	M++	M++	M—	M++
<i>Lathyrus sativus</i> L.	<i>C. chinensis</i>	M—	M++	M—	M—++
	<i>C. analis</i>	M+	NR	NR	NR
	<i>C. chinensis</i>	M+	M+	T	M+
<i>Pisum sativum</i> L.	<i>Sitophilus</i> sp.	T	T	NR	NR
	<i>C. pisorum</i>	T	NR	T	NR
	<i>Sitophilus</i> sp.	T	T	NR	NR
<i>Lens culinaris</i>	<i>C. chenensis</i>	M—++	M—++	M++	M++
	<i>C. chinensis</i>	M+	M+	M—	M+
<i>Vigna catieng</i> Walp.	<i>C. analis</i>	M+	T	NR	NR
	<i>C. chinensis</i>	M—	M—	NR	NR

Annex 3 (Continued)

Name of the pulses	Name of the pest species	Name of the districts			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
<i>Glycine max</i> Merr.	Bruchid eggs	T	T	T	NR
<i>Phaseolus vulgaris</i> L.	Bruchid eggs	T	NR	NR	NR
	<i>C. chinensis</i>	M+	M+	T	M+
<i>Cajanus cajan</i> Milsp.	<i>C. analis</i>	M+	NR	NR	NR
	<i>C. maculatus</i>	M+	M+	NR	NR
	<i>Sitophilus</i> sp.	T	T	NR	NR
<i>Pisum arvense</i> L.	<i>C. pisorum</i>	T	T	T	NR
<i>Vigna aconitifolia</i> Jack.	<i>C. chinensis</i>	M+	M+	NR	NR
<i>Dolichos lab lab</i> Roxb	<i>C. chinensis</i>	T	T	NR	NR

+ = Presence of eggs on the seeds of stored pulses.

M+++ = Maximum egg on seeds (above 25%)

M++ = Moderate egg on seeds (10-2)

M+ = Minimum egg on seeds (4-9%)

T = Trace egg on seeds (below 5%)

NR = No egg on seeds

Annex 4. The district wise occurrence of parasitoids and their hosts

Natural enemies/parasitoids	Name of the host insect	Name of the Stored pulse	District wise distribution
<i>Dinarmus vagabundus</i> (Timberlake) (Hymenoptera : Pteromalidae)	<i>C. chinensis</i> Linn. & <i>C. analis</i> Fabr.	<i>Vigna mungo</i> & <i>V. mungosilvestries</i>	Coochbehar, Jalpaiguri
<i>Dinarmus</i> sp. (Hymenoptera : Pteromalidae)	<i>C. maculatus</i> Fabr. <i>C. chinensis</i> Linn.	<i>Cajanus cajan</i>	Coochbehar, Jalpaiguri Darjeeling, Uttar Dinajpur
<i>Cerocephala dinoderi</i> (Gahan) (Hymenoptera : Pteromalidae)	<i>Sitophilus</i> sp.	<i>Vigna radiata</i>	Coochbehar

Annex 4. (Continued)

Natural enemies/parasitoids	Name of the host insect	Name of the Stored pulse	District wise distribution
<i>Bracon</i> sp. (Hymenoptera : Braconidae)	<i>C. cephalonica</i> Staint.	<i>Vigna radiata</i>	Coochbehar
<i>Uscana mukerjii</i> (Mani) (Hymenoptera : Trichogrammatidae)	<i>C. chinensis</i> Lim. <i>C. analis</i> Fabr.	Green gram & Black gram <i>Vigna radiata</i> , <i>Vigna mungo</i> & <i>V. mungo silvestries</i>	Coochbehar, Jalpaiguri

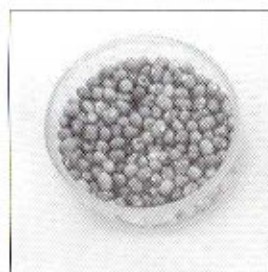
Annex 5. Check list of hymenopterans parasitoids of stored pulses in different agro-ecological zones of India

Parasitoid / Systematic position	Host	Zone of occurrence	References
Larval-pupal ectoparasitoid :			
<i>Dinarmus vagabundus</i> (Timberlake)	<i>Callosobruchus chinensis</i>	NEPZ NWPZ	Mani (1939), Chatterji (1954), Dhir (1977),
Family : Pteromalidae	<i>C. analis</i>	SZ	Bouceck <i>et al.</i> (1978), Mani (1984), Raja <i>et al.</i> (2000),
Sub-fam : Pteromalinae	<i>C. maculatus</i>	CZ	Ghosal <i>et al.</i> (2003)
Tribe : Metaponini			
<i>D. maculatus</i> (Masi)	<i>Callosobruchus</i> sp.	NEPZ SZ CZ	Chema and Mista (1962), Dhir (1977), Boucek <i>et al.</i> (1978), Mani (1989)
<i>Ibid</i>			
<i>D. laticeps</i> (Ashmead)	<i>Ibid</i>	NEPZ NWPZ	Mani (1939), Pruthi and Mani (1940), Boucek <i>et al.</i> (1978), Gupta <i>et al.</i> (1997),
<i>Ibid</i>			Mani (1989)

Annex 5. (Continued)

Parasitoid / Systematic position	Host	Zone of occurrence	References
<i>D. acutus</i> (Walker)	<i>Ibid</i>	NEPZ	Kundras (1976), Boucek <i>et al</i> (1978), Mani (1989), Verma (1990), Saxena and Saxena (1997), Gupta <i>et al.</i> (1997)
<i>Ibid</i>			
<i>D. colemani</i> (Crawford)	<i>Ibid</i>	NWPZ	Mani (1939), Boucek <i>et al.</i> (1978), Mani (1989)
<i>Ibid</i>		NEPZ	
<i>D. basalis</i> (Rondani)	<i>Ibid</i>	SZ	
<i>Ibid</i>			Ayyar and Mani (1939), Mani (1938), Pruthi and Mani (1940), Boucek <i>et al.</i> (1978), Mani (1989)
<i>Anisopteromalus calandrea</i> (Howard)	<i>C. chinensis</i>	Cosmopolitan	Ayyar and Mani (1937), Mani (1938), Pruthi and Mani (1940), Boucek <i>et al.</i> (1978), Mani (1989), Boucek <i>et al.</i> (1978), Mani (1989)
Family : Pteromalidae	<i>Sitophilus</i> spp.		
Sub-fam : Pteromalinae	<i>C. phaseoli</i> (Gyll.)		
<i>Lariophagus distinguendus</i> (Forster)	<i>Bruchus bruchialis</i> Fabr.	Cosmopolitan	Boucek <i>et al.</i> (1978), Mani (1989)
Family : Pteromalidae	<i>Rhizopertha dominica</i> (F.)		
Sub-fam : Pteromalinae	<i>Sitophilus</i> spp.		
<i>Cerocephala dinoderi</i> (Gahan)	<i>Sitophilus</i> spp.	S.Z.	Boucek <i>et al.</i> (1978), Mani (1989)
Fam : Pteromalidae	<i>Dinoderus minutus</i>		
Sub-fam : Cerocephalini			
Tribe : Cerocephalini			
Egg parasitoid :			
<i>Uscana</i> (= <i>Chaetostrixa</i>) <i>mukerjii</i> (Mani)	<i>Callosobruchus</i> spp.	NEPZ	Mani (1935), Mukerji and Bhuiya (1936), Chatterji (1953), Chatterji (1954), Pajni and Singh (1973)
Fam : Trichogrammatidae		NWPZ	Kapila and Agarwal (1995)
Sub-fam :			Pajni <i>et al.</i> (1996)
Trichogrammatinae			
Tribe :			
Trichogrammatini			

Annex 6. Fourteen species of legume seeds



1. Green gram
(*Vigna radiata* Linn.)



2. Grass pea
(*Lathyrus sativus* L.)



3. Cow pea
(black-eyed)
(*Vigna catiung* Walp.)



4. Red gram
(*Cajanus cajan* Milsp.)



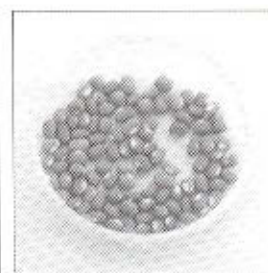
5. Pea
(*Pisum sativum* L.)



6. Bengal gram
(*Cicer arietinum* L.)



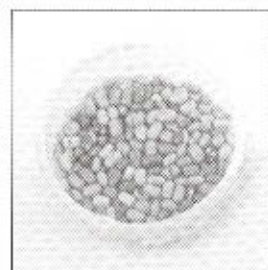
7. Lentil
(*Lens esculentum* Moench.)



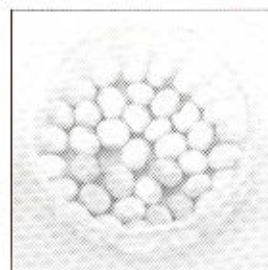
8. Black gram or
Urd (*Vigna mungo*
mungo L.)



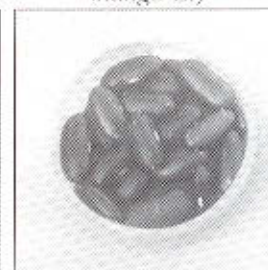
9. Horse gram
(*Dolichos biflorus* Roxb.)



10. Moth bean
(*Vigna aconitifolia* Jacq.)



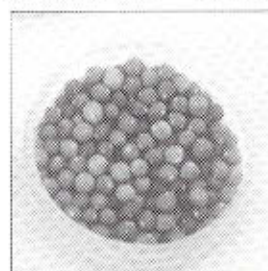
11. Soybean
(*Glycine max* Merr.)



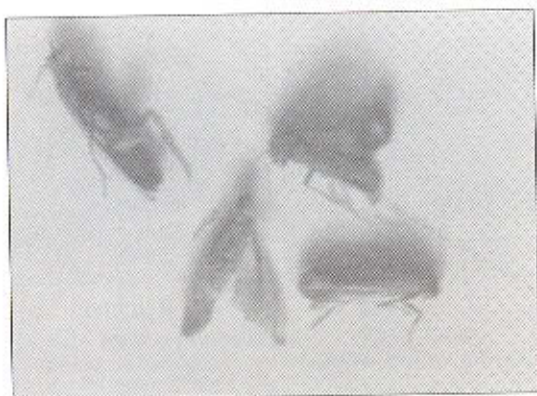
12. Kidney bean
(*Phaseolus vulgaris* L.)



13. Black gram or
thakri kalai
(*Vigna mungo silvestris* L.)



14. Small pea or
garden pea
(*Pisum arvense* L.)

Annex 7. Insect pests of stored pulses

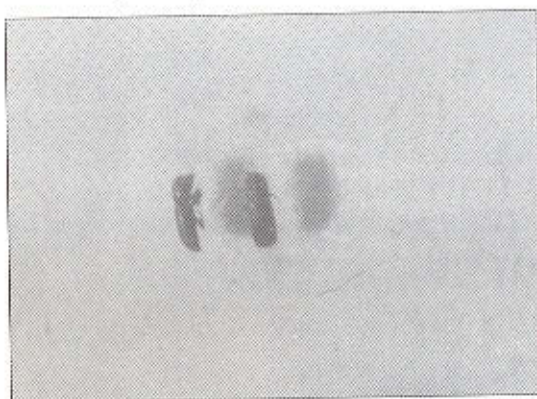
Grain moth, *Corcyra cephalonica* Stainton
(Lepidoptera: Galleriidae)



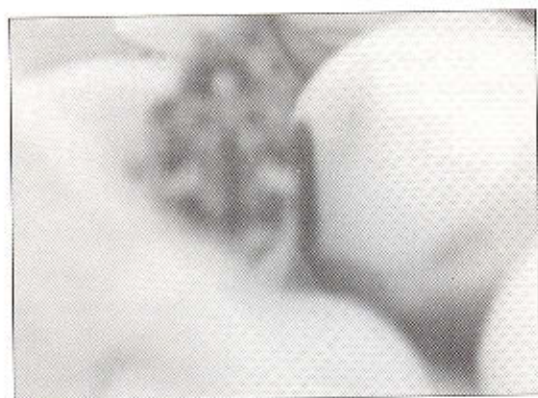
Grain weevil, *Sitophilus* sp.
(Coleoptera: Curculionidae)



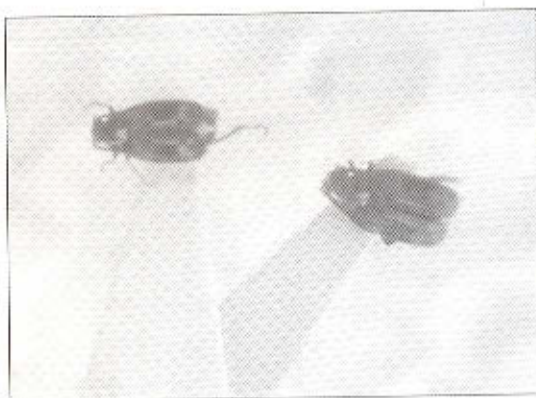
Pulse beetle, *Callosobruchus chinensis* Linn.
(Coleoptera: Bruchidae)



Red floor beetle, *Tribolium* sp.
(Coleoptera: Tenebrionidae)



Pea buggy weevil, *Callosobruchus pisorum* Linn.
(Coleoptera: Bruchidae)

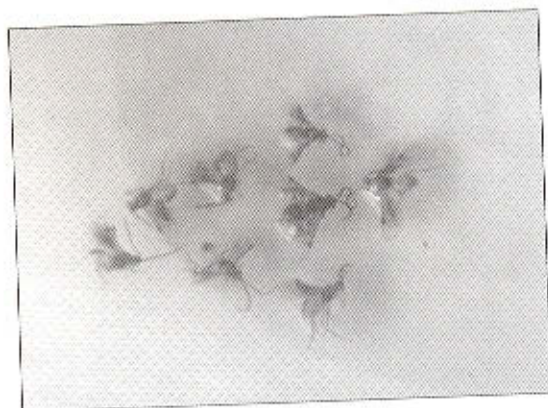


Callosobruchus analis Fabricious
(Coleoptera: Bruchidae)

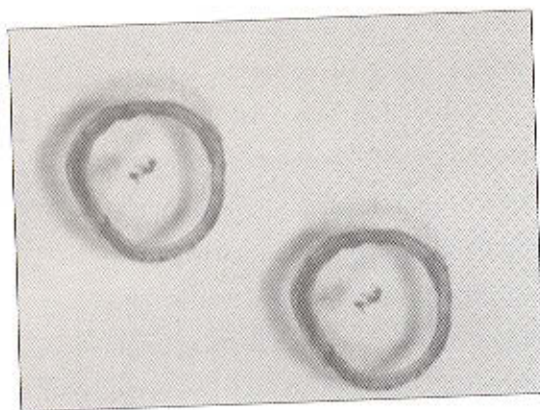
Annex 8. Parasitoids of insect pests of stored pulses



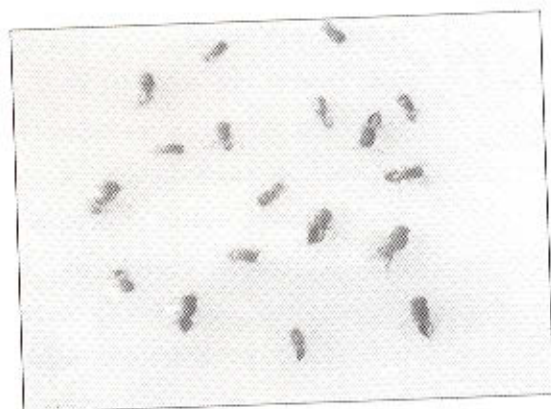
Egg-parasitoid of pulse beetle,
Uscana mukerjii (Mani)
(Hymenoptera:Chalcidoidea:Trichogrammatidae)



Larval parasitoid of grain moth.
Bracon sp.
(Hymenoptera:Ichneumonoidae: Braconidae)



Larval-parasitoid of grain weevil
Cerocephala dinoderi Gahan
(Hymenoptera:Chalcidoidea:Pteromalidae)



Larval-pupal ectoparasitoid of pulse beetle.
Dinarmus vagabundus (Timberlake)
(Hymenoptera:Chalcidoidea:Pteromalidae)

PRODUCTIVITY AND PROFITABILITY OF SPRING RICE (*Oryza sativa* L.) -BASED SEQUENTIAL CROPPING UNDER RAINFED CONDITION IN MID-HILLS OF N-W HIMALAYAS

VED PRAKASH¹, SUBHASH CHANDRA¹ AND A.K. SRIVASTVA²

ABSTRACT

*A field experiment was conducted at Experimental Farm, Hawalbagh, VPKAS, Almora on a sandy-loam soil from 1995 to 1999, to determine the productivity and profitability of different spring rice-based crop sequences. Spring rice (*Oryza sativa* L.) - lentil (*Lens culinaris medikus*) - capsicum (*Capsicum annum*) - gardenpea, (*Pisum sativum* L.) sequence recorded the highest rice equivalent yield (47.03 t/ ha), gross return (Rs. 2,49,115/ ha), net returns (Rs. 1,48,120/ ha) and benefit : cost ratio (2.51). Spring rice-lentil-tomato (*Lycopersicum esculentum* Miller nom cons.) - garden pea ranked second in terms of gross return (Rs. 2,49,102/ha), net return (Rs. 1,47,602/ha) and B:C ratio (2.51). Traditional cropping sequence (spring rice-wheat- (*Triticum aestivum* L. emend Fiori & Paol.) - finger millet - [*Eleusine coracana* (L.) Gaertn] - fallow produced the lowest rice equivalent yield (6.66 t/ha), gross return (Rs. 56,579/ha), net return (Rs. 4,036/ha) and B : C ratio (1.08). The spring rice - lentil-capsicum-gardenpea sequence also proved most efficient in terms of both production and economic efficiency.*

Key Words : Spring rice-based cropping systems, Rice Yield equivalents, Gross returns Net returns, Land use efficiency, Production efficiency, Economic efficiency.

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INTRODUCTION

Intensification of cropping sequence is essential to fulfil the demand of food, fibre and vegetables with increasing human population, corresponding to the need in the area. Now-a-days in the cropping systems pulses, oilseeds and vegetables are receiving more attention, owing to their increased demand in turn fetching higher market prices. Inclusion of these crops in a sequence improves the profitability of the cropping system (Tomar and Tiwari, 1990; Gangwar and Katiyal, 2001). In Uttarakhand hills, under rainfed conditions, spring rice (March - Sept) - wheat (Oct. - May) - finger millet (May - Oct.) - fallow (Nov. -Feb.) is the predominant 2 years cropping system (Table 1). The total productivity and profitability per unit area and time of this sequence is quite low due to poor yield and low prices of the component crops.

The agro-climatic condition of the region is such that certain vegetables like tomato and capsicum can be grown even under rainfed conditions, provided some amount of water is available for their seedling establishment. Therefore, it was thought appropriate, to evaluate different spring rice-based crop sequences involving pulses and vegetables for their productivity and profitability, under rainfed conditions in mid-hills of N-W Himalayas.

MATERIALS AND METHODS

The field study was conducted during 1994-95 to 1997-98 at experimental farm, Hawalbagh of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora located at 29° 36' N latitude and 79° 40' E longitude with an altitude of 1250 m above mean sea level. The soil of the experimental site was sandy loam in texture, neutral in reaction, low in available N, medium in available P and K. Treatments comprised 8 cropping sequences, viz. Spring rice - wheat - finger millet (Local) - fallow; Spring rice-wheat - finger millet (VL. *Mandua 204*) - toria; Spring rice - wheat - capsicum - gardenpea; Spring rice - wheat - tomato - gardenpea; Spring rice - gram - tomato - gardenpea; Spring rice - gram - capsicum - gardenpea; Spring rice - lentil - tomato - gardenpea and spring rice - lentil - capsicum - gardenpea were evaluated in randomized block design with 3 replications (Table 1).

The recommended doses of fertilizers ($N:P_2O_5:K_2O$ Kg/ha) were 40:20:20 in spring rice and finger millet, 60:30:20 in wheat, 20:40:20 in lentil, 20:60:40 in gram and gardenpea, 50:30:20 in toria and 100:50:50 + 20 t FYM/ha in tomato and capsicum. The recommended varieties i.e. 'VL Dhan 206' in spring rice, 'Local' and 'VL. Mandua 204' in finger millet, 'VL Gehun 616' in wheat, 'VL Masoor 4' in lentil, 'T-9' in toria, 'VL 86' in gram, 'VL. matar 1' in gardenpea 'Sioux' in tomato and 'California wonder' in capsicum were used. Spring rice, finger millet, wheat and toria were planted in March end, June 1st fortnight, October beginning and 2nd fortnight of September, respectively whereas lentil, gram and gardenpea (dual purpose grown for green pods) were planted in 2nd fortnight of October.

Twenty-five days old seedlings of tomato and capsicum were transplanted in May. Crops included in different sequences were raised with recommended package of practices. The yields of all crops were converted into rice equivalent on price basis. Land use efficiency (%) was calculated dividing the total duration of crop sequences by 730 (as all the sequences were of 2 years duration). Production efficiency (kg/ha/day) was calculated by dividing the total rice equivalent yield with total duration of the sequence and economic efficiency (Rs/ha/day) was worked out using net returns divided by total duration of sequence (Singh and Verma, 1998). The temperature and rainfall recorded during the period of investigation is presented in figure. 1.

Table 1. Yield and straw yield of component crops under 2 years crop sequences

Crop sequences			Yield of respective crop (t/ha)							
Kharif	Rabi	Kharif	1995-1997			1997-1999				
1	2	3	1	2	3	1	2	3	4	
Spring rice - wheat - finger millet - fallow			2.43 (7.08)	2.88 (4.78)	3.39 (5.67)	-	1.77 (5.42)	0.72 (1.45)	2.32 (5.45)	-
Spring rice - wheat - finger millet - toria			2.38 (6.95)	2.94 (4.67)	2.87 (5.33)	0.86	1.75 (5.69)	0.74 (1.50)	2.08 (5.00)	0.90
Spring rice - wheat - capsicum - garden pea			2.31 (7.45)	2.85 (4.98)	14.92	7.20	1.77 (5.56)	0.88 (1.62)	20.67	9.12
Spring rice - wheat - tomato - garden pea			2.22 (7.43)	2.95 (4.72)	25.42	8.58	1.90 (5.42)	0.69 (1.45)	21.89	8.81
Spring rice - gram - tomato - garden pea			2.13 (7.50)	1.50 (2.02)	29.80	7.45	2.06 (6.31)	1.05 (1.60)	24.77	9.89
Spring rice - gram - capsicum - garden pea			2.20 (7.08)	1.55 (1.90)	16.83	8.50	2.15 (6.04)	0.88 (1.25)	23.89	9.43
Spring rice - lentil - tomato - garden pea			2.34 (6.63)	1.20 (1.80)	28.42	7.03	1.88 (5.90)	1.20 (1.70)	26.97	8.12
Spring rice - lentil - capsicum - garden pea			2.21 (6.65)	1.23 (1.97)	18.80	6.89	1.83 (5.76)	1.39 (1.65)	25.72	7.99

() straw yield of component crops

Table 2. Yield and straw yield of crops under 2 years crop sequences (pooled data of 2 cycles)

Crop sequences			Yield of respective crop (t/ha)							
Kharif	Rabi	Kharif	Yield				Straw yield			
1	2	3	1	2	3	4	1	2	3	4
Spring rice - wheat	- finger millet - fallow		2.10	1.80	2.85	-	6.24	3.10	5.56	-
Spring rice - wheat	- finger millet - toria		2.07	1.84	2.48	0.88	6.32	3.09	5.17	-
Spring rice - wheat	- capsicum - garden pea		2.04	1.87	16.13	8.16	6.50	3.30	-	-
Spring rice - wheat	- tomato - garden pea		2.06	1.82	22.54	8.70	6.42	3.08	-	-
Spring rice - gram	- tomato - garden pea		2.09	1.27	25.06	8.67	6.91	1.81	-	-
Spring rice - gram	- capsicum - garden pea		2.17	1.16	20.36	9.00	6.56	1.58	-	-
Spring rice - lentil	- tomato - garden pea		2.11	1.21	27.69	7.58	6.26	1.75	-	-
Spring rice - lentil	- capsicum - garden pea		2.02	1.31	22.26	7.44	6.20	1.81	-	-

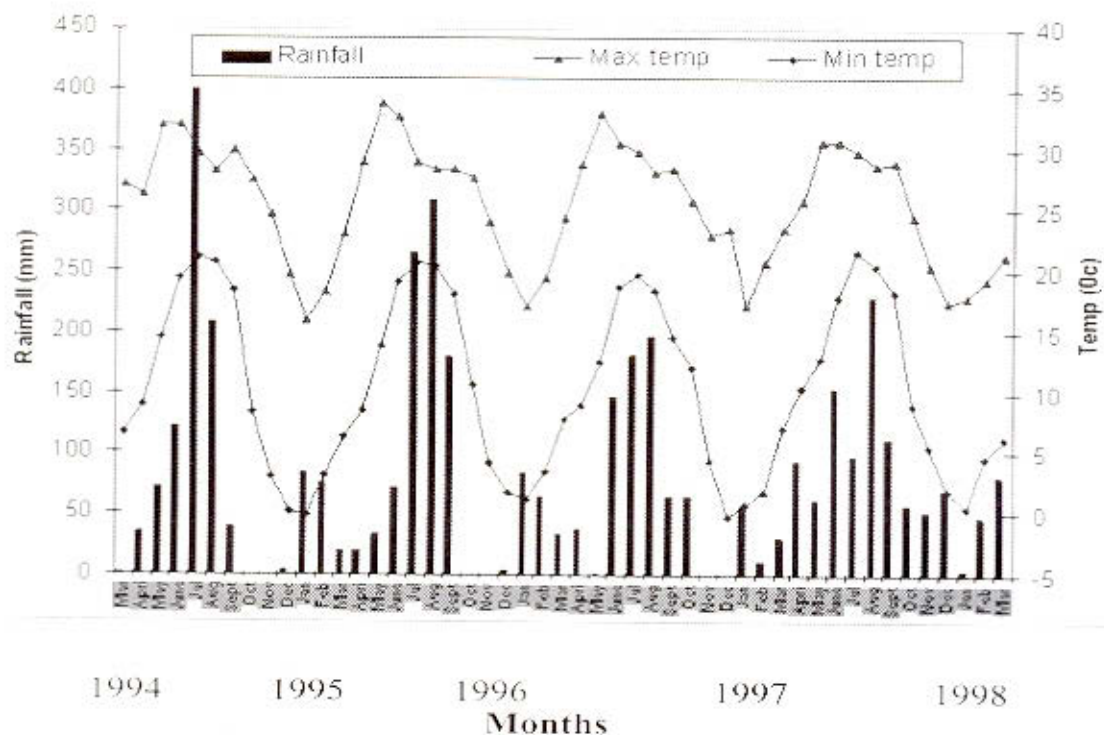


Fig. 1 Rainfall and temperature pattern during the course of study

RESULTS AND DISCUSSION

Rice equivalent yield:

The highest total rice equivalent yield was obtained under spring rice - lentil-capsicum-gardenpea sequence (47.03 t/ha), which was at par with spring rice-gram-capsicum-gardenpea (46.23 t/ha), spring rice-gram-tomato-gardenpea (45.60 t/ha) and spring rice-lentil-tomato-gardenpea (44.93 t/ha). However, these yields were significantly higher than rest of sequential cropping in test (Table 3). Traditional cropping sequence (spring rice-wheat-finger millet-fallow) recorded the lowest rice equivalent yield (6.66 t/ha), which however, was at par with spring rice - wheat - finger millet - toria sequence (8.75 t/ha). All the cropping systems involving vegetables were found significantly superior as compared to only cereals consisting of sequential cropping. It was mainly due to higher yield of vegetables, coupled with their higher prices. Yields of component crops 1995-97 and 1997-99 are shown in table 1 and 2.

Table 3. System productivity, land use and production efficiency under different crop sequences (pooled data of 2 cycles)

Crop sequences		Rice Eq. Yield (t/ha)	Total duration of crop sequence (days)	Land use efficiency (%)	Prodn. Efficiency (kg/ha/day)
Kharif	Rabi				
Spring rice -	wheat - finger millet - fallow	6.58	2.10	67.8	9.01
Spring rice -	wheat - finger millet - toria	8.75	2.07	83.2	11.99
Spring rice -	wheat - capsicum - garden pea	38.29	2.04	84.8	52.45
Spring rice -	wheat - tomato - garden pea	41.77	2.06	83.4	57.21
Spring rice -	gram - tomato - garden pea	45.60	2.09	81.2	64.46
Spring rice -	gram - capsicum - garden pea	46.23	2.17	82.6	63.33
Spring rice -	lentil - tomato - garden pea	44.93	2.11	79.7	61.55
Spring rice -	lentil - capsicum - garden pea	47.03	2.02	81.1	64.42
CD at 5%		3.12			

Land use and production efficiency:

The highest Land Use Efficiency (LUE) was recorded in spring rice- wheat-capsicum-gardenpea sequence (84.8%), which occupied the field for maximum number of days (619), while it was the lowest (67.8%) in spring rice-wheat-finger millet-fallow traditional sequence, wherein field remained occupied for 495 days only. In other sequences, the LUE varied from 79.7 - 83.4 per cent (Table 3).

Monetary returns:

Inclusion of pulses and vegetables in cropping sequence enhanced the gross and net returns significantly over traditional sequential cropping. Spring rice-lentil-capsicum-gardenpea gave the highest gross (Rs. 2,49,115/ha) as well as net returns (Rs. 1,48,120/ha), which were statistically at par with spring rice-lentil-tomato-garden pea, spring rice-gram-capsicum-gardenpea and spring rice-gram-tomato-gardenpea crop sequences (Table 4). However, these returns were significantly higher than rest of the cropping sequences. Spring rice-wheat-tomato-gardenpea sequence recorded significantly higher gross (Rs. 2,24,015/ha) and net return (Rs. 1,20,015/ha) than spring rice-wheat-capsicum-gardenpea sequence. However, both the sequences were found significantly superior to the traditional spring rice-wheat- finger millet-fallow sequence and spring rice-wheat-finger millet -toria sequence. It might be due to inclusion of vegetables and pulses in the sequence and their higher selling prices. Inclusion of oilseed (toria) in the traditional sequence, during fallow period (spring rice-wheat-finger millet-fallow) provided additional gross return (Rs. 10,233/ha) and net return (Rs. 1,233/ha). Inclusion of legumes and vegetables together in the spring rice-based cropping system increased the gross returns by 246.1 - 340.3 % and net returns by 154.3 - 267.0 % over the spring-rice-wheat-finger millet-fallow predominant sequence under rainfed condition of the region.

Benefit : Cost ratio

Rotation involving pulses and vegetables both registered higher B:C ratio (2.44 to 2.51) as compared to those involving either vegetables (1.91-2.15) or oilseed (1.89) only (Table 4). However, spring rice-lentil-capsicum-garden pea and spring rice-lentil-tomato-gardenpea sequences recorded the highest B:C ratio (2.51) followed by spring rice-gram-capsicum-garden pea (2.45). The lowest B:C ratio was obtained under spring rice-wheat-finger millet-fallow traditional sequence (1.08).

Table 4. Monetary returns as influenced by different 2 years spring rice based cropping sequences (pooled data of 2 cycles)

Treatments			Returns (Rs./ha)		B:C ratio
Kharif	Rabi	Kharif - Rabi	Gross	Net	
Spring rice -	wheat -	finger millet - fallow	56579	4036	1.08
Spring rice -	wheat -	finger millet - toria	66812	5269	1.09
Spring rice -	wheat -	capsicum - garden pea	207144	102644	1.98
Spring rice -	wheat -	tomato - garden pea	224015	120015	2.15
Spring rice -	gram -	tomato - garden pea	242669	141169	2.44
Spring rice -	gram -	capsicum - garden pea	245788	143788	2.45
Spring rice -	lentil -	tomato - garden pea	249102	147602	2.51
Spring rice -	lentil -	capsicum - garden pea	249115	148120	2.51
CD at 5%			15012	10860	

Traditional sequential cropping (spring rice - wheat-finger millet-fallow) and addition of toria to it during fallow period, had production efficiency 9.01 and 11.99 kg/ha/day, respectively (Table 4). Incorporation of high tonnage crops like tomato/capsicum/gardenpea in the traditional sequence coupled with their high market values recorded very high production efficiency ranging from 52.45 - 64.42 kg/ha/day. When wheat was replaced either by lentil or gram, it improved the production efficiency by almost 8.6 kg/ha/day.

Thus, the results revealed that there is a scope to enhance the total productivity and profitability per unit area and time with the inclusion of pulses like lentil, gram and vegetables like capsicum, tomato and gardenpea in the traditional cropping sequence (spring rice-wheat-finger millet-fallow), under rainfed conditions in mid-hills of North-Western Himalayas.

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SPECIFIC AND GENERAL COMBINING ABILITY FOR YIELD AND TUBER DRY MATTER OF POTATO (*Solanum tuberosum* L.) CROP

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ABSTRACT

The variances due to general and specific combining ability showed that non-additive component was predominant and additive variance was of little value for the characters tuber number/plot, average tuber weight, total yield, marketable yield and per cent tuber dry matter. GCA-parent and mid-parent progeny correlations were not high enough to be useful in predicting mean performance of the progeny. Maximum values of mid parent- progeny ($r=0.404$) and GCA-parent ($r=0.620$) correlations were found for average tuber weight. MS/82-638, Kufri Ashoka, JE 812 and Kufri Pukhraj were found to be important general combiners for yield. These parents also possessed good general combining ability for yield contributing characters like tuber number and/or average tuber weight. EB/C 899 $\times$ CP 2383, Kufri Jyoti $\times$ CP 2383, CP 3204 $\times$ Kufri Pukhraj, CP 2359 $\times$ Kufri Pukhraj and CP 3204 $\times$ CP 2366 cross populations were the best based on their per se performance and specific combining ability effects. These crosses hold promise for selection of outstanding hybrids for raising 60-days crops.

Key Words : *Solanum tuberosum* L., Combining ability, Early bulking, 60-days crop, yield, Tuber number, Average tuber weight, Per cent dry matter .

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INTRODUCTION

For further increase in area under potato (*Solanum tuberosum* L.) and better competition of the crop in intensive agriculture, in addition to medium and long duration varieties, short duration varieties are required to be developed (Shekhawat, 1994). Advantages of such short duration varieties are multiple. Potato in the Indian plains is generally harvested at about 90-110 days after planting. It can, however, be harvested at any time after about 60 days of planting. Very early bulking varieties giving yield of about 20-25 tonnes/ha in 60 days can be sandwiched between the crops in different farming systems without limiting the biodiversity of associated crops (Shekhawat et al., 1999). Such varieties can allow taking rice-potato-wheat as sequential crops. Short duration variety can enable the farmers to take the potato crop anytime for two months during September to May resulting in staggered potato production which can solve to some extent the problem of glut/storage. Knowledge of combining ability is important for planning hybridization for the breeding programmes. Most of the studies on combining ability in potato were carried out on crop of 90 or more than 90 days duration. The information on combining ability in 60-days crop is lacking. Keeping in view the importance of short duration varieties, present study was undertaken to estimate combining ability of 21 parents and their crosses for 5 economic characters in 60-days crop.

MATERIALS AND METHODS

Twenty-one potato genotypes representing advance generation clones, germplasm accessions, and exotic and Indian varieties were used as parents. Of these, 15 genotypes (CP 2023, CP 2287, CP 2359, CP 3142, CP 3165, CP 3204, Kufri Ashoka, Kufri Jyoti, EB/C 899, JE 812, JW 160, JX 115, JX 455, JY 712 and MS/82-638) were used as female parents (lines) and 6 (CP 1704, CP 2366, CP 2383, Kufri Pukhraj, MS/82-797 and EX/A 680-16) were used as male parents (testers). All the lines were crossed to each of the testers to produce true seeds during summer 1996 at Central Potato Research Station, Kufri (31° 08'N, 77° 18'E, 2530m amsl). Seedlings and subsequent clonal generations were raised at Central potato Research Station, Jalandhar (31° 02'N, 75° 02'E, 237m amsl). Seedlings were raised in the last week of September 1996. At harvest three tubers per seedling for each of the 24 randomly selected genotypes per progeny were retained to

form three replications of first clonal generation. The same procedure was applied to form material for second, third and fourth clonal generations. The 90 progenies were evaluated in the field for two successive generations i.e. Third Clonal Generation (TCG) and Fourth Clonal Generation (FCG) during the autumn crop seasons of 1999-2000 and 2000-2001. Trials in these two clonal generations were laid in Randomised Block Design with a plot size of 2.88 square metres comprising 2 rows planted at intra and inter row spacings of 20 and 60 cm, respectively. The recommended agronomic practices were followed. The crop was harvested 60 days after planting. Observations were recorded on tuber numbers/plot, average tuber weight (g), total tuber yield/plot (kg), marketable tuber yield/plot (kg) and per cent dry matter.

Combining ability analysis was done based on Kempthorne (1957). A fixed effects model was used to test the significance of combining ability effects. Homogeneity of error variance was tested by two-tailed F-test.

RESULTS AND DISCUSSION

Carrying out combining ability study over generations is very important (Brown et al. 1987; Gopal et al., 1992). Keeping this in view, progenies were evaluated over two (TCG and FCG) generations in the present study to get an unbiased estimate of combining ability effects.

Pooled analysis of variance showed that the generation mean squares were significant for average tuber weight, tuber no., marketable yield and total yield but non significant for per cent dry matter (Table 1). Replication mean square was not significant for all the 5 characters indicating that these characters were not influenced by slight change in the environment. Combining ability differences due to parents and female $\times$ male interaction were significant for all the 5 characters. The estimate due to female $\times$ generation, male $\times$ generation, female $\times$ male $\times$ generation interactions were non significant for all the traits. These findings are in agreement to those of Tai (1976) who reported that interaction of General Combining Ability (GCA) and Specific Combining Ability (SCA) with years were in general non-significant.

Table 1. Analysis of variance for combining ability

Source	d.f.	Mean square for				
		Tuber no. /plot	Average tuber weight	Marketable yield (kg/plot)	Total yield (kg/plot)	% Dry matter
Generations	1	1467.31**	330.31**	0.59*	2.55**	0.43
Replications within generations	4	33.07	3.69	0.04	0.27	0.29
Females	14	11675.50**	194.26**	6.29**	7.43**	15.95**
Males	5	10455.24**	998.60**	8.53**	7.72**	21.58**
Female $\times$ male	70	3075.06**	167.03**	4.71**	4.86**	7.57**
Female $\times$ generation	14	170.62	10.02	0.12	0.09	0.03
Males generation	5	186.11	6.79	0.12	0.04	0.01
Female $\times$ male	70	242.72	12.75	0.11	0.15	0.05
$\times$ generation	356	203.95	13.40	0.13	0.15	0.18
Error						

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

The estimates of σ^2_{sca} were of much higher magnitude than σ^2_{gea} for all the 5 characters (Table 2) revealing thereby the predominance of non-additive gene action for these characters. The proportion of σ^2_{gea} to total genetic variance was, however, comparatively better for tuber number/plot and average tuber weight compared to other three characters. Our estimate of SCA variance for tuber dry matter confirmed the previous findings (Gaur et al., 1985, 1993; Kumar and Kang, 2001). Importance of non-additive gene action for tuber number, was in agreement with the earlier findings (Gaur et al., 1993; Gopal and Minocha, 1998; Tai, 1976). However GCA was reported more important than SCA for tuber number, by some workers (Gaur et al., 1983). The estimate of SCA variance for yield and average tuber weight in the present study confirmed the findings of other workers (Kumar and Kang, 2001; Plaisted et al., 1962). Plaisted et al. (1962) stated that large expression of SCA variance may be a characteristic of tetraploid potatoes. Dellaert and Swiezynski (1989), however, argued that the importance of SCA effects relative to GCA effects seems to depend on character studied, the kind of material and eventually the environmental conditions.

Table 2. Estimates of variance components pooled over third and fourth clonal generations

Estimates	Tuber no. /plot	Average tuber weight	Marketable yield (kg/plot)	Total yield (kg/plot)	% Dry matter
$\sigma^2_{gca}(\text{females})$	240.90	0.83	0.04	0.07	0.23
$\sigma^2_{gca}(\text{males})$	82.63	9.31	0.04	0.03	0.16
$\sigma^2_{gca}(\text{pooled})$	166.25	4.83	0.043	0.054	0.197
σ^2_{sca}	472.06	25.71	0.767	0.785	1.253
$\sigma^2_{gca}(\text{females})$	-4.01	-0.15	0.00	0.00	0.00
$\times$ generations					
$\sigma^2_{gca}(\text{males})$	-1.26	-0.13	0.00	0.00	0.00
$\times$ generations					
σ^2_{sca}	12.92	-0.22	-0.01	0.00	-0.05
$\times$ generations					
σ^2_{gca}	0.260	0.158	0.053	0.064	0.136
$(\sigma^2_{gca} - \sigma^2_{sca})$					

Predication of progeny performance from the relation of parents and progeny can be important. Such relations were studied by computing mid parent-progeny and GCA-parent correlations. Mid parent-progeny correlations ($r=0.185$ to 0.404) were significant ($P<0.05$) for all characters except marketable yield (Table 3). GCA-parent correlations ($r=0.357$ to 0.620) were significant only for two characters viz., tuber number and average tuber weight. Maximum values of mid parent- progeny ($r=0.404$) and GCA-parent ($r=0.620$) correlations were found for average tuber weight. This indicates the usefulness of genotypes with good average tuber weight at 60-days harvest. These correlations, however, were not high enough to be useful in predicting mean performance of the progeny. It was expected because non-additive gene action was of much higher magnitude than the additive one (Table 2). These findings are in conformity with earlier reports (Gopal, 1998; Kumar and Kang, 2001).

Table 3. Mid parent-progeny and GCA-parent correlations for various characters

Character	Correlation	
	Mid parent -progeny	GCA-parent
Tuber number(per plot)	0.243*	0.579**
Average tuber weight (g)	0.404**	0.620**
Total yield (kg/plot)	0.230*	0.367
Marketable yield (kg/plot)	0.185	0.357
Per cent dry matter	0.316**	0.395

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

The parents used in this study are frequently involved in various potato breeding programmes in India. The information about the general combining ability effects is therefore of interest to potato breeders. For specifically knowing the combining ability of the parents, a fixed effect model was used considering the sets of parents as a complete population. MS/82-638, Kufri Ashoka, JE 812 and Kufri Pukhraj possessed very good general combining ability both for total and marketable tuber yield (Table 4). Among these culture MS/82-638 and Kufri Ashoka were very good general combiners for tuber number while JE 812 was very good general combiners for average tuber weight. Kufri Pukhraj was the only parent with good general combining ability for both the major yield contributing traits, tuber number and average tuber weight. JE 812, CP 3142, MS/82-797 and CP2366 were very good general combiners for average tuber weight. Important good general combiners for tuber number were Kufri Ashoka, JW 160, MS/82-638 and EX/A 680-16. Gaur et al. (1983, 1985) reported EX/A 680-16 as good general combiner for tuber yield and average tuber weight under normal (90 days) harvest conditions. However, our results showed that for a 60 day crop (a very early harvest crop), it was a poor general combiner for yield and average tuber weight and good general combiner for tuber number. Our earlier study in a 75 day crop, revealed EX/A 680-16 to be average general combiner for yield; poor general combiner for average tuber weight and good general combiner for tuber number (Kumar and Kang, 2001). CP 3142, Kufri Jyoti, JE 812 and EX/A 680-16 were important good general combiners for per cent dry matter. In general, good general combiners for dry matter were average or poor general combiners

for yield. However, JE 812 and CP 2366 were good general combiners both for yield and per cent dry matter. Six males used in the present study represented one released Indian cultivar, three exotic *Tuberosum* genotypes, one *Andigena* genotype and one advance generation breeding clone. The results based on these should be reliable enough.

Significant positive as well as negative SCA effects indicated that progenies were significantly worse or better than was expected on the basis of GCA of the parents. The number of crosses with significant positive SCA effects for per cent dry matter, tuber no., average tuber weight, total yield and marketable yield were 32, 31, 28, 34 and 32, respectively. Many crosses had significant heterosis. Most of the crosses involving EX/A 680-16 as one of the parent had positive heterosis for tuber yield, whereas those with CP 1704 had in general negative heterosis for tuber yield. Maximum heterosis over mid-parent value in desired direction was 84.87% in cross CP 2359 X EX/A 680-16. The correlation coefficients of specific combining ability with progeny performance and heterosis over mid-parent value were high ($r=0.8394$ and $r=0.6346$, respectively) for total yield. Based on per se performance and specific combining ability effects top 5 promising crosses for various characters are mentioned in Table 5. Most of these crosses also had positive heterosis. Top 10 cross combinations for tuber number and per cent dry matter involved atleast one good general combiner for the respective trait. However, top 10 cross combinations for total yield, marketable yield and average tuber weight involved either atleast one good general combiner or both average general combiners for the respective trait. On the basis of mean performance crosses EB/C 899 $\times$ CP 2383, Kufri Jyoti $\times$ CP 2383 and CP 2359 $\times$ Kufri Pukhraj provided considerable scope for selecting genotypes with high yield and moderately high dry matter. These cross combinations had positive SCA effects for tuber yield.

The results of the present study shows that selection of parents based on their per se performance is not effective. Parents can be selected on the basis of their general combining ability. Breeding programme can take account of large non-additive gene action by progeny testing (Brown et al., 1987). Progeny test can help to identify valuable crosses before the build up of a larger population based on selected crosses.

Table 4. Estimates of general combining ability (GCA) effects

Parent	GCA effects for				
	Tuber no. /plot	Average tuber weight	Marketable yield (kg/plot)	Total yield (kg/plot)	% Dry matter
Females					
CP 2023	-6.56**	0.23	-0.19**	-0.19**	-0.09
CP 2287	-33.72**	1.36*	-0.96**	-1.05**	-0.91**
CP 2359	-2.36	1.86**	0.20**	0.21**	-0.18**
CP 3142	-15.95**	2.88**	-0.06	-0.08	1.14**
CP 3165	-8.84**	0.63	-0.11*	-0.17**	-0.01
CP 3204	14.80**	-2.83**	0.10*	0.15*	0.17**
K. Ashoka	32.19**	-2.49**	0.51**	0.59**	-0.30**
K. Jyoti	-3.50	0.96	0.09	0.02	1.08**
EB/C 899	6.72**	-2.00**	0.02	0.03	-0.51**
JE 812	-5.70**	3.39**	0.47**	0.41**	0.83**
JW 160	28.97**	-4.97**	-0.04	0.10	-0.83**
JX 115	-11.97**	2.15**	-0.02	0.01	-0.02
JX 455	-7.36**	-0.02	-0.30**	-0.34**	0.17**
JY 712	-9.97**	-1.24*	-0.50**	-0.54**	0.42**
MS/82 -638	23.25**	0.08	0.78**	0.85**	-0.95**
S.E. females	2.07	0.53	0.05	0.06	0.06
Males					
CP 1704	7.85**	-3.30**	-0.34**	-0.29**	-0.43**
CP 236 6	-5.69**	2.31**	0.23**	0.20**	0.35**
CP 2383	-1.06	0.30	0.04	0.02	0.08*
K.Pukhraj	6.40**	0.68*	0.42**	0.43**	-0.74**
MS/82 -797	-18.19**	4.40**	0.02	-0.01	0.17**
EX/A 680 -16	10.68**	-4.40**	-0.36**	-0.34**	0.56**
S.E. males	1.24	0.32	0.03	0.03	0.04

*, ** significant at 5% and 1% level, respectively

Table 5. Promising cross combinations for various characters

Character	Cross combination	SCA	per se performance	Mid- parent heterosis (%)
Tuber no. (per plot)	Kufri Ashoka CP 2383	58.56**	262.83	67.68**
	CP 3204 CP 2366	55.41**	237.67	50.58**
	Kufri Ashoka EX/A 680 -16	19.15**	235.17	80.32**
	CP 2359 Kufri Pukhraj	27.29**	228.33	17.60**
	MS/82 -638 CP 1704	22.43**	226.67	17.60**
	Average tuber	11.12**	53.43	30.19**
weight(g)	JX 455 MS/82 -797	5.38**	51.10	0.69
	CP 2359 MS/82 -797	6.46**	50.65	2.10
	CP 3165 CP 1704	14.94**	50.20	24.98**
	Kufri Jyoti CP 2366	6.79**	47.98	20.16**
	EB/C 899 CP 2383	2.19**	8.67	38.30**
	Kufri Jyoti CP 2383	2.03**	8.50	53.85**
Total yield (kg/plot)	CP 3204 Kufri Pukhraj	1.06**	8.07	0.52
	CP 2359 Kufri Pukhraj	0.96**	8.03	13.81**

Table 5. (Continued)

Character	Cross combination		SCA	per se performance	Mid - parent heterosis (%)
Marketable yield (kg/plot)	CP 3204	CP	1.22**	8.00	21.52**
	2366				
	Kufri Jyoti	CP	2.17**	8.30	59.11**
	2383				
	EB/C 899	CP	2.12**	8.18	40.09**
Per cent dry matter	2383				
	CP 2359	Kufri	1.01**	7.63	14.50
	Pukhraj				
	CP 3142		1.37**	17.15	-1.67
	EX/A 680 -16				
	JY 712	CP	1.73**	16.57	16.19**
	2366				
	CP 3204		2.15**	16.57	3.27*
	MS/82 -797				
	CP 2023	CP	2.12**	16.18	7.53**
	2383				
	Kufri Jyoti		0.37**	16.08	-4.03**
	EX/A 680 -16				

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

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WHEAT PRODUCTIVITY AT DIFFERENT SOWING DATES IN VARIOUS AGROCLIMATIC ZONES OF INDIA

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ABSTRACT

The yield data of 28 locations of All India Coordinated Wheat Improvement Project's agronomic trial on dates of sowing x varieties were compiled under early, normal, late and very late sown conditions from 1970-71 to 1998-99. Means across the locations/zones and years showed that maximum grain yield was obtained by normal sowing (39.4 q/ha). Delayed wheat sowing, from normal to late and late to very late condition, resulted in reduction of grain yield @ 26.8 and 44.2 kg/ha/day or 15.5 and 26.5 %, respectively. Even early wheat sowing decreased the grain yield by about 4 % compared to normal sowing. Among the zones, NWPZ and CZ recorded almost similar yield followed by NEPZ. Delaying wheat sowing (normal to late) resulted in decrease in yield by 15.5, 32.0, 27.6, 32.9 and 26.8 kg/ha/day under NHZ, NWPZ, NEPZ, CZ and PZ, respectively for timely sown varieties. The corresponding yield loss was 7.6, 18.5, 17.7, 17.0 and 15.5 per cent. For late sown varieties, delay in wheat sowing (late to very late) decreased the grain yield by 42.7, 44.8, 51.6 and 44.2 kg/ha/day or 22.8, 27.1, 30.9 and 25.6 % under NWPZ, NEPZ, CZ and PZ, respectively.

Key Words : Wheat yield, sowing time, yield decline

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second most important crop after rice and occupies approximately 27 million hectare area with a production of 74.25 million metric tonnes in India. It is grown under different agroclimatic conditions having variable productivity levels. Considering the environmental and technological adaptation, the country is broadly divided in to 5 wheat growing regions viz., Northern Hill Zone (Jammu and Kashmir, Himachal Pradesh and hills of Uttar Pradesh), North Western Plain Zone (Punjab, Haryana, Western Uttar Pradesh and some parts of Rajasthan), North Eastern Plain Zone (Eastern Uttar Pradesh, Bihar, West Bengal, Orissa and Eastern states), Central Zone (Madhya Pradesh, Gujrat, Southern Rajasthan and Bundel Khand region of Uttar Pradesh) and Peninsular Zone (Maharashtra and Karnataka). The growing period of wheat is variable from one agroclimatic zone to another that affect the vegetative and grain filling duration leading to differences in attainable yield. The maximum wheat growing duration is in Northern Hills Zone and minimum in Peninsular Zone. The delayed wheat sowing also squeezes the growing duration leading to yield reduction. A detailed study by Jain (1993), reported that genetic gains have been slower under late sown compared to normal sown irrigated wheat.

Farmers generally take more than one crop in a year to maximize their total production and profits. In this process wheat crop is generally preceded by crops like rice, cotton, sugarcane, maize, sorghum, potato, toria and pigeon pea etc. In this plethora of cropping sequences, there are some crops like rice, cotton, sugarcane, potato, toria, pigeon pea that delays the wheat sowing in different parts of the country. Wheat after potato is generally sown in the first week of January. Under late and very late sown conditions, temperature is low at seedling establishment stage and hot dry spell prevails during grain filling. There is accelerated/forced maturity due to high temperature and/or water stress that reduces grain size and weight. The quantum of decrease in wheat yield due to late and very late sowing, in different parts of the country on regional level, is not well established. An effort was made by Singh (1986) to compile the 10 years data of dates of sowing trial of different zones. He reported that yield decreased by early and late sowing in different zones, but he did not quantify the yield decline per day under late and very late sowing situations.

MATERIALS AND METHODS

Since the inception of All India Coordinated Wheat Improvement Project, second year entries of advanced varietal trial along with checks (ruling varieties of the zone) are being evaluated under different dates of sowing across the country at about 30 locations. The dates of sowing were early, normal, late and very late, which varied for different agroclimatic zones (Table 1). The experiment was conducted at 28 locations (3 in NHZ, 6 in NWPZ, 8 in NEPZ, 7 in CZ and 4 in PZ) under two categories i.e. normal sown entries/varieties at three dates of sowing (early, normal and late) and late sown entries/varieties at two dates of sowing (late and very late). The crop was grown following recommended package of practices with respect to irrigation scheduling, fertilizer application and weed control measures. The location wise yield data, for dates of sowing under irrigated condition from 1970-71 to 1998-99, were compiled. Average yield of all entries and checks under early, normal, late and very late sown conditions was calculated. For each year, difference in sowing time from normal to late and late to very late was also worked out for every location. The average decline in yield at each location and in each zone from normal to late for timely sown varieties/entries and from late to very late for late sown varieties/entries was calculated in kg/ha/day and as well as in per cent. This was done by dividing difference in yield (normal to late and late to very late) by number of days between two sowing dates. Standard error of mean (standard deviation divided by square root of number of years) was calculated for early, normal, late and very late sown conditions for each location.

Table 1. Date of wheat sowing in different agroclimatic zones of India

Zones	Date of sowing			
	Early	Normal	Late	Very late
NHZ	15 th Oct- 21 st Oct	26 th Oct- 4 th Nov	19 th Nov- 25 th Nov	
NWPZ	29 th Oct- 5 th Nov	12 th Nov-18 th Nov	10 th Dec-16 th Dec	1 st Jan-7 th Jan
NEPZ	29 th Oct- 5 th Nov	12 th Nov-18 th Nov	10 th Dec-16 th Dec	1 st Jan-7 th Jan
CZ	22 nd Oct- 28 th Oct	5 th Nov-11 th Nov	26 th Nov-2 nd Dec	22 nd Dec-28 th Dec
PZ	22 nd Oct- 28 th Oct	5 th Nov-11 th Nov	26 th Nov-2 nd Dec	17 th Dec-23 th Dec

RESULTS AND DISCUSSION

Northern Hill Zone

In Northern hill zone, three centers namely Almora, Palampur and Shimla were involved in the conduct of experiment. On an average, the maximum grain yield was recorded under early sowing (35.3 q/ha) followed by normal sowing (34.8 q/ha). The decline in yield, from normal to late sowing, was 15.5 kg /ha/day which turns out to be 7.6 per cent (Table 2). At Almora (15 years mean), the maximum yield (46.5 q/ha) was recorded when crop was sown between 15th and 21st October. Delay in sowing from normal (26th Oct to 4th Nov) to late (19-25th Nov) decreased the grain yield @ 17.6 kg/ha/day. At Palampur (mean of 4 years), the maximum yield was obtained in normal sown (26.9 q/ha) as compared to early sown wheat (24.0 q/ha). Similar trend was observed at Shimla also. To conclude, the maximum attainable yield in this zone was at Almora and the decline in wheat yield ranged from 14.0 to 17.6 kg/ha/day by delaying the wheat sowing beyond first week of November.

Table 2. Zone and location wise yield decline due to late and very late sowing of wheat

Zones	Average of timely sown varieties						Average of late sown varieties				
and		Mean yield (q/ha)			Decline in yield		Mean yield (q/ha)		Decline in yield		
		Early	Normal	Late	kg/ha/day	%	Years	Late	Very late	kg/ha/day	%
Locations	Years	Early	Normal	Late	kg/ha/day	%	Years	Late	Very late	kg/ha/day	%
NHZ											
Almora	15	46.5	44.5	41.2	17.6	7.3					
	stdev	11.3	11.5	8.4							
	SEm	2.9	3.0	2.2							
Palampur	4	24.0	26.9	24.6	14.7	8.4					
	stdev	4.9	2.2	5.6							
	SEm	2.5	1.1	2.8							
Shimla	3		33.0	30.5	14.0	7.5					
	stdev		9.4	14.8							
	SEm		5.4	8.5							
mean		35.3	34.8	32.1	15.5	7.6					

Continued Table 2

NWPZ											
IARI,	7	40.7	48.1	42.7	22.4	11.2	5	43.8	32.8	57.4	25.2
	stdev	8.8	3.8	3.8				3.9	5.4		
	SEm	3.3	1.4	1.4				1.7	2.4		
Ludhiana	22	46.5	46.5	35.2	38.2	24.4	10	36.9	25.5	50.7	31.0
	stdev	8.2	5.5	5.5				6.0	5.0		
	SEm	1.8	1.2	1.2				1.9	1.6		
Hisar	20	43.4	46.1	38.6	31.1	16.3	8	38.4	29.9	41.3	22.2
	stdev	9.8	8.5	8.2				9.1	8.1		
	SEm	2.2	1.9	1.8				3.2	2.8		
Pantnagar	22	45.8	46.5	36.8	37.9	20.9	10	39.6	31.8	38.0	19.7
	stdev	7.2	7.2	6.4				6.2	5.4		
	SEm	1.5	1.5	1.4				1.9	1.7		
Durgapura	18	30.7	39.0	28.2	41.5	27.6	6	32.6	25.3	40.0	22.5
	stdev	10.6	11.1	8.0				8.0	7.9		
Table 2 (Continued)											
	SEm	2.5	2.6	1.9				3.3	3.2		
Sriganaganagar	44.2	45.3	40.5	21.1	10.7	4	40.5	33.9	28.8	16.2	
	stdev	5.3	7.2	4.2				4.2	3.7		
	SEm	2.6	3.6	2.1				2.1	1.9		
mean		41.9	45.3	37.0	32.0	18.5		38.6	29.8	42.7	22.8
NEPZ											
Kanpur	16	37.1	39.0	30.9	34.6	20.7	5	37.2	29.8	34.8	20.0
	stdev	9.9	7.9	8.4				4.5	5.4		
	SEm	2.5	2.0	2.1				2.0	2.4		
Faizabad	11	39.8	40.9	30.4	44.8	25.5	5	32.8	25.1	42.6	23.6
	stdev	5.6	8.4	7.8				8.6	3.4		
	SEm	1.7	2.5	2.3				3.9	1.5		
Varanasi	19	35.6	36.3	32.9	12.7	9.4	13	35.0	26.4	39.2	24.6
	stdev	2.6	7.4	5.8				5.9	4.3		
	SEm	0.6	1.7	1.3				1.6	1.2		
IARI Pusa	10	37.4	39.5	35.2	21.8	11.0	7	37.2	28.2	47.4	24.2
	stdev	6.5	7.0	5.5				6.0	9.0		
	SEm	2.1	2.2	1.7				2.3	3.4		

Continued Table 2

Ranchi	8	45.6	40.1	34.0	22.8	15.2	4	36.2	22.9	59.8	36.7
	stdev	3.0	3.0	6.5				9.2	10.2		
	SEm	1.1	1.1	2.3				4.6	5.1		
Chiplima	12	29.6	29.5	21.9	29.7	25.7	3	26.0	20.7	26.5	20.4
	stdev	11.7	10.5	5.3				5.6	6.6		
	SEm	3.4	3.0	1.5				3.2	3.8		
Kalyani	13	33.3	39.9	31.0	39.2	22.3	2	36.6	26.2	46.2	28.4
	stdev	5.5	7.2	7.2				1.6	1.4		
	SEm	1.5	2.0	2.0				1.1	1.0		
Sabour	13	34.1	36.6	32.3	15.5	11.9	6	32.5	20.0	61.6	38.6
	stdev	2.9	2.8	4.0				5.6	8.5		
	SEm	0.8	0.8	1.1				2.3	3.5		
mean		36.6	37.7	31.1	27.6	17.7		34.2	24.9	44.8	27.1

Table 2 (Continued)

CZ

Udaipur	20	55.4	55.6	42.6	52.1	23.5	5	40.0	30.1	47.1	24.8
	stdev	5.7	5.0	5.7				8.4	9.7		
	SEm	1.3	1.1	1.3				3.7	4.4		
Powerkheda	17	34.2	37.9	34.5	12.8	8.9	5	41.4	29.8	54.7	28.2
	stdev	10.9	8.7	6.9				6.7	8.4		
	SEm	2.6	2.1	1.7				3.0	3.8		
Indore	10	40.2	48.0	42.7	32.8	11.0	5	42.2	28.4	59.0	32.7
	stdev	9.2	10.2	10.7				15.5	12.9		
	SEm	2.9	3.2	3.4				6.9	5.8		
Junagarh	21	32.7	37.4	31.7	26.2	15.2	6	28.5	17.4	52.0	38.9
	stdev	8.8	5.5	5.1				4.1	6.4		
	SEm	1.9	1.2	1.1				1.7	2.6		
Vijapur	20	32.4	40.7	34.0	26.6	16.5	4	39.3	28.2	56.3	28.3
	stdev	8.9	8.9	8.4				8.8	4.4		
	SEm	2.0	2.0	1.9				4.4	2.2		
Gwalior	11	48.6	52.8	40.1	50.9	24.1	4	45.3	29.9	59.1	33.9
	stdev	2.2	4.9	6.3				3.1	12.0		
	SEm	0.7	1.5	1.9				1.6	6.0		
Bilaspur	10	36.4	35.4	28.4	29.1	19.8	5	29.2	20.6	32.6	29.3
	stdev	3.4	6.4	6.8				8.7	4.7		

Continued Table 2

	SEm	1.1	2.0	2.1				3.9	2.1		
mean		40.0	44.0	36.3	32.9	17.0		38.0	26.3	51.6	30.9
PZ											
Dharwad	21	38.7	38.5	30.8	36.5	20.1	5	34.8	29.5	23.0	15.2
	stdev	7.5	8.0	9.8				5.4	1.9		
	SEm	1.6	1.7	2.1				2.4	0.9		
Niphad	19	35.8	36.1	31.8	19.0	12.0	8	36.5	25.5	51.6	30.1
	stdev	6.5	6.6	7.5				7.1	7.0		
	SEm	1.5	1.5	1.7				2.5	2.5		
Pune	15	36.1	35.9	31.2	19.4	13.1	5	35.5	26.3	41.0	25.8
Table 2 (Continued)											
	stdev	7.6	7.7	7.3				9.3	12.6		
	SEm	2.0	2.0	1.9				4.2	5.6		
Akola	19	30.8	30.1	26.9	12.4	10.6	3	28.7	19.8	35.6	31.0
	stdev	7.7	8.4	7.5				1.9	4.6		
	SEm	1.8	1.9	1.7				1.1	2.7		
mean		35.4	35.2	30.2	21.8	14.0		33.9	25.3	37.8	25.6

North Western Plain Zone

In this zone, dates of sowing x varieties experiments were conducted at six centers (New Delhi, Ludhiana, Hisar, Pantnagar Durgapura and Sriganaganagar) for timely and late sown varieties (Table 2). Average across the locations revealed that maximum yield, for timely sown varieties, was recorded by normal sowing (45.3 q/ha) and delayed sowing, from mid November to mid December, reduced grain yield @ 32 kg/ha/day (18.5 %). Advancing the sowing, from mid November to first week of November or end of October, also reduced grain yield by 7.5 % in this zone. For late sown entries/varieties, the decline in grain yield was 42.7 kg/ha/day or 22.8 % if the sowing was delayed from mid December to 1st week of January. Among the various centers, the maximum decline in wheat yield was at Durgapura (41.5 kg/ha/day) for timely sown varieties and at New Delhi (57.4 kg/ha/day) for late sown varieties. Average of 10 years data from Ludhiana showed that very late sowing (1st week of January) reduces grain yield @ 50.7 kg/ha/day or 31 % compared to yield observed under late sowing condition. For timely sown entries/varieties the yield declined by 24.4 per cent (38.2 kg/ha/day) when sowing was delayed from mid November to mid December. From the same place, in a study of 7

dates of sowing, Dhillon and Ortiz Monasterio (1993) reported that yield of aestivum wheat starts declining after 25th November and durum wheat after 15th November sowing. In this zone, the most conducive region for wheat cultivation in India, the decline in wheat yield ranged from 21.1 kg/ha/day at Sriganaganagar to 41.5 kg/ha/day at Durgapura for timely sown varieties.

The corresponding per cent reduction was 10.7 to 24.4 %. The extent of loss in grain yield further escalates to 28.8 to 57.4 kg/ha/day (16.2 to 31 %) as sowing was delayed from mid December to mid January. These findings collaborates the results of Hobbs (1985) and Randhawa *et al.*, (1981), who were of the view that wheat sowing beyond November reduces grain yield between 1 to 1.5 % per day. Generally, standard error of mean was lower for normal sown varieties compared to late sown genotypes. This was due to the fact that former group of varieties was tested almost double the number of years compared to latter one. Standard error of mean was almost similar for various locations, indicating the proper conduct of experiments across the locations and years.

North Eastern Plain Zone

The data of eight centers namely Kanpur, Faizabad, Varanasi, Pusa, Ranchi, Chiplima, Kalyani and Sabour were considered for calculating the decline in yield due to late sowing (Table 2). Average across the locations and years displayed a similar trend as in the case of North Western Plain Zone. Maximum grain yield (37.7 q/ha) was recorded when crop was sown timely i.e. mid of November. Each day delay in wheat sowing, from mid November to mid December for timely sown varieties and from mid December to 1st week of January for late sown varieties, reduced grain yield by 27.6 and 44.8 kg/ha/day, respectively. On an average, this yield reduction was 17.7 % under late sown and 27.1 % under very late sown conditions.

The range of yield decline was from 12.7 to 44.8 kg/ha/day from mid November to mid December and further delay escalates the yield loss by 26.5 to 61.6 kg/ha/day at various locations. Maximum yield decline for timely and late sown entries was at Faizabad and Sabour, respectively. By comparing the average yield of NWPZ and NEPZ, it was clear that former zone produces 14.4, 20.1, 18.9 and 19.7 % higher grain yield compared to latter under early, normal, late and very late sown conditions, respectively. The corresponding absolute yield difference was 5.3, 7.6, 5.9 and 4.9 q/ha. This is the

zone where maximum area is under late sown wheat compared to other zones. Interestingly, under very late sown category, yield decline at the centers of Uttar Pradesh and Bihar ranges from 34.8 to 42.6 kg/ha/day and from 47.4 to 61.6 kg/ha/day, respectively. Randhawa et al., (1976) also reported that delayed sowing of wheat beyond November reduces grain yield by 30-50 kg/ha/day. Standard error of mean at all the centers was lower under timely sown varieties compared to late sown genotypes. This was due to the availability of data for more number of years under former category than latter one.

Central Zone

In this zone, data of seven centers, viz. Udaipur, Powerkheda, Indore Junagarh Vijapur Gwalior and Bilaspur, representing three states (Rajasthan, Gujrat and Madhya Pradesh), were compiled for timely and late sown varieties (Table 2). Average across the locations and years revealed that maximum grain yield (44.0 q/ha) was observed under normal sown condition (5-11th Nov), which was almost similar to the grain yield recorded in NWPZ (45.3 q/ha). Delaying wheat sowing, from first week of November to last week of November for timely sown varieties and from last week of November to last week of December for late sown varieties, reduced grain yield @ 32.9 and 51.6 kg/ha/day, respectively. On an average, this yield reduction was 17 % under late sown and 30.9 % under very late sown conditions. In this zone, the decline in yield was similar as in case of NWPZ for timely sown varieties but almost 9 kg/ha/day more reduction in yield for late sown varieties, which was maximum compared to other zones.

For late sown entries/varieties, the sharp decrease in yield in central zone can be attributed to less grain filling period and sharp increase in temperature leading to force maturity of wheat crop. Even advancement in wheat sowing (22nd -28th Oct) decreased the grain yield by 9 %. The range of yield decline was from 12.8 to 52.1 kg/ha/day by delaying wheat sowing from normal to late and from 32.6 to 59.1 kg/hay/day by late to very late sowing. Under very late sown situation, it is interesting to note that all the centers of this zone showed yield decline between 50-60 kg/ha/day except Bilaspur and Udaipur. Generally, people believe that maximum wheat productivity could be realized from centers falling under NWPZ especially in Punjab. Whereas, average of 20 years data from Udaipur center, containing heavy soil with high fertility, recorded grain yield of

55.4, 55.6, 42.6 and 30.1 q/ha under early, normal, late and very late sowing conditions, which was 19.1, 19.5, 21.0 and 18.0 % higher, respectively compared to the yield recorded at Ludhiana (mean of 22 years). This showed that good soil fertility and high solar radiation could give maximum grain yield even with slightly shorter grain filling periods. By comparing the average yield of CZ and NEPZ, it was clear that former zone produces 9.3, 16.7, 16.7 and 5.6 % higher grain yield compared to latter one under early, normal, late and very late sown conditions, respectively with corresponding yield difference of 3.4, 6.3, 5.2 and 1.4 q/ha. Therefore, it can be said that Central Zone have more yield potential than North Eastern Plain Zone, which has very diverse and fragile agro-ecosystem. Under all the categories of sowing, the standard error of mean was comparable. The centers where number of years are less, the standard error of mean was slightly higher.

Peninsular zone

In this zone, four centers i.e. Dharwad, Niphad, Pune and Akola were involved in the conduct of trial (Table 2). Average across the locations and years recorded similar grain yield under early (35.4 q/ha) and normal (35.2 q/ha) sowing condition. Delaying wheat sowing, from first week of November to last week of November for timely sown varieties and from last week of November to third week of December for late sown varieties, reduced grain yield @ 21.8 and 37.8 kg/ha/day, respectively. On an average, this yield reduction was 14 % under late sown and 25.6 % under very late sown conditions. Among the centers under study, maximum yield reduction was observed at Dharwad (36.5 kg/ha/day) for timely sown entries and at Niphad (51.6 kg/ha/day) for late sown entries.

The range of yield decline was from 12.4 to 36.5 kg/ha/day by delaying wheat sowing from normal to late and from 23.0 to 51.6 kg/ha/day by late to very late situation. Average yield of this zone under different categories was almost similar to the yield recorded in North Eastern Plain Zone. By comparing the average yield of CZ and PZ, it was very clear that this zone recorded almost 11.5, 20, 16.8 and 3.8 % lower grain yield under early, normal, late and very late sowing situations, respectively.

CONCLUSION

All India average across the zones revealed that maximum grain yield (39.4 q/ha) was obtained by normal sowing. As wheat sowing was delayed from normal to late and late to very late condition, the grain yield reduction was @ 26.8 and 44.2 kg/ha/day, respectively. This yield reduction was 15.5 and 26.5 % under late and very late sown conditions, respectively. Even early wheat sowing decreased the grain yield by about 4 % compared to normal sowing.

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STABILITY ANALYSIS OF EARLY MATURING SUGARCANE (*Saccharum hybrid* spp.) GENOTYPES

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ABSTRACT

Developing crop cultivars that perform well across a wide range of environmental conditions has long been a major challenge. Eight early sugarcane genotypes were evaluated under irrigated conditions to investigate the response and adaptability of different hybrids in six locations of Nepal during 1999. The analysis of variance showed significant variation among genotypes, environments and their interactions. Genotype CoSe 95422 was most ideal and stable over locations as it showed the highest mean value for cane yield approaching to unit regression and low deviation from regression. Co 89029 produced more cane yield and exhibited average stability. CoSe 95435 performed well in favorable environment and BO 130 in unfavorable environment i.e. unstable over locations. Genotype Co94024 produced the lowest cane yield and below average stability. Stability result is from a single year experiment, however, CoSe 95422 can be selected for getting stable cane yield over locations.

Key Words : Genotype x environment interaction, Regression coefficient, Stability, Sugarcane.

INTRODUCTION

Sugarcane crop is influenced by environmental variation (Tyagi *et al.*, 1998). Therefore, for sustainable production we must ensure that varieties should be stable and well adapted to the range of conditions to which they are likely to be subjected (Innes, 1995). The performance of a genotype is determined by its Genotypic make-up (G), the

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environment (E) and the interactions that occur between G and E (Simmonds, 1981). Stability analysis has been used by many researchers (Bilbro & Ray, 1976; Eberhat & Russell, 1966; Finlay & Wikinson, 1963; Hedge & Vidyachandra, 1998; Guimaras et al., 1988; Joshi *et al.*, 2002) to decide whether the performance of the genotype is satisfactory. Bista and Joshi, 2004 have used simple method called Response Differences Stability model for genotype selection in rice. The present study was undertaken to investigate the response and adaptability of different sugarcane hybrids in different locations of Nepal

Sugarcane (*Saccharum hybrid* spp.) is one of the most important cash crops in the world. The place of sugar industry in Nepal is next to grain and oil mills (Shakya, 2001). This industry is providing employment for nearly 7500 persons (Shrestha, 1998). Sugarcane consumption in Nepal is increasing due to the population growth and the increase in per capita consumption resulting from change in food habit (Chaudhary, 2002). His Majesty's the Government of Nepal have given due priority to establish new sugar factories in different parts of Tarai districts to fulfill ever growing sugar demand of the country. There are altogether eleven sugar factories established at different parts of Nepal. To fulfill the demand of sugar mills area under sugarcane crop has been increased tremendously in diverse agro climatic conditions of Nepal. Sugarcane varieties are necessary to develop suitable to such diverse areas. There are so far two-released sugarcane varieties in Nepal and many genotypes are in pipelines.

MATERIALS AND METHODS

The experimental material consisted of eight promising early maturing sugarcane genotypes including one standard check BO 99 (Table 1). Most of the genotypes were introduced from India. These genotypes were evaluated under irrigated in six locations viz. 1. Eastern Sugar mill, Amahibelha, Sunsari, 2. Everest Sugar mill, Ramnagar, Mohottari, 3. Indu-Shankar Sugar mill, Hariwan, Sarlahi, 4. Shri Ram Sugar mill, Garuda, Rautahat, 5. Sugarcane Research Programme, Jitpur, Bara and 6. Mahalaxmi Sugar mill, Kapilbastu, Nepal. The experimental design was randomized block with four replications at each location. The plot size was 6- x 4.5-m with 5 rows in each plot at 90 cm apart. Sugarcane genotypes were planted during the month of October 1999 and harvested during first week of November 2000. There budded setts of cane were planted at the rate of 12 buds/meter in furrow method. The amount of N:P:K used in the experiment was 150:60:40 kg/ha. Cane from central three rows at 4 m length were

harvested and cane yield were recorded. Irrigation and other cultural operations were given as per the recommendation. Analysis of Variance (ANOVA) was conducted according to procedures outlined by Gomez and Gomez (1984) and combined analysis as outlined by McIntosh (1983). The environment-wise ANOVA indicated the genotypic effects of significant at all sites. After testing the homogeneity of variances, data were subjected to stability analysis. Stability analysis was carried out following the model of Eberhart and Russel (1966). Eberhart and Russel (1966) defined the stable genotypes as that with a high mean, unit regression coefficient and the deviations from regression as small as possible.

Table 1. Promising early maturing sugarcane genotypes used in stability analysis

SN	Genotype	Definition	Remarks
1	Co 89029	Coimbatore, Tamil Nadu, India	All these genotypes are hybrids introduced in 1966 in Jitpur, Nepal as a Zonal Trial of Coordinated Sugarcane North Central Zone of All India Research Project
2	Co 94023	Coimbatore, Tamil Nadu, India	
3	Co 94024	Coimbatore, Tamil Nadu, India	
4	BO 130	Bihar Orissa, Bihar, India	
5	CoSe 95421	Coimbatore Seorohi, UP, India	
6	CoSe 95422	Coimbatore Seorohi, UP, India	
7	CoSe 95435	Coimbatore Seorohi, UP, India	
8	BO 99	Bihar Orissa, Bihar, India	

RESULTS AND DISCUSSION

Cane yield of eight sugarcane genotypes at six locations are given in Table 2. Standard deviation and coefficient of variation are also presented to measure the variability within genotypes and locations. The Highest cane yield was produced by CoSe 95422 in SRP, Jitpur followed by CoSe 95435 in SRO Jitpur. Co 94024 produced lowest cane yield in Eastern Sugar mill Amahibelha and Everest Sugar mill, Ramnagar. Averaging over locations, CoSe 95422 yielded the highest cane followed by CoSe 95435 and Co 94024 produced the lowest cane among these genotypes. Cane was harvested maximum at SRP Jitpur followed by at Shri Ram Sugar mill, Garuda. Eastern Sugar mill, Amahibelha harvested the lowest cane. Variation was less within genotypes compared to within locations (Table 2). The highest CV was found in Co94024 among genotypes and in SRP Jitpur among locations.

The Analysis of Variance showed highly significant differences among genotypes in each location for cane yield. This leads to study genotype x location interaction (Singh and Khan, 1966) and pooled analysis from 6 locations are given in Table 3. Three sources

of variance, genotypes, locations and genotype x location interaction were highly significant, indicating the importance of environment on the expression of character. Similar indication was reported by Singh et al., (1983). Stability parameters were estimated because of highly significant interaction of genotypes by locations. ANOVA was partitioned and presented in Table 4. Two stability parameters, regression coefficient (b_i) and deviation from regression (s^2_d) are given in Table 5.

The relationship sbetween yield and b_i , yield and (s^2_d) and between yield and environment index are portrayed in figure 1 and 2. This helps to pick up the genotypes considering their adaptability and stability to all, favorable and unfavorable environments. Figure 2 helps to identify genotypes suitable to poor environment and good environment. For example CoSe 95322 produced the highest cane yield in poor environment but BO 130 perform relatively poor even in good environments. CoSe 95422 has unit regression coefficient and Co 94023 and Co 89029 have deviations from regressing near to zero.

Table 2. Summary statistics for cane yield (t/ha) in early sugarcane genotypes

Genotype	Locations						Mean	SD	CV%
	Eastern, Amahibelha	Everest, Ramnagar	Indu- Shankar, Hariwan	Shri Ram, Garuda	SRP, Jitpur	Mahalaxmi Kapilbastu			
Co89029	69.73	70.49	69.15	72.29	76.16	67.51	70.89	4.72	6.65
Co94023	48.61	53.37	59.37	58.33	57.43	52.51	54.90	5.78	10.54
Co94024	43.6	46.32	56.37	55.47	49.45	56.51	51.28	7.29	14.21
BO 130	62.37	58.42	67.25	58.12	55.37	59.49	60.17	5.95	9.89
CoSe95421	59.46	69.65	69.53	66.53	72.52	67.49	67.53	6.25	9.25
CoSe95422	76.45	75.57	79.33	75.46	86.27	73.46	77.76	6.50	8.37
CoSe95435	65.14	72.52	63.54	71.56	82.69	71.46	71.15	8.94	12.56
BO 99	50.35	52.7	48.44	60.39	50.44	60.47	53.79	6.22	11.56
Mean	59.46	62.38	64.12	64.77	66.29	63.59			
SD	11.52	11.47	10.33	9.01	14.63	8.53			
CV %	19.37	18.39	16.11	13.90	22.07	13.42			

* Eastern, Eastern Sugar mill, Amahibelha, Sunsari, Everest, Everest Gugar mill, Ramnagar, Mohottari, Indu- Shankar, Indu-Shankar Sugar mill, Hariwan, Sarlahi, Shri Ram, Shri Ram Sugar mill, Garuda, Rautahat, SRP, Sugarcane Research Programme, Jitpur, Bara, Mahalaxmi, Mahalaxmi Sugar mill, Kapilbastu.

Table 3. Analysis of Variance pooled over 6 locations for cane yield in sugarcane

Source of variation	df	SS	MS	F
Locations (L)	5	874.40	174.88	4.15**
Replication within locations	18	709.75	39.43	
Sugarcane genotypes (G)	7	15862.06	2266.01	84.01**
L x G	35	2929.76	83.71	3.10**
Pooled error	126	3398.73	26.97	
Total	191	23774.69		

**Significant at 1%

Table 4. Analysis of variance when stability parameters are estimated

Source of variation	df	SS	MS	F
Genotypes (G)	7	3965.51	566.50	31.765**
Locations (L) + (G x L)	40	932.376	23.309	
L (linear)	1	218.60	218.60	
G x L (linear)	7	130.655	18.665	
Pooled deviations	32	570.694	17.834	
Co 89029	4	32.844	8.211	1.151
Co 94023	4	26.425	6.606	0.926
Co 94024	4	101.411	25.353	3.554**
BO 130	4	71.989	17.98	2.521*
CoSe 95 421	4	-9.543	2.385	0.334
CoSe 95422	4	73.971	18.493	2.521*
CoSe 95435	4	136.142	34.035	4.771**
BO 99	4	137.455	34.363	4.817**
Pooled error	144	1027.152	7.133	

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

Table 5. Stability parameters of sugarcane genotypes for cane yield

Genotype	bi	SE (bi)	S^2_d
Co 89029	0.3747	0.548	1.079
Co 94023	1.4995	0.492	-0.527
Co 94024	1.4756	0.963	18.221
BO 130	-0.6839	0.812	10.858
CoSe 95421	1.6090	-0.295	-9.519
CoSe 95422	1.0707	0.823	11.361
CoSe 95435	1.8616	1.116	26.904
BO	0.4329	1.121	27.232

Genotypes falling in the upper right quadrant (Figure 1) have above average cane yields and regression coefficients greater than one. These genotypes are highly responsive to the environment producing superior cane yields under favorable environments. Genotypes in the lower left quadrant response less to changes in environment as their regression coefficients are less than 1 with cane yield below average. They are less adapted to favorable environments and differ in adaptation to unfavorable environments. From this result three types of genotypes can be selected one for favorable environments, second for unfavorable environments and third for stable over all locations.

Genotypes x locations interaction (linear) was non-significant may be due to individual buffering capacity for stability in some varieties. Singh et al., (1983) reported similar assumption. Individual deviation from linear regression was significant for CO 94024, BO 130, CoSe 95422, CoSe 95435 and BO 99. Genotypes with high mean value, unit regression coefficient and zero deviation from regression is said to be an ideal and stable one (Eberhart and Russel, 1966). Among the tested genotypes CoSe 95422 was most ideal and stable one as it showed the highest mean value (77.79 t/ha), approaching to unit regression ($b=1.0707$) and low deviation from regression ($S^2_d=11.361$). Hence this genotype has wider adaptability and is suitable over wider range of locations. However, CoSe 95435 had higher mean value (71.15 t/ha) but due to more than one regression coefficient (1.8616) and high deviation from regression (26.904) proved unstable over location and only suitable to favorable environments. Co 89029 has also

higher mean value (70.89 t/ha) and exhibited average stability. Genotype CoSe 94024 possessed the lowest cane yield (51.28 t/ha) and possessed below average stability for locations.

CONCLUSION

This experiment was conducted in six locations across Tarai belt of Nepal in a single year. It is better to relate adaptability and stability performance with the characteristics of genotypes. These results are valid for areas with conditions similar to those of the experiment sites. The growth and behavior of the genotypes differ from season to season and from year to year as a result of seasonal and yearly variation in weather patterns. Therefore one can't generalize the conclusions on yield stability for other seasons or years. To generalize the conclusions from experimentation one has to conduct experiments over many seasons and years.

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COMBINING ABILITY ANALYSIS FOR MORPHOLOGICAL AND YIELD TRAITS IN INTRA-*Gossypium hirsutum* L. CROSSES

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ABSTRACT

Combining ability has been studied in a 6 x 6 diallel cross in Upland cotton. The Analysis of Variance revealed highly significant differences among the thirty F_1 and F_2 hybrid means and their respective 6 parental values. In both generations, the mean squares due to General Combining Ability (GCA) and Specific Combining Ability (SCA) were highly significant for plant height, monopodia, sympodia, bolls per plant, and seed cotton yield per plant except that sympodia had a non-significant mean square due to GCA in the F_2 generation. In the F_1 generation, GCA components of variance were greater and more important for plant height and monopodia, showing the predominance of additive gene action. The variance due to SCA was much higher in magnitude than GCA for sympodia bolls per plant and seed cotton yield which indicated that these traits were controlled by dominance-type gene action. In the F_2 , only plant height had greater variance due to GCA than SCA; in other traits, SCA genetic variance was greater than GCA for monopodia, sympodia, bolls per plant and seed cotton yield and revealed the predominance of non-additive gene action for the inheritance of these traits. Smaller values of genetic variances with respect to GCA and SCA were obtained for reciprocals. Cultivar CIM-1100 was found to be the best general combiner for plant height, sympodia, bolls and seed cotton yield per plant, while the cultivar CIM-109 showed its worth to have the least monopodia. Involvement of CIM-1100 in the most of the F_1 and F_2 hybrids and their reciprocals results in the synthesis of superior genotypes for most of the traits studied.

Key Words : F_1 and F_2 Hybrids, General and Specific Combining Ability, Additive and Dominant Gene Actions, Upland cotton.

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INTRODUCTION

In cotton breeding, for identification of potential parents on the basis of progeny performance requires large number of crosses, which is very laborious and expensive. Diallel analysis is a mating design whereby the selected parents are crossed in a certain order and it is used to predicting combining ability of the parents and elucidating the nature of gene action involved in the inheritance of traits. Combining ability as defined by Sprague and Tatum (1942) and Griffing (1956) is one of such statistical procedures for analysis of diallel crosses in a generalized theoretical form. It works as a principal method for screening of germplasm and to determine the ability of the genotypes to be included or not in a breeding programme on the basis of their GCA, SCA and reciprocal effects. So, combining ability is very contributive in choosing potential parents with desired genetic variance through GCA and SCA and in some cases through maternal effects.

Significant genetic variances due to GCA and SCA were noticed by Azhar and Akbar (1992), Baloch *et al.* (1997), Baloch *et al.*, (1999), Baloch *et al.*, (1999), Kalwar and Babar (1999), Ali *et al.*, (2000), Hassan *et al.*, (2000) for different morphological and yield traits in *Gossypium hirsutum*. Kalwar and Babar (1999) for sympodia and seed cotton yield; Panhwar *et al.* (2002) for sympodia, bolls per plant and seed cotton yield; Waldia *et al.*, (1984), Irfanullah *et al.*, (1993), Baloch *et al.*, (1995), Raveendran *et al.*, (1996) and Hassan *et al.*, (1999) for bolls per plant and seed cotton yield who observed non-additive type of gene action for different traits. However, McCarty *et al.*, (1996), Baloch *et al.*, (1997), Tang *et al.*, (1993a) and Tang *et al.*, (1993b) had observed additive type of gene action for most of the traits in upland cotton. Such contradictions may be due to different genetic background of the cultivars used and different environmental conditions under which the cotton crop is grown.

In view of the economic importance of combining ability and the importance of selected hybrids in segregating generations, a research project was undertaken to evaluate the genetic variance and effects due to GCA, SCA and reciprocals for plant height, monopodia, sympodia, bolls per plant and seed cotton yield per plant in F_1 and F_2 generations in a set of 6 x 6 diallel cross experiment in upland cotton.

MATERIALS AND METHODS

The crossing block (F_0), F_1 and F_2 experiments were conducted at the Agricultural Research Institute, D.I. Khan 29020 Pakistan. Six diverse genotypes of upland cotton (*Gossypium hirsutum* L.) viz. CIM-109, CIM-240, CIM-1100, FH-682, BH-36 and CRIS-9 were sown during May 1996 in a non-replicated crossing block by dibbling on a well prepared seed bed. Each genotype was planted in five rows, 27 m long, spaced 60 and 100 cm within and between the rows, respectively to ensure easy crossing and to handle the breeding material carefully. All cultivars were crossed in a complete diallel fashion (Griffing, 1956). The F_1 and F_2 experiments of a 6×6 complete diallel cross, having thirty hybrids (including reciprocals) alongwith six parents were sown in a Randomized Complete Block Design during May 1997 and 1998, respectively. In F_1 generation, each genotype was planted in a single 3.30 m long row, having three replications, while in F_2 the plant population per entry was increased and each genotype was planted in four rows, 6.30 m long with four replications. In both the experiments, the plant and row spacings were maintained at 30 and 75 cm, respectively. All cultural practices were carried out as per recommended package for cotton production for the locality and all the three crops were maintained under a uniform agronomic package to discourage environmental variability to the maximum possible extent. Picking was made in November-December every year on single plant basis and ginning was done with eight saw-gin. In all the experiments the data were recorded for plant height (cm), monopodia and sympodia per plant, and bolls and seed cotton yield per plant (g). The data were subjected to ANOVA technique using MSTATC computer software (Bricker, 1991) individually for all the traits, to assess statistical differences among F_1 s, F_2 s and their parental lines. The data were further subjected to Combining ability analyses as outlined by Griffing's (1956) Method-I based on Eisenhart's Model-II.

RESULTS AND DISCUSSION

The means of F_1 and F_2 hybrid and their parental lines tested through ANOVA showed highly significant differences ($P=0.01$) for all the traits which allowed to arbitrate the components of genetic variations due to GCA and SCA and their effect on the hybrids (Table 1). In F_1 generation, mean squares due to GCA and SCA were highly significant for all the traits. For reciprocals, mean squares were highly significant for bolls and seed

cotton yield, merely significant for sympodia and nonsignificant for plant height and monopodia. In F_2 generation, the mean squares due to GCA, SCA and reciprocals were highly significant for all the traits except sympodia having nonsignificant GCA (Table 1). Significant mean squares due to GCA were also observed for different parameters by Azhar and Akbar (1992) and Baloch *et al.* (1999) for bolls per plant and seed cotton yield; Ali *et al.*, (2002) for plant height, sympodia, bolls per plant and seed cotton yield, Hasan *et al.*, (2002) for seed cotton yield, bolls per plant and nonsignificant for plant height and Kalwar and Babar (1999) observed significant mean squares due to GCA for sympodia, bolls per plant and seed cotton yield. Significant mean squares due to SCA were obtained by the other research workers like Baloch *et al.*, (1997) and Baloch *et al.*, (1999) for bolls per plant and seed cotton yield, Hassan *et al.*, (1999) for plant height, seed cotton yield and non-significant for bolls per plant, Ali *et al.*, (2000) and Hassan *et al.*, (2000) for plant height, bolls per plant and seed cotton yield. Researchers achieved significant reciprocal effects for various parameters i.e. Hassan *et al.*, (1999) for plant height, bolls per plant and seed cotton yield; Kalwar and Babar (1999) for sympodia, bolls per plant and seed cotton yield, while Hassan *et al.*, (2000) noticed non-significant reciprocal effects for plant height, bolls per plant and seed cotton yield.

Table 1. Mean Squares for ANOVA (Mean values) and Combining Ability in a 6x6 F_1 and F_2 Diallel Cross of Upland Cotton

Source of Variation	Degree of Freedom	Plant Height	Monopodia /Plant	Sympodia /Plant	Bolls/ Plant	Seed Cotton Yield/ Plant
F_1 Generation						
Replicates	2	2.54**	0.14**	7.14**	10.33**	13.19**
Genotypes	35	1095.64**	0.98**	34.34**	261.82**	4472.99**
Error	70	207.37**	0.03**	4.38**	3.82**	25.34**
G.C.A.	5	1664.05**	1.72**	7.73**	333.52**	16.47**
S.C.A.	15	195.38**	0.18**	21.19**	56.53**	4.41**
Reciprocals	15	102.08 ^{NS}	0.01 ^{NS}	2.94*	35.93**	1.87**
Error	70	69.12	0.01	1.46	1.27	0.72
F_2 Generation						
Replicates	3	30.05**	0.01**	5.24**	3.13**	39.72**
Genotypes	35	392.40**	1.26**	13.28**	83.14**	1343.96**
Error	105	35.90**	0.01**	4.47**	5.78**	28.56**
G.C.A.	5	302.58**	1.43**	1.37 ^{NS}	69.45**	1193.13**
S.C.A.	15	37.41**	0.25**	4.69**	21.15**	341.23**
Reciprocals	15	90.63**	0.01**	2.60**	4.20**	45.04**
Error	105	8.98	0.002	1.12	1.44	7.14

GCA components of genetic variance were greater and more important for plant height in both generations (Table 2) and in F_1 for monopodia only showing the predominance of additive type of gene action and through simple selection the plant height can be manipulated. Raveendran *et al.*, (1996) for all the traits except seed cotton yield and bolls per plant have also reported quite analogous results and additive type of variances. Variance due to F_1 SCA was much higher in magnitude than GCA (Table 2) and were more substantial for sympodia (91.02%), bolls (43.40%) and seed cotton yield (50.70%) which indicate that these traits were controlled by dominance type of gene action. The genetic variance of F_2 SCA was larger than GCA for monopodia (57.14), sympodia (56.68), bolls (62.38) and seed cotton yield per plant (66.45), indicating predominance of non-additive type of gene action for inheritance of these traits and the said breeding material can be used for hybrid cotton production on the basis of heterosis (Table 2).

In case of reciprocal variances, all the traits exhibited smaller variances due to reciprocals as compared to GCA and SCA in both generations (Table 2) except for Plant height (46.14) in F_2 . In both generations, the variances due to reciprocals for sympodia (5.88%, 20.16%) were second ranking to SCA, but greater than GCA. It is pertinent that maternal effects were due to plasma gene action, which rarely is found in diallel studies. It was also proved that sympodia was governed by dominance type of gene action. Genetic variances due to SCA were much higher in range than GCA and prominent for sympodia, bolls per plant and seed cotton yield in both generations and also for monopodia in F_2 indicated that these traits were controlled by dominance type of gene action. These findings are in corroboration to the conclusions drawn by Kalwar and Babar (1999) for sympodia and seed cotton yield; Panhwar *et al.*, (2002) for sympodia, bolls per plant and seed cotton yield; Waldia *et al.*, (1984), Irfanullah *et al.*, (1993), Baloch *et al.*, (1995), Raveendran *et al.*, (1996) and Hassan *et al.*, (1999) for bolls per plant and seed cotton yield who observed non-additive type of gene action for different traits.

However, McCarty *et al.*, (1996), Baloch *et al.*, (1997), Tang *et al.*, (1993a) and Tang *et al.*, (1993b) had observed additive type of gene action for the most of the traits. Such contradictions may be due to different genetic background of the cultivars used and different environmental conditions. Other results are presented in seriatim including mean performance of the F_1 and F_2 hybrids along with parental cultivars and genetic effects of GCA, SCA and reciprocals.

Table 2. Estimates of Components of Variance due to GCA, SCA and Reciprocal Effects in a 6 x 6 F₁ and F₂ Diallel Cross of Upland Cotton

Components of Variation	Plant Height	Mono podia/ Plant	Sympodia /Plant	Bolls/ Plant	Seed Cotton Yield/Plant
F₁ Generation					
G.C.A.	122.73 (43.58)	0.13 (54.39)	-1.07 (-8.50)	23.23 (31.43)	322.59 (24.39)
S.C.A.	73.31 (26.03)	0.10 (41.84)	11.46 (91.02)	32.08 (43.40)	670.43 (50.70)
Reciprocals	16.48 (5.85)	-0.001 (-0.41)	0.74 (5.88)	17.33 (23.45)	320.92 (24.27)
Error	69.12 (24.54)	0.01 (4.18)	1.46 (11.60)	1.27 (1.72)	8.45 (0.64)
Total	281.64 (100)	0.239 (100)	12.59 (100)	73.91 (100)	1322.38 (100)
F₂ Generation					
G.C.A.	22.17 (25.06)	0.10 (40.82)	-0.27 (-7.36)	4.08 (22.25)	71.89 (24.65)
S.C.A.	16.51 (18.51)	0.14 (57.14)	2.08 (56.68)	11.44 (62.38)	193.83 (66.45)
Reciprocals	40.83 (46.13)	0.003 (1.22)	0.74 (20.16)	1.38 (7.52)	18.82 (6.45)
Error	8.98 (10.15)	0.002 (0.82)	1.12 (30.52)	1.44 (7.85)	7.14 (2.45)
Total	88.49 (100)	0.245 (100)	3.67 (100)	18.34 (100)	291.68 (100)

Components of Variance: Upper row.

Percentages of Components of Variance: Lower row (In parenthesis).

Plant Height

The highest and statistically equal plant height (Table 3) of 168 to 187 cm was exhibited by the 6 F₁ derivatives and reciprocals of cultivar CIM-1100. The shortest plants were recorded in the cultivar CIM-240 (105 cm) and its crosses as a maternal parent with CIM-109 (117 cm) and CRIS-9 (119 cm). In F₂ generation, the maximum and statistically at par plant height of 160 and 161 cm was exhibited by CIM-1100 x BH-36 and FII-682 x BH-36, respectively. The hybrid BH-36xCRIS-9 (116 cm) possessed the shortest plants. Plant height is positively correlated with bolls and seed cotton yield per plant if lodging does not occur, the increase in height is desirable upto a certain extent.

CIM-1100 was the best general combiner by having the highest positive GCA effects of plant height in F_1 (13.91) and F_2 (5.97) generations. FH-682 (9.19, 3.99) and BH-36 (3.66, 3.12) closely followed it in the respective generations (Table 4). The cultivars i.e. CIM-240, CIM-109 and CRIS-9 showed negative GCA effects that suit the evolution of short stature cotton cultivars being liked by the breeders.

Among the F_1 hybrids, in SCA for plant height (Table 5), 10 hybrids showed positive SCA effects ranging from 1.24 (CIM-240 x CRIS-9) to 12.87 (CIM-109 x CIM-1100), while 5 crosses manifested negative SCA effects varying from -0.44 (CIM-240 x FH-682) to -6.39 (CIM-109 x CRIS-9). Maximum and at par SCA effects were achieved by hybrid CIM-109 x CIM-1100 (12.87) and CIM-1100 x CRIS-9) and 5.55 (CIM-1100 x BH-36), while 6 hybrids manifested negative SCA effects varying from -0.08 (CIM-240 x BH-36) to -8.79 (BH-36 x CRIS-9). Maximum and equal SCA effects were scored by hybrids CIM-1100 x BH-36 (5.55) and FH-682 x BH-36 (5.40). For reciprocals in F_1 (Table 6), 9 entries revealed positive reciprocal effects ranging from 0.13 to 12.23, while 6 reciprocals manifested negative reciprocal effects fluctuating from -1.12 to -7.63. In F_2 generation, 8 hybrids revealed positive reciprocal effects ranging from 1.38 to 13.25, while 6 reciprocals exhibited negative reciprocal effects (-1.88 to -10.38).

CIM-1100 F_1 hybrids (CIM-109 x CIM-1100 x CRIS-9) were the leading and the best specific combinations for exhibition of the highest SCA effects for plant height. In these crosses, CIM-1100 had a prominent GCA, while the cultivars CIM-109 and CRIS-9 were not in a position to have even the positive GCA for the said trait. It is concluded that the crosses involved low x high and high x low parents performed well in F_1 SCA determination. The results are in line with the findings of Irfanullah *et al.*, (1993) who communicated that when a parent with the best GCA was used as pollen parent produced better combinations.

Hussain and Khan (1991) has also reported that in intra-specific crosses the cultivars with good GCA produced the cross combinations having good SCA effects. In F_2 generation, the above F_1 hybrids have not shown their stability but only one hybrid having third ranking SCA effects. The F_2 hybrids CIM-100 x BH-36 and FH-682 x BH-36 have shown maximum SCA effects for plant height having high x low and low x low GCA parents. These results are also supported by Dever and Gannaway (1992) and Galanopoulou and Roupakias (1999) who opined that F_2 hybrids despite of by inbreeding depression offer more heterogeneous population alongwith their different effects as

compared to their F_1 hybrids and parents. The above results are also in close agreement with the findings of Ali *et al.*, (2000) and Hassan *et al.*, (2000) who observed similar values of GCA and SCA for plant height. The crosses CIM-240 x CIM-109 and FH-682 x CIM-1100 in F_1 ; BH-36 x FH-682 and BH-36 x CIM-1100 in F_2 have shown maximum reciprocal effects, which may be due to plasma gene action and found rare. Hassan *et al.*, (1999) and Hassan *et al.*, (2000) noticed significant and non-significant reciprocal effects plant height.

Monopodia per Plant

In both generations, the lowest and at par means for monopodia (Table 3) were manifested by cross combinations CIM-240 x CIM-109 (0.64, 0.57) and CIM-109 x CRIS-9 (0.67, 0.60). Maximum monopodia were displayed by parent cultivar CIM-1100 (4.00) followed by its hybrid CIM-1100 x BH-36 (1.80) and its reciprocal (1.64) in F_1 and CIM-1100 x FH-682 (1.50) and CIM-240 x CIM-1100 (1.40) in F_2 generation. In both the generations (Table 4), except CIM-1100 by having positive GCA effects (0.75, 0.69), all the cultivars showed negative GCA effects for monopodia ranged in F_1 [-0.02 (BH-36) to -0.27 (CIM-109)] and F_2 [-0.04 (BH-36) to -0.22 (CIM-109)]. Cultivar CIM-109 showed supreme negative GCA effects in both generations which are greatly desirable from breeding point of view as by discouraging the monopodia which are negatively correlated with seed cotton yield.

In case of SCA effects (Table 5), 7 F_1 hybrids manifested negative and the lowest SCA effects ranging from -0.002 (CIM-109 x CIM-240) to -0.39 (CIM-1100 x FH-682), while 8 hybrids elucidated positive SCA effects ranged from 0.01 to 0.16. In F_2 hybrids SCA, 8 hybrids revealed negative SCA effects ranged from -0.02 (CIM-109 x CIM-240) to -0.46 (CIM-1100 x FH-682), while positive F_2 SCA effects ranged from 0.05 to 0.14. In reciprocals (Table 6), 3 F_1 reciprocals manifested negative reciprocal effects ranged from -0.01 to -0.12 and 12 reciprocals revealed positive reciprocal effects ranged from 0.03 to 13. In F_2 , 4 reciprocals revealed negative reciprocal effects ranged from -0.01 to -0.10, while 11 exhibited positive reciprocal effects ranging from 0.03 to 0.10. The F_1 crosses CIM-1100 x FH-682, CIM-1100 x CRIS-9, CIM-109 x CIM-1100 and CIM-240 x CIM-1100 have desirable and maximum negative SCA value for monopodia. In these crosses, CIM-1100 had a positive GCA, but the other cultivars were having negative GCA for the said trait. It is concluded that these crosses involved high x low and low x

high parents and performed well in SCA determination. Baloch *et al.*, (1999) also reported that GCA and SCA were independent and GCA is not the criterion for predicting the SCA. However, Hussain and Khan (1991) have reported that in intra-specific crosses the cultivars with good GCA produced the cross combinations having good SCA. In case of F_2 SCA effects, the same four crosses showed their stability and were the best cross combination by having desirable negative SCA value for monopodia even after transgressive segregation and inbreeding depression, which further confirm the possibilities of improvement through selection. But Dever and Gannaway (1992) and Galanopoulou and Roupakias (1999) who opined that F_2 hybrids despite of by inbreeding depression offer more heterogenous population-alongwith their different effects as compared to their F_1 hybrids. Such contradictions may be due to different genetic background of the cultivars used and different environmental conditions.

Sympodia per Plant

The maximum sympodia per plant in F_1 generation (Table 3) were exhibited by the hybrid CIM-109 x CIM-1100 (33.00) which was at par with 3 other hybrids ranged from 29.67 to 31.33. In F_2 mean values, the maximum sympodia (25.87) were also exhibited by the same hybrid as mentioned in F_1 and was at par with CIM-1100 x CRIS-9 (24.21). All the cultivars as compared to hybrids manifested the lowest sympodia ranging from 14.69 to 21.68 and the sympodia 14.69 and 16.09 were produced by CIM-1100 in both generations. In both the generations, cultivars CIM-1100 and CIM-109 were the best general combiners for sympodia (Table 4) and showed the highest positive GCA effects in F_1 (1.35, 0.34) and in F_2 (0.32, 0.39) generations followed by CRIS-9 (0.15) in F_2 only.

Other cultivars revealed negative GCA effects for sympodia in F_1 ranging from [-0.05(FH-682) to -1.02 (CRIS-9)] and F_2 [-0.12 (BH-36) to -0.43 (FH-682)]. Cultivars CIM-109 and CIM-1100 showed maximum positive GCA effects in both generations, which are greatly desirable from breeding point of view because sympodia is positively correlated with bolls and seed cotton yield per plant. In case of SCA effects (Table 5), 11 F_1 hybrids manifested superlative positive SCA effects ranging from 0.66 to 3.59, while 4 combinations showed negative SCA effects ranging from -0.12 to -0.59. In F_2 hybrids SCA, 8 hybrids elucidated positive SCA effects ranging from 0.003 to 2.40 and 7 were

having negative (-0.27 to -1.31). In reciprocals (Table 6), 7 F_1 reciprocals manifested positive maternal effects ranging from 0.17 to 2.33 and 8 reciprocals revealed negative - 0.17 to -2.67). In F_2 , 10 reciprocals revealed the topmost positive cytoplasmic effects ranging from 0.09 to 2.53, while 5 reciprocals exhibited negative reciprocal effects ranging from -0.19 to 1.13. In F_1 generation, CIM-109 x CIM-1100 was the leading specific combination for exhibition of the highest SCA for sympodia. In the said promising cross, both cultivars had prominent GCA effects.

It was further elucidated that CIM-240 x CIM-1100 and CIM-1100 x FH-682 were the second and third top ranking hybrids for sympodia. In case of F_2 , the same F_1 hybrid having promising SCA effects for sympodia, while CIM-1100xCRIS-9 was second ranked hybrid. All these crosses involved high x high, low x high and high x low GCA parents and performed well. It was concluded that the hybrid CIM-109 x CIM-1100 even after segregation exhibited the highest value for sympodia and by selection the said morphological parameter could be improved to a significant level. Baloch *et al.*, (1996) and Galanopoulou and Roupakias (1999) have also reported similar results.

Table 3. Means performance of F_1 and F_2 hybrids alongwith their six parental cultivars of Upland Cotton

Fland ID Hybrids	Plant Height (cm)		Monopodia Plant		Sympodia per Plant		Bolls per Plant		Seed Cotton Yield per Plant (g)	
	F_1 Hybrids	F_2 Hybrids	F_1 Hybrids	F_2 Hybrids	F_1 Hybrids	F_2 Hybrids	F_1 Hybrids	F_2 Hybrids	F_1 Hybrids	F_2 Hybrids
CIM-109xCIM-240	141 f-l	122 lm	0.70 jk	0.65 mn	25.33 ej	17.89 fg	32 j-m	28 kp	101.89 gh	71.25 lmn
CIM-109xCIM-1100	178 ab	144 bed	1.43 cd	1.30 cd	33.00 a	25.87 a	52 a	37 be	162.68 bed	96.56 def
CIM-109xFH-682	160 b-g	134 e-l	0.95 f-j	0.85 h-k	25.00 f-k	20.66 c-g	30 l-o	30 j-n	74.53 no	68.25 mno
CIM-109xBH-36	139 g-n	124 j-m	1.00 f-l	0.90 g-j	25.67 e-j	19.13 c-g	35 hij	32 f-l	95.55hij	69.75 mno
CIM-109xCRIS-9	125 k-o	127 i-l	0.67 k	0.60 n	23.67 i-m	21.94 bc	37 fgh	35 c-f	89.61 ijk	87.93 gh
CIM-240 x CIM-109	117 no	134 e-i	0.64 k	0.58 n	24.00 h-l	20.13 c-g	27 op	27 n-q	74.14 no	69.78 mno
CIM-240xCIM-109	135 h-n	140 e-f	1.50 c	1.40 bc	29.67 a-d	21.17 cde	45 bc	34 c-g	160.55 cd	101.19 d
CIM-240xCIM-1100	131 j-n	136 d-h	1.00 f-l	0.90 g-j	26.33 d-l	19.31 e-g	23 qr	25 pq	75.59 no	63.63 o
CIM-240xFH-682	143 f-l	124 j-m	0.90 g-k	0.85 h-k	24.00 h-l	20.00 e-g	34 h-k	28 m-q	109.86 fg	74.14 j-m
CIM-240 x BH-36	119 mno	125 jkl	0.80 h-k	0.70 lmn	24.67 g-l	19.75 e-g	31 k-n	31 g-l	80.43 lmn	77.32 i-l
CIM-240xCRIS-9	160 b-g	140 e-f	1.39 cde	1.20 de	28.33 b-f	20.81 c-f	53 a	38 bc	180.92 a	109.42 c
CIM-1100xCIM-109	137 g-n	123 hlm	1.45 cd	1.30 cd	28.67 b-e	20.76 c-g	20 r	32 f-k	59.49 p	88.07 gh
CIM-1100xCIM-240	187 a	150 b	1.46 cd	1.20 de	26.00 c-l	21.13 cde	47 b	44 a	164.16 bc	138.10 a
CIM-1100xFH-682	176 abc	160 a	1.80 b	1.50 b	26-67 c-l	19.30 c-g	40 def	38 bed	137.16 e	100.24 de

Table 3 (Continued)

F1 and F2 Hybrids	Plant Height (cm)		Monopodia Plant		Sympodia per Plant		Bolls per Plant		Seed Cotton Yield per Plant (g)	
	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids
CIM-1100x BH-36	171 a-d	137 c-h	1.49 c	1.20 de	27.67 c-g	24.21 ab	51 a	39 b	169.98 b	121.84 b
CIM-1100x CRIS-9	151 d-j	131 g-i	0.75 ijk	0.67 hmn	27.67 c-g	18.88 d-g	36 ghi	31 h-m	114.80 f	74.33 i-m
FH-682 x CIM-109	141 f-m	131 g-i	0.98 f-l	0.85 hk	25.33 c-j	19.69 c-g	26 pq	29 h-o	83.83 klm	77.84 i-l
FH-682 x CI-240	163 b-f	144 bcd	1.40 cde	1.15 c	31.33 ab	21.76 bcd	43 cd	40 b	155.19 d	122.60 b
FH-682 x CIM-1100	157 b-h	161 a	1.20 def	1.00 fg	26.33 dl	21.00 cde	29 m-p	26 opq	87.49 jkl	68.77 mno
FH-682 x CRIS-9	153 c-j	136 d-h	1.10 fg	0.95 gh	25.67 c-j	19.16 c-g	33 l-l	29 h-o	91.90 ijk	73.98 klm
BH-36 x CIM-109	146 e-k	145 bc	0.95 f-j	0.85 hk	28.00 b-g	20.91 cde	29 m-p	30 i-m	77.16 mno	63.98 no
BH-36 x CIM-240	121 l-o	140 c-f	0.80 h-k	0.65 mn	25.33 c-j	19.81 c-g	22 r	34 f-l	59.12 p	91.29 fg
BH-36 x CIM-1100	168 a-e	140 c-f	1.64 bc	1.30 cd	30.00 abc	21.92 bc	52 a	35 d-g	183.58 a	102.53 cd
BH-36 x FH-682	157 b-h	135 e-i	1.15 efg	0.93 ghi	25.67 c-j	17.81 g	29 m-p	25 q	88.00 jkl	71.38 lmn
BH-36 x CRIS-9	163 b-f	116 m	1.20 def	0.97 gh	24.67 g-l	21.25 b-e	39 efg	30 i-m	113.62 f	81.64 hi
CRIS-9 x CIM-109	140 f-n	125 jkl	0.90 gk	0.80 il	25.00 f-k	21.09 cde	41 de	34 efg	101.03 h	93.06 rfg

Table 3 (Continued)

F ₁ and F ₂ Hybrids	Plant Height (cm)		MonopodliPlant		Sympodia per Plant		Bolls per Plant		Seed Cotton Yield per Plant (g)	
	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids	F ₁ Hybrids	F ₂ Hybrids
CRIS-9 x CIM-240	132 l-m	131 h-k	0.88 g-k	0.78 j-m	22.33 j-n	19.24 e-g	28 nop	28 m-q	75.92 mno	74.05 j-m
CRIS-9 x CIM-1100	170 a-d	137 e-h	1.50 e	1.36 c	27.33 c-h	20.31 e-g	53 a	39 b	188.81 a	119.96 b
CRIS-9 x FH-682	159 b-g	139 e-g	1.05 fgh	0.96 gh	26.00 e-l	18.83 d-g	35 hij	31 g-l	116.26 f	81.04 h-k
CRIS-9 x BH-36	144 f-l	134 e-i	0.95 f-j	0.85 h-k	25.67 e-j	18.63 efg	36 ghi	35 d-g	97.67 hj	91.55 fg
CIM-109	125 k-o	136 d-i	0.75 ijk	0.75 klm	21.54 lmn	20.08 e-g	39 efg	33 f-j	94.77 hij	78.46 i-l
CIM-240	105 o	121 lm	0.80 h-k	0.80 i-l	21.68 k-n	20.69 e-g	20 r	28 l-p	54.31 p	81.38 hij
CIM-1100	141 f-m	140 cde	4.00 a	4.00 a	16.09 o	14.69 h	30 ko	29 k-o	87.73 jkl	78.01 i-l
FH-682	155 b-l	138 e-h	0.89 g-k	0.89 g-j	19.35 no	19.69 e-g	31 k-n	30 i-m	89.73 ijk	75.14 i-m
BH-36	144 f-l	141 cde	1.13 efg	1.13 ef	20.55 mn	20.76 e-g	34 h-k	29 k-n	88.06 jkl	72.25 lm
CRIS-9	124 k-o	132 f-j	1.00 fl	1.00 fg	19.87 n	20.06 e-g	32 j-m	34 e-h	71.57 o	90.89 fg
LSD (0.05)	13.45	8.401	0.277	0.133	3.408	2.965	3.182	3.370	8.197	7.49

Bolls per Plant

The maximum and statistically number of bolls per plant (Table 3) were achieved by five F_1 hybrids of CIM-1100 viz: CRIS-9 x CIM-1100 (53), CIM-1100 x CIM-109 (53) and its reciprocal (52), BH-36 x CIM-1100 (52) and CIM-1100 x CRIS-9 (51). It was closely followed by two other hybrids ranging from 45 to 47 bolls per plant. The cultivar CIM-240 and its crosses almost with other cultivars produced the least number of bolls. In F_2 generation, the maximum bolls were recorded in hybrid CIM-1100 x FH-682 (44) and it was followed by six other hybrids of CIM-1100 ranging from 37 to 40. The lowest bolls (25) were produced by the hybrids CIM-240 x FH-682 and BH-36 x FH-682. CIM-1100 was found to be the best general combiner by having maximal positive GCA effects and the foremost position for bolls per plant in F_1 (7.61) and F_2 (4.04) generations (Table 4). It was followed by CIM-109 (2.11, 0.14) and CRIS-9 (1.94, 1.22) in both generations. Other three cultivars showed negative GCA effects by having poor GCA for bolls per plant ranging from -0.97 to -8.06 and -1.30 to -2.78 in F_1 and F_2 generations, respectively. In case of F_1 hybrids SCA effects (Table 5), 8 specific combinations showed positive SCA effects ranging from 0.06 to 7.39, while 7 hybrids manifested negative SCA effects ranged from -0.19 to -4.53. In F_1 generation, the maximum and at par SCA effects were achieved by the hybrids CIM-109 x CIM-1100 (7.39) and CIM-1100 x CRIS-9 (7.06). In F_2 hybrids CSA, 8 hybrids revealed positive SCA effects ranging from 0.01 to 7.01, while 7 crosses manifested negative SCA effects ranging from -0.29 to -4.16. Majority of the CIM-1100 derivatives obtained the maximum and positive SCA effects for bolls and due consideration may be given during planning the breeding programme. In case of F_1 reciprocals (Table 6), 7 reciprocals revealed positive maternal effects ranging from 1.50 to 12.50, while 7 reciprocals manifested negative reciprocal effects ranging from -0.50 to -3.00. In F_2 generation, 8 reciprocals revealed positive reciprocal effects ranged from 0.25 to 2.00, while 6 exhibited negative reciprocal effects ranged from -0.50 to -3.00.

CIM-1100 and its hybrids with other cultivars viz: CIM-109, FH-682 and CRIS-9 revealed economic improvement in bolls per plant and its further confirmation was also made in F_2 studies after segregation and showed stability as leading general combiner for majority of traits followed closely by CIM-109, FH-682 and CRIS-9. These results are in close agreement with the findings of Galanopoulou and Roupakias (1999) that genotypes in F_1 did not predict the yield of the bulk in the following generations but the combined

performance of the hybrids and combinations in the F_1 and F_2 generations could be a good indicator to identify the promising population. The present results also got support from the findings of Waldia *et al.*, (1984), Irfanullah *et al.*, (1993), Baloch *et al.*, (1997) and Hassan *et al.*, (2000) who also concluded that best yielding parents having high GCA produced best yielding combinations. These results are also in conformity with the findings regarding high and significant GCA variance in F_2 by Tang *et al.*, (1993a) for seed cotton yield; Coyle and Smith (1997) for yield and yield components also reported prominent GCA as compared to SCA effects and concluded that the best yielding parents having high GCA produced the best yielding combinations. However, researchers like Raveendhran *et al.*, (1996) and Tang *et al.*, (1996) were of the opinion that the higher GCA of parents did not confer higher SCA, and the GCA and SCA of different parameters were independent. Baloch *et al.*, (1995) also opined that the higher GCA hybrids did not predict higher SCA. Hassan *et al.*, (1999) and Kalwar and Babar (1999) achieved significant reciprocal effects for bolls per plant, while Hassan *et al.*, (2000) noticed non-significant reciprocal effects for bolls per plant.

Table 4. Estimates of GCA Effects in a 6 x 6 F_1 and F_2 Diallel Cross of Upland Cotton

Cultivars	Plant Height	Monopodia/ Plant	Sympodia / Plant	Bolls / Plant	Seed Cotton Yield / Plant
F_1 Generation					
CIM-109	-4.35	-0.27	0.34	2.11	-1.99
CIM-240	-19.33	-0.24	-0.47	-8.06	-24.69
CIM-1100	13.91	0.75	1.35	7.61	37.69
FH-682	9.19	-0.10	-0.05	-2.64	-4.54
BH-36	3.66	-0.02	-0.13	-0.97	-5.03
CRIS-9	-3.07	-0.13	-1.02	1.94	-1.44
CD _(gen)	6.75	0.08	0.98	0.92	2.36
F_2 Generation					
CIM-109	-2.36	-0.22	0.39	0.14	-6.05
CIM-240	-6.28	-0.19	-0.30	-2.78	-6.87
CIM-1100	5.97	0.69	0.30	-2.78	-6.87
FH-682	3.99	-0.11	-0.43	-1.32	-3.66
BH-36	3.12	-0.04	-0.12	-1.30	-6.17
CRIS-9	-4.44	-0.12	0.15	1.22	4.17
CD _(gen)	2.42	0.40	0.85	0.97	2.22

Table 5: Estimates of SCA Effect in a 6 x 6 F₁ and F₂ Diallel Cross of Upland Cotton

F ₁ and F ₂ Hybrids	F ₁ Generation					F ₂ Generation				
	Plant Height	Monopodia / Plant	Sympodia/ Plant	Bolls /Plant	Seed Cotton Yield/ Plant	Plant Height	Monopodia/ Plant	Sympodia/ Plant	Bolls/Plant	Seed Cotton Yield/ Plant
CIM-109xCIM-240	6.01	-0.002	-0.59	0.06	7.55	1.28	-0.02	-1.31	-2.01	-2.72
CIM-109xCIM-1100	12.87	-0.25	3.59	7.39	28.96	2.78	-0.27	2.40	1.30	4.32
CIM-109xFH-682	4.25	0.05	0.66	-1.86	-5.95	-4.87	0.05	-0.42	-0.85	-5.16
CIM-109xBH-36	-3.51	0.09	1.24	-4.53	-13.77	-1.62	0.09	-0.48	0.01	-7.07
CIM-109xCRIS-9	-6.39	0.01	-0.37	-0.44	-8.39	-2.56	-0.01	0.75	1.11	6.22
CIM-240xCIM-1100	-5.41	-0.21	2.90	-2.44	-10.12	-3.68	-0.20	0.72	-0.29	-3.21
CIM-240xFH-682	-0.44	0.16	0.97	-0.19	1.80	0.80	0.13	0.003	-1.06	-4.89
CIM-240xBH-36	1.30	-0.07	-0.12	1.64	7.07	-0.08	-0.06	0.10	2.55	9.60
CIM-240xCRIS-9	1.24	0.03	-0.40	0.22	-2.84	3.11	0.004	-0.58	-0.97	-7.77
CIM-1100xFH-682	4.98	-0.39	1.98	4.64	19.38	1.80	-0.46	1.32	7.01	29.30
CIM-1100xBH-36	7.74	-0.18	1.73	3.97	20.57	5.55	-0.30	0.18	1.36	2.84
CIM-1100xCRIS-9	12.79	-0.30	1.79	7.06	36.01	0.49	-0.34	1.56	1.97	12.02
FH-682xBH-36	-2.13	0.13	0.80	-2.78	-9.83	5.40	0.07	-0.27	-4.16	-6.25
FH-682 x CRIS-9	2.89	0.13	1.52	-0.69	2.92	2.59	0.14	-0.95	-1.81	-9.31
BH-36 x CRIS-9	6.05	0.05	0.93	1.14	4.98	-8.79	0.02	-0.32	0.42	2.44
CD (sq-skl)	15.10	0.18	2.19	2.05	5.28	5.42	0.08	1.91	2.17	4.92
Cd (sq-skl)	13.51	0.16	1.96	1.83	4.72	4.84	0.07	1.71	1.95	4.41

Table 6. Estimates of Reciprocal Effects in a 6 x 6 F₁ and F₂ Diallel Cross of Upland Cotton

F ₁ and F ₂ Reciprocals	F ₁ Generation					F ₂ Generation				
	Plant Height	Monopodia/ Plant	Sympodia/ Plant	Bolls/Plant	Seed Cotton Yield/Plant	Plant Height	Monopodia/ Plant	Sympodia/ Plant	Bolls/Plant	Seed Cotton Yield/Plant
CIM-240x CIM-109	12.23	0.03	0.67	2.50	13.88	-6.38	0.04	-1.12	0.88	0.74
CIM-1100x CIM-109	8.98	0.02	2.33	-0.50	-9.12	1.88	0.05	2.53	-0.50	-6.44
FH-682 x CIM-109	4.78	0.10	-1.33	-3.00	-20.14	1.50	0.09	0.89	-0.50	-3.04
BH-36 x CIM-109	-3.36	0.03	-1.17	3.00	9.20	-10.38	0.03	-0.89	0.63	2.89
CRIS-9 x CIM-109	-7.63	-0.12	-0.67	-2.00	-5.71	1.38	-0.10	0.43	0.25	-2.57
CIM-1100x CIM-240	-1.12	0.03	0.50	12.50	50.54	8.50	0.05	0.21	1.25	6.56
FH-682 x CIM-240	-5.05	0.01	0.50	-1.50	-4.12	2.50	0.03	-0.19	-1.88	-7.11
BH-36 x CIM-240	10.90	0.05	-0.67	6.00	25.37	-7.75	0.10	0.09	-3.00	-8.57
CRIS-9 x CIM-240	-6.09	-0.04	1.17	1.50	2.25	-3.13	-0.04	0.26	1.75	1.63
FH-682 x CIM-1100	12.04	0.03	-2.67	2.00	4.49	3.25	0.03	-0.32	2.00	7.75
BH-36 x CIM-1100	4.27	0.08	-1.67	-6.00	-23.21	10.13	0.10	-1.13	1.63	-1.15
CRIS-9 x CIM-1100	0.37	-0.01	0.17	-1.00	-9.42	0.00	-0.08	1.95	0.00	0.94
BH-36 x FH-682	0.13	0.03	0.33	0.00	-0.26	13.25	0.04	1.59	0.50	-1.31
CRIS-9 x FH-682	-2.97	0.03	-0.17	-1.00	-12.18	-1.88	-0.01	0.17	-1.13	-3.68
CRIS-9 x BH-36	9.40	0.13	-0.50	1.50	7.98	-9.13	0.06	1.31	-2.13	-4.96
CD (rep-80)	16.54	0.19	2.40	2.25	5.78	5.93	0.09	2.09	2.38	5.39

Seed Cotton Yield per Plant (g)

In F_1 generation, the highest and statistically seed cotton yield (Table 3) was recorded in F_1 hybrids CRIS-9 x CIM-1100 (188.81 g), BH-36 x CIM-1100 (183.58 g) and CIM-1100 x CIM-109 (180.92 g). These were followed by second top scoring hybrids i.e. CIM-1100 x CRIS-9 (169.98 g), CIM-1100 x FH-682 (164.16 g), CIM-109 x CIM-1100 (162.68 g), CIM-240 x CIM-1100 (160.56 g) and FH-682 x CIM-1100 (155.19 g). The parental cultivars of these promising crosses were having nearly half the yield in comparison to their hybrids ranging from 54.31 to 94.77 g per plant. The lowest seed cotton yield of 54.31 g was manifested by the cultivar CIM-240. In F_2 generation, the highest seed cotton yield of 138.10 g was obtained in F_2 hybrid CIM-1100 x FH-682 followed by three other hybrids of CIM-1100 i.e. FH-682 x CIM-1100 (122.60 g), CIM-1100 x CRIS-9 (121.84 g) and its reciprocal CRIS-9 x CIM-1100 (119.96 g). The lowest yield was recorded in the hybrid CIM-240 x FH-682 (63.63 g). CIM-1100 hybrids having the maximum yield may be utilized in the segregating generations to evolve cultivars with better yield potential. CIM-1100 was found to be the best general combiner by accomplishing leading positive GCA effects for seed cotton yield in F_1 (37.69) and F_2 (18.56) generations (Table 4). It was followed by CRIS-9 (4.17) in F_2 only, but all other cultivars showed negative GCA effects by having poor GCA for yield in both generations. In case of F_1 SCA effects (Table 5), 9 specific cross combinations showed positive SCA effects ranging from 1.80 to 36.01, while 6 hybrids manifested negative SCA effects ranging from -2.84 to -13.77. The highest and at par SCA effects of 36.01 and 28.96 were obtained by the hybrids CIM-1100 x CRIS-9 and CIM-109 x CIM-1100, respectively. In F_2 generation, 7 hybrids revealed positive SCA effects ranging from 2.44 to 29.30, while 8 crosses manifested negative SCA effects ranging from -2.72 to -9.31. Majority of the CIM-1100 derivatives obtained maximum and positive SCA effects for seed cotton yield and due consideration may be given during formulation of future breeding programme. In F_1 reciprocals (Table 6), 7 reciprocals revealed positive maternal effects ranged from 2.25 to 50.54, while 8 reciprocals manifested negative reciprocal effects ranging from -0.26 to -23.21. In F_2 reciprocals, 6 reciprocals revealed positive reciprocal effects ranging from 0.74 to 7.75, while 9 reciprocals exhibited negative reciprocal effects ranged from -1.15 to -8.57.

The F_1 hybrids i.e. CIM-109 x CIM-1100, CIM-1100 x CRIS-9 and CIM-1100 x BH-36 were the leading and the best specific combination for exhibition of the highest

SCA effects for seed cotton yield. In these hybrids, CIM-1100 had a prominent GCA effects for seed cotton yield, but the cultivars CRIS-9, CIM-109 and BH-36 were not in a position to have even positive value for the said traits. These promising crosses involved Low x high and high x low parents and performed well in SCA determination. These results are in line with the findings of Irfanullah *et al.*, (1993) who communicated that when a parent with the best GCA was used as pollen parent produced better combinations, but in later two hybrids the case is in reverse. Outcome of the present studies is that the parent with the best GCA on their utilization as one of the parents produces good hybrid combinations. Similar results have also been reported by Waldia *et al.*, (1984), Hussain and Khan (1991), Irfanullah *et al.*, (1993), Baloch *et al.*, (1997), Hassan *et al.*, (2000) and Panhwar *et al.* (2000) who concluded that the parent with high GCA effects were found to produce high yielding hybrids. No doubt, the contradiction between the research findings may due to different factors like breeding material used and peculiar climatic conditions under which the experiments were conducted. In case of F_2 SCA effects, CIM-1100 x FH-682 was the best cross combination by having maximum SCA effects for seed cotton yield. In above hybrid, CIM-1100 was having highest GCA for above traits but FH-682 was having negative GCA effects. Therefore, high x low GCA parents produced the best cross combination for seed cotton yield. These results are also supported by Dever and Gannaway (1992) and Galanopoulou and Roupakias (1999) who opined that F_2 hybrids despite of by inbreeding depression offer more heterogeneous population alongwith their different effects as compared to their F_1 hybrids and parents.

From the above results it was concluded that F_2 hybrids i.e. CIM-1100 x FH-682, CIM-1100 x CRIS-9 and CIM-109 x CIM-1100 even after segregation exhibited the highest and second ranked value for the most of the traits and by artificial selection the morphological and yield traits can be improved to a significant level. In comparison to F_1 generation, the the said hybrids were also having leading position for most of the traits and their best performance have been confirmed in F_2 generation even after inbreeding depression and segregation. F_1 hybrids having maximum SCA effects for some traits attained the second and third position in F_2 generation for SCA effects due to high magnitude of inbreeding depression suggesting dominant genes functioning for these traits which will require repeated selection. F_1 hybrids with 2nd and third position for SCA gave transgressive segregates by having lower magnitude of inbreeding depression

and additive genes were responsible for these traits which can be improved through simple selection. Baloch *et al.*, (1996) and Galanopoulou and Roupakias (1999) have also reported similar results.

CONCLUSION

It is concluded that cultivar CIM-1100 was found as the best general combiner for majority of the traits followed by CRIS-9 and CIM-109. Majority of the F_1 and F_2 hybrids of CIM-1100 and their reciprocals like CRIS-9 X CIM-1100, BH-36 X CIM-1100, CIM-1100 X CIM-109, CIM-1100 X CRIS-9, CIM-1100 X FH-682, CIM-109 X CIM-1100, CIM-240 X CIM-1100 and FH682 x CIM-1100 performed well and can be used in hybrid cotton production. Results also revealed that yield components governed by non-additive type of gene action and such selections in promising hybrids could be used in hybrid cotton production for increased yield. Moreover, selection in top performing hybrids could be used in hybrid cotton production for increased yield. Moreover, selection in top performing hybrids can also be studied in segregating generations.

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PARTICIPATORY RESEARCH FOR AGRICULTURAL DEVELOPMENT: A CASE BARANI VILLAGE DEVELOPMENT PROJECT IN PUNJAB, PAKISTAN

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ABSTRACT

This paper is a synthesis of three-year experiences and farmers' assessment of technology validation in participatory manner at integrated research sites of Barani Village Development Project. Farmers' problems were identified and prioritized through Participatory Rural Appraisal (PRA). Farmers along with a team of researchers and extensionists in a participatory mode developed technical modules that can intervene their problems. The participatory research in project area is being conducted in collaboration with national and international research institutes for the last three years. During the first two years (2001-03) a number of technological packages from national institutes were identified and tested for wider dissemination during the coming years. All the collaborating research institutes conducted experiments and assessment of participatory research trials was conducted each year. Each intervention was replicated with two to four farmers at all the three research sites. Each year host farmers involved in technology testing were interviewed. The knowledge gained both of the technologies produced by the research component, and farmers' objectives and constraints, would support the wider dissemination of the project's interventions resulting in additional production and income from crop and livestock interventions.

Key Words : Integrated Research sites, Participatory research, Technology validation, Barani Village development Project

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INTRODUCTION

The Barani Village Development Project (BVDP) is in essence a rural development project with a strong adaptive research and technology transfer base to improve the socio-economic condition of the rural communities. The project commenced in 1999-2000 and is scheduled to run for six years until 2004-05. The project components are: Community and women development; Soil conservation; On-farm water management; Agricultural extension; Livestock development and Applied Research. The Applied Research Component of the BVDP aims to overcome the production constraints, including limited water resources, degraded rangelands, low yield potential, under stress environment, poor soil fertility, marginal lands, inadequate and inefficient use of fertilisers and non certified seed, through participatory manner.

The applied research in project area is being conducted in collaboration with national and international research institutes. The Barani Agricultural Research Institute (BARI), Barani Livestock Production Research Institute (BLPRI), Soil and Water Conservation Research Institute (SAWCRI), Fodder Research Institute, Sargodha and Social Sciences Institute, NARC, Islamabad were collaborating to execute integrated research agenda for different agro-ecological zones of Pothwar. ICARDA is associated in the project to provide technical backup for poverty alleviation through productivity improvements integrated with sustainable natural resource management practices. These programs are working on three target sites in Barani Pothwar for the last 3 years. These are in a process to develop appropriate technologies that would adequately address the dry agricultural productivity issues.

The Barani Village Development Project in the rainfed Pothwar region was originally a development project designed to help poor subsistence rural communities to improve their livelihoods. But it has gone far beyond this humble aim to become a classic example of a new style of scientific research called "participatory research".

Farmer participatory research has been defined as "the collaboration of farmers and scientists in agricultural research and development" (Bentley 1994:140). The need to improve our understanding of farmers' conditions and incorporate their perspectives into the development and testing of new agricultural technology is not new. The current interest in farmers' participation is related in large part to Farming Systems Research

(FSR) (Tripp 1989). The FSR perspective recognizes that most small farms are an integration of multiple enterprises that require the management of diverse household resources to meet a range of subsistence, income, and community goals. A farming systems perspective also implies a commitment to include farmers' criteria and goals when setting research priorities (Tripp and Woolley, 1989). Technologies generated from research system particularly new varieties can be adopted rapidly if delivered in a manner that is understood by the farmers.

The world experience over the years has shown that the best way for adoption of knowledge is through participatory approach and involvement of farmers in selecting need based technologies and other intervention measures. This way the farmers become more organized, vigilant, realistic, learn to work in community, make their own day to day decisions and start working like expert and without depending on extension staff and input dealers for crop production process. The approach involves farmers in the research process at a basic, decision-making level, and recognizes that their knowledge and experience can strengthen the process. The results would not only improve the lives of the farmers, but have also equipped them with a new understanding of their natural resources in the uncertain rainfed environment.

MATERIALS AND METHODS

Viable technological components from national institutes were identified and tested, for wider dissemination, at three integrated research sites selected through a comprehensive site selection criterion representing all the ecologies of rainfed Pothwar. Concerning detailed characterization, to identify constraints and issues and in order to prioritize research activities from three villages, Jarmot Kalan (Tehsil Gujar Khan) from high rainfall zone, Hafizabad (Tehsil Jand) from medium and Kaslian (Tehsil P.D.Khan) from low rainfall were selected.

A more informal method of investigation called Participatory Rural Appraisal (PRA) was used in which rural community was involved in analyzing: (a) production systems; (b) problem diagnosis; and (c) setting priorities for research and development planning followed by developing household profile.

In the first phase different technologies were tested to select the most promising technologies compatible with different farm situations, to be further disseminate in the project area, in the second phase. Farmers managed trials provide farmers' views, their acceptance of the intervention and information on the compatibility (fit) of the intervention with in the farming systems and an opportunity to further fine tune (Hildebrand and Poey, 1985).

The results are based on the three years assessment studies by social scientists engaged in the applied research team. Analytical procedure was adopted to understand the development process of different interventions and to get response from the host farmers. A set of different questionnaires along with checklist was developed to collect farmers' response in a systematic way for different technological interventions each year. Information was mainly collected on parameters such as farmers knowledge, participation level, difference in yield and cost with farmers' practice and successful/failure of the experiment etc along with socio economic characteristics of the farmers involved in participatory research hosting different research trials.

During first year 24 farmers, second year 32 and third year 57 farmers who had hosted different interventions/trials were interviewed from the three integrated research sites. Response of host farmers about each intervention was summarized.

RESULTS AND DISCUSSION

Characteristics of Farm Households

The farm size was divided into four categories depending upon the cultivated area owned by each household. Other demographic characteristics of the farm households were also taken in farm household profile. Most of the farm households fell into the first category of farm size. So there was a large number of small farmers who could directly benefit from the research output and it also fulfils the most important criterion set for the selection of the villages as integrated research sites. On an average each farmer had hosted more than two different trials. Majority of the farmers were small having less than 2 hectares of land in the target area but their participation in technological development processes during three years was much less as shown in Table 1 and Table 2.

Table 1. Characteristics of Farm Households at Integrated Research Sites

Farm Size	Frequency	Education (years)	Cultivated Land (ha)
< 2 ha	596 (77)	6	0.8
2-5 ha	167 (20)	5	2.6
5-10 ha	15 (2)	8	6.5
>10 ha	3 (0.6)	9	12.2
Overall	793 (100)	6	1.5

Note: The figures given in the parenthesis are the percentages

Table 2. Characteristics of Host Farmers (Average of three years)

Farm Size	Host farmers	Education (years)	Cultivated Land (ha)	No. of Trials	Member of CO (%)
< 2 ha	16 (42)	8	1.3	1.7	75
2-5 ha	15 (40)	7	3.8	1.9	89
>5 -10 ha	4 (11)	6	7.9	2.3	56
>10 ha	3 (8)	9	22.0	5.1	90
Overall	113 (100)	7	4.7	2.0	79

Note: The figures given in the parenthesis are the percentages

A number of research activities are going on at three sites by collaborating research institutions. Numerous promising technologies are emerging through the participatory research along with empowerment of the farmers with the latest research developments. Low cost structures to conserve soil and water were developed and experimented at two sites. The cost of these structures varies from Rs. 1500 to 2500 that is within the resource limit of small farmers and many times less than the structures already being constructed by Soil Conservation Department. Evaluation and standardization of these cost effective

outlets and farm water control structures is in process to standardize various cost effective outlets and farm water control structures for safe disposal of surplus rainwater across the fields, improving the soil-moisture and preventing the soil losses. Various moisture conservation practices like green manuring, gypsum application and deep tillage is also being done with the involvement of farmers.

These experiments have provided laboratory analyses by taking samples and studying different chemical and physical changes through various soil analyses studying physical and chemical properties, plant analysis, gypsum analysis for all macro and micronutrients and moisture contents. The improved varieties of legumes along with wheat and groundnut are giving higher yield than the farmers' practices. Through participatory research these technologies are not only adopted but also being disseminated further through informal seed production by the farmers.

The interventions to enhance fodder productivity are very much accepted by the farming communities at all sites. Introduction of new summer and winter fodder varieties have significantly contributed to the food and fodder security of the rainfed farmers. These varieties are not only giving 50-100 % higher yield but are also good in quality as well. Productivity enhancement of livestock through better and least cost urea molasses and genetic improvement by providing breeding services would make livestock a more productive and economical enterprise in the rainfed Pothwar region.

The results of some of the interventions from the experiments during the initial years are summarized in Table 3 that clearly indicate that the improved varieties of food and fodder crops had contributed significantly in food and fodder security. A number of other long-term technological trails like livestock breed improvement, range land development etc are also underway that would bring improvement in the livelihood of the resource poor farmers. Moreover the results of the formal survey of host farmers for the assessment of technological interventions are also summarized in appendices.

Table 3. Results of Some of Promising Interventions at Three Sites

Interventions	Type/ Variety	Hafizabad		Jarmot		Kaslian	
		Irrigated	Rainfed	Irrigated	Rainfed	Rabi Irrigated	
Soil & Water Conservation Structures (Survey results)	# of Structure	7		12			
	Cost per unit	1500-2000		1000-1500			No Experiment
	Increase in yield	20%		10-15%			
	Control erosion	Fully		Fully			
	Future Intention	Adopt with own resources but need technical guidance					
Wheat	Farmer Preference	Inqlab 91		Inqlab 91		Inqlab 91	
	Status	Already adopted more drought tolerant than other varieties					
Groundnut		Yield kg/ha & % increase					
	Yield difference		+ 75%		- 75%		
	Other attributes	Bold grain size, uniform grains, less spread of plant, localized pods formation but marketing problem due to consumer preference					
	Variety	% Improvement in green fodder & dry matter yield than local varieties					
	Berseem agaiti	35 (35)			33 (61)		
Winter Fodder	Oats S-2000	43 (25)		59 (96)	33 (54)	22 (61)	66 (54)
	Barley Jau 87	28 (21)		11 (54)	26 (30)	18 (40)	24 (23)
	Fodder quality	More palatable, increase milk yield and fodder availability in May June from improved berseem than local					
	Maize (SG2002)	98 (98)				41 (28)	Khamf Rainfed
	Sorghum JS263	107 (100)				53 (50)	23 (19)
	Pearl Millet	102 (57)				23 (21)	74 (30)

Table 3 (Continued)

Interventions	Type/ Variety	Hafizabad		Jarmot		Kaslian
		Irrigated	Rainfed	Irrigated	Rainfed	Rabi Irrigated
Summer Fodder	Sudan Grass *	83 (20)			20 (-4)	16 (22)
	Cow Pea Rawan 2003*	88 (20)			40 (-2)	-25 (-38)
	Fodder quality	Remain green upto December 1.5 months more than local varieties and more palatable also more grain and dry stalk yield				
	Farmers' future intentions	As a measure of success for adoption informal seed production of berseem, oat, maize, sorghum and millet started by the farmers and high fellow farmers interest				
	Farmers views	+1.5 liter/day		+0.5-2 liter/day		-1.0 liter/day
	OF Exp. (buffalo)	+ 2.03 liter/day		+ 1.75 liter/day		-
UMMB**	Benefit/Cost Ratio	4.72		4.08		
	OF Exp. (Cow)	+ 1.25 liter/day		+ 1.30 liter/day		
	Benefit/Cost Ratio	2.88		2.97		
	Beside increase in the milk, animal health also improves with the use of UMMB					

Source: ICARDA, 2004 and Survey results 2002 and 2003

Note: The figures given in the parenthesis are the percent change in dry matter yield than local

* New introduction therefore compared with local sorghum

**UMMB Composition: Molasses (40%), urea (6%), slaked lime (10%), common salt (5%), mineral mixture (5%), cottonseed meal (10%), maize gluten (30%) and wheat bran (14%)

Transfer of knowledge and technological package to farmers is of significant important in participatory research and plays a vital role in technology diffusion and adoption. Many innovations have spread from farmer to farmer without the intervention of any formal agricultural extension services, such as the diffusion of the moldboard plow in many parts of Africa (*M. Blackie*, personal communication) or the diffusion of velvetbean (*Mucuna* spp.) in Mesoamerica (Buckles, 1995). Farmers exchange information as well,

Social networks plays a fundamental role in the adoption of new technologies, particularly if they require collective action, such as constructing contour dikes for soil erosion and water control, which cannot be accomplished by a single individual (Smale and Ruttan, 1997). Social networks also affect the flow of farmers' own experimental information. For example, the propensity of rice farmers in Sierra Leone to discuss new rice varieties (Richards, 1986) contrasts with the concern of many Ghanaian farmers that excessive interest in a neighbor's farming activities may be linked to witchcraft (Tripp 2000). Keeping in view all these facts the project activities are implemented with best possible scientific accords. Efforts are made to involve the farmers at different stages of planning and execution of the interventions. Farmers are involved even in the annual planning meetings and future plan is finalized according to the needs and demand of the community. Inspite of all these efforts still there are a number of weaknesses in the participatory research process due to little passive role of the farming community, time bound activities and many other associated problems with research at farmers' fields. The participation level and knowledge of farmers was also explored (Table 4.) to identify possible measures to make them proactive so that the fruits of participatory research can be realized.

Table 4. Farmers' Participation in the Research Trials at Integrated Research Sites

	Rabi fodder	Kharif fodder	Wheat	Green Manuring	Mustard	Pulses	G.Nut
Area of trial	Percent Response						
Less	90	33	50	33	33	70	40
Appropriate		67	50	67	67	30	60
Sowing of trial							
Timely	100	25	100	100	100	100	100
Late		75					
Farmer selection							
Nominated by CO	30	20	70	33	17	15	10
Farmer Contact	25	50	0	0	0	33	40
Researcher contact	45	30	30	67	83	52	40

Table 4 (Continued)

	Rabi fodder	Kharif fodder	Wheat	Green Manuring	Mustard	Pulses	G.Nut
Area of trial	Percent Response						
Sowing by							
Farmer only	33	33					50
Researcher only			10	30	17		
Both	67*	67	90*	70*	83*	100*	50*
Researcher + community							
Harvesting by							
Farmer only	100	100	100	100	100	100	100
Researcher only							
Both							
Researcher + community							
Technology Know How	Partial	Partial	Partial	Partial	Nil	Little	Partial
Farmers prepared seed of best variety separately	15	30	65	na	70	75	80

Survey results 2003 *Seed and fertilizers were applied by the research staff (not by farmer)

CONCLUSIONS

The results Access to technology -- improved seeds, livestock, forestry, agricultural, animal husbandry and other farm techniques, and information - are the basic elements of any strategy to promote food security and eradicate poverty. The technology generated should be adapted to the requirements of small farmers in resource-poor areas, keeping in view their specific needs, survival strategies, agro-ecological and cultural environments. This will only happen, if small farmers are much more closely involved in the generation and diffusion of technology.

It could be concluded that the participatory research under Barani Village Development Project would Pave a new way for sustainable livelihood of the resource poor farmers through increased productivity of both crop and livestock sector in an integrated fashion.

Many of the project's interventions are almost at take off stage where the integration of other development agencies is prerequisite for wider dissemination and adoption of promising technologies at wider scale. However some modifications and improvements are also very vital in the participatory research process.

Farmers should be actively involved in all the practices particularly in the use of different inputs and evaluation of crop yield. Results should be shared with the community. The research trial should be designed, managed and analyzed equally by the both parties. The involvement of farmers at evaluation process is of much importance at this stage of technology selection for dissemination.

The results of the samples taken by the researchers should be shared with the farmers rather evaluation should be conducted on participatory manner. This would increase the understanding of processes, components of new technology into the analysis under farmers' biophysical conditions and their management. Training, guidelines, technical support and published literature would be worthwhile for capacity building and empowerment.

Although the department of extension and soil conservation have been involved in the project from the outset yet they were not a part of the research component. Now they should be regarded as partners in the adaptive research and technology transfer program and should be closely involved in the participatory research and technology development both at Integrated Research Sites and for transfer of technology in the similar agro ecological environment.

The knowledge gained both of the technologies produced by the research component, and farmers' objectives and constraints, would support the wider dissemination of the project's results.

Annex A. Farmers Assessment of Technologies at Hafizabad Research Site

Technologies	Tech. know how	Input knowledge	Tech. Preference	Future intention (Host)	Fellow farmers interest	Yield difference	Constraint
Rabi fodder	Nil	Nil	Berseem, <i>Lucern</i> , oat	Adoption	High	25-50%	Seed supply
Kharif fodder	Nil	Partial	Sorghum, maize, millet	Adopt (partial seed produce)	High	50-100%	Seed supply
Wheat varietal trials	Partial	Partial	Not clear	Trial	No	25%	Less information sharing
Fertilizer (wheat) trial	Partial	Poor	Not clear	No	Medium	27%	Less information
Pulses varietal trials		Nil	Lentil	Replicate	Medium to high	Not compared	Small plot, less participation
Green Manuring	Full	Partial	Guar/jantar	Not adopt	Low	50%	Motivator, High risk
Range/forestry	Optimal		<i>Phullahi</i> (local)	Adopt	Moderate		Moisture
Ground nut	Nil	Partial	<i>New</i>	Adopt	High	50-100%	Market
Structures	Full	Full	New	Replicate	High	20%	Tech. Supp.

Annex B. Farmers Assessment of Technologies at Jarmot Research Site

Technologies	Tech. know how	Input knowledge	Tech. Preference	Future intention (Host)	Fellow farmers interest	Yield difference	Constraint
Rabi fodder	Nil	Partial	Berseem, oat,	Repeat trial for seed	High	50% (same oat)	Irrig. Water
Kharif fodder	Nil	Partial	Sorg, millet	Adopt	High	80%	Seed supply
Wheat varietal trials	Little	Partial	Inqlab 91	-	Low to medium	25%	Less information
Fertilizer (wheat) trial	Nil	Poor	-	Repeat trial	Medium	4%	Less information
Gypsum (Wheat) trial	Partial	Nil	Not clear	No	Low	10%	Less information

Annex B. (Continued)

Technologies	Tech. know how	Input knowledge	Tech. Preference	Future intention (Host)	Fellow farmers interest	Yield difference	Constraint
Pulses varietal trials	Partial	Partial	Mash	Adopt	Medium	60% (mash)	Less participation
Groundnut	Partial	Partial	Chakori, banki	Adopt	High	50-100 Kg	Seed, Market
Green Manuring	Full	Nil	Cowpea	Not adopt	Little	2.75 md/k (1-5)	Rotavator, grazing
Soil & water cons. Structures		Full	New	Adopt	Medium	10-15%	Tech supp

Annex C. Farmers Assessment of Technologies at Kaslian Research Site

Site/ Technologies	Tech. know how	Input knowledge	Tech. Preference	Future intention (Host)	Fellow farmers interest	Yield difference	Constraint
Rabi fodder	Nil	Partial	Oat	Repeat for seed	High	Better quality	Seed availability
Kharif fodder	Nil	Partial	Sorghum/ Millet	Adopt/ repeat trial	High	25 %	Salinity, seed
Wheat varietal	Nil	Partial	Inqlab 91	Already adopted	Low	Same	
Wheat fertilizer	Full	Partial	Not clear	No	Low	Same	
Barley	Nil	Partial	-	For fodder	Low	2 md/k	
Pulses (mungbean)	Nil	Partial	First time	Experimental basis	Low	Not compared	Salinity
Range Forestry	Full	-	Kikar	Replicate	High	-	Grazing

Note: 1 md = 40 kg

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STUDY ON SEEDLING TRAITS FOR DROUGHT TOLERANCE IN WHEAT UNDER MOISTURE STRESS CONDITIONS

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ABSTRACT

Four varieties of spring wheat viz. Pak81, Rawal87, Inqlab91, and Kohsar95 were studied under different moisture regimes using triplicated 2-factor factorial experiment in CRD. Analysis of variance was highly significant for all the traits except EI and ERI. Significant differences among treatment means for all the traits were observed at $P<0.01$ except for fresh root weight, which showed significant difference at $P<0.05$. The estimates of genotypic variance for E%, EI and R/S were found higher among seedling traits. The highest value of heritability was recorded for R/S (99.82%) followed by fresh shoot weight (98.86%), fresh root weight (98.51%), dry shoot weight (97.75%) and dry root weight (85.25%). Highly significant and positive correlation was recorded between EI and E% ($r=0.5296$), between dry shoot weight and fresh shoot weight ($r=0.9876$), between dry root weight and fresh root weight ($r=0.808$) and between R/S and dry root weight (0.6043). Results of different traits indicated that these are under the control of additive genes and can be improved by selection. The variety Kohsar 95(V₅) exceeded all the varieties regarding percentage emergence at different moisture regimes. Higher emergence percentage will lead to a better crop. Stand resulting in higher great yield.

Key Words : *Triticum aestivum*; seedling traits; genetic variability; drought tolerance; moisture stress

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INTRODUCTION

The planting depth of wheat often is increased to place the seeds in soil with proper moisture contents when low surface moisture restricts germination and seedling development. However, planting seed deeply in dry soil often results in low emergence, slow seedling development and thin stands. Even if moisture is adequate for germination of seeds, continued lack of precipitation might dehydrate seedlings and stop their growth until additional rain occurs to rehydrate them. The ability of seedlings to tolerate this moisture stress is important for establishing stands of wheat. In addition, deep planting and delayed emergence depletes carbohydrate reserves in the endosperm that are needed by the seedlings. Worldwide drought stress is one of the most limiting factors to crop production. Autumn droughts often result in reduced seed germination and seedling establishment (Schonfeld *et al.*, 1988). Semi-arid areas are characterized by limited and erratic precipitation frequently resulting in droughts at different periods during the growing season. Early vigour is considered an essential component of crop plant development under most environmental conditions (Ludlow and Muchow, 1990). Crop varieties with early seedling vigour and good stand establishment tend to maximize the use of available soil water, resulting in increased dry matter accumulation and improved grain yield.

Wheat varieties differ inherently for their ability to withstand drought conditions. However, under field conditions, selection for seedling vigour can mask the genetic potential of seedlings, but controlled conditions make such practice easy (Khan *et al.*, 2002). Plant characteristics that are responsible for differences in early seedling vigour among and within plant species have not been fully explored. Simple plant characteristics such as kernel weight, percentage germination, and seedling weight and height have been identified as good indicators of seedling vigour (Acevedo *et al.*, 1991; Regan *et al.*, 1992). Most studies on drought tolerance of wheat and traits contributing to tolerance have focused on the late-vegetative and reproductive periods of growth, and the effects of stress during those periods on yield (Baalbaki *et al.*, 1998). So this study was designed to determine the ability of wheat seedlings to withstand desiccation and the effect of the stress at different developmental stages of seedling emergence.

MATERIALS AND METHODS

The experiment was conducted in the laboratory of Barani Agricultural Research Station, Fatehjang during October 2004. Four varieties of spring wheat viz. Pak81(V₁), Rawal87(V₂), Inqlab91(V₃), and Kohsar 95(V₄) were sown in pots filled with river sand using triplicated 2-factor factorial experiment in CRD. Four doses of water were given to the varieties viz. 50ml(T₁), 100ml(T₂), 150ml(T₃) and 200ml(T₄). The doses were adjusted by reviewing data on rainfall, recorded at BARS, Fatehjang for last five years during the germination phase of seed. The experiment was inspected daily to record the data on percentage emergence, emergence index and temperature during the course of experiment. After three weeks seedlings were uprooted and washed carefully in tap water to remove sand particles. Data on parameters like percentage emergence, emergence index, emergence rate index, fresh shoot weight, fresh root weight, dry shoot weight, dry root weight and root/shoot ratio were recorded. Percentage emergence was calculated according to the formula of Smith and Millet (1964).

$$\text{Emergence \%age} = \frac{\text{Seedlings emerged in 21 DAP} \times 100}{\text{Total number of seeds planted}}$$

Emergence index (EI) is an estimate of emergence rate for cultivars in each replication and was calculated according to the formula suggested by Mock and Eberhart (1972).

$$\text{Emergence index (EI)} = \frac{3 (\text{Plants emerged in a day}) (\text{DAP})}{\text{Plants emerged in 21 DAP}}$$

Where DAP = Days after planting

Emergence rate index (ERI) was calculated as ratio of EI to E %.

$$\text{Emergence rate index (ERI)} = \text{EI} / \text{E\%}$$

The root-shoot ratio was calculated by dividing the dried root weight with the dried shoot weight.

$$\text{R/S} = \text{Dried root weight/Dried shoot weight}$$

The means thus obtained were subjected to analysis of variance by the standard method of Steel & Torrie (1980). Genetic components of variance were obtained as outlined by Johnson et al., (1956) and Mahmud & Kramer (1951). Heritability estimates were calculated using procedures given by Allard (1960). Phenotypic correlation coefficients were worked out between the traits following Snedecor, (1956).

RESULTS AND DISCUSSION

Analysis of variance was performed for all the eight seedling traits as a prerequisite for measuring genetic diversity. According to the results (Table I) difference among the varieties were highly significant for all the traits except emergence index and emergence rate index, indicating notable genetic variability among wheat varieties. Significant differences among treatment means for all the traits were observed at $P < 0.01$ except for fresh root weight, which showed significant difference at $P < 0.05$. The main effect due to different moisture levels, varieties and their interactions were highly significant for all traits except percentage emergence, emergence index, and emergence rate. The C.V (%) (Table II) was found maximum for fresh root weight, dry root weight and emergence rate index (26.8, 22.58 and 22.01%) respectively. Medhi and Asghar (1999) and Khan *et al.*, (2002) reported similar results. In agricultural experiment, CV% is a good index of reliability of experiment. These estimates are frequently used by the breeder to ascertain the precision of traits in an experiment.

Information about the genetic properties of the given population can be drawn from the relative magnitude of the components of variance. In general, the estimates of genetic variances were smaller than their respective phenotypic variances for all the seedling traits evaluated. Likewise, estimates of genetic variance were greater than the estimates of environmental variances for most of the traits. The estimates of genotypic variance for E% (592.45), EI (5.107) and R/S (1.1063) were found higher among seedling traits, thus indicating the presence of greater genetic variability for these traits. Information on heritability provides the relative practicability of selection for a particular character. The estimates of broad sense heritability recorded from wheat varieties at different moisture levels ranged from 7.69% to 99.82%. The highest value of heritability was recorded for R/S followed by fresh shoot weight (98.86%), fresh root weight (98.51%), dry shoot weight (97.75%) and dry root weight (85.25%) which suggested that selection for these traits will also be effective in future breeding programs of wheat in rainfed areas.

Simple correlation coefficient for all seedling traits was estimated (Table III). The simple correlation coefficients of emergence percentage showed positive and highly significant correlation with emergence index, whereas, it was negatively and significantly correlated with emergence rate index, fresh shoot weight, fresh root weight, dry shoot

weight, dry root weight and R/S. These results are in agreement with Medhi and Asghar (1999). Emergence index showed positive and significant correlation with fresh root weight, while other traits were negatively correlated with it. Emergence rate index was positive and significantly correlated with fresh shoot weight, fresh root weight and dry shoot weight whereas, dry root weight was positively and non-significantly correlated with it. Emergence rate index was negatively and non-significantly correlated with R/S. It was also shown that fresh shoot weight was positively and significantly correlated with dry shoot weight, while non-significantly correlated with fresh root weight and dry root weight.

It was negatively and significantly correlated with R/S. Fresh root weight was positively and significantly correlated with dry root weight, whereas, dry shoot weight and R/S was non-significantly and positively correlated with fresh root weight. Dry shoot weight was positively and non-significantly correlated with dry root weight while R/S indicated negative and highly significant correlation with dry shoot weight. However, dry root weight was positively and highly significantly correlated with R/S.

The different parameters studied in the present investigation can be useful for screening wheat varieties at seedling stage. Higher values of heritability for R/S, fresh shoot weight, fresh root weight, dry shoot weight and dry root weight indicated that these traits were under the control of additive genes and can be improved by selection. Highly significant and positive correlation between E% and EI, between fresh shoot weight and dry shoot weight, between fresh root weight and dry root weight and between dry root weight and R/S was recorded which suggested a directional model for direct and/or indirect improvement in these traits. Looking at the mean values it is concluded that Kohsar95 (V_4) exceeded all the varieties regarding percentage emergence at different moisture regimes. Therefore, high percentage emergence will lead to higher number of seedlings per acre resulting in better crop stand, which is a prerequisite to enhance per acre grain yield.

Table I. Analysis of variance of eight seedling traits studied in four wheat varieties

SOV	df	E%	EI	ERI	FSW	FRW	DSW	DRW	R/S
Varieties	3	645.62*	8.31 ^{NS}	.013 NS	0.001 **	0.00013 **	0.001 **	0.0003* *	1.107**
Treatments	3	14595.27* *	200.06* *	0.30* *	0.001 **	0.00008 *	0.001 **	0.00015 **	2.201**
VxT	9	98.74 ^{NS}	2.83 ^{NS}	0.005 NS	0.001 **	0.001**	0.001 **	0.001**	3.65**
Error	32	159.51	9.61	0.008 0.23	0.000 0.23	0.00003 0.008	0.000 0.008	0.00003	0.0022

* Significant at $P < 0.05$; ** Significant at $p < 0.01$ NS Non-significant

Table II. Means ($\bar{x}$), coefficient of variation (CV%) genotypic variance (δ_g), phenotypic variance (δ_p) environmental variance (δ_e) and broad sense heritability (h^2) of seedling traits in four wheat varieties at different moisture regimes

Treatments	E%	EI	ERI	FSW	FRW	DSW	DRW	R/S
V1T1	16.667	7.067	0.460	0.020	0.051	0.017	0.047	2.783
V2T1	12.500	6.200	0.493	0.084	0.015	0.078	0.011	0.147
V3T1	16.667	7.200	0.490	0.011	0.030	0.007	0.018	2.390
V4T1	25.000	6.333	0.300	0.003	0.004	0.002	0.003	1.293
V1T2	62.500	5.700	0.117	0.008	0.020	0.005	0.010	1.960
V2T2	58.333	5.767	0.103	0.013	0.008	0.007	0.030	4.437
V3T2	62.500	6.100	0.097	0.015	0.017	0.011	0.012	1.193
V4T2	83.333	6.000	0.073	0.020	0.040	0.015	0.027	1.783
V1T3	100.000	11.800	0.120	0.016	0.025	0.008	0.021	2.623
V2T3	79.167	8.467	0.110	0.014	0.015	0.009	0.013	1.427
V3T3	91.667	9.600	0.110	0.017	0.016	0.012	0.013	1.100
V4T3	91.667	9.800	0.107	0.014	0.017	0.011	0.014	1.270
V1T4	95.833	16.467	0.170	0.013	0.011	0.008	0.008	0.980
V2T4	79.167	13.667	0.173	0.018	0.019	0.010	0.015	1.483
V3T4	95.833	16.467	0.170	0.032	0.040	0.019	0.031	1.617
V4T4	100.000	12.967	0.130	0.010	0.013	0.007	0.009	1.277

Means (x)	66.92	9.35	0.0201	0.019	0.021	0.014	0.018	1.735
CV%	18.87	13.15	22.01	19.66	26.80	17.31	22.58	8.69
δ_g	592.45	5.107	0.01033	0.00099	0.00012	0.0010	0.00029	1.1063
δ_p	751.96	14.7167	0.01833	0.00102	0.00015	0.00101	0.00032	1.10847
δ_c	159.51	9.61	0.008	0.000023	0.00003	0.000008	0.00003	0.0022
$h^2(bs)\%$	18.02	20.19	7.69	98.86	98.51	97.75	85.25	99.82

Table III. Simple correlation coefficients of eight seedling traits studied in four wheat varieties

Traits	E%	EI	ERI	FSW	FRW	DSW	DRW
EI	0.5296**						
ERI	-0.7890**	-0.081**					
FSW	-0.3337*	-0.039 ^{NS}	0.4438**				
FRW	-0.1647**	0.051*	0.3082*	0.157312 ^{NS}			
DSW	-0.3951**	-0.116**	0.4812**	0.98763**	0.0974 ^{NS}		
DRW	-0.1907**	-0.023 ^{NS}	0.2249 ^{NS}	0.119303 ^{NS}	0.8080**	0.0528 ^{NS}	
R/S	-0.0920**	-0.196**	-0.0742 ^{NS}	-0.38917**	0.2070 ^{NS}	-0.4252**	0.6043**

* Significant at $P < 0.05$; ** Significant at $p < 0.01$ NS Non-significant

Where, E% = Emergence percentage, EI = Emergence index, ERI = Emergence rate index, FSW = Fresh Shoot Weight, FRW = Fresh Root Weight, DSW = Dry Shoot Weight and DRW = Dry Root Weight, R/S = Root Shoot Ratio.

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RELEASE OF VERSATILE DESI CHICKPEA VARIETY 'PUNJAB 2000' FOR GENERAL CULTIVATION IN THE PUNJAB PROVINCE OF PAKISTAN

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ABSTRACT

The versatile desi chickpea variety pb.2000 was developed and released to meet the needs of both rainfed and irrigated areas of Punjab Province of Pakistan. The variety pb.2000 was developed through hybridization using a female parent C-87, a chlorosis resistant desi variety suitable for irrigated areas and male parent C-44, the desi bold seeded variety highly adopted in low rainfall areas of 'Thal'. The cross was made during 1988-89 and segregating populations were handled adopting pedigree method of breeding. The pure lines showing promise were selected in F₄ Generation during 1992-93, numbered and tested in Yield Nursery during 1993-94. The line 93081 found most promising was further evaluated along with other promising lines in Station Yield Trials, Adaptation Yield Trials, National Uniform Yield Trials and Sowing Date Yield Trials during 1994-95 to 1998-99 against standard desi check varieties Pb-91/C-44, under both rainfed and irrigated conditions throughout the Punjab Province and the Country. On an average of 50 different yield trials conducted under rainfed and irrigated conditions, 93081 with an average yield of 1679 kg ha⁻¹ produced 27.8% higher yield than the check varieties Pb-91/C-44 which produced 1314 kg ha⁻¹. 93081 has a high yield potential of 3500 kg ha⁻¹, carries tolerance to blight and wilt diseases, resistance to iron-deficiency chlorosis and also has a bold seed size. 93081 was released by Punjab Seed Council for general cultivation by the name of Punjab 2000, being versatile variety it was recommended for planting on both rainfed and irrigated areas of Punjab.

Key Words : Chickpea, *Cicer arietinum* L. Rainfed areas, Irrigated areas, Versatile variety.

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INTRODUCTION

Pulses are important both as food and crops. Among pulses, chickpea, the major pulse crop contributing 72.8% to the total pulses grown in the country, occupied an area of 961.4 thousand ha in Pakistan. Out of which the Punjab Province alone contributed 860.0 thousand ha which was 89.5% of the total chickpea area planted in the country during 2002-03 (Anon., 2003). In Punjab, 90.2% of the chickpea crop is planted as rainfed out of this rainfed area 88.2% is concentrated in the rainfed tract of 'Thal' comprising of the districts of Bhakkar, Khushab, Layyah, Mianwali and parts of Jhang (Anon., 2002-03). It is because chickpea is the only crop which has a potential to grow under semi desert conditions of 'Thal' comprising of sand dunes and interdunal valleys having scanty soil moisture & soil fertility. Consequential upon the predominance of rainfed area, the production of the crop in the country depends upon the kind of crop harvested in rainfed area of 'Thal' where the success of the crop depends largely on the availability of soil moisture. The adequate rains received in 'Thal' during the crop season of 1997-98 resulted into a record production of 646.2 thousand tonnes in Punjab with the highest provincial average yield of 711 kg ha⁻¹ which raised the national production to the highest level of 767.1 thousand tonnes and the national average yield to 696 kg ha⁻¹ (Anon., 2000-01). The chickpea variety C-44 is well adopted under 'Thal' conditions and it is the predominant variety of the 'Thal' region where it covers over three fourth of the total chickpea area in Punjab. Consequently, the chickpea markets are also concentrated in 'Thal' where most of the chickpea grain constitutes the produce of bold seeded chickpea variety C-44 which is Locally known as 'Bittal' quality (bold seeded quality). The Chickpea grain of 'Bittal' quality is transported from 'Thal' to throughout the province/country.

In Irrigated areas, the chickpea area was dropped from 26% during 1971-72 to as low as 6.8% in 2000-01. However, the trend of planting chickpea is Increasing among the farmers to combat the water-shortage crisis since chickpea crop requires only one irrigation after soaking dose. The irrigated area of chickpea crop in Punjab has increased by 19.5% from 53.4 thousand ha in 2000-01 to 63.8 thousand ha in 2001-02 and further by 31.7% from 63.8 thousand ha to 84.0 thousand ha in 2002-03, (Anon., 2002-03). The farmers are planting chickpea crop by buying the Bittal quality produce of C-44 from the market and using it as seed due to its attractive bold size. Consequently, their crops are

affected by Iron-deficiency chlorosis after first irrigation/rainfall when the clay loam soils get compact while in the sandy soils of 'Thal' which do not get compact even the susceptible variety C-44 is not affected by iron-deficiency chlorosis (Ali, *et al.*, 1984). The sources of resistance to iron-deficiency chlorosis are available (Ali, *et al.*, 1988a) and the chlorosis is conditioned by a single recessive gene (Ali, *et al.*, 1988 b). Moreover, the varieties developed for rainfed areas of 'Thal' have less adaptation in Irrigated areas and vice versa. Therefore, a need was felt to develop a versatile variety, which can successfully be planted in rainfed as well as Irrigated areas.

MATERIALS AND METHODS

The chickpea variety development work was carried out at Pulses Research Institute, Faisalabad during 1988-89 to 1998-99. In hybridization programme, a cross was made between the female parent C-87, an Iron-deficiency Chlorosis resistant desi variety suitable for irrigated areas, and the male parent C-44, the desi variety highly adopted under low rainfall conditions of 'Thal', during 1988-89. The F_1 generation was raised during 1989-90, the seed of which was planted in F_2 during 1990-91. The segregating populations (F_2 - F_4) were handled adopting Pedigree method of selection. The single plant selections were made in F_2 at maturity. The plant progeny rows were studied in F_3 and single plant selections were made during 1991-92. The plant progenies were raised and Uniform pure lines showing promise were selected in F_4 during 1992-93 and these lines were numbered and tested in yield Nursery during 1993-94. The line 93081 found promising in yield nursery was evaluated along with other lines for yield in 9 Station Yield Trials including 6 under irrigated conditions at Faisalabad(2), Sialkot(2) and Kallurkot(2), and 3 under rainfed conditions at Kallurkot(2) and Attock(1), during 1994-95 and 1995-96. The variety 93081 was evaluated in 11 Adaptation Yield Trials conducted under both rainfed and irrigated conditions throughout the Punjab province during 1995-96 to 1997-98 and in 27 National Uniform Yield Trials conducted under rainfed and irrigated conditions throughout the country by the National Coordinator (Pulses), NARC, Islamabad during 1995-96 to 1998-99. The variety 93081 was also evaluated in Sowing Dates Yield Trials at Faisalabad during 1996-97 and 1998-99. The Yield Nursery was laid out in augmented design while all the yield trials were laid out in Randomized Complete Block Design with 4 replications. The sowing Dates Yield Trial was laid out in Split Plot Design with 4 replications. 93081 was raised adopting the

agronomic practices already established for C-44 and Pb.91. 93081 was also tested against Ascochyta blight and Fusarium wilt diseases as well as against iron-deficiency chlorosis during 1995-96 to 1998-99. The data were subjected to analysis of variance and LSD.05 was estimated for separation of means adopting the procedures laid down by Little & Hills (1978). The varietal characteristics of 93081 were studied and agronomic practices were recommended. The variety was exposed to artificially created disease conditions of fungal diseases Ascochyta blight and Fusarium wilt and also against abiotic disease of iron-deficiency chlorosis. The variety 93081 was rated against Ascochyta blight and wilt diseases adopting the international disease scoring techniques developed by Nene *et al.* (1981)

RESULTS AND DISCUSSION

I. Yield performance:

The variety 93081 yielded significantly higher than the check varieties Pb.91 and C-44 in Yield Nursery, Station Yield Trials, Adaptation Yield Trials, National Uniform Yield Trials and sowing Dates Yield Trails (Table 1).

Table 1. Summary of yield performance of 93081 in different yield trials during 1993-94 to 1998-99

Sl. No.	Year	Detail of Yield Trials		Yield kg/ha		% incr.	LSD 0.5 Kg ha ⁻¹
		Type of Trial	No	93081	Pb.91		
1	1993-94	Yield Nursery (Irrigated)	1	3500	1979	76.9	Non rep.
2	1994-95 to 1995-96	Station Yield Trials, i) Irrigated ii) Rainfed	6 3	1894 707	1445 559	31.1 26.5	324-574 175-275
3	1995-96 to 1997-98	Adaptation Yield Trials (Irrigated + Rainfed)	11	1603	1387	15.6	178-561
4	1995-96 to 1998-99	National Uniform Yield Trials (Irrigated + Rainfed)	27	1653	1270*	30.2	-
5	1996-97 and 1998-99	Sowing Date Yield Trials i) 17-10-96 and 24-10-98 ii) 03-11-96 and 06-11-98	2	2519 2182	1937 1892	30.0 15.3	285-325
		Weighted Average	50	1679	1314	27.8	-

• Pb-91/ C-44

a. Yield nursery:

The variety 93081 yielded 3500 kg ha⁻¹ which was 76.9% higher than the yield of 1979 kg ha⁻¹ produced by the check variety Pb.91 in Yield Nursery planted under irrigated conditions at Faisalabad during 1993-94.

b. Station Yield Trials:

On an average of 6 yield trials conducted under irrigated conditions at Faisalabad, Sialkot and Kallurkot, the variety 93081 produced 1894 kg ha⁻¹ which was 31.1% higher than the yield of 1445 kg ha⁻¹ produced by the check variety Pb.91. While under rainfed conditions at Kallurkot and Attock, on an average of 3 trials, the variety 93081 produced 707 kg ha⁻¹ which was 26.5% higher than the yield of 559 kg ha⁻¹ produced by the check Pb.91, during 1994-95 to 1995-96.

c. Adaptations Yield Trials:

On an average of 11 Adaptation Yield Trials, conducted under irrigated and rainfed conditions throughout the Punjab province, during 1995-96 to 1997-98, the variety 93081 yielded 1603 Kg ha⁻¹ which was 15.6% higher than the yield of 1387 Kg ha⁻¹ produced by the check variety Pb.91 during 1995-96 to 1997-98.

d. National Uniform Yield Trials.

On an average of 27 trials conducted throughout the country, the variety 93081 yielded 1653 Kg ha⁻¹ which was 30.2% higher than the yield of 1270 Kg ha⁻¹ produced by the check varieties Pb. 91/ C-44 during 1995-96 to 1998-99.

e. Sowing Dates Yield Trials.

During 1996-97 and 1998-99, the variety 93081 planted on 17.10.96 and 24.10.98 produced an average yield of 2519 kg ha⁻¹ which was 30.0% higher than the yield of 1937 kg ha⁻¹ produced by the check variety Pb.91 planted on these dates while the variety 93081 planted on 3.11.96 and 6.11.98 produced an average yield of 2182 kg ha⁻¹ which was 15.3% higher than the yield of 1892 kg ha⁻¹ produced by the check variety Pb.91 planted on these dates.

On an average of 50 yield trials, the variety 93081 yielded 1679 kg ha⁻¹ which was 27.8% higher than the yield of 1314 kg ha⁻¹ produced by the check varieties Pb.91/C.44.

II. Varietal Characteristics of 93081.

a.	Description of the Variety.	
	Leaf Compound, Rachis length	=6.6 cm
	Leaf let	=Long
	Foliage colour	=Light green
	Plant type	=Semi erect
	Pods	=Bold
	Seed	=Bold and Oblong
	Days to flowering	=112
	Days to maturity	=170
	Yield components	
	No. of primary branches Per plant	=9.6
	No. of secondary branches per plant	=27.6
	No. of pods per plant	=61
	No. of seeds per pod	=1.5
	Yield per plant (g)	=274
	1000 - grain weight (g)	=230
	1000 - grain weight of C (g) -44	=268
	Pb.91	=287
	'Bittal' 98	

b. Distinctness of the Variety 93081.

Leaflets long, foliage relatively light green, plant semi erect, and pods bold and oblong and seeds bold.

III. Agronomic Requirements of 93081.

The variety 93081 being a cross between local varieties gave high yield adopting the agronomic practices already established for the desi type commercial varieties C-44 and Pb-91. The following agronomic practices were recommended for the cultivation of the variety 93081.

a. Sowing Time:

The optimum time of sowing for different areas of the Punjab Province is given as under:

Northern Punjab	15th Sept. to 15th Oct.
'Thal' area 1st to	31st October.
Central and southern Punjab	15th Oct. to 15th Nov.

b. Seeding Rate:

The seed rate of 62.5 Kg per ha is recommended for obtaining an optimum plant population of 212.5-225 thousand plants per ha as previously recommended for bold seeded varieties of chickpea.

c. Planting Geometry:

The row to row spacing of 30 and 45 cm under normal and rich soil conditions, respectively and a plant to plant distance of 15-20 cm is recommended using the recommended seeding rate as already recommended for bushy type of desi chickpea varieties.

d. Water requirements:

The variety 93081 also performed well with one irrigation at flowering as already recommended for desi chickpea varieties under irrigated conditions.

e. Fertilizer Requirements:

The variety 93081 also performed good under the prevailing standard fertilizer dose of NPK as 27.5:92.5:0 Kg per ha.

IV. Reaction to Diseases:

The variety 93081 remained under study against the major diseases i.e. blight and wilt and iron-deficiency chlorosis along with standard check varieties during 1995-96 to 1998-99. The results obtained under artificial disease conditions created at AARI Faisalabad are produced in Table 2.

Table 2. The average reaction of 93081 against blight and wilt diseases and iron-deficiency chlorosis during 1995-96 to 1998-99

Sl. No.	Varieties	Wilt (in percentage)	Blight (1-9 Scale)	Iron-deficiency Chlorosis
1	93081	21-30	3	Resistant
2	C-87	21-30	3	Resistant
3	C-44	31-40	5	Susceptible
4	Pb.91	31-40	5	Resistant
5	Bittal -98	21-30	3	Resistant

The variety 93081 was found moderately resistant to both the major diseases of Ascochyta blight and Fusarium wilt and resistant to iron-deficiency chlorosis.

The variety 93081, an out come of a cross between the locally adopted varieties, on an average of 50 trials, produced 1679 Kg ha⁻¹ which was 27.8% higher than the yield of 1314 Kg ha⁻¹ produced by the check varieties Pb.91/C-44 under rainfed and irrigated conditions. It has a wide adaptability and a high yield potential of 3500 Kg ha⁻¹. It has no specific agronomic requirements and it can successfully be grown adopting the agronomic practices already established for the prevailing bold seeded commercial chickpea varieties. It also carries tolerance to Ascochyta blight and Fusarium wilt as well as resistance to iron-deficiency chlorosis. The variety 93081 has bold seed size. Based upon these characters, variety 93081 was released by the Punjab Seed Council for general cultivation by the name of Pb.2000, and it being versatile variety was recommended for planting on both rainfed and Irrigated areas of Punjab.

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PREDOMINANT NATURAL ENEMIES OF INSECT PESTS IN AGROECOSYSTEMS AT ARALAGANWILA IN THE NORTH CENTRAL PROVINCE OF SRI LANKA

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ABSTRACT

Different crops were established and maintained under pesticide free conditions plots in research field at Aralaganwila, North Central Province of Srilanka. Insect pests and their natural enemies associated with the crops were collected and immature stages were reared in the laboratory with their associated hosts for investigations and adult emergence. The adults were collected, processed and identified. In the identification individual specimens were classified up to specific, genus or family names. Identified specimens included predators and parasitoids belonging to different orders. This report includes the information of identified species belonging to order Areneae, Coleoptera, Diptera, Hymenoptera and Heteroptera and hosts associated with them. The most predominant predatory species belonged to orders of Areneae and Coleoptera and parasitic species belonged to orders of Hymenoptera and Diptera. This report gives some species as their first record. Key specimens were kept for reference at the Entomology Division of the Horticultural Crop Research and Development Institute, Peradeniya and Regional Agricultural Research and Development Center, Aralaganwila. Results highlighted the indigenous occurrence of many species of natural enemies in the agro-ecosystem of the region. Populations of natural enemies showed seasonal fluctuations in the area.

Key Words : Hosts, IPM, Parasitoid, Pest, Predator.

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INTRODUCTION

Farmers in Sri Lanka mostly rely on chemical pesticides for the control of pest problems. They apply pesticides as routine applications irrespective of pest infestations or damage symptoms. These applications usually totaled over 25, 20 and 13 times respectively for chilli, cabbage and bean cultivations during a cropping season (Anon, 2005a). This reliance and indiscriminate use of pesticides not only increases cost of production but also leads to many hazardous and adverse conditions (De Silva, 1960; Nargarkatti & Jayanth, 1982; Ponnambalam, 1983; Kodagoda, 1983). Integrated Pest Management (IPM) is highly effective, eco-friendly and does not cause hazardous and adverse effects (Pimental, 1981; Ketipearachchi, 1992). IPM approach demands an extensive knowledge on indigenous natural enemies as it promotes biological control through parasitoids and predators. But, information is scarce in this field under local agro-ecosystems (Ketipearachchi, 2002; De Silva, 1960; 1961; Simmonds, 1978; Fernando, 1964; 1965; 1966). Research and development programs are not giving much attention for the biological control of these pests in the field level. This situation demands extensive research on indigenous natural enemies.

Aralaganwila in the Mahaweli System B (eastern part of the North Central Province) is an area highly developed for irrigated agriculture after mid 1980s. Until then these lands were covered by a natural ecosystem that comprised with many natural plant and animal species. At present a major portion of the lands is utilized for paddy cultivation, during yala (dry season) and maha (rainy season). The extent of lands utilized for rice is higher during maha than during yala and that utilized for other field crops (OFC) and vegetables is higher during yala than during maha. The replacement of natural ecosystem by agro-ecosystem in the region might have changed the interactions among hosts, pests and their natural enemies. The present study is aimed to investigate predominant natural enemies of major insect pests associated with crop species in the agro-ecosystem at Aralaganwila. A part of the results of this study was reported previously and included information of 80 Hymenopteran parasitoids and hyper parasitoids (Ketipearachchi, 2002). This report includes additional information.

MATERIALS AND METHODS

The study was conducted at the Regional Agricultural Research and Development Center at Aralaganwila. Annual crops of different species were monthly established in 100 m² plots. These crop species included pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*), green gram (*Vigna radiata* L.), groundnut (*Arachis hypogaea* L.), chilli (*Capsicum annum* L.), eggplant (*Solanum* sp.), *Cucurbita pepo*, *Lufa acutangula*, cucumber (*Cucumis sativus*), *Momordica charantia*, *Cucurbita moschata*, onion (*Allium* spp.), radish (*Raphanus sativus* L.), cabbage (*Brassica oleracea* var. capitata), sesame (*Sesamum indicum* L.) and maize (*Zea mays* L.). Semi perennial crops, *Asparagus officinalis* and *Solanum violaceum* G. were grown each in 500 m² plots during *yala* and *maha*. These crops were maintained in the research field under insecticide free conditions.

Immature stages and natural enemies of pest species associated with the crops were frequently collected and reared in the laboratory. Eggs were reared in test tubes plugged with cotton wool and other immature stages were cultured in plastic containers with ventilated windows covered with nylon mesh. Immature stages of pests were fed daily with tender shoots, pods or fruits of crops they preferred and that of predators were fed with hosts. Emerging adults were collected and processed for identification. The identities of these specimens were made by comparing them with the reference collections maintained at the center and use of literature. Specimens of the species were also sent to the International Institute of Entomology (IIE) in London for confirmation of identities. The taxonomists, R. G. Booth, G. M. Stonedahl, J. A. Murphy, I. M. White, B. Bolton and N. P. Wyatt identified these specimens. Samples of some uncommon or new species were kept at the insect museum of Horticultural Crop Research and Development Institute at Peradeniya and the Regional Agricultural Research and Development Center at Aralaganwila for reference.

RESULTS AND DISCUSSION

The natural enemies collected from this study included parasitoids, hyper-parasitoids and predators of arthropod pest species (Ketipearachchi, 2002). Information in this paper was limited to parasitic species of Diptera and predatory species of Araneae, Coleoptera, Heteroptera and Hymenoptera (Table 1). Many of the species collected in this study have

been identified only up to genus. This was mainly due to the unavailability of services of experts and information on these species in the Asian region for detailed classification.

Observations indicated that spiders, ladybird beetles and Hemiptera species were the most predominant predator species and dragonflies, damselflies, lacewings, grasshoppers, birds and snakes were the occasional predator species associated with different crop pests. Decaying bodies of some defoliating larvae were occasionally noticed in these fields. A pathogenic infection may be the cause of death of these larvae. Observations indicated seasonal occurrences of parasitoid species. Many parasitoid species were abundant during maha than during yala. The species listed in the above represent only a portion of the natural enemy complex existed in the agro-ecosystem. Thus, further research is suggested for the discovery of many probable parasitic or pathogenic and some predatory species that have not been reported so far from these areas and highlight their significance in relation to seasonal abundance.

In the natural ecosystems, a dynamic equilibrium exists between parasitoids and predators and their hosts (Pimental, 1981). But, similar equilibrium does not exist in agro-ecosystems due to the influences of crops, varieties, cultivation cycles and agronomic practices. An insect pest of widespread distribution and host range may have several natural enemies. However, many natural enemies show a very high degree of host specificity (Ghosh, 1989). Presence of different natural enemy species is a positive indication for natural control of different pest species. This study proved the presence of many species of predatory and parasitic natural enemies. These species may be common in agro-ecosystems of the dry zone.

They limit the reproduction and population build up of pest species. Information of some species indicated under *Leucopis* sp., Chloropridae, *Atherigona* sp., *Nematocera*, *Phoridae*, *Sarcophagidae*, *Syphidae*, some species of *Tachinidae*, *Stratiomyidae*, species of spiders, *Brumoides* sp., *Ophionea* sp., *Coccinella transversalis*, *Micraspis discolor*, *Propylea dissecta*, *Serangium parcesetosum*, *Orius* sp., *Creontiades pallidifer*, *Camponotus* spp., *Leptogenys* sp., *Lophomyrmex* sp., *Meranoplus bicolor*, *Paratrechina* sp., *Polyrhachis exercita*, *Solenopsis* sp. and *Tapinoma* sp. was not found as natural enemies of crop pests in previous reports of De Silva (1960 and 1961), Jesudasan and Yogaratnam (1984), Fernando (1964; 1965 and 1966), and Ketipearachchi (1992 and 2002). Thus, such species are treated as indigenous species for the first time with this

report. As information on bionomics of local parasitoids and predators is scarce, further studies are suggested on these species.

Many countries successfully manage pest populations by means of on going continuous biological control programs. Only a few species (*Goniozus nephantidis*, *Bracon hebetor*, *Eriborus trochenteratus*, *Brachimeria nephantidis* and *Cyrtobagous salviniae*) are being cultured and released in biological pest control programs of Sri Lanka (Anon, 2005b). The indigenous parasitoid and predator species may also be exploited through mass culture and release techniques. Hence, the results demand further research on potentials of using them for mass culture and release. Standard cultural practices, IPM, maintenance of fodder trees or artificial diet and inhabiting sites and reduction of discriminate uses of pesticides in farmer fields favor the build up of natural enemy populations. Agronomist should urge farmers to adopt them and promote biological pest control in agro-ecosystems.

Table 1. List of parasitoids and predators, their hosts and habitats in agro ecosystem at Aralaganwila

Species name	Associated hosts and/or habitats	Remarks
1. <i>Atherigona</i> (<i>Acritochaeta</i>) <i>orientalis</i> Schiner (Diptera: Muscidae)	Parasitic on larvae of <i>Maruca testulalis</i> and <i>Vigna anguiculata</i> on green gram	Mostly sapro phytic on decaying materials and sometimes facultative on insect larvae (Anon, 2003).
2. Genus et sp. indet. (Diptera: Phoridae)	Larva parasitic on pupa of <i>Euproctis</i> sp. defoliator on <i>Cajanus cajan</i>	Some Phorid species parasitize on Lepidoptera, Coleoptera, Hymenoptera and Isoptera species (Anon, 2003)
03. Genus et sp. indet. (Diptera: Sarcophagidae)	Parasitic on defoliating lepidopteron insects on groundnuts	Some sarcophagus species show obligatory parasitism on Orthoptera, Lepidoptera and Coleoptera species (Anon, 2003). De Silva in 1961 reported the indigenous occurrence of sarcophagids
04. Genus et sp. indet. (Diptera: Syphidae)	Parasitic on tephritid fruit flies on pods of cucurbits	

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| 05. <i>Carcelia</i> sp. (Diptera: Tachinidae) | Parasitic on lepidopteron defoliator on <i>Cucurbita moschata</i> | <i>Carcelia</i> sp. is locally found and hosts include <i>Orgyia postica</i> , <i>Orgyia</i> spp., <i>Helicoverpa</i> sp. and <i>Euproctis</i> sp. and many other lepidopteron (Anon, 2003; De Silva, 1961). |
| 06. <i>Exorista</i> sp. (Diptera: Tachinidae) | Parasitic on <i>Euproctis</i> sp., defoliator on groundnuts | Major parasitoid of Lepidopteron, Coleoptera, and Hemiptera species (Anon, 2003). Indigenous <i>Exorista</i> species was reported by De Silva (1961) |
| 07. <i>Peribaea</i> sp. (Diptera: Tachinidae) | Parasitic on defoliating larvae of <i>Euproctis</i> sp. on groundnuts and pigeon pea and aphid predatory Syrphids on cucumber and radish | Tachinids parasitize mostly on Lepidoptera and sometimes on Orthoptera, Coleoptera and Hymenoptera larvae (Anon, 2003). De Silva (1961) reported several parasitic Tachinid species in Sri Lanka. |
| 08. <i>Sisyropa</i> sp. (Diptera: Tachinidae) | Parasitic on defoliating Psychid and <i>Euproctis</i> larvae on <i>Cajanus cajan</i> and Syrphids (predator of aphids) on cucumber and radish. | Tachinids parasitize mostly on Lepidoptera and sometimes on Orthoptera, Coleoptera and Hymenoptera larvae (Anon, 2003). De Silva (1961) reported several parasitic Tachinid species in Sri Lanka. |
| 09. <i>Zygobothria</i> sp. (Diptera: Tachinidae) | Parasitic on larvae of <i>Acherontia atropos</i> on <i>Solanum</i> sp. | Tachinids parasitize mostly on Lepidoptera and sometimes on Orthoptera, Coleoptera and Hymenoptera larvae (Anon, 2003). De Silva (1961) reported the occurrence of several parasitic Tachinid species in Sri Lanka |
| 10. Genus et sp. indet. (Diptera : Tachinidae: Eryciini) | Parasitic on larvae of Psychidae on <i>Asparagus</i> crop. | Eryciini parasitize mostly on Lepidoptera species (Anon, 2003). De Silva in 1961 reported indigenous parasitic Tachinids species |
| 11. <i>Leucopis</i> sp. (Diptera: Chamaemyiidae) | Larva predatory on <i>Aphis gossypii</i> on cucumber and chili and <i>Aphis craccivora</i> Koch on groundnuts | Larvae of Chamaemyiidae are predatory on Homoptera and Hemiptera species (Kesten, 1975, Anon, 2003) |
| 12. Genus et sp. indet. (Diptera: Chloropidae) | Associated with aphid and mealy bug infested foliages of cucumber, cowpea and chili | Some are predatory on eggs of spiders, mantids and aphids (Nartshuk, 1976; Anon, 2003) |

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| 13. Genus et sp. indet. 2 species (Diptera: Nematocera) | Preys on larvae of <i>Syrphid</i> sp. or aphids on cabbage, radish, cowpea, cucumber and egg plant | Nicastro <i>et al.</i> , (1995) |
| 14. <i>Ischiodon scutellaris</i> Fabricius (Diptera: Syrphidae) | Larva predatory on <i>Aphis gossypii</i> complex on cucumber and chilli | Larva preys on aphid, psyllid and coccinellid species (Anon, 2003). The species is present locally (De Silva, 1961). |
| 15. <i>Paragus yerburiensis</i> Stuckenberg (Diptera: Syrphidae) | Larva was predatory on <i>Aphis gossypii</i> on cucumber | A specialized predator species of aphids, psyllids and some other pest groups (Anon, 2003). Several syrphid species were present locally (De Silva, 1961). |
| 16. Genus et sp. indet. (Diptera: Stratiomyidae) | Predatory on insect species on chilli crop | Anon (2003) |
| 17. <i>Araneus</i> sp. (Araneae: Araneidae) | Predatory on insect species on the foliage of groundnuts, cowpea, <i>Cajanus cajan</i> , chilli and <i>Solanum</i> sp. | A nocturnal predator preys on larvae and adults of Lepidoptera and nymphs of Hemiptera and Homoptera species (Naton, 1976). |
| 18. <i>Larinia</i> sp. (Araneae: Araneidae) | Predatory on insects associated with the foliage of chilli and cowpea | Predatory on Hemiptera species (Anon, 2003). |
| 19. <i>Cheiracanthium</i> sp. (Araneae: Clubionidae) | Predatory on insects associated with the foliage of cucumber, groundnuts, chilli and <i>Cajanus cajan</i> | Predatory on Hemiptera, Diptera species (Anon, 2003; Leech and Brown, 1994) |
| 20. <i>Clubiona</i> sp. (Araneae: Clubionidae) | Predatory on insect species on the foliage of cucumber | Predatory on Hemiptera species (Naton, 1976; Anon, 2003). |
| 21. <i>Aphantaulax</i> sp. (Araneae: Gnaphosidae) | Predatory on insect species infested on onion foliage | Naton (1976) described predatory behavior and description |
| 22. <i>Oxyopes</i> spp. (2 species) (Araneae: Oxyopidae) | Predatory on insects infested on foliage of groundnuts and <i>Solanum</i> sp. | Diurnal hunting predators on Hemiptera, Lepidoptera, Diptera, Orthoptera, Coleoptera and Thysanoptera species in fields of highlands and lowlands (Anon, 2003). It builds no webs (Schepard <i>et al.</i> , 1987; Quezada <i>et al.</i> , 1976). |

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| 23. <i>Bianor</i> sp. (Araneae: Salticidae) | Predatory on insects infested on chilli crop | |
| 24. <i>Phintella</i> sp. (Araneae: Salticidae) | Predatory on insect infested on foliage of <i>Solanum</i> sp. | Predatory on mirid bugs and leafhoppers (Homoptera) and (Anon, 2003) |
| 25. <i>Plexippus petersi</i> Karsch (Araneae: Salticidae) | Predatory on <i>Musca domestica</i> inside the shelter | Predatory on leafhoppers (Homoptera) and <i>Musca domestica</i> (Diptera) (Meah <i>et al.</i> , 1986; Anon, 2003) |
| 26. <i>Runcinia</i> sp. (Araneae : Thomisidae) | Predatory on insects infested on chilli foliage | (Mel'nik <i>et al.</i> , 1976) |
| 27. <i>Thomisus</i> sp. (Araneae: Thomisidae) | Predatory on insects infested on foliages of chilli, groundnuts, <i>Solanum</i> sp. and <i>Cajanus cajan</i> | Naton (1976) described predatory behavior and description |
| 28. <i>Brumoides suturalis</i> Fabricius (Coleoptera: Coccinellidae) | Larva predatory on nymphs and adults of aphids on cucumber and chilli, green gram and cowpea and mealy bugs infested on <i>Solanum violaceum</i> | Common ladybird beetles and larva is a general predator on aphids and other Homoptera species. Widespread in Oriental region (Anon, 2003). |
| 29. <i>Ophionea</i> sp. (Coleoptera: Carabidae) | Adults predatory on the defoliating larvae infested on sesame, maize, green gram, pigeon pea and cowpea. | Beetles and the larvae are active predators (Schepard <i>et al.</i> , 1987) |
| 30. <i>Cheilomenes sexmaculata</i> Fabricius (Coleoptera: Coccinellidae) | Larva predatory on aphids infested on Maize, cucumber, chilli, groundnut, green gram and cowpea foliages and on mealy bugs infested on <i>Solanum violaceum</i> | Common ladybird beetles. Larva is a general predator of aphids and other Homoptera species. Widespread in the Oriental region (Anon, 2003; De Silva, 1961). |
| 31. <i>Coccinella transversalis</i> Fabricius (Coleoptera: Coccinellidae) | Larva predatory on aphids infested on maize, cucumber, chilli, green gram and cowpea foliages | Common ladybird beetles. General predators of aphids and other Homoptera species and <i>Helicoverpa armigera</i> . Widespread in the Oriental region (Anon, 2003). |

32. <i>Harmonia octamaculata</i> Fabricius (Coleoptera: Coccinellidae)	Larva predatory on aphids on maize and cucumber	Common ladybird beetles. General predators of aphids, other Homoptera species and <i>Cnaphalocrocis medinalis</i> . Widespread in the Oriental region (De Silva, 1961).
33. <i>Illeis</i> sp. (Coleoptera: Coccinellidae)	Predatory of aphid complex infested on chilli, pigeon pea, cowpea and green gram	De Silva in 1961 reported the occurrence of indigenous <i>Illeis</i> spp. predatory on aphids
34. <i>Micraspis discolor</i> Fabricius (Coleoptera: Coccinellidae)	Larva and adult predatory on Aphids infested on chilli and maize	Common ladybird beetles. This species feeds on aphids and other Homoptera species and also on some Hemiptera species.
35. <i>Propylea dissecta</i> Mulsant (Coleoptera: Coccinellidae)	Larvae predatory on Aphids infested on cucumber, chilli, cowpea and green gram	This was the first record from Sri Lanka. The species belongs to general predators on aphids and other Homoptera species. Widespread in the oriental region
36. <i>Scymnus latemaculatus</i> Motschulsky (syn. <i>Scymnus quadrillum</i> Motschulsky) (Coleoptera: Coccinellidae)	Larva preyed on <i>Aphis gossypii</i> complex infested on cucumber and chilli	The presence of <i>Scymnus</i> spp. was reported by De Silva in 1961. This is a general predator of aphid and widespread in Indian subcontinent (Kapur, 1942).
37. <i>Scymnus</i> spp. (Coleoptera: Coccinellidae)	Larva predatory on Aphids on cucumber, chilli and groundnut and Pseudococcids on <i>Solanum</i> spp.	The presence of <i>Scymnus</i> spp. was reported by De Silva in 1961. This is a general predator of aphid and widespread in Indian subcontinent (Kapur, 1942)
38. <i>Serangium parcesetosum</i> Sic. (Coccinellidae)	Larva predatory on <i>Coccidohystrix insolita</i> Green on <i>Solanum</i> spp. and nymphs and adults of <i>Aphis</i> spp. on groundnut and cucumber	Timofeyeva and Hoang Duc Nhuan (1979)
39. <i>Orius</i> sp. (Heteroptera: Anthocoridae)	Predatory on aphids and thrips infested on chilli	Predatory on aphids, thrips and mites (Hatala and Kiss, 2001; Takai, 1998)
40. <i>Anoplocnemis compressa</i> Dallas (Hemiptera: Coreidae)	Predatory of insects infested on <i>Cajanus cajan</i>	The presence of coreid species was reported by De Silva in 1961
41. Genus et sp. indet. (Hemiptera: Coreidae)	Predatory of insects infested on <i>Cajanus cajan</i>	The presence of coreid species was reported by De Silva in 1961

42. <i>Creontiades pallidifer</i> Walker (Hemiptera: Miridae)	Predatory on homopterans infested on chilli	Predator of whitefly (Urbaneja <i>et al.</i> , 2001)
43. <i>Camponotus</i> spp. (Hymenoptera: Formicidae)	Predatory on insects infested on chilli and maize	Predatory on <i>Coccus viridis</i> , some Lepidoptera and Coleoptera species (Anon, 2003; Youngs, 1983; Hughes <i>et al.</i> , 1994)
44. <i>Leptogenys</i> sp. (Hymenoptera: Formicidae)	Predatory on insects infested on <i>Vigna</i> sp.	Beneficial biological control agent in tropical forests (Anon, 2003; Dejean and Evraerts, 1997)
45. <i>Lophomyrmex</i> sp. (Hymenoptera: Formicidae)	Predatory on insects infested on cowpea, chilli and <i>Cucumis sativus</i>	Formicid insects are beneficial biological control agent in tropical forests (Anon, 2003)
46. <i>Meranophus bicolor</i> Guérin Minéville (Hymenoptera: Formicidae)	Predatory on insects on <i>Cucumis sativus</i>	Predatory on many species including <i>Callosobruchus</i> , <i>Lasioderma</i> , <i>Sitophilus</i> and <i>Araccerus</i>
47. <i>Paratrechina</i> sp. (Hymenoptera: Formicidae)	Predatory on insects infested on chilli and <i>Cucumis sativus</i>	Beneficial species for biological control (Anon, 2003)
48. <i>Polyrhachis exercita</i> Walker (Hymenoptera: Formicidae)	Predatory on insects infested on <i>Cucumis sativus</i>	Beneficial species for biological control (Anon, 2003; Dejean <i>et al.</i> , 1994; Hughes <i>et al.</i> , 1994)
49. <i>Solenopsis geminata</i> Fabricius (Hymenoptera: Formicidae)	Predatory on many insect species in uplands	Predatory on eggs and larvae of Lepidoptera and eggs of black bug (Anon, 2003; Shepard <i>et al.</i> , 1987)
50. <i>Tapinoma melanocephalum</i> F. (Hymenoptera: Formicidae)	Predatory on insects on <i>Cucumis sativus</i>	Hosts include insects of Phasmitidae and some mites (Anon, 2003; Osborne <i>et al.</i> , 1995)

CONCLUSION

Many indigenous natural enemy species are present in agro-ecosystem of the dry zone of Sri Lanka. Activities that favor the build up of their populations promote biological pest control in agro-ecosystems. Research and development programs are necessary for the discovery of such species, their potentials and technologies for biological pest control programs.

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