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BEHAVIOUR TO THE ADOPTION OF FERTILIZERS IN CULTIVATING MANGO IN BANGLADESH

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ABSTRACT

The study attempted to determine i) the extent of fertilizers adoption in mango cultivation ii) the relationships of each of the selected characteristics of the cultivators with their extent of adoption of fertilizers in growing mango. The study was conducted in sadar upazilla of Nawabganj district and the growers of the same were considered population. A sample of 100 mango growers was selected at random from previously selected 12 villages. The findings revealed that nearly half (49 %) of the mango growers had low adoption while 31 % had very low adoption and the rest (15%) had no adoption of fertilizers in their mango orchard. A little proportion of the mango growers used Urea (12-15 %) and Triple Super Phosphate (10-13 %) as per recommended dose while a very negligible proportion of the growers (3-7%) used Muriate of Potash as per recommended dose. Education, family education, family income, cosmopolitaness of the mango growers had significant positive relationships with the adoption behaviour of the mango cultivators towards fertilizer use.

Keywords: Mango, Fertilizers, Urea, Triple Super Phosphate, Muriate of Potash.

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INTRODUCTION

In Bangladesh self-sufficiency in food production was an imperative demand to feed her rapidly growing population since independence. Fortunately, in the recent time, satisfactory performance has been achieved in agriculture specifically in food grain production. The secret behind this success, in view of an expert, is intensification of agriculture resulting from regular use of high yielding varieties, expansion of irrigation facilities and wider use of agrochemicals. It is estimated that total consumption of fertilizers has increased by about four folds from 0.87 million tons in 1980-81 to 3.04 million tons in 1996-97 with a growth rate of 8.36% per annum (Islam, et. al., 1999). The achievement in food grain production has been settled at the cost of soil degradation, genetic erosion and environmental and human health hazards. But a very disappointing situation comes forward when we take a look in the production of horticultural crops.

For instance, it could be mentioned that 187220 metric tons of mango produced from 124715 acres of land (BBS, 2000) which is very poor as compared to the neighboring countries India and Pakistan. The aforesaid situation indicates that mango growers as well as concerned personnel are reluctant to adopt proper management of fertilizers in the mango orchard. It is also reported that spraying difficulties of pesticides in the large mango trees, insect infestation and disease attack during flowering period, falling of mango trees due to its heavy timber demand etc. were considered as the major factors behind such trend of low production in mango cultivation (Amzad & Ahmed, 1994). The above facts lead the researcher to analyse the extent of adoption of fertilizers what is actually being practiced at the farmers' level with the following specific objectives.

1. To assess the extent of adoption of fertilizers by the mango growers.
2. To study the extent of doses of urea, TSP and MP practiced by growers in cultivating mango
3. To explore the growers' characteristics associated with adoption behaviour of fertilizer.

MATERIALS AND METHODS

The study was conducted at Sadar upazilla of Nawabganj district. It is famous for varieties of quality mango production. The mango growers of Nawabganj Sadar upazilla were considered as the population of this study. A multistage sampling procedure was followed in selecting sample. Nawabganj Sadar upazilla consists of 14 unions. First, three unions were selected randomly. A list of all the villages of these three unions was prepared and from the total number of 31 villages 12 were selected randomly. A list of all mango growers was prepared with the help of local village leaders and the concerned Block supervisors. The total

number of such mango growers was 246 from which a sample of 100 was selected at random. The researchers themselves collected data through personal interviews with the help of interview schedule having both open and closed form questions after rapport development from door to door visit. Appropriate scales were developed to operationalize some of the characteristics of the mango growers. The statistical measures such as range, mean, standard deviation, percentage used to describe both the independent and dependent variables. To find out the relationship of selected characteristics of the mango growers with their adoption behavior of mango cultivators, Pearson's Product Moment Co-efficient of Correlation was used. 0.05 level of probability was used as the basis for rejection of any null hypothesis.

Measurement of adoption of fertilizers

This variable was measured by computing a fertilizer adoption score based on the extent of use of three inorganic fertilizers namely, Urea, TSP and MP for three age groups of mango plant. The fertilizer adoption score was computing by assigning scores as follows:

Fertilizer dose applied	Weighting scores
As per recommended dose	4
20 % deviation ($\pm$) of recommended dose	3
40 % deviation ($\pm$) of recommended dose	2
More than 40 % deviation ($\pm$) of recommended dose	1
No use	0

Adoption of fertilizer score of a mango grower was computed by summing up his/her scores obtained against the three fertilizers he/she used for three age groups of mango plants during 1998-99. Theoretically, the score could range from 0 to 36, zero indicating no use of fertilizers and 36 indicating proper use of fertilizers as per recommendation.

RESULTS AND DISCUSSION

It is an undeniable fact that individual's behaviour is greatly influenced by his inherent characteristics. And as such it is quite likely that individual's knowledge on mango cultivation is likely to be influenced by his characteristics. Considering this view in mind, some selected characteristics of the mango growers were ascertained and described. The basic statistical values in respect of the individual characteristics have been presented in Table 2.

Table 2: Characteristics profile of the mango growers with basic statistical values (N=100)

Characteristics	Scoring method	Categories	Number and percentage of growers	Mean score	Standard deviation
Age	Number of years	Young (27-35)	15	53.01	14.197
		Middle aged (36-50)	28		
		Old (>50)	57		
Education	Year of schooling	Illiterate (0)	5	7.95	5.109
		Can sign only (.5)	21		
		Primary (1-5)	6		
		Secondary (6-10)	36		
		Above secondary (above 10)	32		
Family education	Year of schooling	very low education (.3-4)	14	7.59	2.79
		low education (4.4-6.8)	22		
		Moderate education (7-9.8)	42		
		Higher education (above 10)	22		
Family size	Number of member	Small (1-4)	20	6.32	2.15
		Medium (5-6)	36		
		large (above 6)	44		
Farm size	Area in hectare	Small farm (.13-1.13)	14	3.159	2.178
		Medium farm (1.14-3.27)	48		
		large farm (above 3.27)	38		
Family income	Thousand (Taka)	Low income (15.80-60)	24	135	101.97
		Medium income (60-100)	21		
		High income (above 100)	55		
Innovativeness	Scale of score	Low innovative (14-35)	56	35.02	10.425
		Moderately innovative (36-60)	42		
		Highly innovative (above 60)	2		

Table 2 (Continued)

Cosmopolite- ness	Scale of score	Low cosmopolite (<0)	33	10.59	2.91
		Moderately cosmopolite (10-14)	57		
		Highly cosmopolite (above 14)	10		
Extension contact	Scale of score	Low extension contact(10-15)	52	15.55	4.78
		Medium extension contact (16-25)	46		
		High extension contact (above 25)	2		
Organizational participation	Scale of score	Low participation (2-9)	50	13.38	11.791
		Medium participation(10-20)	31		
		High participation(above 20)	19		

Adoption of fertilizers

The mango growers used all the three inorganic fertilizers namely, Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) in varying doses. Fertilizer adoption scores of the mango growers ranged from 0 to 22, the average being 12.41 and standard deviation of 6.31 against the possible range if 0 to 36. On the basis of these scores, the mango growers were classified into four categories: "No adoption" (0), "very low adoption" (upto 10), "low adoption" (11-17) and medium adoption" (18-22). The distribution of mango growers according to their adoption of fertilizer in mango is presented in Table 3.

Table 3. Distribution of mango growers according to their adoption of fertilizer in mango cultivation (N=100)

Categories	Number and percentage of growers	Mean	Standard deviation
No adoption (0)	15	12.41	6.31
Very low adoption (up to 10)	16		
Low adoption (11-17)	49		
Medium adoption (18-22) *	20		

About half (49 %) of the mango growers had "low adoption" of fertilizers in their mango orchard compared to 31 % of them having "very low adoption" and 15 % no adoption. A proportion of one-fifth (20 %) of the mango growers had "medium adoption" of fertilizers

meaning that these growers used fertilizers moderately deviating from the recommended doses. Thus, almost all the mango growers adopted fertilizer practices to the extent of “low to very low”. In fact, very few growers had mango plants below 10 years age and those who had some such plants did not use any fertilizer. However, very few used fertilizers as per recommended dose shown in Table 4, Table 5 and Table 6. These findings indicate the need to train the mango growers regarding the use of balanced fertilizers in mango cultivation.

Adoption of urea

Table 4 indicates that majority (85 %) of the mango growers used urea for cultivation of mango fruit. Each of 85 percent growers has three age groups of plants and they apply urea simultaneously for the same at varying doses.

Only a little proportion (12-15 %) of the mango growers used urea as per recommended dose. For the plants of 10-15 years 13 % growers used urea as per recommendation while 12 % for the plants of 16-20 years and 15 % for the plants of above 20 years. The rest overwhelming majority (85-88 %) used urea as per deviation mostly over than recommended dose regardless of age of the plants. It is an indication of the fact that the mango growers have no clear conception about the recommended doses of urea as well as the bad effects of over using the same.

Table 4. Distribution of the mango growers (n=100) according to their use of urea in plants of different age groups

Mango growers		Mango growers using urea by doses					Total
Not using urea	Using urea	Age of plant	Use as per recommended dose	Use 20 (+) deviation from recommended dose	Use 40 (+) deviation from recommended dose	Use >40(+) deviation from recommended dose	
1	2	3	4	5	6	7	8
		10-15 yrs	11 (13)	13 (15)	26 (31)	35 (41)	85 (100)
15	85	16-20 yrs	10 (12)	18 (21)	29 (34)	28 (33)	85 (100)
		>20 yrs	13 (15)	20 (24)	30 (33)	22 (26)	85 (100)

Figure in the parentheses indicate %

Adoption of Triple Super Phosphate (TSP)

Table 5 indicates that a significant proportion (85 %) of the mango growers used TSP for mango cultivation. Each of 85 percent growers has three age groups of plants and they apply TSP for each group of plants at varying doses.

The proportion of mango growers used TSP as per recommended dose was negligible (10-13 %). Among the users of TSP, 29-39 % used this fertilizer at the rate of 20 % deviation from the recommended dose for plants of different age groups compared to 17-38 % used this fertilizer at the rate of 40 % deviation and 21-39 % used at the rate of above 40 % deviation (Table 5). Thus, the overwhelming majority (at least 87 %) of the TSP users indiscriminately used this fertilizer to their plants ignoring the recommended doses proposed by the scientists for plants of different ages. It seems that the mango growers have yet to aware of the recommended doses of TSP as well as the adverse consequences of over using it.

Table 5. Distribution of the mango growers (n=100) according to their use of TSP in plants of different age groups

Mango growers			Mango growers using TSP by doses				Total
Not using TSP	Using TSP	Age of plant	Use as per recommended dose	Use 20 (+) deviation from recommended dose	Use 40 (+) deviation from recommended dose	Use >40(+) deviation from recommended dose	
1	2	3	4	5	6	7	8
		10-15 yrs	8 (10)	25 (29)	32 (38)	20 (24)	85 (100)
15	85	16-20 yrs	11 (13)	31 (37)	25 (29)	18 (21)	85 (100)
		>20 yrs	9 (11)	29 (34)	14 (17)	33 (39)	85 (100)

Figure in the parentheses indicate %

Adoption of Muriate of Potash

Three quarters (75 %) of the mango growers used MP for the production of mango. However, very small proportion (3-7 %) of them used MP as per recommendation (Table 6).

Table 6. Distribution of the mango growers (n=100) according to their use of MP in plants of different age groups

Mango growers			Mango growers using MP by doses				Total
Not using MP	Using MP	Age of plant	Use as per recommended dose	Use 20 (+) deviation from recommended dose	Use 40 (+) deviation from recommended dose	Use >40(+) deviation from recommended dose	
1	2	3	4	5	6	7	8
		10-15 yrs	2(3)	10 (13)	28 (37)	35(47)	75 (100)
25	75	16-20 yrs	3(4)	17 (23)	23 (31)	32(43)	75 (100)
		>20 yrs	5 (7)	21 (35)	26 (35)	23 (31)	75 (100)

Figure in the parentheses indicate %

The vast majority (93-97 %) of the mango growers was not found to follow the recommended rate as proposed by the expert. In case of MP management, it is found that a proportion of 31-47 % growers committed more than 40 % deviation from the recommendation while 31-37 % users caused 40 % deviation and 13-28 % of the same made 20 % deviation. In most cases deviation takes places at the farmers level in the form of over adoption. One-fourth of the mango growers did not use any MP fertilizer in their mango plants.

Relationship between dependent and independent variables

The ten characteristics of the mango growers were the independent variables of the study. The variables were: Age, education, family education, family size, farm size, family income, innovativeness, cosmopolitaness, extension contact and organizational participation of the mango growers. The dependent variables are adoption of fertilizers.

Table 7. Relationships between selected characteristics of the mango growers and their adoption of fertilizers in mango plants (N=100)

Selected characteristics of the growers	Correlation co-efficient (r) with dependent variable
Age	-0.065
Education	0.287**
Family education	0.304***
Family size	0.095
Farm size	0.035
Family income	0.208*
Innovativeness	0.149
Cosmopolitaness	0.259*
Extension contact	0.135
Organizational participation	0.166
Critical value	NS= Not significant
0.197P=0.05	* = Significant at $p<0.05$
0.265P=0.01	** = Significant at $p<0.01$
0.301P=0.001	***=Significant at $p<0.001$

The relationship between each of the ten selected characteristics of the mango growers with their adoption of fertilizers was studied by the test of co-efficient of correlation. The results of these tests are shown in Table 7. The four variables namely, education, family education, family income and cosmopolitaness of the mango growers were significantly correlated.

Education and adoption of fertilizers

The education of mango growers had a significant positive relationship with their adoption of fertilizers. This finding is similar with the findings of Jha, and Shaktawat (1972); Rajaguna (1973); Rajendra (1973); Shankar, (1979); Shukla, (1975); Islam and Kashem (1997). The important way in which literacy and education contribute to the adoption behaviour of a farmer is by expanding the horizon of his awareness and consciousness which makes him relatively more rational and innovative in farming activities (Dasgupta, 1989). The growers who had higher education also had higher adoption of fertilizers. Education enables a grower to gain accurate knowledge through using printed materials for information on agricultural innovations and thus increases their power of understandings. Consequently, their outlook is broadened and horizon of knowledge is expanded, which leads them for rapid adoption.

Family education and adoption of fertilizers

The family education of the mango growers had a significant positive relationship with their adoption of fertilizers. The growers having higher family education had comparatively higher extent of adoption. As has been discussed in the proceeding chapter, early awareness and technically accurate information of innovations become available to the family environment leading rapid adoption by the growers.

Family income and adoption of fertilizers

The existence of the positive relationship between the family income and adoption of fertilizers was found. This finding supports the findings of Hoque *et al.* (1988); Singh (1983); Patel and Patel (1973); Rajaguna and Satapathy (1973); Rajendra (1973). Growers with high family income and large farm size usually have more access to information sources and production inputs. Consequently, they become aware and enable to apply fertilizers in growing mango.

Cosmopoliteness and adoption of fertilizers

The finding, significant positive association between cosmopoliteness and adoption of fertilizers, is in conformity with the findings of Karim (1973); Islam and Kashem (1997). It implies that the growers who were more cosmopolite had adopted the fertilizer practices to higher extent. Due to cosmopolite behaviour of the growers, they might have interacted with various things, personalities, and organizations, which helped them gain knowledge on various aspects of using fertilizer. Consequently, their adoption of fertilizer becomes higher.

CONCLUSION

Based on the findings, the following conclusion may be drawn:

1. All most all the mango growers adopted fertilizer practices to the extent of "Low to very low". Among the users, very few growers used fertilizers as per recommended dose. One-fourth of the mango growers did not use any MP fertilizers in their mango plants while the case of urea and TSP were found improving to some extent.
2. Majority of the mango growers did not have clear conception regarding the recommended doses of fertilizers. This indicates the need for proper training of the mango growers on how to use production inputs.

3. Education and family education of the mango growers having positive relationship with their adoption of fertilizers, one may conclude that mango production can be improved if educational levels of the growers could be upgraded.
4. Family income is a factor for the adoption of production inputs like fertilizers in mango production. This indicates the need for increasing the income of the growers.
5. Mango production will continue to decline unless balanced fertilizers with proper dose are ensured to apply in the mango orchard.

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EFFECT OF INOCULUM, BORON AND VARIETY ON NUTRIENTS CONTENT AND THEIR UPTAKE BY PLANT TOPS OF SOYBEAN

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ABSTRACT

A pot experiment was conducted in the premises of Bangabandhu Sheikh Mujibur Rahman Agriculture University (BSMRAU), Gazipur, during rabi season, 1997-98 to observe the effects of inoculum, boron (B) and variety on nutrients content and their uptake by plant tops of soybean. The experiment was laid out in a complete randomized design with three replications of each treatment having two factors (i.e. variety and fertilizer). Two soybean varieties, PB-1 and G-2 were used in this experiment. Eight fertilizer treatment consisted of 7 levels of B (0, 0.50, 1.0, 1.5, 2.0, 2.5 and 3.0 kg B/ha designated as B₀, B_{0.5}, B_{1.0}, B_{1.5}, B_{2.0}, B_{2.5} and B_{3.0} respectively) and two levels of inoculum (with and without inoculum designated as I and I₀). Results indicated favourable effect of inoculum, B and variety on nutrients content and their uptake by plant tops of soybean. Inoculated plants along with B at the rate of 1.5 kg/ha produced significantly higher nutrients content and their uptake over inoculated plants. The highest N (3.78%), P(0.18%) and K (1.82%) contents and their uptake (81.15, 3.95 and 39.16 mg/plant) were produced by the application of B at the rate of 1.5 kg/ha with Bradyrhizobium inoculation. The soybean variety, G-2 was superior to Sohag (PB-1) in respect of nutrients content (N,P,K) and their uptake by plant tops of soybean. Inoculation alone also significantly increased higher nutrient uptake over control.

Key words: Soybean, boron, inoculum, nutrients, variety

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INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is an excellent source of protein. It contains 40-45% protein, 18-20% edible oil, 24-26% carbohydrate and a good amount of vitamins (Kaul & Das, 1986). It thus can play an important role in supplementing oil-protein deficiency in Bangladesh. It is being cultivated in Bangladesh as a minor crop and little attention is given on the improvement of its yield potentiality. Moreover, the yield of soybean is low in Bangladesh as compared to the other countries (Nasreen & Bhuiyan, 1997). There is a great possibility to increase its production by selecting high yielding varieties, applying adequate manures, fertilizers (both major and minor), seed inoculation and adopting proper management practices. Soybean, like other legumes, has the ability to fix atmospheric N through symbiosis with root nodule bacteria (*B. japonicum*) and thus enrich the soil fertility (Mahabal, 1986).

It fixes about 270 kg N/ha compared to 58 to 157 kg N/ha by other pulses (Hoque, 1978). This can meet around 80-85% of the crop's demand for nitrogen. Hanway and Weber (1971) noted that unfertilized but effectively nodulated soybean accumulated as high as 247 kg N/ha, while non-nodulated soybean even with 263 kg N/ha application accumulated only 198 kg N/ha. Boron(B) has a primary role in cell wall biosynthesis (Teasdale & Richards, 1990). Berger (1949) concluded that "the normal development of cell wall is upset when B becomes deficient".

Boron influenced the absorption of N, P, K and its deficiency changed the equilibrium of optimum of these three macronutrients (Raj, 1985). Boron deficiency in soil has been found to be associated with sterility in legumes and crucifers in some fertility trials recently carried out in Bangladesh (Jahiruddin, 1992).

Research work on the B fertilization in soybean and its effect on nutrient content and their uptake in plant tops of soybean is insufficient in Bangladesh. But the role of *Bradyrhizobium* inoculation, B application on various legumes are well recognized (Jain & Rewari, 1973; Howeler *et al.*, 1978; Hunt *et al.* 1981; Robson, 1983; Agbenin *et al.* 1990; Dwivedi *et al.*, 1992; Mahajan *et al.* 1994; Zaman *et al.*, 1996; Bhuiyan *et al.*, 1996, 1997 & Rahman *et al.* 1998). Research results on soybean are available in relation to single application of B or rhizobial inoculum, but no information is available regarding the effects of inoculum alone or along with different levels of B. Therefore, the pot experiment was conducted to study the effects of *Bradyrhizobium* inoculum, B and variety on nutrients content and their uptake by plant tops of soybean.

MATERIALS AND METHODS

The pot experiments were conducted in the premise of Bangabandhu Sheikh Mujibur Rahman Agriculture University (BSMRAU), Gazipur, Bangladesh during December, 1996 to February, 1997 to observe the effects of *Bradyrhizobium* inoculum, B and variety on nutrients content and their uptake of soybean. The experiment was laid out in a Complete Randomized Design with three replications of each treatment having two factors (i.e. variety and fertilizer). Two soybean varieties, PB-1 and G-2 were used in this experiment. Fertilizer treatments consisted of 7 levels of B(0, 0.50 , 1.0, 1.5, 2.0, 2.5 and 3.0 kg B/ha designated as B₀, B_{0.5}, B_{1.0} , B_{1.5} , B_{2.0} , B_{2.5} and B_{3.0} respectively) and two levels of inoculum (with and without inoculum designated as I and I₀).

Each pot (Wagner pot) was filled with 4.5 kg of previously washed and dried coarse sand. The sand was washed first with tap water and then with distilled water to make it free from plant nutrients as far as possible. Pots were arranged according to the experimental design and placed one meter apart from each other. Required amount of seeds of soybean (var. PB-1 and G-2) was inoculated with peat based inoculant (obtained from BARI) of *Bradyrhizobium* strain (RGM 980) immediately before sowing using gum arabic as the sticking agent. Seeds were sown on December 15, 1996. Necessary shading by newspaper was provided to preserve soil moisture until germination. Initially 3 plants were maintained in each pot, which was decreased to 1 at 10 days after emergence.

Just after the emergence of the seedlings, 500 ml modified Hoagland nutrients solution lacking B (Down & Hellmers, 1975; Haider *et al.*, 1991) was applied daily in each pot which was increased to 1 litre after 30 days of emergence. The excess solution was drained through the drainage hole. Molybdenum as sodium molybdate and boron as boric acid were applied in pot after 10 days of sowing according to treatments. For laboratory analysis, the plant was collected from each unit pot at flowering stage after 65 days from the date of emergence.

Plants were carefully uprooted with the help of a weeder, so that no nodule or plant root was left in the sand. Collected plants were brought immediately to the laboratory and then sand was removed from the roots keeping the nodules intact. These were separated from the shoots (Plant tops) at the cotyledonary node. Plants tops were also separated from root and dried in an oven at 65^o C for 48 hours and weighed. Oven dried shoots were put in a desiccators for chemical analysis. Data on nutrients content and their uptake by plant tops were analyzed statistically following aforesaid design and mean differences were adjudged by DMRT as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Nitrogen content and its uptake

Data on total N content and its uptake by plant tops as influenced by B fertilization with *Bradyrhizobium* inoculation are shown in Table 1. Average N content in plant tops varied from 3.39 to 3.78% due to the treatment variations. Nitrogen content in plant tops increased gradually with increasing rate of B application up to 1.5 kg/ha, but above that rate N content was decreased to 3.74%, 3.71% and 3.68% in IB_{2.0}, IB_{2.5} and IB_{3.0} treatments, respectively. N uptake by plant tops were also significantly increased with increasing rate of B application up to 1.5 kg/ha. Further addition of B (above 1.5 kg/ha) progressively decreased the N uptake by plant tops.

Maximum N uptake (81.15 mg/plant) was recorded with B application @ 1.5 kg/ha in presence of *Bradyrhizobium* inoculation which was 31.67% higher as compared to inoculated control treatments. Mahajan *et al.* (1994) reported that N content and uptake increased due to application of B (0.5 kg/ha). Agbenin *et al.* (1990) found higher N content in cowpea leaves due to application of B (3 kg/ha). Inoculation alone significantly increased 40.7 % higher N content in plant tops of soybean over control. (Table 2). Inoculated plants (IB₀) without B showed 60% higher N uptake as compared to uninoculated control treatment. The effect of variety on N content of the plant was also significant (Table 3).

The variety, G-2 was found to be superior to PB-1 in this respect. There was also significant difference between the varieties in respect of N uptake. The N uptake in G-2 variety was 26% higher as compared to PB-1.

Phosphorus content and its uptake

Phosphorus content and uptake by plant tops were affected by the treatments of inoculum and B (Table 1). The highest P content (0.18%) was recorded in inoculated plants supplied with 1.0 kg B/ha. The values in those treatment was 12.5% higher as compared with inoculated control plants.

Phosphorus content and its uptake varied with the variation of B treatments. The highest P content (0.18%) and its uptake (3.95 mg/plant) were noted in IB_{1.0} and IB_{1.5} treatments, respectively.

Table 1. Effect of boron with inoculation on N, P and K content and their uptake by plant tops of soybean at flowering stage

Treatment	Nutrient content in plant tops (%)			Nutrient uptake by plant tops (mg/plant)		
	N	P	K	N	P	K
I ₀ B ₀	2.41 d	0.13 c	1.46 c	38.51 d	2.05 d	23.19 c
IB ₀	3.39 c	0.16 b	1.60 bc	61.63 c	2.84 c	28.31 bc
IB _{0.5}	3.62 b	0.17 ab	1.73 ab	68.91 bc	3.23 bc	33.09 ab
IB _{1.0}	3.68 ab	0.18 a	1.78 a	75.48 ab	3.67 ab	36.51 a
IB _{1.5}	3.78 a	0.18 a	1.82 a	81.15 a	3.95 a	39.16 a
IB _{2.0}	3.74 a	0.18 a	1.80 a	79.15 ab	3.84 ab	38.02 a
IB _{2.5}	3.71 ab	0.18 a	1.79 a	75.24 ab	3.71 ab	36.27 a
IB _{3.0}	3.68 ab	0.18 a	1.78 a	72.41 ac	3.52 ab	35.13 a
LSD(01)	0.11	0.01	0.16	11.50	0.66	6.36
CV(%)	1.98	7.8	5.82	10.53	12.47	11.94

Figures in column having common letter(s) do not differ significantly at 1% level of significance by DMRT.

The values under higher levels of B were identical. Mahajan *et al.* (1994) observed that application of B (0.5 kg/ha) increased P content and uptake in groundnut kernels. *Bradyrhizobium* inoculation alone had 23.08% increased P content in plant tops as compared to uninoculated control treatment (Table 2). *Bradyrhizobium* inoculation alone also increased higher P uptake as compared to uninoculated control treatment. Individual effect of variety on P content in plant tops was not significant (Table 3) but the effect of variety on P uptake by plant tops was significant. Variety, G-2 was found to be superior to PB-1 in respect of P uptake.

Table 2. Effect of inoculum on N, P and K content and their uptake by plant tops of soybean at flowering stage

Treatment	Nutrient content in plant tops (%)			Nutrient uptake by plant tops (mg/plant)		
	N	P	K	N	P	K
Control	2.41 d	0.13 c	1.46 c	38.51 d	2.05 d	23.19 c
Inoculum	3.39 c	0.16 b	1.60 bc	61.63 c	2.84 c	28.31 bc

Figures in column having common letter(s) do not differ significantly at 1% level of significance by DMRT.

Potassium content and its uptake

Data on K content and its uptake by plant tops as influenced by boron with *B. japonicum* inoculation are shown in Table 1. Potassium content and its uptake by plant tops varied significantly with the variation of B treatments. Increment of B level up to 1.5 kg/ha had showed increasing trend of K content and its uptake by plant tops. The higher values (1.82% and 39.16 mg/plant) were observed in IB_{1.5} treatment which was identically followed by IB_{2.0} (1.8% and 38.02 mg/plant).

The lowest K content (1.46%) and uptake (23.19 mg/plant) were noted in absolute control (I₀B₀) treatment. Agbenin *et al.* (1990) reported that K content in cowpea leaves increased with increasing level of B (3 kg/ha) application. Inoculation with *Bradyrhizobium japonicum* strain had substantial increment in K content and uptake in soybean plant (Table 2). The mean values as recorded in IB₀ treatment (1.60% and 28.31 mg/plant) were 9.6% and 22.0% higher than that in uninoculated control (I₀B₀) treatment.

The effect of variety on K content in plant tops was significant (Table 3). The variety, G-2 seemed to contain an average of 4.2% higher K content as compared to PB-1. The nutrients uptake by G-2 variety was significantly higher (26.9%) than the other one. Interaction effects of variety and fertilizer have been found insignificant.

Table 3. Effect of variety on N, P and K content and their uptake by plant tops of soybean at flowering stage

Treatment	Nutrient content in plant tops (%)			Nutrient uptake by plant tops (mg/plant)		
	N	P	K	N	P	K
PB-1	3.46 b	0.17	1.68 b*	61.13 b	2.99 b*	29.71 b
G-2	3.57 a	0.17	1.75 a	76.96 a	3.71 a	37.71 a

Figures in column having common letter(s) do not differ significantly at 1% level of significance by DMRT.

* Significant at 5% level.

CONCLUSION

From the study, it may be concluded that the effect of inoculum, boron and variety on N, P, K concentration and their uptake by plant tops of soybean were found significant. Response of boron at the rate of 1.5 kg. B/ha with *Bradyrhizobium* inoculum were the best in respect of N, P and K content and uptake by plant tops of soybean at flowering stage. Results also indicated that the soybean variety, G-2 performed better in comparison to PB-1 variety.

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EFFECT OF SOWING DATE ON THE VIABILITY AND VIGOUR OF TOSSA JUTE (*Corchorus olitorius* L.) SEED IN LATE SOWN CONDITION

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ABSTRACT

Quality of tossa jute seed obtained from different sowing dates was evaluated by using germination test, speed of germination, seedling evaluation test, electrical conductivity and accelerated ageing test. It was found that sowing date had a small effect on seed viability, but had larger effect on seed vigour. Germination percentage ranged from 87.00 to 97.7 in O-9897 and 78.25 to 95.75 in OM-1. The seeds obtained from 5th October sowing showed the lowest germination percentage in both the varieties. Seedling growth of the variety OM-1 was better than that of O-9897 and 5th October sowing produced the lowest seedling dry weight in both the varieties. Electrical conductivity of seeds of O-9897 was higher than seeds of OM-1. In O-9897, it varied from 254 to 322 $\mu\text{S cm}^{-1}$ and in OM-1 it varied from 250 to 306 $\mu\text{S cm}^{-1}$. In general, ageing rate of OM-1 was faster than O-9897. Germination percentage of seeds decreased gradually with the increase in ageing time. Sowing dates also influenced on the ageing pattern of jute seeds. Seeds collected from 5th October sowing ended its life only at 4 days of ageing. While jute seeds obtained from July-August sowing completed its life by five days ageing. Jute seeds produced from September sowing was much better than that of other sowings and took 6 days of ageing to end their lives. Among the three dates of September sowing, jute seeds obtained from 15th September were superior in terms of germinability of aged seeds.

Keywords : Jute, sowing time, seed, *Corchorus olitorius*.

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INTRODUCTION

Jute (*Corchorus* spp.) is the main cash crop of Bangladesh and plays an important role in Bangladesh economy. Nearly, 1.06 million tons of jute is produced from an area of 0.086 million hectares of land (BBS, 2000). Bangladesh earns about 6% of the total foreign exchange by exporting raw jute and jute goods. Although jute is cultivated in Bangladesh from an ancient time but its production is in declining trend. The main reason of declining jute production in Bangladesh is its lowering price in international market as well as narrowing area. Such decrease of jute area predicted a great challenge to sustain jute production in Bangladesh.

Jute production in Bangladesh may be sustained by increasing fibre yield in unit area. Although yield is the function of genetics and environment, quality seeds stand first in yield improvement of any crop. High quality seed is the basic input and the use of other inputs and technologies of crop production are worthless if quality seed is not ensured. Therefore, production of quality jute seed is the first step of higher productivity of jute crop.

Traditionally, jute seed is produced from fibre crop where seed is sown in the month of March-April and a small portion of crop is kept at the corner of the field after the harvest of fibre crop. As jute is a short day crop (Kundu *et al.*, 1959), it remains in vegetative phase upto October and then starts flowering. Such seed crops staying in the field, for long time face many natural hazards and produce poor quality seeds (Hossain *et al.*, 1994). Recently Bangladesh Jute Research Institute has developed late sown technology where seed crop is established in the month of August-September instead of March-April. But adequate studies have not been done in relation to seed quality of late sown jute over a wide range of sowing times.

Qualitative parameters of seed are genetically controlled but their expression is better under suitable environmental and technological conditions (Blum & Pnuel, 1990). Several authors (Srivastava *et al.*, 1976; Salim and co-workers, 1997) reported that sowing time is one of the important factors that affect differently on seed quality of different crops.

Balles *et al.*, (1978) observed that July sowing increased soybean seed viability and vigour compare to May or June sowing, while Castillo *et al.*, (1994) did not find any effect of sowing times on quality of pea seeds. Such information relating to effect of sowing times on seed quality of late tossa jute are yet to be elucidated. Therefore, the present study aims to determine the effect of sowing date on the seed quality of tossa jute in late sowing condition.

MATERIALS AND METHODS

The experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during July 2001 to March 2002. The location of the experimental site was 24°N latitude and 90°16' longitude with an elevation of 8.4 meters above mean sea level. The soil of the experimental field belonged to shallow reddish-brown terrace type under Salna series of Madhupur tract. The soil was silty clay in nature, containing 33% clay, 30% silt and 26% sand with a pH 6.5.

The climate was sub-tropical in nature having frequent rainfall during August, September and October with gradual fall of temperature from the month of October. Important meteorological parameters viz. mean maximum and minimum temperature, relative humidity and rainfall experienced by the seed crop during growing season are shown in Figure 1.

Two varieties of tossa jute namely O-9897 and OM-1 were sown at ten days interval on 15 July, 25 July, 5 August, 15 August, 25 August, 5 September, 15 September, 25 September and 5 October, 2001.

The design of the experiment was split plot with three replications. Unit plot size was 4m x 3m and distance between plot to plot was 1m. Sowing times were assigned in main plots and varieties in sub plots.

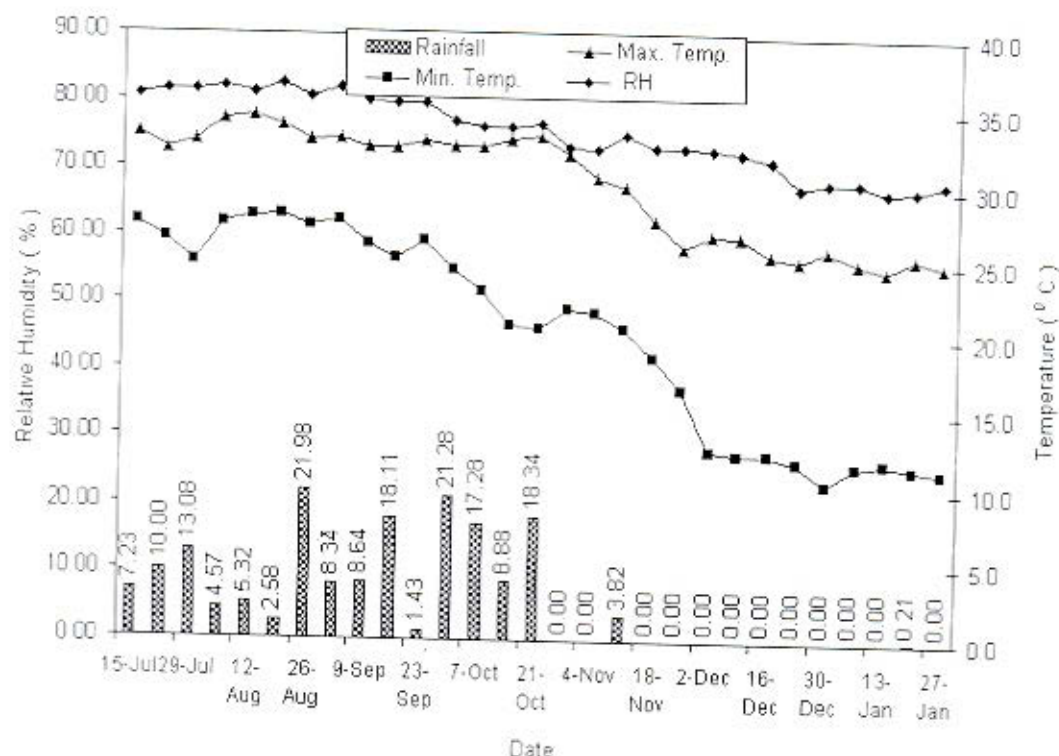
The crop was fertilized with urea, triple super phosphate and muriate of potash at the rate of 220-153-20 kg ha⁻¹. One-third of urea and all other fertilizers were applied as basal during final land preparation. Rest of the urea was top dressed in two equal amounts at 20 and 35 days after sowing. Jute seeds were sown at the rate of 2.5 kg ha⁻¹ in 30 cm apart rows. Light irrigation was given just after sowing for better establishment of the seedlings. The excess seedlings were thinned out at 20 days after sowing. Two weedings were also done at 20 and 35 days after sowing just before the top dressing of urea. Miticide, insecticide and fungicides were sprayed prophylactically with recommended doses to protect the crop from insect-pests.

When 70% pods attained brown colour, then it was considered as ready for harvesting. The harvested crop from each sowing date was dried in the sun for 5 days. Jute seeds were then threshed out by beating the pods with stick, cleaned and dried in the sun on the cemented floor till its moisture comes down to 7-8%. The dried seeds from each sowing time were stored in airtight plastic containers for determination of qualitative parameters.

Assessment of seed quality

The quality of jute seeds collected from nine sowing times was assessed by germination test, speed of germination, seedling evaluation test, electrical conductivity test and accelerated ageing test according to the following procedures.

Fig 1



$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

Speed of germination

The speed of germination of seed sample was monitored by counting the germinated seedling at an interval of 24 hours and continued for five days. Coefficient of germination and vigour index were calculated using the following formula (Copeland, 1976).

$$\text{Coefficient of germination} = \frac{100(A_1 + A_2 + \dots A_x)}{A_1T_1 + A_2T_2 + \dots A_xT_x}$$

Where

A = number of seed germinated

T = time corresponding to A

X = number of days to final count

$$\text{Vigor index} = \frac{\text{Number of seeds germinated (first count)}}{\text{Number of days to first count}} + \frac{\text{Number of seeds germinated (last count)}}{\text{Number of days to last count}}$$

Evaluation of seedling

Seedling shoot and root length were measured on day 5 of the germination test. Ten plant samples from each Petri dish were harvested and shoot and root length of individual seedling was recorded. The shoot and root were also dried at 70°C for 72 hours for dry matter yield.

Electrical conductivity test

For electrical conductivity test, 2g seeds of each sample were taken in a conical flask containing 50 ml de-ionized water and incubated at 20°C for 20 hours. After 20 hours, water of the beaker containing seeds was decanted in order to separate the seeds. The electrical

conductivity of the decanted water containing seed leachate was measured with a conductivity meter (Model – CM - 30ET). Five replicates of measurements were made for each sample of seed.

Accelerated ageing test

The seeds were kept in ageing chamber at 45°C and 100% relative humidity for a duration of 1, 2, 3, 4, 5, 6 and 7 days. After accelerated ageing, seeds were dried in the sun and the percentage survival of the seeds was determined by standard germination test at 30°C (Delouche & Baskin, 1973). The procedure of ageing technique is illustrated below.

Wire mesh net (9 x 9 mesh size) was used to make trays of 18 cm x 3.5 cm x 3 cm to contain 1000 to 1200 seeds. An iron sheet was used to fabricate 30 cm x 20.5 cm x 7.5 cm box. The box had two inner ridges to hold the wire mesh trays above the water level. A gap of 10 mm was maintained between the water surface and the wire mesh trays with seeds. The boxes were put inside an incubator at 45°C. The boxes were covered with lids and kept airtight so that no vapour can escape from the ageing box.

Transformation of data

Data which were obtained by counting and expressed as percentages, were transformed according to the following rules (Gomez & Gomez, 1984):

Rule 1: For percentage data lying with in the range of 30 to 70%, no transformation was used;

Rule 2: For percentage data lying with in the range either 0 to 30% or 70 to 100% but not both, a square root transformation was used;

Rule 3: For percentage data that did not follow the ranges specified in either rule 1 or rule 2, the arc sine transformation was used.

Statistical analysis

All data were analyzed by Analysis of Variance (ANOVA) (Gomez & Gomez, 1984) using MSTAT package and the means were compared according to Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Germination test

There were varietal differences for percent germination in late tossa jute seed which were further influenced by different sowing times. Germination test of seeds obtained from

different sowing times indicated that germination percentage of O-9897 was higher than that of OM-1 (Table 1). Germination percentage ranged from 87.00 to 97.75 in O-9897 and 78.25 to 95.75 in OM-1. Differences in germination percentage of two varieties may be due to their differences in seed size.

Germination of seeds obtained from 15 July to 25 September sowing of O-9897 showed the similar results (94.50 to 97.75%), while the seeds of 5th October sowing germinated the least (87.00%). The effect of sowing times on germination capacity of seeds of OM-1 was similar to that O-9897 but it was more affected under delayed sowing condition. Seeds obtained from 5th October sowing of OM-1 resulted in lowest percentage of germination (78.25%).

Jute seeds obtained from 5th October sowing might not have got enough time for maturation and immature seeds might be responsible for rotten seeds and development of more number of abnormal jute seedling. Figure 2 depicted that jute seed started to germinate within 24 hours and completed by 3 days.

This result is in disagreement with the findings of Verma and Arora (1978) who observed that *Corchorus olitorius* jute seed required five days to complete germination at 30°C. The seeds of O-9897 collected from September sowings germinated more than 70% within first 1 day. Except 5th October, seeds obtained from other sowings germinated more than 90% within 2 days and completed by 3 days. The rate of germination of seeds derived from 5th October sowing was much slower and took 4 days to complete its germination. On the contrary seeds collected from OM-1 of September sowing germinated around 40% within 1 day and around 80% within 2 days except seeds of 5th October sowing which took four days to complete its 90% germination.

This result also is in disagreement with the findings of Jain and Saha (1971) who found that 90% seeds of both the species germinated within first 24 hours at 30°C. The results revealed that seeds of O-9897 germinated faster than OM-1 and it was favoured in September sowings. Seeds collected from 5th October sowing of both the varieties germinated very slowly and it was profound in seeds of OM-1 than that of O-9897.

Table 1. Effect of sowing dates and variety on the germination percentage along with transformation made (shown in parenthesis) of tossa jute seed in late sowing condition

Sowing dates	Germination (%)	
	O-9897	OM-1
15 July	97.50aA (9.874)	95.00aA (9.747)
25 July	97.50aA (9.874)	95.75aA (9.785)
05 Aug	97.50aA (9.874)	95.50aA (9.772)
15 Aug	94.50aA (9.721)	93.00aA (9.644)
25 Aug	97.75aA (9.886)	94.00aA (9.695)
05 Sept	96.50aA (9.823)	94.25aA (9.708)
15 Sept	96.00aA (9.798)	92.00aA (9.598)
25 Sept	96.50aA (9.823)	94.50aA (9.721)
05 Oct	87.00bB (9.327)	78.25bB (8.846)

Means in the column with same small letter and in rows with same capital letter are not significantly different at 0.05 level by DMRT.

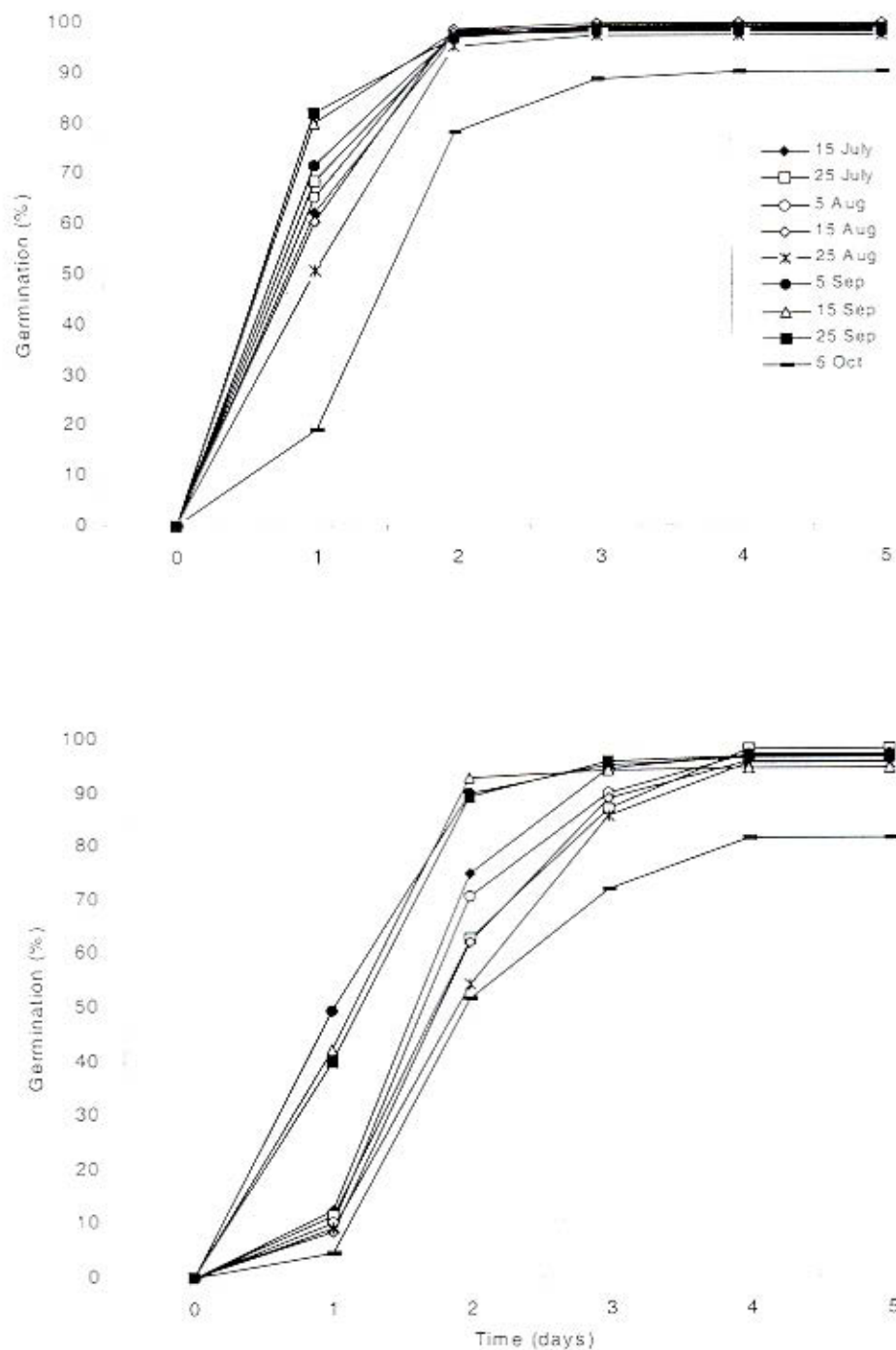


Figure 2. Effects of sowing dates on the rate of germination of tossa jute var. O-9897 and OM-1 collected from different sowing times

Seedling characteristics

Seedling characteristics like shoot length, root length, shoot dry weight, root dry weight and total dry weight were evaluated and mostly it varied significantly over the variety and sowing dates (Table 2). In general seedling growth of the variety OM-1 was better than that of O-9897 which might be attributed to its bigger seed size (Talukder and Ali, 1977). Bigger seeds of OM-1 supplied more nutrients to growing seedlings which enhanced the seedling growth. Sowing times effects indicated that 15th September sowing produced the highest shoot dry weight and 5th September produced the highest root dry weight in both the varieties. Although, highest total dry weight of O-9897 was found from the seedling of 15th September ($0.964 \text{ mg plant}^{-1}$) and that of OM-1 from 5th September sowing ($0.978 \text{ mg plant}^{-1}$), it was similar to seedling dry weight of other sowing times except 5th October. Seedling dry weight of O-9897 from 5 October sowing was only $0.780 \text{ mg plant}^{-1}$ and it was $0.878 \text{ mg plant}^{-1}$ in OM-1. Poor seed size resulted from short lived plants of 5th October sowing might have caused the poor seedling growth in both the varieties. Seedling growth is associated with seed size (Austin & Conden, 1967) and growth is dependent on either shoot or root growth or both.

Electrical conductivity test

Electrical conductivity test provides a quick decision about seed quality. Electrical conductivity is related to deterioration processes of seeds as degradation of cell membranes and leakage out of the cells (Delouche & Baskin, 1973). Other factors such as water quality, water quantity, period of imbibition, number of seeds tested and temperature also affect electrical conductivity test of seeds (Loeffler *et al.*, 1988).

Electrical conductivity differed significantly within the seeds of two varieties as well as the seeds obtained from different sowing times (Table 3). Electrical conductivity of seeds of O-9897 was higher than seeds of OM-1. In O-9897, it varied from 254 to $322 \mu\text{S cm}^{-1}$ and in OM-1 it varied from 250 to $306 \mu\text{S cm}^{-1}$. Higher electrical conductivity in the seeds of O-9897 may be associated with its smaller seed size as Mugnisjah and Nakamura (1986) observed higher electrical conductivity in smaller soybean seeds. Tao (1978) explained this phenomenon as the small seeds having a greater surface area per unit weight and induced higher rate of leakage out of the cells which increased electrical conductivity of seeds. Effects of sowing dates on electrical conductivity of seeds obtained from 15th July to 25th September sowings were inconsistent although it was profound on the seeds of 5th October sowing. In both the varieties higher electrical conductivity was observed from the small sized seeds of 5th October sowing where it was 322 and $306 \mu\text{S cm}^{-1}$ in O-9897 and OM-1 respectively.

Table 2. Effect of sowing date and variety on the 5 days old seedling characteristics of tossa jute seed in late sowing condition

Sowing dates	Shoot length (cm)		Root length (cm)		Shoot dry weight (mg plant ⁻¹)		Root dry weight (mg plant ⁻¹)		Total dry weight (mg plant ⁻¹)	
	O-9897	OM-1	O-9897	OM-1	O-9897	OM-1	O-9897	OM-1	O-9897	OM-1
15 July	4.74aA	4.42aA	2.55bB	2.78aA	0.703abB	0.745abA	0.155bcC	0.168bB	0.858bcB	0.913abA
25 July	4.68aA	4.44aA	2.78aA	2.89aA	0.703abB	0.745abA	0.180abA	0.172bB	0.883bB	0.917abA
05 Aug	4.44aA	4.48aA	2.70aA	2.82aA	0.715abA	0.754abA	0.169abA	0.176bB	0.874bB	0.930abA
15 Aug	4.57aA	4.40aA	2.47bB	2.77aA	0.681abB	0.738abA	0.165bB	0.175bB	0.846bcB	0.905abA
25 Aug	4.50aA	4.78aA	2.90aA	2.98aA	0.672abB	0.745abA	0.166bB	0.189abA	0.894abB	0.934abA
05 Sep	4.77aA	4.70aA	2.95aA	2.97aA	0.738aA	0.785abA	0.188aA	0.198aA	0.926abA	0.983aA
15 Sep	4.85aA	4.74aA	2.88abA	2.99aA	0.781aA	0.790aA	0.183abA	0.185abA	0.964aA	0.978aA
25 Sep	4.85aA	4.80aA	2.52bB	2.77aA	0.697abB	0.743abA	0.155bcC	0.190abA	0.894abB	0.914abA
05 Oct	4.75aA	4.66aA	2.38bB	2.58bB	0.637bB	0.703bB	0.143cC	0.168bB	0.780cC	0.878bB

Means in the column with same small letter and in rows with same capital letter are not significantly different at 0.05 level by DMRT.

Table 3. Electrical conductivity and speed of germination of two varieties (O-9897 and OM-1) of tossa jute seed in late sowing condition

Sowing dates	Electrical conductivity ($\mu\text{S cm}^{-1}$)		Vigour index		Coefficient of germination	
	O-9897	OM-1	O-9897	OM-1	O-9897	OM-1
15 July	261fG	256cH	80.33bcB	52.44cD	71.91cC	49.59bcE
25 July	254gH	250dI	83.46abA	47.96bcE	75.53bcB	42.49cF
05 Aug	270eF	257cH	82.00bB	48.54bcE	74.39bcB	44.71cF
15 Aug	271eF	258cH	73.63cC	44.56cE	66.71cC	41.61cF
25 Aug	280dE	250dI	79.87bcB	46.10cE	71.49cC	43.06cF
05 Sept	281cD	264bG	84.67abA	71.69aC	78.40bB	64.08aD
15 Sept	286cD	259bG	88.79abA	67.85aC	83.93abA	63.66aD
25 Sept	293bC	260bG	90.00aA	57.04bD	84.82aA	53.26bE
05 Oct	322aA	306aB	50.04dE	37.17dF	51.85dE	41.20cF

Means in the column (small letter) and in rows (capital letter) are not significantly different at 0.05 level by DMRT.

Speed of germination

Higher values of coefficient of germination or vigour index indicate higher speed of germination. There were varietal differences in speed of germination where the variety O-9897 showed higher vigour index and coefficient of germination (Table 3). The highest vigour index (90.00) and coefficient of germination (84.82) of O-9897 was observed from the seeds obtained from 25th September sowing. Contrary, highest vigour index (71.69) and coefficient of germination (64.08) of OM-1 was observed from the seeds of 5th September sowing. Vigour indices and coefficient of germination of OM-1 were much lower than that of O-9897 in all sowing times. The lowest vigour index and coefficient of germination of both the varieties were found from the seeds of 5th October sowing.

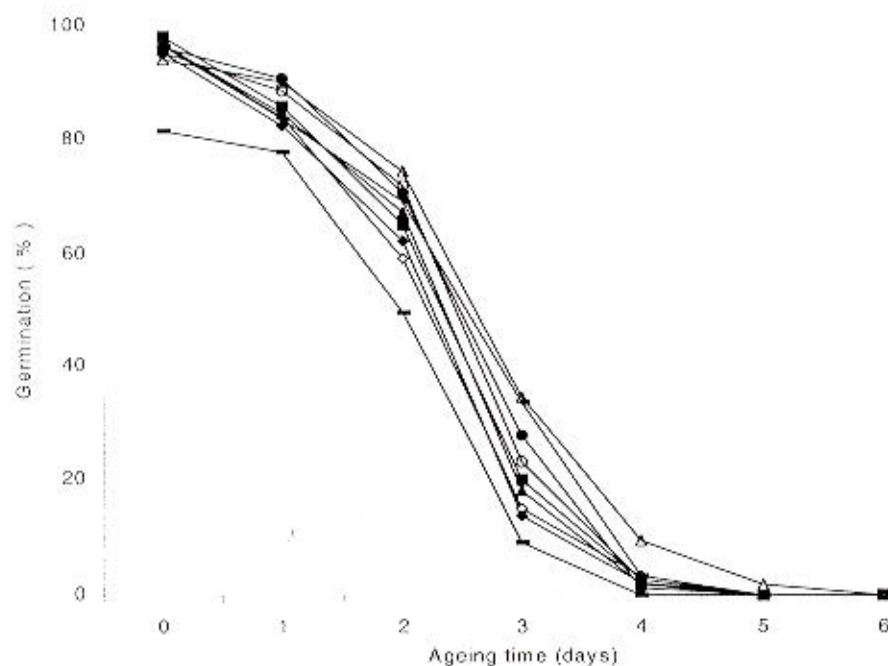
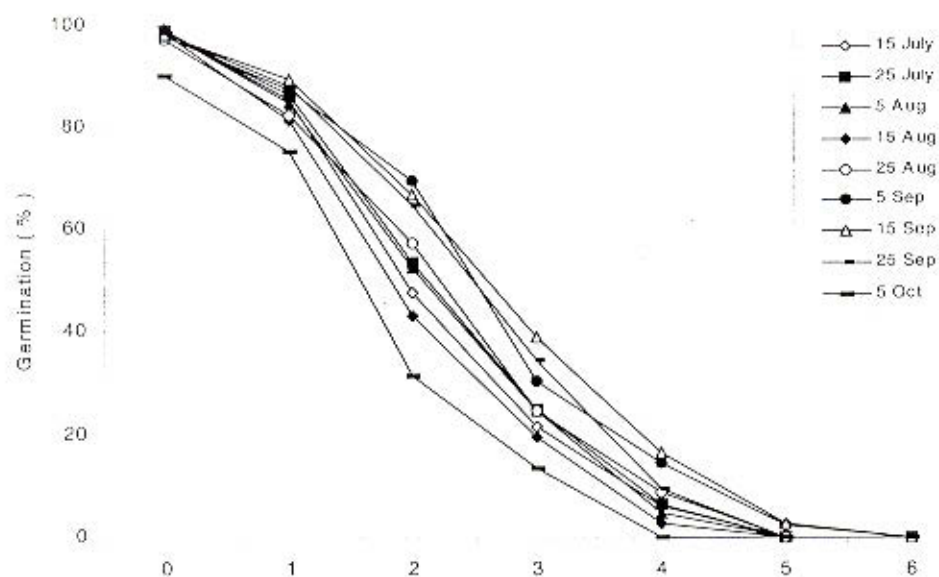


Figure 3. Effect of accelerated ageing on the germination percentage of jute seeds var. O-9897 and OM-1 obtained from different sowing dates

Accelerated ageing test

Accelerated ageing of seeds of two tossa jute varieties showed a distinct different scenario in germination pattern over time (Figure 3). In general ageing rate of OM-1 was faster than O-9897. Germination percentage of O-9897 seeds ranged 90.00 to 99.25 and OM-1 from 81.25 to 98.88 before ageing which decreased gradually with the increase of ageing time. Decrease in germination of aged seeds occurred due to either decline of phosphatase activity, alpha amylase activity and sugar content (Mitra & co-workers, 1974) or denaturation of protein (Nautiyal *et al.*, 1985) or decrease in glutamic acid decarboxylase activity within the seeds (Mora & Echandi, 1976) Such changes in physiological and biochemical processes in aged seeds results in either death of seeds or production of abnormal seedling at the end.

Sowing dates also influenced the ageing pattern of jute seeds. Seeds collected from 5th October sowing ended its life only 4 days of ageing. While jute seeds obtained from July-August sowing completed its life by five days. Jute seeds produced from September sowing was much better than that of other sowings and took 6 days of ageing to end its lives. Among the three dates of September sowing, jute seeds obtained from 15th September was superior in terms of germinability. Siddique *et al.*, (2002) also obtained variation in quality of pea seeds obtained from different sowing dates.

The results revealed that jute seed yield and seed quality (viability and vigour) varied significantly due to varieties itself as well as sowing dates. It was found that sowing date had a small effect on seed viability but had larger effect on seed vigour. Among the two varieties, sowing dates showed profound effect on seed quality. Late sowing till September considerably increased the seed quality of jute. Further delay in sowing reduced drastically seed quality of tossa jute. For the best quality seed, sowing of tossa jute by 5th September is recommended.

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IMPACT OF TRADE LIBERALIZATION ON AGRICULTURE: EVIDENCE OF BANGLADESH

JAHANGIR ALAM¹

ABSTRACT

Bangladesh has liberalized its economy through reduction of tariff rates and withdrawal of agricultural subsidies although the country, as a least developed one, was exempted from reduction commitments. The un-weighted average tariff rate for all agricultural products declined to 15 per cent in 2002-03 from 55 per cent in 1991-92. Subsidies on irrigation and fertilizer declined from 2.53 per cent of the value of unassisted output in 1988-89 to 0.45 per cent in 2002-2003. Moreover, there is a very low rate of subsidies on agricultural exports. However, the impact of trade liberalization policies was not favourable on the agricultural economy of Bangladesh. Total agricultural export increased by about 2 per cent and agricultural import increased by 9 per cent per year over the 1990s. Import of maize and pulses increased significantly over that period. Besides commercial import of food grains increased and the magnitude of food aid dropped over the same period. It revealed that Bangladesh had to face more loss than it enjoyed gains from eventualities of recent trade liberalization. In view of the above circumstances, more investment on yield increasing technology generation and adoption is necessary to meet the current deficit in food items and accelerate the speed of diversity in agriculture.

Keywords: Agricultural Economics, Bangladesh, Trade liberalization, Subsidies, Agricultural export, Agricultural import.

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INTRODUCTION

Keynes's interventionism got into problem towards the late 1970s with increased stagnation in output and employment accompanied by high inflation. The oil price shocks in 1972-73 and in 1979-80 put the world economy into a severe recession. Finance became the most crucial factor world wide. Consequently, a wave of economic liberalism provoked reform all over the world (Alam, 2004).

The green revolution in the 1960s, 1970s and after made a great contribution to increased food production in the developing countries. The high level protection of agriculture in the developed countries including USA and Western European countries also stimulated agricultural production. Moreover, as a result of overproduction in some of the developed countries, international prices of agricultural commodities started to decline. In recognition of this situation, the agricultural exporting countries began to reduce agricultural protection and deregulate production control. They also started negotiation on agricultural trade in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) to open the market with a view to reboot international food prices and increase trade (Ohaga, 1999). In April 1994, an agreement was signed at Marrakesh, Morocco integrating food into the global free commodity market. The principle of free market economy became applicable to all commodities including agricultural commodities.

Objective

The long-term objective of agreement on agriculture is to establish a fair and market-oriented agricultural trading system and initiate a reform process through the negotiation of commitments on support and protection. It was thought that a substantial progressive reduction in agricultural support and protection will be made over an agreed period of time that will result in correction and prevention of restrictions and distortion in world agricultural markets. The main objective of this paper is to make an assessment of Bangladesh's progress in the process of trade liberalization and analyze its impact on agricultural trade and production in the country.

MATERIALS AND METHODS

This study was based on secondary data collected from published and unpublished sources of various national and international agencies. The main sources of data were various publications of the Government of Bangladesh (GOB), Bangladesh Bureau of Statistics (BBS), Bangladesh Bank, World Bank and Food and Agricultural Organization of the United Nations (FAO). Some of the specific documents consulted were Bangladesh Economic Review (various issues), Handbook of Agricultural Statistics, Economic Trends, Statistical Yearbook of Bangladesh, National Accounts Statistics of Bangladesh and the Legal Text of

the Uruguay Round of Multilateral Trade Negotiations. In addition, various unpublished documents of the Export Promotion Bureau, National Board of Revenue, Ministry of Food, Ministry of Finance, and Ministry of Commerce were intensively used for obtaining data for this study.

Bangladesh liberalized her economy very quickly during early 1990s and continued her reform agenda even in later years. Data on tariff rates for different commodities and subsidies on agriculture were assembled for the last decade of the 20th century and after (reform period) for establishing trend of those variables over the years. It was then interesting to see what happened to Bangladesh economy after showing adherence to WTO rules on liberalization of trade in agriculture. For that purpose the trends of agricultural exports, imports, food aid and foreign assistance were examined by tabular and graphical forms. The impact of trade liberalization and reform was also analyzed on macro-economic performance of the country. Finally, the magnitude of current food deficit was determined by comparing recent dietary pattern with that of an expected pattern to reflect on policy issues for development of the agricultural sector in Bangladesh.

RESULTS AND DISCUSSION

Commitments on agriculture

The agenda for liberalization of agriculture consists of three components: market access, domestic support and export competition (WTO, 1995). The provisions under market access called for reduction of tariff and non-tariff barriers. Under domestic support, countries were required to reduce trade distorting domestic supports. Under the provision of export competition, countries were committed to reduce the value of export subsidies. Being a least developed country (LDC), Bangladesh was exempted from those reduction commitments.

Market access

The Uruguay Round Agreement on Agriculture (URAA) under its commitment on market access called for conversion of all non-tariff trade barriers into tariff equivalents, reduction of bound tariffs over time, and setting of low import tariffs for a fixed quota of import. Under tariffication, member countries were required to convert non-tariff barriers during the base period (1986-88) into tariff equivalents and to establish a base rate of duty for individual commodities covered by the URAA. The average reduction of tariffs after tariffication of non-tariff barriers was set at 24 per cent for developing countries and 36 per cent for industrialized countries. Industrialized countries had a time frame of six years within which to decrease their tariff levels while developing countries had 10 years. Minimum access had to be established at not less than 3-5 per cent of domestic consumption during the base

period (1986-88). As a LDC, Bangladesh was not required to undertake any such commitment, but she had to bind tariffs on all agricultural products.

Market access reform in Bangladesh began in the early 1980s with a reduction in import duties and was followed by a reduction in quotas in 1985 and a simplification of tariffs in 1986. The most intense period for trade reforms occurred in the 1990s with a movement toward lower tariff rates (Table 1).

Table 1. Un-weighted average tariff rates for different commodity groups in Bangladesh

Commodity group	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99
Primary commodity	55.2	47.7	34.9	31.6	24.6	22.3	21.9	21.4
Intermediate inputs	49.5	41.6	31.8	23.2	20.2	19.6	19.2	18.9
Capital goods	45.0	38.7	26.2	13.9	12.3	12.5	12.1	12.3
Final consumer goods	80.3	63.6	49.9	38.6	33.7	32.3	30.6	29.0
All commodities	57.3	47.4	36.1	25.9	22.3	21.5	20.7	20.3

Commodity group	FY00	FY01	FY02	FY03
Primary commodity	17.1	17.7	15.6	14.9
Intermediate inputs	15.6	15.7	20.1	21.0
Capital goods	16.1	11.3	7.0	8.0
Final consumer goods	31.0	29.6	26.0	22.6
All commodities	19.5	18.6	17.1	16.4

Source: National Board of Revenue.

In 2002-2003, the un-weighted average tariffs for all agricultural products declined to 15 per cent from 55 per cent in 1991-92. In a similar way, the import-weighted average tariff fell to 12 per cent from 23 per cent in the same period. The magnitude of decline in tariff rates for all other commodities showed almost the same trend (Table 2).

The reduction of tariff rates for most of the crops including food grains and pulses was quite significant (Table A-1). Under the minimum access level provision, the current access opportunity is more than the threshold for all commodities, except for potatoes and sugar.

Table 2. Import weighted average tariff rates for different commodity groups in Bangladesh

Commodity group	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99
Primary commodity	23.4	23.2	27.2	17.3	13.2	16.3	13.6	9.5
Intermediate inputs	24.1	23.7	22.9	26.3	22.7	22.2	21.3	21.3
Capital goods	18.7	18.5	16.2	12.5	9.5	10.4	8.2	8.1
Final consumer goods	47.3	36.5	36.7	26.5	24.1	23.1	20.1	17.6
All commodities	24.1	23.6	24.1	20.8	17.0	18.0	16.0	14.1

Commodity group	FY00	FY01	FY02	FY03
Primary commodity	13.6	14.9	9.4	12.0
Intermediate inputs	15.1	15.0	16.2	15.8
Capital goods	9.9	10.4	3.3	7.7
Final consumer goods	16.5	20.3	14.0	11.9
All commodities	13.8	15.1	9.7	12.4

Source: National Board of Revenue.

Domestic support

The Uruguay Round Agreement on Agriculture (URAoA) under its domestic support policies did not include expenditure on research, extension, disease control, food security, and rural development etc. (green box measures) in reduction commitments. Nevertheless, subsidies on inputs and price support for outputs were categorized under trade distorting

policies and were required to be kept within the limit of 5% of the value of output for the developed countries, and 10% for the developing countries. The total aggregate measure of support (AMS) was to be reduced by 20% for developed countries and 13.3% for developing countries (with no reduction for LDCs) over the implementation period.

Bangladesh provides support to agricultural research, extension, training, marketing and infrastructure that are nondistortionary in character. These supports fall under the green box area and are excluded from AMS reduction commitments. During the 1970s and early 1980s agricultural inputs were heavily subsidized and price support for agricultural output were also significant. These subsidies and supports were gradually reduced and became quite insignificant during the 1990s. Table 3 shows that Bangladesh did not provide any price support to any of the agricultural commodities after the 1995-96 financial year. Subsidies on fertilizer and irrigation accounted for 2.53% of the value of unassisted output in 1988-89, which declined gradually to less than one-tenth of one per cent in 1998-99. The calculated producer subsidy equivalent (PSE) slightly increased over first three years of the new millennium, but still it hovers around a half of only one per cent, very insignificant in comparison with that of about 40% for European Union and 35% for OECD countries (Alam, 2004).

Table 3. Producer Subsidy Equivalent (PSE) in Bangladesh

Year	Input subsidy (% of unassisted output)	Price support (% of unassisted output)	Total subsidy (PSE)
1995-96	0.83	0.01	0.84
1996-97	0.62	0	0.62
1997-98	0.43	0	0.43
1998-99	0.08	0	0.08
1999-2000	0.21	0	0.21
2000-2001	0.24	0	0.24
2001-2002	0.48	0	0.48
2002-2003	0.45	0	0.45

Export subsidies

Under the commitment on export subsidies members were required to reduce the value of mainly direct export subsidies to a level 36 per cent below the 1986-90 base period level over the six-year implementation period, and the quantity of subsidized exports by 21

per cent over the same period. In the case of developing countries, the reductions were two-thirds of those of developed countries over a ten-year period and subject to certain conditions, there were no commitments on reduction of the costs of marketing of agricultural exports or internal transport and freight charges on export shipments. LDCs were not obliged to reduce export subsidies but were required to freeze such subsidies at the 1986-90 period levels.

Bangladesh declared no export subsidies in her schedule of UR commitments. However, there may be some elements of subsidies enjoyed by the country's export regime. They include a small amount of direct subsidy on export of vegetables, export subsidies in the form of lower interest rates than market interest rates, tariff concessions on import of capital machinery, and some sort of subsidy on export credit guarantee schemes.

It appears from discussion on market access, domestic support and export subsidies that Bangladesh liberalized her economy quite early even though there were time and exemption provisions for the country in the WTO rules.

This was due to pressure from international donors for reform and the country's inability to mobilize resources to support her development programmes without taking assistance from the donors. The country was not, however, benefited from such an early liberalization.

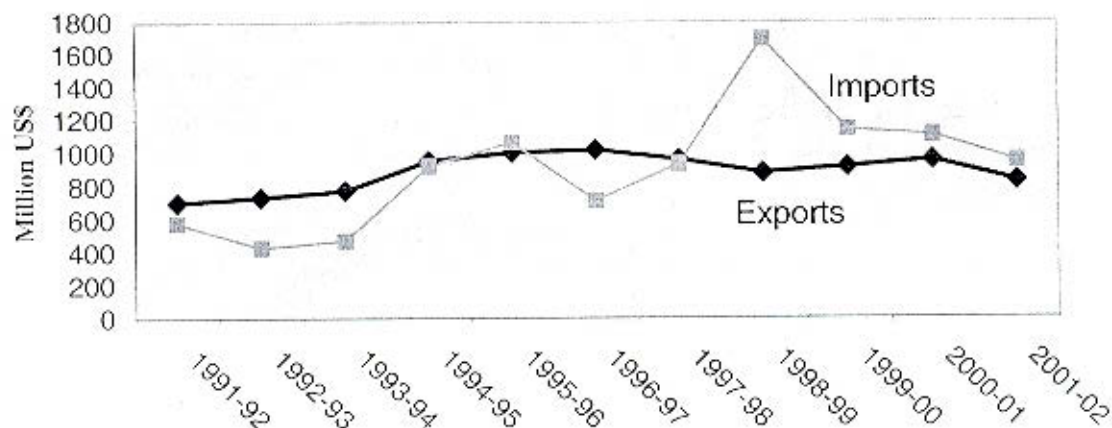
Impact of liberalization

It was interesting to see what has happened to Bangladesh economy after showing adherence to WTO rules on liberalization of trade in agriculture. First, the agricultural export and import situations of Bangladesh over the last eleven years (1991-92 to 2001-02) were examined.

It was observed that total agricultural export increased by about 2 per cent and agricultural import increased by 9 per cent per year over that period (Table A-2 and A-3). Figure 1 shows that agricultural imports superseded the export figure in 1995-96 and after that the import curve continued to flow over the export curve for rest of the years.

The total export earnings of the country increased by 11.9 per cent, while import expenditure increased by 9.59 per cent over the last eleven years. It may be mentioned that most export earnings in Bangladesh come through garment industry, where the bulk of the export earnings go back out of the country to pay for imported raw materials and machinery.

Fig. 1: Agricultural exports and imports.

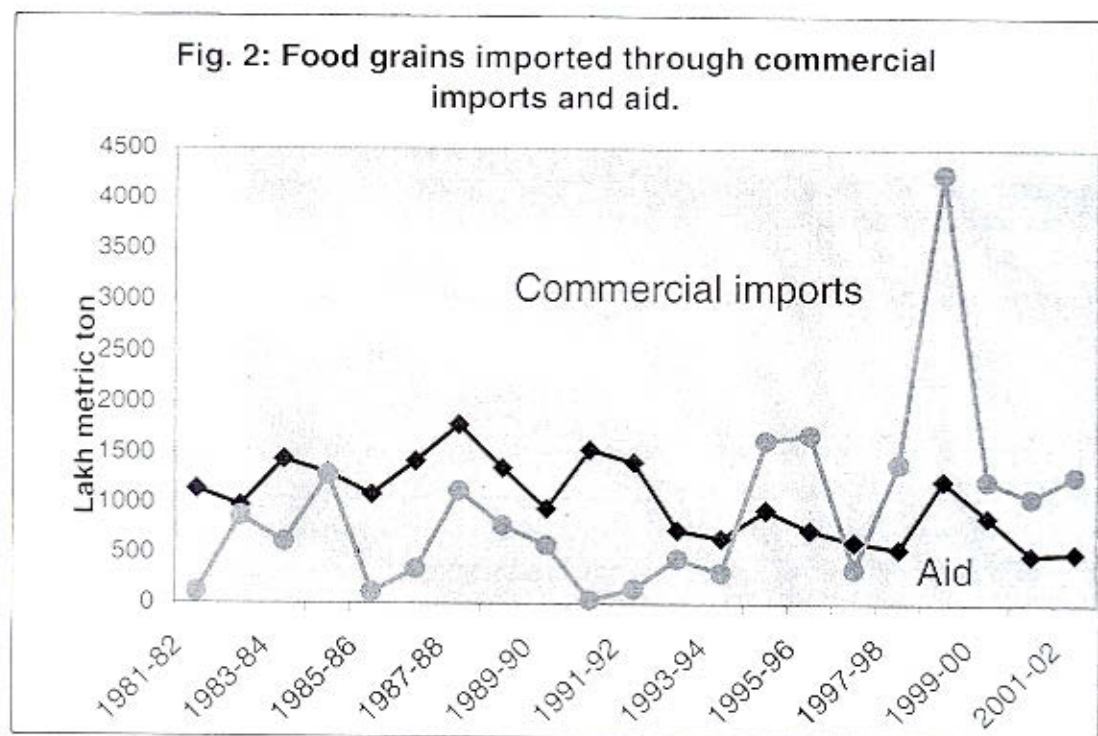


The average annual growth rate of export earnings were negative for jute, jute products, tea and total crops. However, the annual growth rate of export for greater agricultural sector was positive mainly due to high export earnings from frozen food, and hides and skins. The growth rates of import for all agricultural commodities were positive excepting wheat, and were very strong for pulses, maize, edible oil and raw cotton. The situation is unlikely to be changed unless duty-free and quota-free access of Bangladeshi products are ensured to developed countries.

The WTO member countries attending in Ministerial meetings recognized the special difficulties faced by LDCs and called for providing more technical assistance to LDCs for trade development. They also appealed for enhancing the magnitude of food aid and concessional loans to LDCs for their adjustment to a new global situation. Bangladesh, as a LDC, was supposed to be a beneficiary from those assistance. However, the country was not much benefited from such benevolent aid and assistance commitments in recent years.

Bangladeshi people depend more on cereals for consumption of food. The production of cereals has increased in the country over time, but at the same time imports of food-grains continued without any interval (Table A-4). This was not attributed exclusively to trade liberalization, but was also related to other domestic factors like weather, natural calamities, technological development, management of the production system and governance. What is

important to note is that the composition of food-grain imports has significantly changed after trade liberalization. The extent of food aid declined and the magnitude of commercial imports increased during the post liberalization period. Figure 2 shows that commercial imports crossed the line of food aid in 1994-95, reached its peak in 1998-99, and remained above the line of food aid till the last year of observation.



For further examination of the proposition, the growth and composition of foreign assistance to Bangladesh was analyzed. Data presented in Table A-5 shows that the annual growth rate of foreign assistance has declined over the last eleven years. The amount of foreign loans has slightly increased but the amount of donations significantly dropped during the period of liberalization. The evidence confirms the view that Bangladesh had to face more loss than it enjoyed gains from eventualities of recent trade liberalization.

The impact of trade liberalization and reform was not very positive on macro-economic performance. The growth rate of GDP stagnated at around 5 per cent and the overall budget deficit did not show any sign of improvement. The amount of foreign exchange reserve increased in absolute terms but declined in relative terms (in months of

imports). The rate of inflation has, however, declined over the years (Table A-6). The growth rates of real prices of most of the agricultural commodities have also declined.

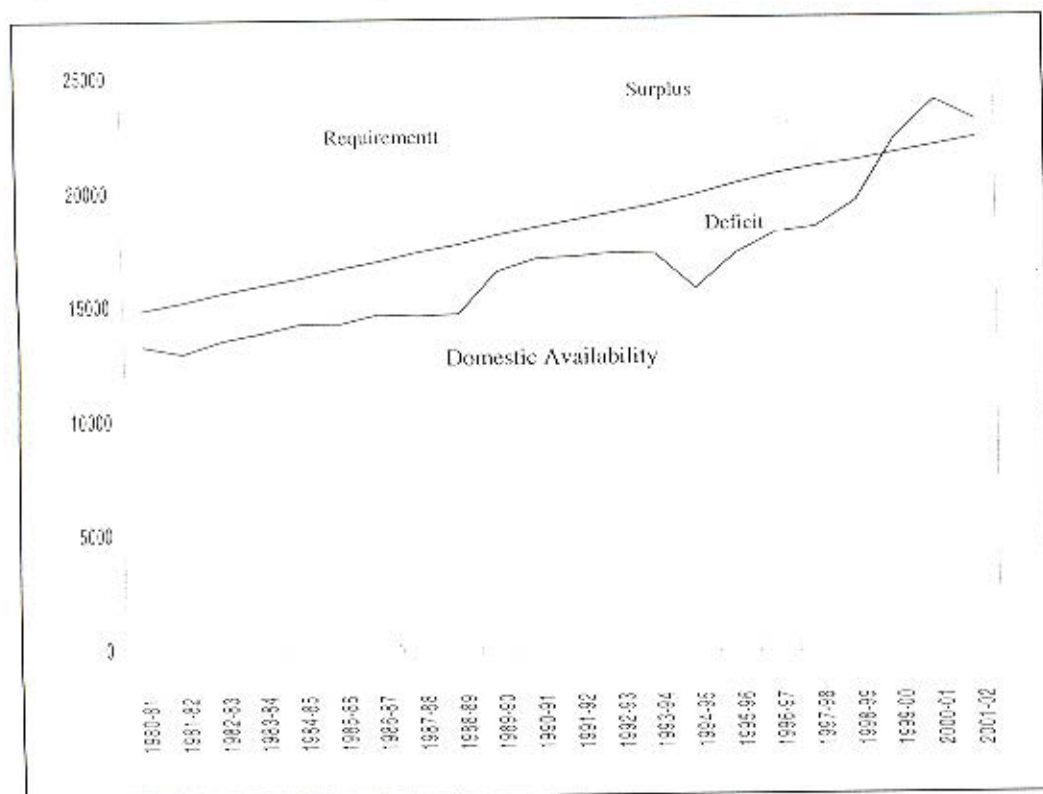
Food self sufficiency and Diversification of agriculture

Government of Bangladesh is committed to achieve self-sufficiency in food production. To that effect the farmers, agricultural scientists and policy makers are working hard for years together. Very recently, the country has produced little surplus of food grains (Figure 3), but there is still a huge deficit in production of other crops. The deficit is much larger for pulses, edible oil, vegetables, fruits and non-crop agricultural products (Table A-7), which has accentuated over time with the increase in population. It is possible to have a significant increase in production of these crops and non-crop sub-sectors provided new technologies are generated and policies are framed conducive to technology adoption, which will promote diversification. This is consistent with the policy of Bangladesh government (GOB, 2003a; 1999), which will require higher investment in agriculture and more support and subsidies in the process of technology generation and adoption.

CONCLUSION

Results of the study show that Bangladesh has liberalized her economy very quickly over 1990s through reduction of tariff rates and withdrawal of agricultural subsidies. However, there was hardly any positive impact of the liberalization efforts on the agricultural sector of Bangladesh. In fact, the growth rate of agricultural imports has much superseded the growth rate of agricultural exports and the country became more dependent on commercial imports of food grains and other agricultural commodities. Thus it appears that the country should now pursue a policy of protecting her agricultural sector and increase support and subsidies on yield increasing technology generation and adoption to meet the current food deficit and accelerate the speed of agriculture diversification.

Fig. 3: Food grain availability (000 MT) from domestic production, (excludes 11.58% of total production) deficit and surplus.



Source: MOA (2003).

Appendices

Table A-1: Un-weighted tariff rates and value-added tax on major agricultural products in Bangladesh

Group	CD+LF+IDS	VAT	SD	Total	CD+LF+IDS	VAT	SD	Total
1991-92					1992-93			
Rice	16.44	14.81	0.00	31.25	8.98	12.38	0.00	21.36
Wheat	16.44	0.00	0.00	16.44	8.98	0.00	0.00	8.98
Maize								
Sugar	81.44	12.25	0.00	93.69	81.48	12.25	0.00	93.73
Oilseed	41.44	0.00	0.00	41.44	27.73	0.00	0.00	27.73
Edible oil: crude	58.94	8.88	0.00	67.82	50.23	6.72	0.00	56.95
Edible oil: refined	93.44	14.05	0.00	107.49	83.48	12.55	0.00	96.03
Onion	31.44	0.00	0.00	31.44	31.48	0.00	0.00	31.48
Chilies(dry)	1.44	5.08	0.00	6.52	12.73	8.63	0.00	21.36
Potato	101.44	0.00	0.00	101.44	76.48	0.00	0.00	76.48
Milk	44.77	8.08	0.00	52.86	45.41	4.86	0.00	50.27
Pulses	21.44	0.00	0.00	21.44	16.48	0.00	0.00	16.48
1995-96					1996-97			
Rice	1.22	0.04	0.00	1.26	1.28	0.00	0.00	1.28
Wheat	8.72	0.67	0.00	9.39	8.78	0.68	0.00	9.46
Maize								
Sugar	31.22	4.71	0.00	35.93	31.28	4.74	0.00	36.02
Oilseed	18.10	1.37	0.00	19.47	16.13	1.39	0.00	17.52
Edible oil: crude	31.22	5.46	0.00	36.68	31.28	4.06	0.00	35.34
Edible oil: refined	38.72	5.84	0.00	44.56	38.78	4.99	0.00	43.77

Table A-1 (Continued).

Group	CD+LF+IDS	VAT	SD	Total	CD+IF+IDS	VAT	SD	Total
1995-96					1996-97			
Onion	31.22	2.36	0.00	33.58	31.28	2.37	0.00	33.65
Chilies(dry)	23.72	0.00	0.00	23.72	23.78	0.00	0.00	23.78
Potato	46.22	3.48	0.00	49.70	46.28	3.50	0.00	49.78
Milk	46.22	5.73	0.00	51.95	46.28	10.10	0.00	56.38
Pulses	12.47	0.95	0.00	13.42	12.53	0.96	0.00	13.49
1998-99					1999-2000			
Rice	1.08	0.00	0.00	1.08	1.00	0.00	0.00	1.00
Wheat	7.08	0.57	0.00	7.65	5.50	0.50	0.00	6.00
Maize								
Sugar	33.58	4.74	0.00	38.32	28.50	3.99	0.00	32.49
Oilseed	14.71	1.18	0.00	15.88	12.58	1.01	0.00	13.59
Edible oil: crude	21.08	2.46	0.00	23.54	18.50	2.49	0.00	20.99
Edible oil: refined	36.91	4.46	0.00	41.37	33.86	4.16	0.00	38.02
Onion	33.58	2.37	0.00	35.95	28.50	2.00	0.00	30.50
Chilies(dry)	22.33	0.00	0.00	22.33	22.25	0.00	0.00	22.25
Potato	43.58	3.12	0.00	46.70	41.00	2.93	0.00	43.93
Milk	43.58	9.48	0.00	53.06	41.00	9.50	2.70	53.21
Pulses	6.08	0.54	0.00	6.62	4.75	0.41	0.00	5.16

Table A-1 (Continued).

Group	CD+LF+IDS	VAT	SD	Total	CD+LF+IDS	VAT	SD	Total
2002-2003					2003-2004			
Rice	7.5	0	0	7.5	7.5	0	0	7.5
Wheat	13.5	0	0	13.5	7.5	0	0	7.5
Maize	6.5	0	0	6.5	7.5	0	0	7.5
Sugar	50.5	0	23.5	74.0	48.0	4.0	30.0	82.0
Oilseed	6.5	0	0	6.5	7.0	0	0	7.0
Edible oil: crude	22.5	0	0	22.5	22.5	0	0	22.5
Edible oil: refined	22.5	0	0	22.5	22.5	0	0	22.5
Onion	29.0	0	0	29.0	29.5	0	0	29.5
Chilies(dry)	22.5	0	0	22.5	22.5	0	0	22.5
Potato	39.0	0	0	39.0	37.0	0	0	37.0
Milk	39	15.0	15.0	74.0	37.0	15.0	25.0	77.0
Pulses	7.5	0	0	7.5	7.5	0	0	7.5

Note: CD = Customs Duties; LF = License Fees; IDS = Infrastructure Development Surcharge;

SD = Supplementary Duty; VAT = Value-Added Tax.

Source: National Board of Revenue and Dowlah (2003).

Table A-2. Export of agricultural commodities from Bangladesh (Million US\$).

Year	Raw Jute	Tea	Frozen food	Agril. products	Jute products	Hides & skins	Crops (Total)	Agril. (Total)	Total export	Agril. as a % of total
1991-92	85	32	131	10	301	144	428	703	1994	35.26
1992-93	74	41	165	15	292	148	422	735	2383	30.84
1993-94	57	38	211	15	284	168	394	773	2534	30.51
1994-95	79	33	306	13	319	202	444	952	3473	27.41
1995-96	91	33	314	22	329	212	475	1001	3884	25.77
1996-97	116	38	321	29	318	195	501	1017	4427	22.97
1997-98	108	47	294	39	281	190	475	959	5172	18.54
1998-99	72	39	274	22	304	168	437	879	5324	16.51
1999-00	72	18	344	18	266	195	374	913	5752	15.87
2000-01	67	22	363	18	230	254	337	954	6467	14.75
2001-02	61	17	276	23	244	207	345	828	5986	13.83
Annual growth rate (%)	- 1.25	- 6.5 5	7.33	6.42	-2.23	3.59	-1.97	1.96	11.9	

Source: Export Promotion Bureau.

Note: Growth rates have been calculated by fitting semi-logarithmic trend lines.

Table A-3. Import of agricultural commodities to Bangladesh (Million US\$)

Year	Rice	Wheat	Oil seeds	Raw cotton	Edible oil	Maize	Pulses	Agril. (Total)	Total import	Agril. as a % of total
1991-92	4	251	30	95	185	0.000	14.666	579.67	3516	16.49
1992-93	0	176	35	91	113	0.002	14.154	429.16	4071	10.54
1993-94	23	145	65	71	140	0.013	28.450	472.46	4191	11.27
1994-95	220	256	80	135	220	0.448	9.279	920.73	5834	15.78
1995-96	358	228	89	185	179	1.959	23.604	1064.56	6947	15.32
1996-97	28	156	62	195	216	2.436	52.365	711.80	7152	9.95
1997-98	247	122	93	207	216	1.452	43.608	930.06	7520	12.37
1998-99	680	317	100	233	287	5.077	70.870	1692.95	8006	21.15
1999-00	115	266	90	277	256	18.923	112.999	1135.92	8374	13.56
2000-01	172	177	64	360	218	26.575	85.749	1103.32	9335	11.82
2001-02	15	171	72	312	251	32.574	92.890	946.46	8540	11.08
Annual growth rate (%)	30.83	-0.25	7.51	15.21	6.08	75.45	22.96	9.04	9.59	

Note: Growth rates have been calculated by fitting semi-logarithmic trend lines.

Table A-4. Domestic production of cereals and import of food grains (000 metric tons)

Year	Production of cereals	Food aid	Commercial imports	Total imports
1981-82	14646	1141	114	1255
1982-83	15276	976	868	1844
1983-84	15740	1441	615	2056
1984-85	16182	1306	1287	2593
1985-86	16177	1087	113	1200
1986-87	16592	1425	342	1767
1987-88	16547	1787	1130	2917
1988-89	16650	1356	780	2136
1989-90	18679	949	584	1533
Growth rate	2.26	1.28	10.18	2.6
(81-90) %	(2.70)	(-2.05)	(18.15)	(2.22)
1990-91	18869	1540	37	1577
1991-92	19400	1414	150	1564
1992-93	19598	735	448	1183
1993-94	19230	654	312	966
1994-95	18174	935	1633	2568
1995-96	19155	738	1689	2427
1996-97	20439	618	349	967
1997-98	20793	549	1402	1951
1998-99	21946	1235	4256	5491
1999-00	25087	870	1234	2104
2000-01	26968	491	1063	1554
2001-02	26138	509	1289	1799
Growth rate	3.29	-6.68	26.15	4.32
(90-02) %	(2.72)	(-9.22)	(29.59)	(1.10)
Growth rate	2.63	-4.3	7.83	0.78
(81-02) %	(2.76)	(-3.84)	(11.55)	(1.71)

Note: (a) Growth rates have been calculated by fitting semi-logarithmic trend lines.

(b) Compound growth rates are given within brackets. This growth rate is calculated depending on the value of a variable at the beginning of a period (first year) and the value of that variable at the end of a period (last year), which may be suddenly higher or lower. To avoid such a problem and to take into account the annual fluctuations of continuous values between the first and the last year, a growth rate of the semi-logarithmic form is usually preferred.

Table A-5. Foreign assistance to Bangladesh (Million US\$)

Year	Donation	Loan	Total
1971-72	245	26	271
1972-73	486	65	551
1973-74	218	243	461
1974-75	375	526	901
1975-76	234	567	801
1976-77	256	279	535
1977-78	393	441	834
1978-79	502	528	1030
1979-80	650	573	1223
Growth rate (71-80) %	7.99	32.02	14.28
1980-81	593	553	1146
1981-82	654	588	1240
1982-83	587	590	1177
1983-84	733	535	1268
1984-85	703	566	1269
1985-86	546	760	1306
1986-87	661	934	1595
1987-88	823	817	1640
1988-89	673	995	1668
1989-90	766	1044	1810
Growth rate (80-90) %	2.2	7.89	5.19
1990-91	831	901	1732
1991-92	817	794	1611
1992-93	818	857	1675
1993-94	710	849	1559
1994-95	890	849	1739
1995-96	677	766	1443
1996-97	736	745	1481
1997-98	503	748	1251
1998-99	669	867	1536
1999-00	726	862	1588
2000-01	504	865	1369
2001-02	479	963	1442
Growth rate (90-02) %	-4.6	0.43	-1.71
Growth rate (71-02) %	2.71	5.9	3.76

Note: Growth rates have been calculated by fitting semi-logarithmic trend lines.

Table A-6: Macro-economic indicators of Bangladesh

Indicators	1991-92	1995-96	1999-2000	2001-02
GDP at current market price (Taka in billion)	1195.4	1663.2	2370.9	2732.0
GDP growth rate at constant (1995-96) prices	5.0	4.6	5.9	4.4
Population (Million)	113.0	120.8	128.1	131.6
Per capita GDP at current prices (Taka)	10579.0	13768.5	18507.9	20760.0
Average exchange rate with US Dollar	38.1453	40.8365	50.3112	57.4347

As percentage of GDP

Consumption	86.1	85.3	82.1	81.8
National savings	19.3	20.0	23.1	23.4
Total investment	17.3	20.0	23.0	23.1
Overall budget deficit	-4.7	-4.7	-6.1	-4.7
Import	11.3	16.9	17.8	18.0
Export	6.3	9.5	12.2	12.6
Rate of inflation (%)	4.6	6.7	3.4	2.4
Foreign exchange reserve (Million US\$)	1608	2039	1602	1583
Foreign exchange reserve (Months of imports)	5.5	3.5	2.3	2.2

Source: GOB (2003), Bangladesh Bank (2003).

Table A-7. Current dietary pattern in Bangladesh compared with an expected pattern

Food items	Adequate intake ¹ (grams)	Target intake ² (grams)	Current intake ³ (grams)	Minimum required intake (grams)	Energy		Food gap (%)
					Kcal	%	
Cereals	490	372	475.8	450	1555.2	70.2	-5.7
Tubers	100	130	70.9	70	61.7	2.8	-1.3
Vegetables	125	132	140.5	150	65.8	3.0	6.3
Pulses	30	66	15.8	30	105.0	4.8	47.3
Edible oil	20	38	12.8	20	180.0	8.2	36.0
Fruits	50	57	28.4	50	50.0	2.3	43.2
Sweeteners	10	28	6.85	10	40.0	1.8	31.5
Fish	45	50	38.5	60	60.0	2.7	35.8
Meat	20	22	13.3	30	33.0	1.5	55.7
Eggs	14	7	5.3	10	16.7	0.7	47.0
Milk	30	47	29.7	50	32.6	1.5	40.6
Total	934	949	837.8	930	2200	100	9.9

Source: Bangladesh National Nutrition Council, Dhaka.

Ministry of Food, Dhaka.

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ONION CULTIVATION AT FARM LEVEL: INPUT USE, PRODUCTIVITY AND RESOURCE USE EFFICIENCY

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ABSTRACT

A study was undertaken to examine the effect of various input uses and to estimate the resource use efficiency in the production of onion. The investigation was based on a sample survey of randomly selected 120 onion growers under Sherpur district. Tabular technique, statistical test (t-test), as well as some functional input-output analyses were made to analyze and interpret the data. The results of the study indicated that the return of onion was positively related with the inputs, family labour, hired labour, ash, TSP, MP and irrigation except seeds, animal labour, cowdung, urea and insecticides. The findings also revealed that onion growers are not efficient in terms of resource allocation. Further, farmers have the scope to increase output by efficient utilization of family labour, cowdung, insecticides and irrigation in the onion cultivation.

Keywords : Onion, input use, productivity, efficiency.

INTRODUCTION

The efficient use of resources is an important indicator of increased production in agriculture, and as such emphasis has now a days been given on input use efficiency. Efficient use of resource can provide the farmers to have higher production from the available resources. The situation is particularly critical in a country like Bangladesh where the low level of resource use is a characteristic feature. Lack of resource always adversely affects the agricultural production. The second important characteristic is the inefficient use of resources. Whatever resources available in the country are not being properly utilized up to the optimum

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level. For example, it is very often observed that the labour used in different crops in Bangladesh is significantly more than what is required. This is because of the underemployed family labour and the cheap labour. On the other hand, inputs like fertilizer, irrigation and even management is always under used. The per hectare recommended amount is seldom used in production (Jabbar & Alam, 1979; Jabbar & Islam, 1981). These situations further aggravates because information on soil type, its relation with fertilizer, irrigation requirement etc are not readily available.

Therefore, the farmers use their own judgment in applying different inputs in onion production. Among the spices onion (*Allium cepa*) ranks first both in crop coverage 34538 ha and production 144,170 tons. It covers 24% of the area under spices and condiments. The average national production is about 4 t ha⁻¹. The area, production and yield of onion have increased only at an average annual rate of 0.67%, 1.24% and 0.57%, during 1974 to 1998, respectively, (Anon, 2002). However, lack of farm level information on onion cultivation practices and its profitability frequently prevents researchers from undertaking priority research areas. Keeping this view in mind, the present study is a modest attempt to assess the impact of input use, farmers' resource use efficiency and productivity of onion at farm level.

MATERIALS AND METHODS

Six villages namely, Kamarerchar, Munshirchar, Charsherpur, Bagerchar charmucharia and Kushomhati under Sherpur District were selected for the study where onion grows extensively. Six unions were purposively selected where a large number of farmers used to cultivate onion. A complete list of onion growers of the selected areas was prepared during 2000-2001 rabi season and a sample of 120 farmers were randomly selected. Selected respondents were interviewed directly with the help of a pre-designed questionnaire. In analyzing the data, tabular as well as statistical techniques were used to fulfill the objectives.

Net return analysis

Profit is actually gross margin minus fixed cost. Therefore, the technique of enterprise costing was applied. For this purpose the activity budget suggested by Dillon and Harddaker (1980) was employed for deriving the profit equation. The profit equation of the following form was used.

$$\Pi_i = P y_i \cdot Y_i + P b_i \cdot B_i - \Pi_{j=1}^n (P x_{ji} \cdot X_{ji}) - TFC$$

Where,

Π_i = profit per hectare from *i*th output,

P_{yi} = per unit price of j th output,

Y_i = total quantity per hectare of j th output,

P_{bi} = per unit price of the by-product of j th output,

B_i = total quantity per hectare by-product of j th output

P_{xji} = per unit price of j th input used for producing j th output

X_{ji} = total quantity per hectare of j th input used for producing of j th output

TFC= total fixed costs involved in producing per hectare j th output

i = the number of individual crop produced by the farmers,

j = the number of relevant individual inputs used for producing of the relevant product.

$n = 1, 2, 3, \dots, n$

Functional analysis

To determine the contribution of variable input to the production of onion, the Cobb-Douglas functional form of regression equation was employed as follows:

$$Y = a X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} X_9^{b_9} X_{10}^{b_{10}} X_{11}^{b_{11}} X_{12}^{b_{12}} e^U$$

The function was linearized by transforming it into the following logarithmic (Double-log) form :

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + b_9 \ln X_9 + b_{10} \ln X_{10} + b_{11} \ln X_{11} + U$$

Where,

Y = Return from onion production (Tk/ha)

a = Constant or intercept value

X_1 = Cost of family labour (Tk/ha)

X_2 = Cost of hired labour (Tk/ha)

X_3 = Cost of animal labour (Tk/ha)

X_4 = Cost of seed (Tk/ha)

X_5 = Cost of cowdung (Tk/ha)

X_6 = Cost of ash (Tk/ha)

X_7 = Cost of urea (Tk/ha)

X_8 = Cost of TSP (Tk/ha)

X_9 = Cost of MP (Tk/ha)

X_{10} = Cost of insecticide (Tk/ha)

X_{11} = Cost of irrigation (Tk/ha)

U = Error term, $b_1, \dots, b_{11}$ = Coefficient of respective variable

A Cobb-Douglas production function was specified to determine possible relationship between the production of onion and inputs used. The inputs of family labour, hired labour, animal labour, seeds, cowdung, ash, urea, TSP, MP, pesticides, and irrigation were considered as the explanatory variable for the onion in the production function analysis.

The other inputs like management, farm size, soil condition, time of sowing and rental value of land which might be affect the farm income substantially excluded from the model. The elasticity of production of factor input from Cobb-Douglas production function were used to calculate the marginal value product (MVP) at Geometric mean level (GM) for the average farms (Yamane, 1973). In order to test the resource use efficiency the ratio of marginal value product (MVP) to the marginal factor cost (MFC) for each input was compared and tested for its equality to 1, i.e. $MVP/MFC=1$ (Yotopoulos, 1967).

The marginal productivity of a particular resource represents the additional gross returns in value term caused by an additional one unit of that resource, while other inputs were kept constant. Since all the variables of the concerned model were measured in monetary value, the slope co-efficient of the explanatory variables in the function represent the MVPs, which have been computed multiplying the production co-efficient of given resource with the ratio of geometric mean (G.M) of gross return to the geometric mean of the given resource.

$$\text{i.e. } \ln Y = \ln a + b_i \ln X_i$$

$$\frac{dy}{dx_i} = b_i \frac{Y}{X_i}$$

$$\frac{dy}{dx_i} = b_i \frac{Y}{X_i}$$

$$\frac{dy}{dx_i} = b_i \frac{Y}{X_i}$$

Y (GM)

$$\text{Therefore, MVP (xi) = } \frac{b_i}{X_i \text{ (GM)}}$$

Where, Y = Mean value (GM) of concerned gross return in Taka

X = Mean value of (GM) of different inputs in Taka (i = 1, 2, ..., 11)

GM = Geometric mean

and dy/dx = Slope of the production function as well as MVP of i th input

Hence, this MVPs indicate value product on Taka, per Taka input cost can express the ratios of MVP and MFC. In order to identify the status of resource use efficiency it was compared that a ratio equal to unity indicates that optimum use of that factor, a ratio more than unity indicates that the gross return could be increases by using more of that resource and a value of less than unity indicates the unprofitable level of resource which should be decreased to minimize the losses. The estimated ratio of MVPxi and MFCxi of different inputs are presented in Table 3.

RESULTS AND DISCUSION

The average input used and its associated costs, yield and return from onion cultivation are presented in table 1. It was found that per hectare use of human labour on an average was 207 mandays among which 87 mandays came from family labour and 120 hired labour. Human labour amounting Tk. 12610 ha⁻¹ was spent, which constituted 31.92 % of total cost of onion production. In the study area, respondents used @ 10 tha⁻¹ cowdung and 2.72 tha⁻¹ ash. Fertilizer rate followed in the field of onion by the growers in the study area were urea 296, TSP 236 and MP 178 kg ha⁻¹, respectively.

The costs of material inputs (seeds, cowdung, ash, fertilizer, insecticides and irrigation) together was Tk. 20816 ha⁻¹, which was 52.71 % of the total cost. But the cost of manure's and fertilizers as calculated to be 15.82 % and 14.38 %, respectively. Thus, human labour and fertilizer constitutes the two major inputs and it was 62.12 % of the total cost of production.

Table 1. Per hectare cost and return of onion on the basis of full costs at Sherpur district during 2001- 2002

Items	Quantity	Costs/ Return (Tk/ha)	Percent of total cost/return
A. Total		39489	100
Family labour (man-days)	87	5262	13.32
Hired labour (man-days)	120	7348	18.60
Animal labour (pair-day)	39	2920	7.39
Materials input (Tk/ha)		20816	52.71
Seed (kg/ha)	6.03	6289	15.92
Cowdung (t/ha)	10	5000	12.66
Ash (t/ha)	2.72	681	1.72
Urea (kg/ha)	296	1781	4.51
TSP (kg/ha)	236	2896	7.33
MP (kg/ha)	178	1574	3.98
Insecticide (Tk/ha)	-	1360	3.44
Irrigation (Tk/ha)	-	1235	3.12
Rental value of land (Tk./ha)		2470	6.25
Interest on operating capital		673	1.70
B. Yield (T/ha)	6.03		
C. Gross return		63000	
Net return (C-A)		23511	

On an average, the yield of onion per hectare was 6.03 t ha^{-1} and the net return per hectare was Tk. 23511. Saha *et al* (1990) found that the yield of onion was 4.71 tha^{-1} and it was lower compared to the yield potentiality exhibited in the present study probably due to low management practices.

Contribution of factor inputs to production of onion

The co-efficient of multiple determination (R^2) was 0.71 which meant that the explanatory variable included in the model explained 71% of the variation in returns from onion production. The F-value of the equation is significant at 1% level of confidence implying that the variation in return from onion production depends mainly upon the explanatory variable included in the model. The contribution of specified factors affecting production of onion can be seen from the estimates of regression equation. The result showed

that some of the co-efficient do not have the expected sign. However, only the co-efficient for family labour, cowdung, insecticides, and irrigation were found to be significant. The magnitude of the co-efficient implied that these inputs had considerable effect on return from onion production and it was statistically significant. The contribution of the selected factors to return from onion are discussed below:

Input-output relationship

Family labour (X_1)

The value of the production co-efficient for family labour was 0.136, which was significant at 1% level. The positive sign indicated that return from onion can be increased by using more family labour. The estimated co-efficient (0.136) revealed that 1% increase of family labour cost. Keeping all other factors remaining constant, would uplift the gross return from onion by 0.136%.

Hired labour(X_2)

The value of the production co-efficient for hired human labour was found to be 0.0066. The positive sign indicated that return from onion can be increased by using more hired human labour. The estimated co-efficient (0.0066) revealed that 1% increase in human hired labour cost with other factors remaining constant, would increase the gross return by 0.0066%.

Animal power (X_3)

The estimated production co-efficient for animal power was observed to be -0.0067 which was insignificant and negative. It revealed that animal power might be over used.

Manures and Fertilizer

The regression co-efficient of cowdung (X_5) was -0.328, negatively significant at 1% level. The negative algebraic sign for cowdung might be due to its over usage. The estimated co-efficient of urea (X_7) was -0.0840 which was significant and negative. The negative regression co-efficient as evident from the aforesaid findings might be due to excessive use of fertilizer by the onion growers. However, the regression co-efficient of ash (X_6), TSP (X_8), and MP (X_9) were positive and insignificant which threw an idea that the return from onion can be increased by using more ash, TSP and MP. Similar negative and insignificant regression co-efficient was reported in potato production by Das (1992).

Meanwhile, the average dose of fertilizer used in onion production as surveyed in the present study was obviously quite high. The recommended doses of fertilizer in onion cultivation are urea 260 kg ha^{-1} , TSP, 200 kg ha^{-1} , MP 160 kg ha^{-1} (Anno, 2000). The sample farmers applied fertilizers @ 296, 236 and 178 kg ha^{-1} , Urea, TSP and MP respectively. The reasons for the increased fertilizer use by the onion growers were seemed to be based on the believe that the higher doses of fertilizer will produce higher yield per unit area of land. Thus, the appearance of negative sign for input like cowdung and urea is quite likely.

Seeds (X_4)

The regression co-efficient of seed was -0.0023 which was negative and insignificant. It indicated that the excessive use of seed might be due to poor field emergence.

Insecticides (X_{10})

The co-efficient of insecticides was -0.184 and it was significant at 1% level. It might be due to the indiscriminate use of insecticides.

Irrigation (X_{11})

The regression co-efficient of irrigation was 0.0959, which was significant at 5% level. It revealed that 1% increased irrigation cost, would increase the gross return by 0.0959% when other factors were kept constant.

The summation of elasticity of different inputs ($\sum b_i$) was 0.12 which was also less than one but greater than zero ($0 < 0.12 < 1$). This indicated that the farmers, in general, allocated their resources in the zone of rational stage of production (stage II) where the diminishing returns to scale prevails, that is, if all the inputs specified in the function were increased by one percent, output would have increased by 0.12 percent

Table 2. Estimated values of co-efficient and related statistics of Cob-Douglas production model

Explanatory variables	Co-efficient	Standard error
Constants	5.708	0.79
Family labour(X_1)	0.136** (3.02)	0.045
Hired labour(X_2)	0.0066 (0.152)	0.043
Animal Labour(X_3)	-0.0067 (-0.174)	0.039
Seed(X_4)	-0.0023 (-0.051)	0.046
Cowdung(X_5)	-0.328** (-3.56)	0.092
Ash(X_6)	0.0694 (1.56)	0.044
Urea(X_7)	-0.0840 (-1.04)	0.080
TSP(X_8)	0.0148 (0.185)	0.08
MP(X_9)	0.0350 (0.466)	0.075
Insecticide(X_{10})	-0.184** (-3.060)	0.060
Irrigation(X_{11})	0.0959* (2.74)	0.035
R^2		0.71
F		5.16**
$\sum bi$		0

Figures in the parentheses indicate "t" value

* significant at 5 percent level,

** significant at 1 percent level

The efficiency or resource use

From Table 3, it is seen that none of the marginal value product of inputs are equal to one. This indicates that the farmers have failed to show their efficiency in using the resources. In the case of family labour, ash, MP, and irrigation, the ratio of MVP and MFC are greater than one and positive. It reveals that the guava farmers did not avail themselves of the opportunity of using the optimal amounts of these inputs. Hence, there are ample opportunities for farmers of the study area to increase the output per hectare by judicious and increased use of these inputs, i.e., more profit can be obtained by increasing investment in those inputs.

Table 3. Ratio on of marginal value product (MVP_{xi}) and marginal factor cost (MFC_{xi}) in different inputs included in Cob-Douglas production function

Input	Geometric mean	Mean ratio of MVP _{xi} and MFC _{xi}
Y	67474.99	-
X ₁	1777.10	5.16
X ₂	7891.19	0.056
X ₃	2531.17	-0.178
X ₄	5656.80	-0.027
X ₅	2687.99	-8.23
X ₆	535.62	8.74
X ₇	1552.89	-3.64
X ₈	2768.76	0.360
X ₉	1509.88	1.56
X ₁₀	1395.90	-8.89
X ₁₁	1594.30	4.05

In the case of cowdung, urea and insecticides, the ratio are negative but greater than one and imply that excessive use of these inputs for guava production leads to reduction of gross return. So, the sampled farmers did not use these input efficiently. In the case of hired labour, and TSP, the ratio is positive but less than one implying that too much use of this resource has gone beyond the economic optimal level.

CONCLUSION

The return from onion was observed to be positively related to the inputs like family labour, hired labour, ash, TSP and irrigation except seeds, animal power, cowdung urea and insecticides. The productivity effects of family labour and irrigation were positive whereas cowdung and insecticides were negative and statistically significant. The study also revealed that in general the farmers were not habituated of using their inputs efficiently. It was evident from the findings that farmers have an ample scope to increase the output by judicious and extended allocation of family labour, hired labour, ash, TSP, MP and irrigation. On the other hand, use of animal power seeds, cowdung, urea and insecticides are practised by the onion growers. So, it can be concluded that onion growers were not observed efficient in terms of resource allocation for yield improvement. Profit can be possible through efficient utilization of production inputs.

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ANALYSIS OF POINTED GOURD (*Trichosanthes dioica* L.) CULTIVATION WITH AND WITHOUT RICE STRAW MULCH: A CASE STUDY

A.K. GHORAI¹

ABSTRACT

Rice straw mulch was applied in pointed gourd field to overcome the problems of heat and moisture stress, reduce weed pressure and improve soil health. Heat and moisture stress reduces its fruit yield due to poor fruit set and under sized fruit development. Rice straw mulch was applied in the crop field @ 0, 8, 12, 16, and 20 Mg ha⁻¹ in combination with different irrigation levels, IW/CPE = 0.5, 1.0, 1.5 and 2.0. Mulching @ 16 Mg ha⁻¹ and irrigation at IW/CPE = 1.5 saved 30 cm irrigation water over irrigation at IW/CPE = 2.0 and performed best. At noon hours, surface and subsurface soil layers were relatively cooler due to mulching by 10 to 12°C and 5 to 6°C, respectively. Mulching recorded higher fruit yield (3742 kg ha⁻¹) over bare soil cultivation (1509 kg ha⁻¹) due to higher fruit set and healthier fruit development. Mulching maintained significantly weed free environment than non-mulched plots. After decomposition, mulching increased available potassium, phosphorus and organic matter content of soil and kept the soil fertile.

Keywords: Soil water conservation, soil health, weed control, Rice straw, *Trichosanthes dioica* L.

INTRODUCTION

Crop yield improvement is a problem under heat and moisture stress particularly in summer months. The water holding capacity of sandy soil is usually very poor and has inherent

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low nutrient status. It is now established that availability of surface and ground water is gradually becoming limiting due to many reasons associated with over exploitation by agriculture and industry, reduced recharge and a huge run-off due to precipitation. It is estimated that even after achieving the full irrigation potential, nearly 50 per cent of the total cultivated area in India will remain rainfed. Problems get worser for vegetable crops, which require frequent irrigation and adequate nutrition for higher output.

With water shortage, and about 70 per cent area in the country is deficient in soil organic carbon. Deficiency of phosphorus is wide spread in Indian soil with, 49.3, 48.8 and 1.9 per cent of soil having low, medium and high P status. Earlier estimates in mid 1970's indicated that available potash status in the soil was low, medium and high in 117 and 130 districts in the country. Role of organic mulch in maintaining better hydrothermal regime, improving soil health, ability to control weed and improvement of crop yield has been well established.

Yield improvement of pointed gourd by maintaining better hydrothermal regime of soil through straw mulching has been reported by Ghorai (1994). Significant profile water storage increase by straw mulch has been reported by Prasad *et al.* (2000) in lentil (*Lens esculenta* Moench) due to less evaporation losses of water from soil surface. Ball Coelho *et al.* (1993) reported increased organic matter content of soil through mulching. Beverly *et al.* (2000) have reported higher phosphorus content of soil due to chopped maize straw and grass mulch application. Medcalf (1956) reported increased availability of potassium and phosphorus content of soil due to mulching.

Wrigley (1981) had reported reduction of soil acidity after decomposition of mulch. Fortunately the crop residue potential of rice-wheat system in India is presently 276 million mg annually which may add 1.55 million mg of nitrogen (N), 0.48 million mg phosphorus and 3.6 million mg of potassium (K_2O), besides considerable amount of micronutrients, and decomposed organic matter. Recycling of these on farm low cost residues will be profitable if utilised as organic mulches which are otherwise under utilized and burnt in rice fields resulting in loss of valuable organic matter and nutrients particularly nitrogen and sulphur and causes environmental pollution (Sharma *et al.*, 2000).

Pointed gourd (*Trichosanthes dioica* L.) is a perennial summer cucurbit and a high value cash crop of eastern India, Bangladesh, and some parts of south east Asia. This is favoured for its delicacy and has high self-life suitable for long transit. The tender fruits contain 92 per cent moisture, 2 per cent protein, 0.3 per cent fat, 3 per cent fibre, 2.2 per cent carbohydrate, 153 mg carotene 100^{-1} edible fruit, 30 mg Ca 100^{-1} edible fruit and 29 mg vitamin C 100^{-1} edible fruit. Till the onset of monsoon season in early June, usually it demands 30 to 33 irrigations (75 mm

each) in dry period (February to early June) for its optimum growth and development.

Heat and moisture stress in summer months restricts its growth and development and hampers fruit setting. Cooper(1973) reported that optimum soil temperature for maximum root extension and branching is 25° to 30°C . The maximum air temperature during summer season of the crop growing area varies from 40° to 45°C . The 53 years average weekly rainfall pattern of the experimental location is shown in Fig.1. Screening of pointed gourd genotypes on the basis of fruit setting were made for heat tolerance in India, Project Directorate of Vegetable Research (1998). These abiotic stresses generate undersized fruits, compels premature fruit drop and thus leads to poor economic return from it. High frequency irrigation (4-5 days interval) and fertiliser requirement of the crop also promotes repeated weed flushes, which competes for its space, water and nutrition with the main crop. Surface mulch suppresses weed growth through its smothering effect and is also an eco-friendly weed control tool by avoiding the toxic effects of herbicide on soil microbes, soil harbouring useful earthworms, vermi and other non-target elements leaving no residual toxicity in the environment (Ghorai *et al.*, 1998). Weed control in tomato by mulch had been reported by Tindall *et al.* (1991).

Experiments were thus conducted with the following objectives to increase the test crop yield under limited water supply at high soil and air temperature condition from a relatively weed free environment using rice straw mulch in summer, keeping the soil fertile.

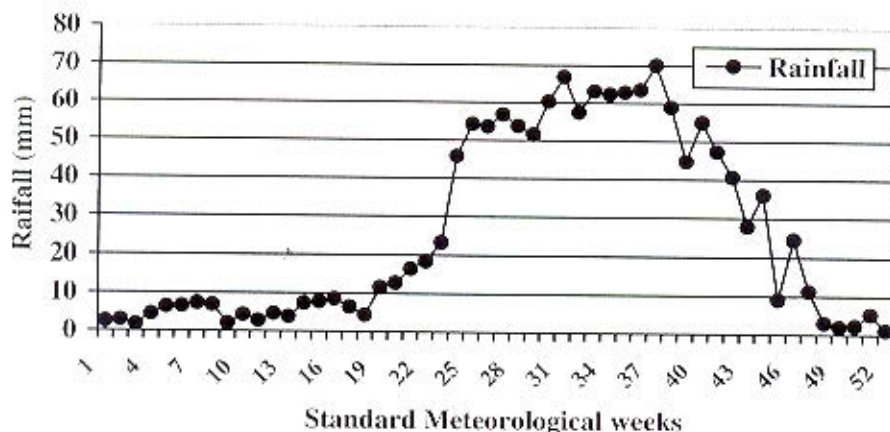


Fig.1 Weekly rainfall distribution of the experimental location (53 years average)

MATERIALS AND METHODS

Experiments were conducted in Water Technology Centre for Eastern Region, ICAR, Orissa, India, at Mendhasal farm ($20^{\circ}30' \text{ N}$ and $87^{\circ} 48' 16'' \text{ E}$), for three consecutive years from 1992 to 1994. Initial soil had the following characters: The soil is acidic in nature (pH 5.61) having a bulk density of 1.53 g cc^{-1} and sandy loam in texture. The available nitrogen, phosphorus and potassium content of soil were 225 kg, 12 kg and 125 Kg ha^{-1} , respectively. The soil had an organic carbon content of 0.36 per cent. Experiments were laid out in split plot design, replicated thrice. The ultimate plot size were $7.6 \text{ m} \times 3.6 \text{ m}$. Main and sub plots were allotted with irrigation and rice straw mulches treatments, respectively. Irrigations were applied on the basis of IW/CPE ratios, i) 0.5, ii) 1.0, iii) 1.5 and iv) 2.0. Where IW was depth of irrigation water in mm and CPE was cumulative pan evaporation value in mm.

Mulch was applied @ 8, 12, 16, and 20 Mg ha^{-1} along with a control treatment. Roots suckers (female: male ratio, 9:1) of pointed gourd (*Trichosanthes dioica* L.) were planted on raised beds in pits filled with well rotten farm yard manure at a spacing of $180 \text{ cm} \times 90 \text{ cm}$. In each pit 3 root suckers were planted. Fertiliser dose applied was 90: 60: 60:: N : P_2O_5 : K_2O . Vines of the 30 days old crop were carefully trailed over straw mulch (rice straw containing 0.36 per cent N, 0.08 per cent P_2O_5 and .71 per cent K_2O).

Before spreading mulch Benzine Hexa Chloride (BHC 10 per cent) was applied on crop field to prevent white ant attack. Length of the growing season is 9 to 10 months starting from February to the month of November. Ratooning was practised on 2nd and 3rd year of cultivation in late January. No other plant protection measure was necessary for the crop in the experimental years.

Green tender fruits, with soft seeds were harvested from the month of March and continued till November. Leaf area was measured using area meter (LI-3100, USA) from fresh leaf samples. For weed control study, weed count per square meter and weed dry weights were taken at monthly intervals in all the years following standard methods. Total fruit sets from every micro plots were counted manually in each picking and converted to a hectare basis for comparison. Average size and fruit weights were recorded from representative large samples. Plant establishments were counted in each micro plots and then converted to a hectare for comparison.

Soil temperatures were monitored at different depths using soil thermometers regularly in the morning and afternoon hours. Soil moisture was determined gravimetrically before and after each irrigation schedule.

The depth of water available in soil was determined using the following formula, $ASW = ((M2-M1) \times B.D. \times di)/100$. ASW, is available soil water in cm, di is the root zone depth in cm, M1 and M2 are the percentage of soil moisture before and after irrigation. Soil moisture were collected from three depths at 15 cm intervals up to 45 cm root zone.

B. D. is the bulk density of soil in g/cc. For chemical analysis soil samples were collected after decomposition of straw mulch up to 15 cm soil depth following standard norms (Jackson, 1967). Soil chemical analysis was made following standard procedures (Jackson, 1967). Organic carbon content of soil was measured following Walkley and Black method, 1934. Soil pH was measured (2:1) using pH meter (WTW, Germany). Available nitrogen content of soil was measured using alkaline $KMnO_4$ method (Subbiah. & Asija, 1956). The available phosphorus content of soil was determined following Truog method (0.0002N sulphuric acid extraction, Truog, 1930) colorimetrically. Available potassium content of soil was measured in flame photometer using 1N ammonium acetate extraction. Statistical analysis were made using standard packages.

RESULTS AND DISCUSSIONS

Moisture conservation by mulch

Mulched plots conserved more soil water before and after each irrigation than non-mulched plots. Before irrigation, under different levels of irrigation and mulch, mulched plots maintained an average of 14 to 40 per cent more soil moisture than non-mulched plots. Twenty-four hours after irrigation, mulched plots retained 7 to 17 per cent more soil water than bare soil cultivation under different irrigation schedules (Fig. 2). Tominaga *et al.* (2002) reported 15 per cent more soil water retention due to mulched crop with harvest residues in sugarcane than bare row planting. Beneficial role of straw mulch application on soil water storage (in 45 cm soil profile) are shown here.

$$Y_{ws} (IW/CPE = 1.5) = 9.0136e^{0.0067x}, R^2 = 0.89^* \quad (1)$$

$$Y_{ws} (IW/CPE = 2.0) = 9.41 e^{0.005x}, R^2 = 0.89^* \quad (2)$$

Here Y_{ws} is the depth of water stored (cm) in 45 cm soil layer and x is the mulch rate in $Mg\ ha^{-1}$. From the expressions it is evident that every mg of straw mulch was able to conserve 0.5 to 0.6 mm more soil moisture in 45 cm root zone over bare soil cultivation. Bond and Willis (1991) have reported higher moisture conservation by mulch as a result of low soil evaporation and transpiration by crops and weeds or both. Mulching @ $16\ mg\ ha^{-1}$ ($IW/CPE = 1.5$, where the crop performance was the best), saved 30 cm irrigation water over

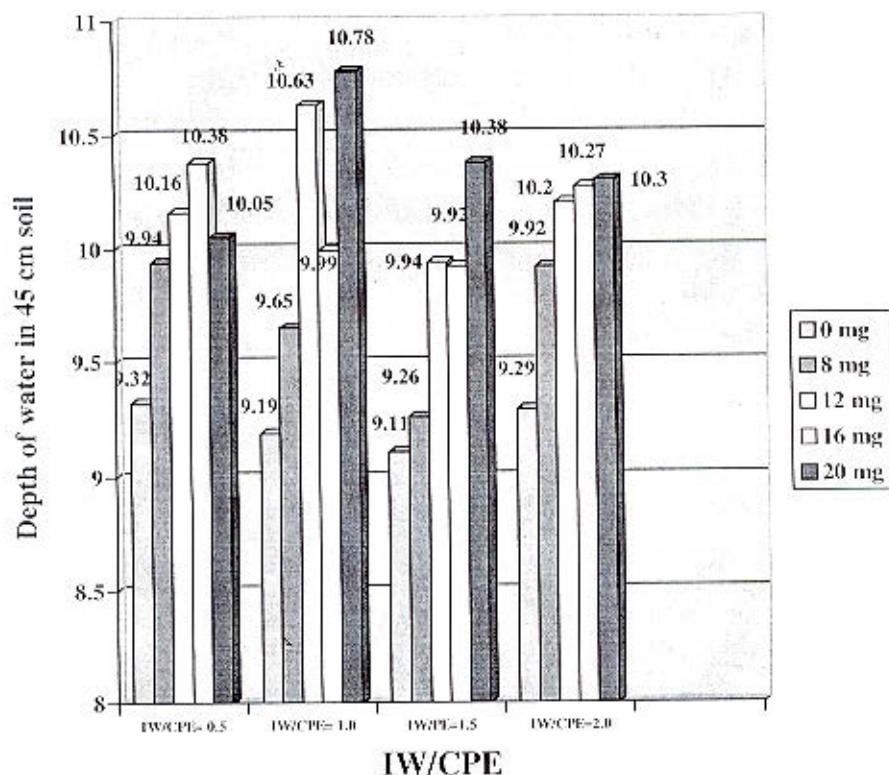


Fig.2 Depth of water stored (in 45 cm soil profile) after irrigation, under different levels of irrigation and mulch

irrigating the crop at $IW/CPE = 2.0$ (total irrigation given was 105 cm), a usual practice. Ghorai *et al.* (1999) reported saving in irrigation water in pointed gourd due to mulching. The optimum schedule of irrigation was found to be $IW/CPE = 1.414$.

Soil temperature moderation using straw mulch

Weekly average soil temperature data from March to June showed that mulching kept the surface (5 cm) and subsurface (30 cm) soil layers relatively cooler than bare soil cultivation in entire summer season. In the morning hour (8.00 a.m.), surface and subsurface soil layers were cooler by 3° to 4°C due to mulching. At noon hour, (Fig. 3) the surface and subsurface soil temperatures were reduced by 10° - 12°C and 5° - 6°C , respectively due to mulching. This arrangement reduced the stress due to high soil temperature in the root zone. Straw mulch maintained low soil temperature in tomato field (Tindal *et al.* 1991). Ghorai (1994) reported soil temperature moderation in pointed gourd field in sandy loam soil using mulch.

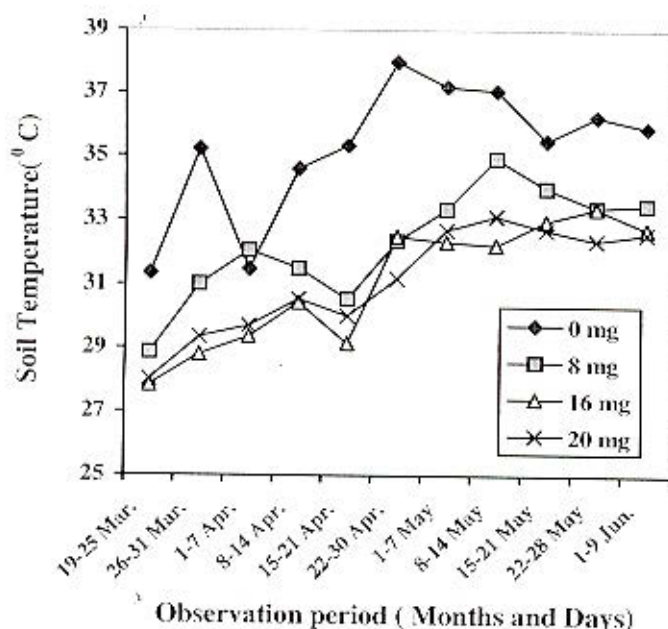


Fig.3 . Effect of rice straw mulch (Mg ha^{-1}) on root zone (30 cm) temperature at 2.00 p.m

Some chemical properties of soil as affected by mulch

Pointed gourd is highly sensitive to an acidic reaction (pH 5.5) and its performance is adversely affected under such condition. At the end of the experiment it was observed that the pH ratio 1:2.5 of the mulched soils were significantly higher than non-mulched plots. The soil pH and mulch relation is shown in following expression.

$$Y_{\text{pH}} (\text{Mean}) = 5.396 + 0.0104 X, R^2 = 0.96^{**} \quad (3)$$

Where Y_{pH} is the pH of soil and x is the straw mulch doses in Mg ha^{-1} . Wrigley (1981) had reported reduction of soil acidity after decomposition of mulch. The redox potential of soil was inversely related to the doses of straw mulch application.

$$Y_{\text{RP}} (\text{Mean}) = 93.307 - 0.720 X, R^2 = 0.97^{**} \quad (4)$$

$$Y_{\text{EC}} (1994) = 56.52 + 1.00 X, R^2 = 0.95^{**} \quad (5)$$

Here Y_{RP} is redox potential (mv) and X is the mulch doses in Mg ha^{-1} . Y_{EC} is the electrical conductivity of soil in $\mu \text{ mhos cm}^{-1}$ at 25°C . The organic matter content of the soil increased linearly due to mulching (Table 1). This came from the decomposed residues of rice straw mulch applied in the crop field. The relationship is given below:

$$Y_{\text{OM}} = 0.3559 + 0.0068 X, R^2 = 0.92^{**} \quad (6)$$

Where Y_{OM} is the organic matter content of soil and x is the doses of straw mulch in mg ha^{-1} . Ball Coelho *et al.* (1993) reported increased organic matter content of soil through mulching. Tindall *et al.* (1991) reported significant increase of organic matter content soil (2.26 per cent) after two years due to straw mulching @ 2.6 mg ha^{-1} (oven dry weight) over bare soil (0.99 per cent) condition. Available soil nitrogen content of soil was not affected by mulching (Table 1). The available phosphorus content of soil showed an increasing trend due to mulching over non-mulched plots. Brady (1980) reported that availability of phosphorus increases due to stable complexes of organic acids with iron and aluminium from added organic matter, which reduces fixation. Beverly *et al.*, 2000, have reported higher phosphorus content of soil due to chopped maize straw and grass mulch application through the following expression:

$$Y_{\text{P}} = 12.43 + 0.2114 X, R^2 = 0.86^* \quad (7)$$

Where Y_{P} is the available phosphorus in kg ha^{-1} and X is the doses of straw mulch in mg ha^{-1} . Decomposed straw much increased the available potassium content of soil. The relation is shown here.

$$Y_{\text{K}} (\text{Mean}) = 100.06 + 6.226 X, R^2 = 0.84^* \quad (8)$$

Where Y_{K} is the available potassium content of soil in kg ha^{-1} and x is the doses of straw mulch in Mg ha^{-1} . Robinson and Chenery (1958) reported addition of 1250 kg potassium due to application of 25 mg ha^{-1} elephant grass as mulch. From the experiments it was observed that mulching after its decomposition increased the organic matter content of soil, improved the soil reaction in acid soil, improved available potassium and phosphorus content of soil. Thus application of mulch is beneficial in keeping the soil fertile along with its other added advantages.

Table 1. Some of the physical and chemical characters of soil as influenced by different levels of straw mulch

Treatments	Soil pH	Electrical conductivity	Organic matter	Redox Potential	Available nutrients		
					Nitrogen	Potassium	Phosphorus
Mulch doses		(μ mols cm^{-1} at 25°C)	(%)	(mv)	Kg ha^{-1}	Kg ha^{-1}	Kg ha^{-1}
0 mg ha^{-1}	5.37	58.14 ^a	0.36	97.00	225	103	12.11
8 mg ha^{-1}	5.45	62.49	0.42	89.33	245	171	14.77
12 mg ha^{-1}	5.54	68.00	0.42	83.83	212	173	15.29
16 mg ha^{-1}	5.63	71.60	0.45	78.83	208	183	14.82
20 mg ha^{-1}	5.65	78.40	0.51	76.83	232	227	17.00
S.E.m $\pm$	0.04	3.19	0.022	2.93	16.50	18.77	2.20
L.S.D	0.08	6.50	0.005	5.98	NS	38.25	NS
(P=0.05)							

Plant population and straw mulch

After three years of plantation it was observed that total number of plants from mulched plots were higher than non-mulched plots (Table 2). It was found that every mg of mulch increased 1170 new plants ha^{-1} after 3 years of plantation. Due to deficit soil moisture and high soil temperature stress in non-mulched plots, the vines could not grow and spread well. It resulted in reduced number of nodal adventitious roots, which are ultimately developed into new plant lets in the successive years in ratoon crops. An inverse relation between root zone soil temperature and ultimate stand establishment of pointed gourd is shown here.

$$Y_{\text{popn}} = 4750334 e^{-0.1450X}, \quad R^2 = 0.99^{**} \quad (9)$$

$$Y_{\text{popn}} = 5863.77 e^{-119705T}, \quad R^2 = 0.99^{**} \quad (10)$$

Here Y_{popn} is the total plant population ha^{-1} , T and x are soil temperature in $^{\circ}\text{C}$ (at 30 cm) and mulch doses in mg ha^{-1} respectively.

Leaf area index and straw mulch

Leaf area indices (measured by LICOR-3100, USA) were significantly higher due to mulching in all the years and dates of observations. It is worth mentioning that high heat and moisture stress in summer resulted in reduced number of leaves per unit area and produced

undersized leaves which was ultimately reflected in poor leaf area indices from non-mulched plots. Sekour *et al.*, (1987) reported increase in leaf area of sweet corn due to mulching through lucanta grass (*Ischaemum timorense* Kunth.) @ 3.5 mg ha⁻¹. A positive relation between doses of straw mulch and LAI of pointed gourd was obtained during the hottest summer month, May. The negative impact of high root zone soil temperature on leaf area index is shown here for convenience.

$$Y_{AFC} = 13.99 - 0.006 X, R^2 = 0.96^{***}$$

$$Y_L (\text{May}) = 0.138 + 0.029 X, R^2 = 0.98^{**} \quad (11)$$

$$Y_L (\text{May}) = 832.758 e^{-0.2269T}, R^2 = 0.85^{**} \quad (12)$$

Here Y_L is the mean leaf area index of pointed gourd (May). R and X are soil temperature in °C (at 30 cm) and mulch doses in mg ha⁻¹ respectively.

Total fruit set, its average weight and size under mulch

Mulching significantly increased the total fruit set per unit area over no mulch bare soil cultivation (Table 2 and 3). Total fruit set ha⁻¹ was increased by 76 to 300 per cent due to mulching @ 14 to 16 mg ha⁻¹ over non-mulched plots. It was again due to favourable environment created by mulch over bare soil in hot summer. The optimum dose of mulch for better fruit set was 14.10 Mg ha⁻¹. Root zone soil temperature showed negative impact on total fruit set and it was observed that every 1°C rise in soil temperature beyond 31°C reduced the fruit set by a number 11160 ha⁻¹.

$$Y_{FSET} = 61072.3 e^{-0.363X}, R^2 = 0.64 \quad (13)$$

$$Y_{FSET} = 473074 - 11159.8 T, R^2 = 0.81^* \quad (14)$$

Here, Y_{FSET} is the total fruit set ha⁻¹. R and X are soil temperature in °C (at 30 cm) and mulch doses in Mg ha⁻¹ respectively. Screening of pointed gourd genotypes on the basis of fruit setting were made for heat tolerance in India, Project Directorate of Vegetable Research (1998). They also found that even the fruits set at high temperature (40°-44 °C) affected physiological maturity and caused premature fruit drop. Hence higher fruit setting is a reality from mulched plot and is an advantage along with other benefits. From the experiments over the years it was also established that straw mulch application can produce heavier and healthier individual tender fruits over no mulch bare soil cultivation which usually have higher market preference and price as well (Table 2). Under sized, deformed and discoloured fruits (in ventral sides) were harvested from non-mulched plots which generally leads to distress sale of the product at a relatively low price. Average length, average weight and average circumference of fruit were increased by 7 to 16 per cent, 4 to 12 per cent and 3 to 6 per cent respectively due to application of straw mulch. Positive response of mulching on fruit quality (average weight, length and circumference) is represented below.

$$Y_{APW} = 27.32 + 0.19 X, R^2 = 0.87^*$$

$$Y_{AFL} = 6.97 + 0.026X, R^2 = 0.90^*$$

$$Y_{AFC} = 13.99 - 0.006 X, R^2 = 0.96^{**}$$

Where Y_{APW} , Y_{AFL} and Y_{AFC} are the mean (three years) fruit weight (g), length (cm) and circumference (cm) respectively and X is the doses of mulch in mg ha^{-1} respectively. While carefully examining the role of root zone temperature on the fruits average weight and its length it was observed that these fruit quality parameters were adversely affected by rise in soil temperature. It is note worthy to mention that the individual fruit weights were reduced by 0.63 g due to every 1°C rise in soil temperature above 31°C . The expressions are shown here for convenience.

$$Y_{APW} = 49.92 - 0.63 T, R^2 = 0.81^*$$

$$Y_{AFL} = 10.54 - 0.10 T, R^2 = 0.92^{**}$$

Here Y_{APW} , Y_{AFL} and Y_{AFC} are the mean (three years) fruit weight (g), length (cm) and circumference (cm) respectively. T is the soil temperature in $^\circ\text{C}$ (at 30 cm). In summer months, quality fruit production through rice straw mulching is now a viable alternative from pointed gourd field.

Table 2. Effect of mulch level and soil temperature (30 cm at 2.00 PM) on fruit size and weight of pointed gourd

Treatments Mulch doses	Mean soil temperature ($^\circ\text{C}$), 30cm at 2.00 p.m.	Average fruit weight (g)	Average fruit length (cm)	Average fruit circum- -ference (cm)	Plant population (ha^{-1})
0 Mgha^{-1}	37.9	29.08	6.21	11.56	19433
8 Mgha^{-1}	32.9	30.80	6.45	11.86	41484
12 Mgha^{-1}	32.6	30.60	6.71	11.89	42459
16 Mgha^{-1}	32.2	31.01	6.58	11.80	43160
20 Mgha^{-1}	32.3	31.85	6.69	11.85	43891
S.E.m $\pm$	--	0.81	0.09	0.108	7019
L.S.D (P=0.05)	--	1.65	0.18	0.22	19367

Weed control and straw mulch

The prevalent weed flora in pointed gourd field consisted of grassy weeds, sedge and broad-leaved weeds etc. Among the grassy weeds, *Cynodon dactylon*, *Echinochloa colonum* and *Digitaria* species were predominant. *Melilotus* spp., *Eclipta alba*, *Ageratum conyzoides* and

Minusa pudica were predominant among broad-leaved weeds. *Cyperus rotundus* was the only nut sedge found in the crop field. Mulched plots were relatively weed free over non-mulched plots for a prolonged period of nine month's (Fig. 4). This weed control was mainly due to smothering effect of mulch (Khan *et.al.*, 1997) that cuts off the sunlight from the active plant parts (weeds) and hindered the growth and development of freshly emerged weeds. The weed dry matter reduced progressively with the increase of mulch doses. The figure shows that if no mulch is applied, at the beginning (1st month) the amount of weed dry matter increases enormously. At this early stage when the crop LAI is low, this has a devastating effect on crop growth.

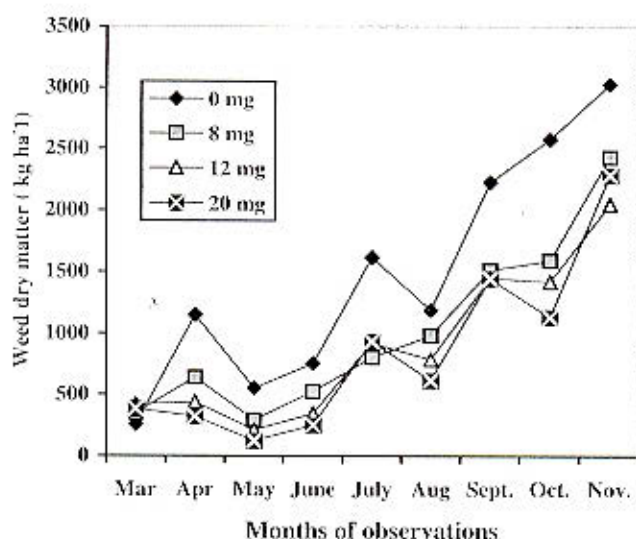


Fig. 4. Effect of mulch on weed dry matter accumulation in pointed gourd field

Mulching reduces this effect. Mulching @ 16 mg ha⁻¹ recorded only 16 to 68 percent of the total weed dry matter produced by non-mulched plots in different months of observations. Mulching @ 16 mg ha⁻¹ reduced the grass, nut sedge and broad-leaved weed population per square meter by 57 to 90, 73 to 91 and 50 to 71 percent respectively over non-mulched plots at different dates of observations over the crop growth period from March to November. As the weed dry matter was low under mulched condition, the competition for water, space and nutrition by weeds with the main crop was obviously reduced. The manpower requirement in manual

weeding will thus be reduced. Ghorai *et al.* (1999) have reported weed control ability of mulch in pointed gourd field. From the experiment it is evident that weed pressure in pointed gourd field can be minimised through rice straw mulching which is cheap and environment friendly as well.

Tender fruit yield and straw mulch

Rice straw mulch significantly increased the tender fruit yield (Table 3) of pointed gourd over no mulch bare soil cultivation. The crop responded well to an irrigation level of IW/CPE = 1.5 in combination with rice straw mulch @ 16 mg ha⁻¹. In this treatment, the fruit yields ranged from 36 to 76 quintals ha⁻¹, over three experimental years. 77 to 323 per cent increase in fruit yield was recorded due to mulching over non-mulch cultivation. This was primarily due to higher fruit set per unit area coupled with heavier and healthier individual fruit development from mulched plots over non-mulched soils (Ghorai, 1994). This increased fruit yield was primarily due to favourable growth environment created by mulch over traditional bare soil cultivation. This system reduced the soil temperature and moisture stress, maintained a relatively weed free climate and improved nutrient status of soil after its decomposition. The optimum doses of straw mulch varied from 14-16 mg/ha⁻¹, in different years.

$$Y (\text{Mean}) = 1726.42e^{0.0009X}, R^2 = 0.78^*$$

$$Y (\text{Mean}) = 307771.76e^{-0.1407T}, R^2 = 0.92^{**}$$

Here Y is tender fruit yield (kg ha⁻¹) and X, doses of mulch in mg/ha⁻¹. T is soil temperature at 30 cm soil depth in °C.

Table 3. Effect of rice straw mulch on yield (kg ha⁻¹) and fruit setting of pointed gourd

Treatments	Yield of tender fruits (kg ha ⁻¹)				Number of fruit set ha ⁻¹		
	1992	1993	1994	Mean	1992	1993	1994
0 mg ha ⁻¹	1910	2034	584	1509	62896	66033	23955
8 mg ha ⁻¹	2671	3675	1458	2601	107913	113852	52925
12 mg ha ⁻¹	2814	5247	1808	3288	149577	159965	666604
16 mg ha ⁻¹	3390	5363	2472	3742	110837	162707	95889
20 mg ha ⁻¹	2617	4752	2051	3140	80379	149641	71760
S.Em. ±	528.9	817	286	543.96	39223	22383	10151
L.S.D (P=0.01)	1074	2240	784	1490	79932*	61351	27824

Reduction of yield due to higher mulching doses may be due to excess water held in soil leading to anaerobic condition and nitrogen deficiency through leaching as quoted by Wrigley (1981) in sugarcane in Mauritius.

Rice straw mulch, thus can provide proper hydrothermal regime suitable for better crop growth and yield. It reduces the stress due to high soil temperature and deficit moisture, particularly on fruit set and its quality and is an eco-friendly weed control tool. This technology can be utilised with advantage for the other commercially important summer cash crops sensitive to heat and moisture stress keeping the soil fertile.

CONCLUSION

Rice straw mulch maintained better hydrothermal regime over the years and improved soil health over bare soil cultivation. Under different levels of irrigation and mulch, mulched plots maintained an average of 14 to 40 per cent more soil moisture than non-mulched plots. Twenty-four hours after irrigation, mulched plots retained 7 to 17 per cent more soil water than bare soil cultivation under different irrigation schedules. Irrigation at IW/CPE = 1.5 with straw mulch 16 mg ha⁻¹ saved 30 cm irrigation water over irrigating the crop at IW/CPE = 2.0. In summer months, the surface and sub surface soils remained cooler due to mulching. Straw mulch increased the available potassium, phosphorus and organic matter content of soil after its decomposition. Mulching recorded higher fruit yield (3742 kg ha⁻¹) over bare soil cultivation (1509 kg ha⁻¹) due to higher fruit set and healthier fruit development. It also reduced the weed menace significantly. There is a wide scope of utilising these beneficial effects of rice straw mulch in other wide spacing cereals, pulses, oilseeds and vegetables, particularly under stress situations while keeping the soil fertile.

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CONFIRMED SOURCES OF ADULT PLANT MULTIPLE RUST RESISTANCE IN WHEAT (*Triticum aestivum* L. *T. Dicoccum* AND *T. Durum*) AND TRITICALE X

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ABSTRACT

Leaf (*Puccinia recondita*), stripe (*P. striiformis*) and stem rust (*P. graminis tritici*) are the major diseases of concern in wheat and triticale in India and breeding for rust resistance is a continuous process. The relative importance of each rust, however, varies with the agroclimatic zones. The leaf and stripe rusts are of major concern in northern hills and north-western plains zones whereas leaf and stem rusts are of much importance in central and peninsular India. Likewise, in north-eastern plains zone, leaf rust is of major importance. In southern hill zone, all three rusts are of importance. Thus, the leaf rust is important for all the wheat growing zones of the country. Keeping in view the success of host resistance in managing the rusts of wheat and triticale X, the rust resistant genotypes identified from Advanced Varietal Trials (AVTs) as well as other international nurseries were re-tested for confirmation of their resistance against three rusts at hot spot locations. Out of total 1403 genotypes tested, 375 were having average coefficient of infection ranging from 0-10.0 and were resistant to either three or two rusts. Out of these, 201 of bread wheat, 40 of macaroni wheat, and 12 genotypes of triticale were resistant to stem, leaf and stripe rusts. In addition, 46, 2 and 1 genotypes of bread, macaroni and triticale, respectively were resistant to only leaf and stem rusts. Likewise, the genotypes resistant to leaf and stripe rusts were 49, 23 and 1 of bread wheat, macaroni and khapali wheat, respectively. These lines have wide genetic base and those identified in AVTs are quite good in agronomic characters. The seeds of these are kept in gene banks of DWR, Karnal and National gene bank at NBPGR, New Delhi.

Keywords: Wheat, Triticale X, Multiple rust resistance, Confirmed sources

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INTRODUCTION

Host resistance plays a major role in the management of diseases in wheat and triticale. Several rust resistant varieties were released during post green revolution era in India. However, evolution of new pathotypes in leaf, stem and stripe rust caused by *Puccinia recondita* Rob. Ex. Desm., *P. striiformis* West., and *P. graminis* Pers. f.sp. *tritici* Erikss. and Henn., respectively, always pose challenges in managing the rusts in India and regular efforts to breed for resistance are required. The varieties like HD 2285 and HD 2329 which were quite popular during eighties and early nineties are no longer able to sustain their yield potential due to susceptibility to new pathotypes and thus suffers yield losses up to 25.8% due to leaf rust (Singh, 1999). Hence these have been replaced by new resistant varieties like PBW 343, HD 2687, UP 2425, DBW 14 etc. Development of resistant genotypes/ varieties is thus, a continuous process. This has emphasized the identification of new donor lines with multiple rust resistance and diverse genetic base for the use in breeding for rust resistance. Keeping this in view, the rust resistant genotypes identified in different disease screening nurseries of national and international and material received from CIMMYT, Mexico, were re-tested at 'hot spot' multilocation to confirm their multiple rust resistance.

MATERIALS AND METHODS

Elite Plant Pathological Screening Nursery (EPPSN) consisting of resistant genotypes identified in AVTs and international nurseries were planted at hot spot locations during 1997-98 to 2002-2003 crop seasons (6 years). The hot spots are the locations where the environment is very congenial for disease development and sufficient races or variants of pathogen are available in nature. These centres for different rusts were as follows:

- Stem rust** : Mahableshwar, Wellington, Indore, Dharwad.
- Leaf rust** : North: Hisar, New Delhi, Karnal, Ludhiana, Pantnagar, Durgapura
- South** : Mahableshwar, Indore, Wellington and Dharwad.
- Stripe rust** : Karnal, Ludhiana and Durgapura

In total, 1,403 entries of bread wheat (*Triticum aestivum* L. emend Fiori & Paol.), durum wheat (*T. durum* Derf.), Khapli wheat (*T. dicoccum* Schubl.) and Triticale X were tested. Some of the entries found resistant in previous year tests to rusts were repeat planted next year for re-testing. Each entry was planted in a row of 1m length. An infector row of a mixture of highly susceptible varieties like Agra local, Sonalika, Lal Bahadur, HD 2285, WL 711 and NP 4, was planted after every 20 test entries as check and rust spreader row. The

screening block was also provided with two lines of susceptible check varieties on the borders to create maximum inoculum pressure of rust pathotypes. The most predominant and virulent pathotypes as mentioned below were used for artificial inoculation on infector lines quite early in the season (Dec- Feb.).

Stem rust: 7G11 (122), 7G43 (295), 11(79G31), 15C (63G31), 19G35 (42), 20G21 (21A-1), 21A-1 (20G21), 21A-2 (75G5), 24G5 (21-1), 37G19 (117-6), 40A(62G29), 42 (19G35), 42B2 (98G51), 62G29 (40A), 62G29-1 (40-1), 63G31 (15C), 104G13 (40), 117-6(37G19), 119G51 (42B2), 122(7G11), 203G15 (11A).

Leaf rust (North): 12-2(1R5), 77-2 (109R31-1), 77-4 (109R31), 77-5(121R63-1), 104-2(21R55), 104B (29R23).

Leaf rust (South): 1R5 (12-2), 12-2 (1R5), 12-3 (49R37), 12-4(5R13), 13R27 (108), 57R27 (108-1), 21R55 (104-2), 21R63 (104-3), 49R37 (12-3), 69R13 (12-4), 45R31 (77), 77A (109R31), 77-2 (109R31-1), 77-3 (125R55), 77-5(121R63-1), 93 R7 (162), 93R (162A), 104-2(21R55), 104-3 (21R63), 108 (13R27), 108-1 (57R27), 109R31 (77A), 109 R31-1 (77-2), 125R55 (77-3), 125R23-1 (77-4), 121R63-1 (77-5), 121R55-1 (77-6), 162 (93R7), 162A (93R15)

Stripe rust: 13(67S8), I(38S102), K(47S102), L(70S69), P(46S103), 46S119.

The inoculation was done using syringes as well as foliar sprays with mixtures of uredospores of different pathotypes of each rust separately. Further spread of rusts was ensured by spraying of water on the spreader rows and by maintaining proper moisture conditions in screening block.

The rust records were taken in modified Petersons' scale (Joshi *et al.* 1988) from flowering to hard dough stage and final disease score was taken in to consideration. The recording of rusts was based on severity of disease on plant parts as per Peterson *et al.* (1948) and the host response was recorded as 0- No visible infection, R- Resistant, MR- Moderately resistant, X- Intermediate, MS- Moderately susceptible, S-Susceptible. The Coefficient of Infection (CI) was calculated by multiplying the percentage of severity by the 'response value' assigned to each infection type as below:

Reaction type	Response value	ACI Value
No visible infection (0)	0	0
Resistant (R)	0.2	0.2-10
Moderately Resistant (MR)	0.4	
Intermediate (X)	0.6	
Moderately Susceptible (MS)	0.8	
Susceptible (S)	1.0	

The Average Coefficient of Infection (ACI) was calculated by taking the average of CI of the entries at each location. The entries having ACI ranging from 0-10 was categorized 'resistant'.

RESULTS AND DISCUSSION

Out of 1,403 genotypes tested, 375 were found resistant to all three or at least two rusts spp. In total, 201 genotypes of bread wheat, 40 of macaroni wheat, and 12 genotypes of triticale were resistant to stem, leaf and stripe rusts. In addition, 49, 2 and 1 genotypes bread, macaroni and triticale respectively were resistant only to leaf and stem rusts. Likewise, the genotypes resistant to leaf and stripe rusts were 49, 23 and 1 of bread wheat, macaroni and khapali wheat, respectively. The details of genotypes, along with their pedigrees are given in Table 1. Most of the genotypes bred in the centers located in peninsular and central India were highly susceptible to stripe rust. Twenty entries received from CIMMYT, Mexico were found resistant to the Indian pathotypes of leaf and stripe rusts. Some of the entries showing almost immunity (ACI= 0) to individual rust are listed below:

Highly resistant to leaf rust: Nineteen entries of wheat, namely HD 2700, HD 2837, HP 1832, HPW 160, HUW 507, HS 443, HS 446, HW 3008, HW 3010, HW 3027, HW 3033, HW 3035, MACS 6086, UP 2456, WH 595, VL 842, PBW 503, PBW 509, PBW 510 and two of triticale, viz. TL 2900, TL 2908.

Highly resistant to stem rust: Four entries of wheat namely, HD 2618, HS 375, HW 2045, RAJ 3974 and seven of Triticale X, DT 90, DT 95, DT 132, DT 133, TL 2908, TL 2861 and TL 2877.

Highly resistant to stripe rust: Forty seven genotypes of bread and macaroni wheat: HI 8591 (d), HS 418, VL 823, VL 824, PBW 500, HD 2780, HW 4028, HS 240, VL 818, VL 829, VL 830, PBW 492, HUW 541, HS 443, VL 852, VL 853, VL 854, HPW 216, SKW 191, SKW 196, CBW 14, UP 2554, CBW 17, HD 2824, HD 2826, WHD 929 (d), HS 437, HW 3097, VL 822, HUW 543, PBW 475, HS 240, HS 424, HI 8653 (d), PDW 283, HD 4694 (d), DWR 251, HD 2805, HS 444, VL 850, HD 2830, HUW 555, PBW 511, UP 2665, AUKD 1(d), AUKD 3 (d), HW 4028. d=*T. durum*

Most of the lines selected from final years of testing were high yielding and may be used as resistant sources in breeding programme against rusts. The genotypes having resistance to leaf and stripe rusts are also good for northern hill and plains as well eastern India, whereas those showing resistance only to stem and leaf rust may be of use in central and peninsular India. A total of 161 entries having varied genetic base have been included in the National Genetic Stock Nursery (NGSN) and sent for utilization at 36 wheat breeding centers across India. The pure seed of resistant entries has been deposited in the germplasm unit of DWR, Karnal and National gene bank at NBPGR, New Delhi for safe storage inside the low temperature module as well as distribution among the wheat and triticale breeders.

Table 1. Multiple rust resistant lines of *T. aestivum*, *T. dicoccum*, *T. durum* and Triticale X and their pedigrees

Entry	Pedigree
A. Resistant to leaf, stem and stripe rusts	
Bread wheat (<i>Triticum aestivum</i>)	
CBW 17	PRINIA/WEAVER//STAR
DL 96-8	(HD 2762):DL 7843//CONDER SEL. 7// AG 3 DL 66/HD 2204
DL 547-2	RAJ 1282/RAJ 821.NAD MUT./HIRA MUT.
DL 975-1	DWARF*6/ 3AG-3/KITE//SKA/OLSON/CMM 67/HD 2329
DL 1107-1	WL 71182/BRESSE/DL896-2//DL 330-1
DWR 202	GLENTON
DWR 247	PRL/VEE#6//SONALIKA
GW 244	VEE/RL 6010/YR/3/VEE/4/GLENARO
GW 260	VEE/RL 6010/R*YR/3/2*VEE 'S'/4/GEN
GW 273	TW 275/77/10/LOK-1
GW 276	CPAN1401/SKA-YACORA/HD 2160
GW 295	CPAN 1827/CPAN 1967//HD 351
HD 2580	TTR 'S'/JUN 'S'
HD 2636	KVZ/CGN//GLT
HD 2639	CNO 79/PRL 'S'//GAA
HD 2643	VEE'S'//HD2407/HD 2329
HD 2646	VEE 'S'/HD 2407//HD 2329
HD 2669	CS/A SCIR//3*PUN/3/MRL 'S'/BUC 'S'
HD 2700	HD 2285 LRG/HUW 328
HD 2724	BOW/PRL
HD 2747	HD 2402/HW 741/HD 2663
HD 2760	HAKN 2009/HD 2285//HW 741

Entry	Pedigree
HD 2777	CPAN 2009/HD 2285//HW 741
HD 2780	DACULA/CHAGUAL/CA 20
HD 2826	J 1316/HD 2347HD 2631//HD 2278
HD 2835	J 1316/HD 2631//HD 2452/LIRA
HD 2837	PARA 2/JUP/BJY/3/VEE*5/4/JUN/4/P60
HI 1436	RAJ1972/RAJ 1923
HI 1459	CPAN 1931/HD 2236//HD 1042
HI 1391	MRL 'S'/BUCK 'S'
HI 1404	VEE 'S'/RL 6010/2YR/3/2 VEE 'S'
HI 1433	HUW 202/HP 1209//WL 711
HI 1434	WH 147/CPAN 188
HI 1436	RAJ 1072/RAJ 1923
HI 1459	CPAN 1931/HD 2236//HD 1042
HI 1462	RAJ 3160/HD 2449
HI 1479	HD 2195/HD 2160//WH 283
HI 1499	WH 147/WH 494
HI 1502	HI 1182/CPAN 1990
HI 1514	HDR 162/DA 17
HP 1718	LOVE 23/BJY 'S'/3/BB/NOR/CNO 'S'/1/MOR 'S'/AD 'S'
HP 1728	RL 6010/6* INIA 66//3* KAUZ
HP 1748	HP 1606/UNNANT C 306
HP 1749	RL 6043/4* NAC 76
HP 1761	RL6010/6*INIA 66//3*KAUZ
HP 1811	GARUDA/UN HD 2285
HP 1815	VEE 'S'/3/BAGE/HORK 'S'//ALDAN 'S'/47 BOW 'S'
HP 1831	VEE 'S'/3/BAGE/HORK 'S'//ALDAN 'S'/4/BOW 'S'

Entry	Pedigree
HP 1832	HP 1606/UNNANT C 306
HPW 42	VEE'S/4/PUN 'S'/CBB//CNO 'S'/#/JAR/ORZ 'S'
HPW 68	INTERMEDIO RUDI/HD 2248
HPW 82	VEE 'S'/MYNA 'S' CM 73815-2M-3Y-O3M-1Y-1B-OY
HPW 143	BB/G11/CJ7//3/TAEST//KAL/BB
HPW 147	CPAN 1869/HIMIO-BA
HPW 152	CPAN 1869/HB 208
HPW 155	BT 2549/FATH
HPW 160	CPAN 1922/CPAN 1929//CPAN 1922
HPW 162	HTON 35
HPW 185	UPT 74303/S 308//CPAN 1830//TL 68/HS 74//3/CPAN 1922
HPW 191	CPAN 1869/HB 208
HPW 211	MO 88/MILAN
HPW 216	HS 277/HS 321
HS 341	RAU 'S'
HS 364	NAC/3/STW/63/AGEL//ANZA/4/BOW 'S'/CEP 7780-ARA
HS 365	HS 207/SKA
HS 375	BB/G 11/CJ 71/TAES 1//KAL/BB
HS 295	CQT/AZ//IAS 55/ALD 'S'/3/ALD 'S'/NAFN/4/PIN 'S'/PEZSI-127
HS 396	PFAU/G/B6/GU/GJ/F.30.70//KAL/B6/5/VEE#7
HS 418	CHIRYA 3
HS 431	Y 81623//BUC/PVN
HS 435	HPW 42/CPAN 3004
HS 437	HS 284/HD 2380
HS 446	PASTOR

Entry	Pedigree
HPW 155	BT 2546/FATH
HPW 211	MO 88/MILAN
HPW 216	HS 277/HS 321
HUW 434	HUW 55/HUW 300/HUW 202
HUW 439	SERI/HUW 234//BOW 'S'/HUW 37
HUW 467	K 8101/HI 617//K 68
HUW 468	CPAN 1962/TON//LIRA 'S'/PRL 'S'
HUW 482	VEE 'S'/BOW 'S'//HUW 300/CCBS 57
HUW 507	PBW 139/WL 1763//CCBS 57/HUW 395
HUW 522	DL 230-16/HUW 234//HD 2278
HUW 550	HUW 234//HD 2189/PBW 54-326-2
HUW 554	CPAN 1990/HUW 300
HW 1084	HW 1042/NP 807
HW 1085	C 306*7/TR 380-14*7/3AG 14
HW 2023	C 306*7//DWRKITE
HW 2044	PBW 226*5/SUNSTAR*6/C 801
HW 2062-1	WH 542*6/CS 2A/2M 4/2
HW 3004	HW 1042//C 306
HW 3005	HW 1042/NP809
HW 3006	TR 380-14*7/3 AG 14//KALYANSONA//VEE "S"
HW 3007	TR 380-14*7/3 AG 14//KALYANSONA//VEE "S"
HW 3008	HW 1042/C 306*2//HW 1042/C306
HW 3009	HW 1042/C306*2//
HW 3010	TIMGHALEN//P//8
HW 3013	HD 2329 //VEE 'S'
HW 3014	HD 2329 //VEE 'S'

Entry	Pedigree
HW 3016	TR 380-14*7/3 AG 14//LALAYAN SONA//VEE 'S'
HW 3019	HD 2329//VEE 'S'
HW 3020	HD 2329//VEE 'S'
HW 3021	HD 2285//HW 1042
HW 3026	TR 380-14*7/3 AG 14/7//KS//FIASALABAD 85
HW 3029	HW 2002//VEER/ 'S'
HW 3032	MACS 2496//UKS
HW 3033	UKS//VER 'S'
HW 3034	WH 542//HW 2001-A
HW 3045	SONALKA*7//ABE//VEE 'S'
HW 3068	HW 1042//C 306
HW 3082	BOW//BUC/BUL//CLRP-6
HW 3083	KAL/CPAN 1883/SUJATA
HW 4028	PBW 226*5//C 86-8/KALYANSONA F4
HW 4011-1	WH 542*6//C86-8/KALYANSONA E ₄
HW 5005	PBW 226/HW 3003
JWJ 3016	KAL/CPAN 1883/SUJATA
K 2008	K 88/K 9006//2*K9006
K 8962	K 7401/HD 2160
K 9107	K 8101/K 68
K 9223	VEE 'S'//NKT 'S' CM 73994-1M-1Y-2M-BY-2M-OY
K 9466	K 7827//HD 2204
K 9563	25/HD 2285
MACS 2778	B. YELLOW/CHAPAL
MACS 3061	CPAN 6120/CPAN 6093
MACS 3063	CPAN 6120/CPAN 6117
MACS 3127	RAJ 1555/CPAN 6120

Entry	Pedigree
MP 1130	WH 147/MP 867//WL 2265/ K. SONA/SR 27
NIAW 34	CIANO 79/PRL 'S'
NIAW 129	CNO 79/PRL 'S'
NIAW 300	TURACO/CHIL
NIAW 301	SERI 82/3/MRS/JUP//HORK 'S'
NIAW 514	U.KALYANASONA/PR-2
NIAW 535	NI 8796/HD 2380//RAJ 1777/CPAN 3024
NIAW 723	NI 9406/MACS 2496//WW 2218/YC-BW-13 CMH-76A-962 NI 9406/YC-BW-13-CMH-76A-962//WW 2218/YC- BW-13
NIAW 835	CMH-76A-962
NW 1001	K 134 (60)/4/TOB/BMAN/BB/3/CAL/PB 71-23A-4A-OA
NW 1012	PARANA#2/1 JUP/BJY 'S'//3/VEE#5
NW 1033	F 677/BUN//515/3/YR/PAM/JUN 'S'
NW 1035	F 74/BUN//STS/3/VEE#7
NW 1067	TR 380 16 306 14/CAHAT 'S'
PBW 342	ND/VG 1944//KAL//BB/3/YACO 'S'//4/VEE 'S'
PBW 343	ND/VG 1944//KAL//BB/3/YACO 'S'//4/VEE#5 'S'
PBW 396	CNO67/MFD//MON'S'/3/SERI
PBW 426	KT BAGE/HP 2449//RAJ 3219/WL 711
PBW 441	PBW 286/RAJ 1973
PBW 445	KAUZ/GEN
PBW 452	PARA/JUP/BJY/3/VEE/4/JUN/5/2*KAUZ
PBW 468	WH 581/CPAN 1959//PBW 302
PBW 474	IAS 58/HD 2281//WG 2348
PBW 491	PBW 282/CPAN 3005//DL 788-2
PBW 493	PBW 154/PBW 343/WH 542

Entry	Pedigree
PBW 498	WL 6736/*2 WEAVER
PBW 500	PBW 351/W 4387
PBW 506	KAUZ/PBW 232
PBW 509	W 1634/PBW 381
PBW 510	W 1634/PBW 381
PBW 514	PBW 282/CPAN 2005//DL 788-2
RAJ 3702	RAJ 1972/RAJ 1973
RAJ 3713	RAJ 1972/RAJ 3179
RAJ 3856	RAU "S"(CM598123-3M-1Y-3M-2Y-1M-0Y-29Y-OM)
RAJ 3897	RAJ 3251//RPG 138//HD 2425
RAJ 3900	RAJ 3037/PBW 160
RAJ 3965	NGWN/32/CPAN 3015
RAJ 4012	WD 232/RAJ 3077
RAJ 4027	HD 2594/DL 788-2
RAJ 4041	WH 594/AJ 3717
RL 1022	RC 10 /RL 22
SKW 196	BSP 93-21 (Sel. From EIGSN 98)
UP 2352	RAJ 2560/UP 319
UP 2383	CPAN 1998/PBN 112//CPAN 1998/UP 2121
UP 2358	CNO 67/MPO//MON 'S'/3/SERI
UP 2418	HD2320/UP 2263
UP 2435	4774(2)//FKN/GB/3/VEE 'S'/4/BUC 'S'/PVN/UP 2121
UP 2447	HUW 286/HW 2001
UP 2458	UP 2273/PBW 288
UP 2456	HD 2550/WH 540/VEE 'S'/BOW 'S'
UP 2473	HD 2550/WH 540/VEE 'S'/BOW 'S'
UP 2481	PBW 258/UP 2113//CPAN 3004

Entry	Pedigree
UP 2544	ATTILA//PSN/BOW/3/ATTILA
UP 2556	DL 802-1/Raj 3077
UP 2600	BL 1496/3/HE//3*CNB 79//2*SERI
UP 2571	PBW 352/WH 595
VL 723	TTR 'SD'/JUN 'S'
VL 751	VEE#5 'S'
VL 759	BUC'S' /CHRC 'S'//PRL 'S'/VEE#61
VL 775	PFAU/VEE#5
VL 791	WEMBLEY/VL404
VL 796	WEMBLEY/VL404
VL 801	HS 240/CPAN 3031
VL 802	CPAN 3018/CPAN 3004//PBW65
VL 803	SERI/CPAN 2099
VL 804	CPAN 3018/CPAN 3004//PBW65
VL 809	WONLRA 47/CPAN 3031
VL 823	WONLRA 47/CPAN 3031
VL 824	LAI 3302/TURACO//TURACO
VL 829	IBWSN 149/CPAN 2099
VL 831	KLAT/SOREN/PSN/BOW
VL 852	ALFROG#4/HD30//CPAN 3004//PBW 65
WH 601	RRV/WW15/3/BJ 'S'/2*ON/BON/4/NAC
WH 672	JUP/ZP//COC/3/PUN/4/GEN
Macaroni wheat or durum (<i>T. durum</i>)	
DWR 1005	ALTAR/HD 4502//RAJ 1555
DWR 1006	SULA/CREX//AAZ
DWR 1010	RAJ 1555/HD 4502//CHEN 'S'/ALTAR 84
GW 1092	WAHA/RUFF'S//RAJ 1555

Entry	Pedigree
GW 1128	JU 38/CPAN 6079
	FG 'S'//VZ 324/CP/VL//156/3/HAUR/4/RUFF 'S'
GW 1129	FG 'S'//TRCB 'S'/YAV 'S'
GW 1139	MACS 2340/TWP 5070
GW 1153	VAN 14
GW 1170	P 5556/3/GALL//FINCH/IL 189
GW 1171	IWP 5061/M/81/1965
GW 1189	SU-CULLUGU-7/VD 90-12
HD 4664	JUP/2P//COC/3/PUN/4/GLEN
HD 4666	HD 4612/HD 4620//PBW34
HD 4672	BRED/PBN 34//ALTAR 84
HD 4684	CRA/MEXI//AUK/3?SRN
HD 4696	AAZ/MORUS-1
HI 1514	HDR 162/DA 17
HI 8498	CR'S'GS'S'/A-9-3-1//RAJ 911
HI 8540	CAS 'S'/ALTAR 84
HI 8591	HI 8144/NI 8625
HS 437	HS 284/HD 2380
HUW 554	CPAN 1990/HUW 300
HW 4011-1	WH 542*6//C 86-8/KALYANSONA
HW 5002	HD 2618//HW 2002 A/CPAN 3057
MACS 6086	HW 2004 (C 306*7/LR 24)
	ICD 79-1479-IAP-5AP-OAP-Tafna-ZDC-34392-2AP-5AP-4AP-OAP
NIDW 9	
NIDW 15	DOM 50
NIDW 71	SERI 82/3/MRS/JUP//HORK 'S'
PDW 289	AJAIA 12/F3 Local (SEL. ETHIO. 135.85)//PLATA 13

Entry	Pedigree
PDW 383	BOW/PRL/BUC
RAJ 6513	SRN/3/TEZ 'S'/YAV 79//HUI 'S'
RAJ 6516	SRN/3/SAPI 'S'/TEAL 'S'/HUI 'S'
RAJ 6553	PIN FOOT 5
RAJ 6557	YAV APOS 79
UAS 2021	THB/CEP 7780//2* MUSK 4
UPD 46	DL 92-2/RAJ 1972
UPD 52	PDW 222/UPD 8
UPD 60	NI 8687/RAJ 1555
WH 921	INIA 66/AA/INIA 66/3/SEN 81
WHD 929	BISU-1/PLATA-16//RISSA)
Triticale X	
DT 74	TR 55/C306/TR125
DT 90	TL 1210 /TR 85
DT 91	4774(2)//FKN/GB/3/VEE 'S'/4/BUC
DT 132	TL 68/DTS 940
DT 133	DT 24/HW 2006 UNNATH LOK-1//DT 63
TL 2861	JNIT 123/TL 2523
TL 2864	EM56TA 7/3 HEADT/3/BCM/GPR
TL 2877	TL 2597 /HD 2420//TL1210
TL 2908	TL 2614/JNIT 141
TL 2910	TL 2614/JNIT 141
TL 2915	JNIT 141/TL 551/M-78-9224/3/TL 2727
UPT 46	DL95-2RAJ 1972

Entry	Pedigree
B. Resistant to stem and leaf rusts only	
<i>T. aestivum</i>	
DWR 240	KAUZ*2//SAP/MON/3/KAUZ
DWR 241	CETTIA 'S'
GW 322	PBW 173/GW 196
GW 324	DL 802-3/GW 503
GW 337	HD 2320/HD 2309//HD 2329
HD 2755	C 306-HYB 65-CPAN 598//HW 2003
HD 2781	BOW/C 306//C 591/HW 2004
HD 2805	VEE#8/JNP/B1Y/F3-7/TRM/4/BCN/51
HD 2815	BOW/C 306*2/HW 2003
HD 2819	CPAN 3004/WR 447//HW 2007
HD 2988	STN 'S'/GOTE 'S'
HI 1489	VEE 'S'/RL 6010/2Yr/3/2 VEE 'S'
HI 1490	KAUZ#2TZPP
HPW 210	29 AD/CPAN 830//20 AD/CPAN 1922
HS 396	PFAU/4/4/BB/GLL/CJ/3/F.30.70//KAL/BB/5/VEE#7
HS 411	PUN/PRL//VEE#6
HS 412	PRL/VEE#5/MYNA/VUL
HW 2017	HD 2402/7/TR 380-14*7/3/ AG 14
HW 2044	HBW 226*5/SUNSTAR*6/C80-1
HW 2045	HD 2402*5/SUNSTAR*6/C80-1
HW 3024	PBW 226*5/TR 380-14*7/3 AG 74
HW 3027	HD 2285//HW 1042
HW 3035	HD 2329//VEE'S'
HW 3037	HW 2012/HW 1042
HW 3064	K.SONA//YR*6/WRT 2385/TR 380 14*7/3 AG 14

Entry	Pedigree
HW 3067	HW 1042//C 306
HUW 510	HD 2278/HUW 234//DL 230-16
HUW 516	S/B/A-CM82355-104-OY-2M-4M
HUW 533	UNNANT C 306/HUW 81//K8027
HUW 526	CCBS 57/WL 1763//HUW 395/PBW 139
HUW 543	HUW 234/HD 2204//DL 230-16
K 9706	K 8565/UP 2003
K 9743	B 1153/DSN 72//HW 2002/LOK 1
K 9904	B 1149/ K 9006// K8565
LOK 41	HW 2006//HW 2002/LOK 1
LOK 42	HW 2006//HW 2002/LOK 1
PBW 486	PBW 343/PBW 154/HD 2160
MP 1142	169-90 C 369/ CBRD//SW 89. 1862
NW 2049	KAUZ/ TRAP//KAUZ
RAJ 4000	HD 2 2564/DL 788-2
RAJ 4005	HD 2596/DL 8022
RAJ 4014	DL 8025/K 9011
VL 818	SPINEBILL "S"/CPAN 2045
VL 832	PBW 65/CPAN 3004
RAJ 4037	DL 788-2/Raj 3717
VL 850	DICKSON 98/CPAN 3031
<i>T. durum</i>	
GW 11	P 5556/3/GALL//FINCH//IL 184
MACS 3208	MACS 9/GW 1
Triticale X	
DT 133	DT 24/HW 2006 UNNATH LOK-1//DT 63

Entry	Pedigree
C. Resistant to leaf and stripe rusts only	
<i>T. aestivum</i>	
CBW 09	P 1089//PBN 1695-14
CBW 12	KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/VEE#10/8/ OPATA
DWR 251	HAHN/2*WEAVER
GW 1182	GW 1051/N1 8625
HD 2816	C 306/KITE-2
HD 2784	ILTS-2264/4/CAR//KAL/BB/3/NAC/5/6 AA
HD 2825	J 1316/HD 2631//CNO/79/PRL/CHIL
HD 2834	SNB/HD 2347//J 1316
HD 2830	KAUZ//SERI/SEP 80120
HP 1731	LIRA 'S'//RRI 'S'/TONI
HS 420	KAJ 3302//CMH 73 A-497/3*CNO 79
HS 424	CPAN 3004//HPW(DL) 30/HS 286
HS 444	CHOIXM 95
HUW 468	CPAN 1962/TONI//LIRA 'S'/ PRL 'S'
HUW 528	WL 7060/TURACO 14
HUW 541	HUW 234//HD 2189/PBW 54
HUW 555	BOW 'S'/URES/HUW 300/PRL
HW 1085	HW 2002-A/CPAN 3057
HW 4028	PBW 226*5//C 86-8/KALYANSONA F4
MACS 6145	C 306+Lr 28
MP 1136	BOW//BUC/BUC/3/WEAVER/4/STAR
NW 2060	KT/BAGE
PBW 443	PBW 304/CPAN 1922
PBW 511	W 4387/UP 2338

Entry	Pedigree
RAJ 4028	HD 2596/PBW 323
SKW 191	UREA
UP 2473	HD 2550/WH 540//VEE 'S'/BOW 'S'
VL 832	PBW 65/CPAN 3031
WH 736	CMH 81, 137/CMH 81.580
<i>T. durum</i>	
AUKD 2	KYDRANASS A 30/SILVER-5
AUKD 3	MAGH 72/RUFO//ALG 86/RU/3/ALTAR 84/ALD/4
DWR 1006	KADU DIC.*4/ LOCAL DIC. //DWR 1005
DWR 2018	MEXI 75/B. YELLOW//CHEN/ALTAR
HD 4676	CPAN 1438/2/HD 4519//T.CARTH/2/NI 146
HD 4687	HI 8162/DON-LRA 60
HD 4692	TIMO/2*DWL 5023//WP 5011/ALT 84
HD 4694	ARAM/BOOMER
HI 8498	RAJ 6070/RAJ 911
HI 8620	A-9-30-1/CPAN 6117
HI 8653	AA2/MORUS-1
MACS 3125	RAJ 1555/CPAN 6120
NIDW 70	TOTUS
NIDW 301	SERI/82/3/MRS/JUP//HORK 'S'
PDW 215	DWL 5031/DWL 5002
PDW 274	PDW 222/RAJ 6419
PDW 275	PDW 222/RAJ 6419
PDW 278	TRYNG-5
PDW 283	AJAIA12/F3 LOCAL(SEL. ETHIO 135 -8)//CHEN/ALTAR 84
PDW 287	CHEN"S"/ALTAR"S"/PDW 235

Entry	Pedigree
RAJ 6553	FINFOOT-5
RAJ 6560	TOPDY-6
WH 896	SEL. FROM SULA
Khapali wheat (<i>T. dicoccum</i>)	
DWR 1013	NP 200/ LOCAL DIC.*4//LOCAL DIC./ACONCHI 89
CIMMYT Material	
Source-7th SMN	
<i>T. aestivum</i>	
SMN 9	CS/TH.CU//GLEN/3/ALD/PVN/4/NANJING 8401 CIGM87-1109-2Y-3/M-IPR-1M-IPR-3B-OPR-1M
SMN 10	EG-A/H567.71//4*EG-A/3/2*CMH79.243 CMH86.540-A-1Y-3B-2Y-1B-1B-1Y-1M-1Y
SMN 11	CAL/NH/H567.71/3/2*NING 7840/4/ CMH87.565-C-1Y-2B-1B-2B-2Y-1M-1Y
SMN 21-DON ERNESTOINTA	CM33203-K-9M-33Y-1M-500Y-OM-1J-OJ-OARG
SMN 26-KAUZ	CM 67458-4Y-2M-1Y-1M-3Y-0B-12M-OY
Source-EIGN-I	
HTWYT-67	KAUZ*2/DOVE*BUC*3*KAUZ
ESWYT-10	PRINIA
ESWYT-31	BSP.93.21
ESWYT-40	CHIL/2*STAR
ESWYT-48	VEE/PJN/2TUI
IBWSN-35	AMSEL/TUI
IBWSN-81	WL 6737/STAR CHIL/2/*STAR
IBWSN-101	WL 6736/2*WEAVER
SAWSN-12	BOCRO
SAWSN-53	PGO/SARA

Entry	Pedigree
SAWSN-66	FILIN
SAWSN-84	TODY/BAU
SAWSN-17	ALTER 84/AE..SQUARROSA(TASU)//OPATA
SAWSN-19	LIRA/SHA 5
SAWSN-204	SRDH/PIFED

CONCLUSION

The rust pathogens in wheat are still able to infect the wheat cultivars up to a great extent and regular transfer of resistant genes effective against newer pathotypes of leaf, stem and stripe rust depending on the degree of risk of different rusts in a particular agroclimatic zone in India and adjoining SAARC countries is necessary to avoid major rust epidemics in future. There are enough genetic variability in agronomically superior genotypes of wheat and tritcale X which may be exploited by the breeders in breeding for resistant varieties

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DISTRIBUTION AND EVOLUTION OF BIOTYPES OF RICE GALL MIDGE (*Orseolia oryzae*) IN ANDHRA PRADESH, INDIA

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ABSTRACT

Distribution and evolution of biotypes of rice gall midge, Orseolia oryzae (Wood-Mason), in the Indian State of Andhra Pradesh was monitored at two geographical scales by extensive field testing of a standard set of ten differential rice varieties during the wet seasons of 1995 to 1998. At a macro scale, distribution observed in the entire state through tests at eight different sites confirmed the presence of three distinct biotypes viz. biotypes 1, 3 and 4 that could be distinguished on the basis of reaction of the differentials. At a micro scale, the distribution limit of biotypes 1 and 3 within the Northern Telangana Zone of the State was noted through field tests at twenty one sites spread across 350 km. Though biotype 3 was distributed throughout the study area, there were pockets in which biotype 1 was prevalent. We also recorded temporal changes in the reaction pattern in the town of Warangal within the course of the study and noted the emergence of new biotypes with virulence against the resistance genes in the most commonly deployed varieties in the area.

Keywords : Rice Gall Midge, *Orseolia oryzae*, Biotypes, Andhra Pradesh.

INTRODUCTION

The Asian rice gall midge, *Orseolia oryzae* (Wood-Mason), is a major insect pest of rice in several Asian countries (Bentur et al., 2003). In India, it is distributed in almost all the States except in the North and North-West. Average annual yield losses due to the pest are estimated to be US \$ 80 million. The external symptom of damage caused by gall midge is

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the production of a silvery-white, tubular leaf sheath gall called a silver shoot. This renders the tiller sterile and causes the yield loss. The pest mainly attacks the crop at vegetative stage during the wet season (June-December). Since the 1970s gall midge in India has been successfully managed through breeding and cultivation of resistant rice varieties (Bentur *et al.*, 2003).

Emergence of new virulent biotypes of gall midge capable of overcoming resistance in popular varieties has been causing concern. The development of a new virulent biotype was first reported in 1986 from the North coastal districts in the State of Andhra Pradesh in response to extensive cultivation of popular resistant varieties such as *Phalguna* (Bentur *et al.*, 1987). Since then reports of development of new biotypes have come from the states of Maharashtra (Prakasa Rao & Kandalkar, 1992), Manipur (Singh, 1992) and Kerala (Nair & Ambika Devi, 1994). In these regions, popular gall midge resistant varieties have become susceptible. In 1993, the appearance of a virulent population capable of overcoming resistance in rice varieties such as *Phalguna* and *Surekha* was reported from a new region, Telangana - 500 km South-West of north coastal region of Andhra Pradesh (Srinivas *et al.*, 1994). This population differed from that of North coast in its virulence pattern.

Through extensive field testing of differential rice varieties in the multi-location coordinated program of the Directorate of Rice Research (DRR), Hyderabad, it has been established that six distinct biotypes of gall midge are prevalent in India (Bentur *et al.*, 2003). Of these, three are present in Andhra Pradesh: biotype 1 in Warangal (Telangana), biotype 3 in Jagtial (Telangana) and biotype 4 in Ragolu (North coast) (Fig. 1). It was intriguing to note the presence of two distinct biotypes within the close vicinity of 120 km or less. This prompted us to undertake the present investigation to address the following questions:

- i) What are the biotypes of gall midge in other regions of Andhra Pradesh not previously surveyed under DRR program?
- ii) What are the fine distribution limits of biotype 1 and 3 within the Telangana region?
- iii) iii) What factors govern evolution of new biotypes at the edges of biotype distribution?

MATERIALS AND METHODS

The distribution of biotypes was studied at two spatial scales: i) *within Andhra Pradesh State*: eight test sites covering the North coast, Northern Telangana in North-West, and South coast zones; ii) *within the Northern Telangana zone* : twenty one test sites distributed across a distance of 350 km. Five of the sites were located 15, 35, 60, 80 and 100 km west of Jagtial while two sites were about 120 and 150 km North West. Another five test

sites were 15, 20, 30, 35 and 50 km North of Jagtial and eight sites were 25, 35, 45, 60, 75, 110, 120 and 190 km South-East of Jagtial which served as the center and as one of the test sites. All the distances are based on odometer readings. Under the State wide spatial scale the central coastal region was also sampled but repeated floods during the study period destroyed the field experiments. The South-Western part (Rayalaseema zone) and central west (forming southern Telangana zone) were not covered since these are not important rice growing areas of the State and the rice gall midge is not a serious pest there.

Field experiments were conducted during the wet seasons of 1995 to 1998. Seeds of the standard set of 10 differentials representing 4 groups (Table 1) were initially obtained from DRR and multiplied at Jagtial prior to use. The field evaluation protocols were the same as those used by Kalode and Bentur (1989). Each test entry was planted in an unreplicated row of 20 plants with 15 X 20 cm spacing between plants and rows, respectively, at each of the test sites either on an experimental farm or in a farmer's field. Planting time was adjusted so as to favour high pest damage. No insecticide was applied throughout the crop. Pest damage was recorded at 30 and 50 Days After Transplanting (DAT).

Both the percentage of damaged plants and the percentage of damaged tillers were recorded. A test was considered valid only if the susceptible check TN1 displayed 80% or higher plant damage on any one of the two observation days. Of the two data sets recorded on 30 and 50 DAT, the set showing higher damage in the susceptible check line was considered. A differential with $\leq 10\%$ plant damage was rated as Resistant (R), while with higher damage it was rated as Susceptible (S). Since response of the differential to gall midge attack is qualitative in nature, the extent of damage in the test row of 20 plants was mainly influenced by the pest pressure, prevailing temperature and humidity conditions at the time of egg hatching and maggot establishment, and possible 'off plants' in the rows. A high level of damage (80%) in TN1 to qualify the test, and the allowance of marginal damage (10%) for lines rated as resistant generally took care of the variation common in field evaluation studies on gall midge (Kalode & Bentur, 1989).

The biotype status of the population at a test site was judged by the reaction pattern of the four groups of differentials (Bentur et al., 2003). Resistant reaction by the differentials in groups 1, 2 and 3 and a susceptible reaction by the check TN1 in the fourth group is represented as a R-R-R-S pattern. This pattern is that of biotype 1. Likewise, S-R-R-S, R-S-R-S and S-S-R-S patterns are those of represented biotypes 2, 3 and 4, respectively (Table 1). Reaction patterns of biotype 5 (R-R-S-S) and biotype 6 (R-S-S-S) were not encountered during the study.

Table 1. Reaction of differential rice varieties against gall midge biotypes in Andhra Pradesh and other parts of India

Group	Differential	R gene	Reaction in Andhra Pradesh			Reaction noted in other States ¹		
			Biotype			Biotype		
			1	3	4	2	5	6
I	W 1263	<i>Gm1</i>	R	R	S	S	R	R
	ARC 6605		R	R	S	S	R	R
II	Phalguna	<i>Gm2</i>	R	S	S	R	R	S
	ARC 5984	<i>Gm5</i>	R	S	S	R	R	S
III	MR 1523		R	R	R	R	S	S
	Velluthacheera	<i>gm3</i>	R	R	R	R	S	S
	T1477		R	R	R	R	S	S
	Aganni		R	R	R	R	S	S
	Ptb 10	<i>Gm4</i>	R	R	R	R	S	S
IV	TN1 (S. Check)	None	S	S	S	S	S	S

¹DRR 2003, Bentur *et al.*, 2003

Biotype 1 reaction was noted at Warangal (1996), Nellore

Biotype 3 reaction was noted at Nirmal, Rudrur, Jagtial, Malyal

Biotype 4 reaction was noted at Ragolu, Warangal (1997), Chodavaram

RESULTS AND DISCUSSION

Biotype distribution within Andhra Pradesh

Thirteen valid tests were conducted at six sites (Table 2). Variation in rating against the differentials within a group was observed in only two of the tests. In three tests MR 1523 was found to be susceptible while other members of the third group were resistant. Based on these results, biotype 3 prevalence was evident at three of the test sites *viz.*, Nirmal, Rudrur and Jagtial; biotype 4 at Ragolu and biotype 1 at Nellore. Despite low pest pressure at Malyal during the three consecutive years of testing and at Chodavaram during 1997, there was a clear indication of the prevalence of biotype 3 and 4, respectively, at these locations. At Warangal, the 1996 data suggested presence of biotype 1 while the 1997 data indicated biotype 4 pattern. Pest pressure during 1998 was too low to consider the results. Fig. 1 shows the distribution pattern of the three biotypes within Andhra Pradesh.

Table 2. Test sites selected for State wide sampling for distribution of gall midge biotypes in Andhra Pradesh and number of valid tests at these sites

Sl. No.	Name	Location	No. of valid tests
1	Nirmal	18.19°N, 77.78°E	2
2	Rudrur	19.20°N, 78.89°E	2
3	Jagtial	18.19°N, 79.80°E	4
4	Warangal	17.18°N, 79.80°E	2
5	Malyal	17.18°N, 79.80°E	1
6	Ragolu	18.19°N, 83.84°E	2
6	Chodavaram	17.18°N, 82.83°E	0
8	Nellore	14.15°N, 80.0°E	1

The distribution pattern of biotypes within Andhra Pradesh based on the present study is consistent with the results of the on-going monitoring studies of DRR (DRR, 1999). The prevalence of biotype 1 at Nellore in the south coastal zone needs further confirmation, as pest pressure was relatively low during the present studies. This region occupies a distinct geographic location, receiving North Western monsoon rains during September to November, and hence its cropping seasons are different from the rest of the State. The varieties popularly grown in this zone are mainly suited for late planting. Because gall midge is not a serious pest in this zone, resistant varieties are not popular. The absence of selection pressure favors the prevalence of biotype 1. The central coast zone is also distinct, because gall midge attack occurs here mainly during the dry season (December to March). Being mainly an endemic region of brown plant hopper and white backed plant hopper, gall midge resistant varieties are not widely grown. Information on biotype status in this region may be useful in the event of a possible pest outbreak.

The present studies also confirmed the presence of biotype 4 in the North coastal zone and showed that its limit of distribution is up to about 100 km South of Ragolu, from where biotype 4 was first reported during 1986 (Bentur et al., 1987). Similarly, the presence of biotype 3 in and around Jagtial, first reported during 1993 (Srinivas et al., 1994), was observed to have increased to an area of about 350 km across. During the early 1980s these two zones had extensive coverage under gall midge resistant varieties such as *Phalguna* and *Surekha* that derived resistance from the *Gm2* gene.

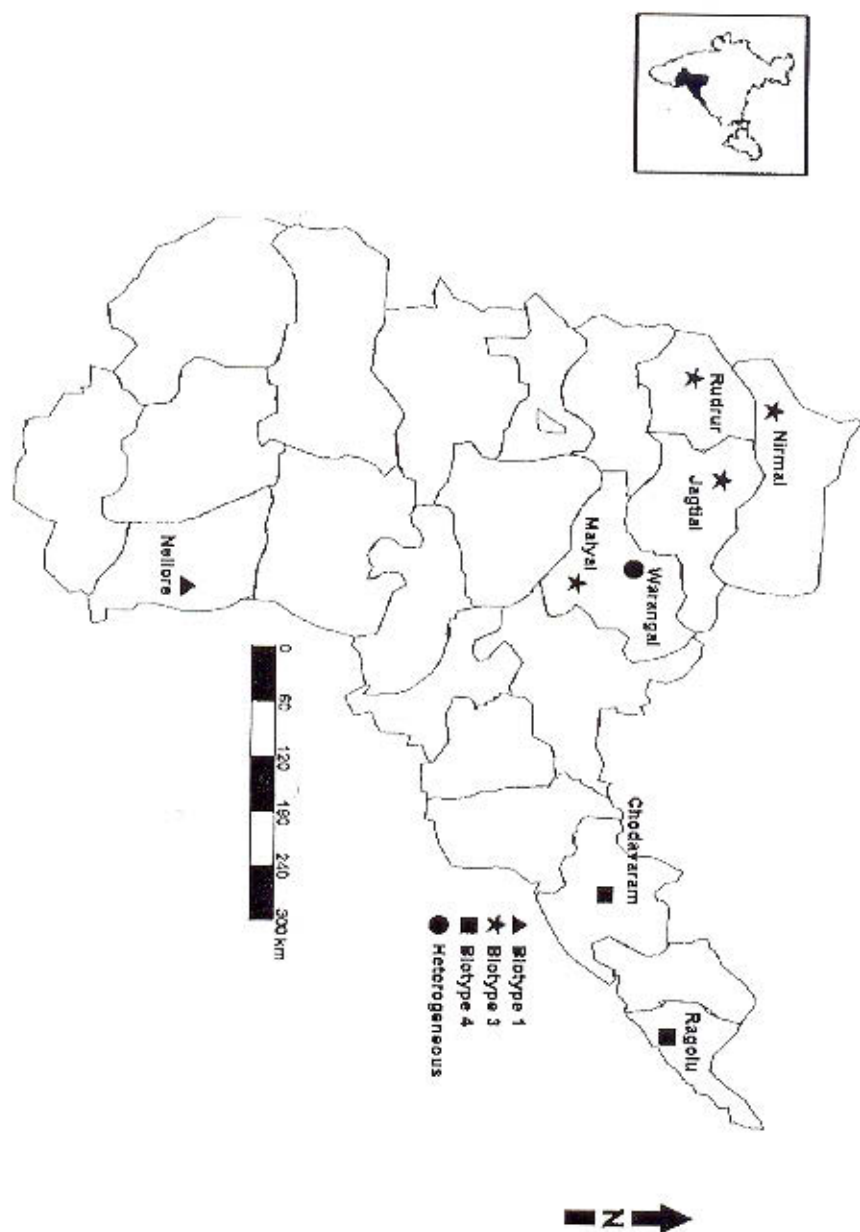


Figure 1. Distribution of rice gall midge (*Orseolia oryzae*) biotypes in Andhra Pradesh state of India

Thus, the two populations of gall midge appeared to have responded differently to similar selection pressure. However, field evaluation in 1974 at Ragolu indicated the susceptibility of varieties having the *Gm1* gene (Anonymous, 1975). Thus the pest population here prior to introduction of the resistant varieties could have had the characteristics of biotype 2 which was then prevalent in the adjoining areas of Orissa State (Kalode and Bentur, 1989). This population, already with virulence against *Gm1*- conferred resistance, may have additionally acquired virulence against *Gm2*- mediated resistance to evolve into biotype 4. In contrast, the population at Jagtial probably had biotype 1 characteristics like the biotype that prevailed in the adjoining areas of Warangal district prior to the cultivation of resistant varieties. The change here was obviously from biotype 1 to biotype 3, with no virulence against *Gm1* conferred resistance.

Biotype distribution within northern Telangana zone

Twenty nine valid tests were conducted in the Telangana zone in the 1994-96 wet seasons. At four test sites the pest pressure was very low during the test seasons. The tests at Warangal, Malyal and Jagtial reported in the State wide survey (above) also formed part of the Northern Telengana zone data set.

The distribution of biotypes at the test sites based on the reaction of the differentials is presented in Fig. 2. All of the twelve test sites North, North-West and West of Jagtial had biotype 3 populations. Towards the South three of the test sites *viz.*, Nemlikonda, Vedhira and Gattududenapally had biotype 3 populations while three sites *viz.*, Kothapally, Manakondur and Elkaturthy had biotype 1 populations (Fig. 2). Reaction at Warangal, as stated above, was biotype 1 pattern during 1996 and biotype 4 pattern during 1997. Despite low pest pressure at Malyal, the reactions of the differentials suggested the prevalence of biotype 3. Thus a mosaic of reaction pattern both in space and time was evident in this zone of the Northern Telangana region.

While new virulent biotypes could have increased in frequency in a region in direct response to selection pressure exerted by the popular resistant varieties, another set of factors may have actually influenced the spread of biotypes. Though micro-level studies were not done with respect to spread of biotype 4, apparently it has not spread much beyond 100 km South since its first appearance in 1986. Being a poor flier, gall midge adults possibly may not have crossed geographic barriers like the prominent river Godavari and the high altitude mountain range that separate the North coast from North-Telangana. Biotype 4 is also reported from Sakoli in Maharashtra State about 500 km West of Ragolu (Prakasa Rao and Kandalkar, 1992; Bentur et al., 2003).

It is not known, however, if this represents a continuous spread of the population or a case of independent evolution at these two locations. On the other hand, the spread of biotype

3 within the North-Telangana does appear to have been influenced by varietal coverage. Warangal and adjoining areas are part of the North Telangana zone with contiguous rice fields and no major geographic barriers. Warangal has an active rice breeding station and most of the gall midge resistant varieties developed there i.e., W1263, Kakatiya, Pothana, Kavya, Erramalellu etc., derive their resistance from the *Gm1* gene. Though not extensively cultivated, these varieties are grown in the adjoining areas. We speculate that these patches of resistant varieties may have been acting as barriers for complete replacement with biotype 3 in the region. Our micro-level distribution map (Fig. 2) supports this view.

Our studies also revealed a temporal change in the reaction pattern at Warangal and adjoining areas during the course of the study. In spite of high pest pressure, differentials from groups 1 and 2 did not show damage during 1996 while similar pest pressure resulted in damage during 1997. Relatively low pest pressure during 1998 did not permit us to verify the results of 1997. At an adjoining site, Manakondur (60 km from Jagtial), tests both during 1994 and 1997 showed biotype 1 reaction. At Gattududenapally (75 km from Jagtial) Phalguna recorded 15% damage even during the 1996 test. During 1999, the composition of biotypes in the Warangal gall midge population was noted in a separate study (Bentur *et al.*, 2000). Based on the reaction of progeny of 237 individual mated females, the test population was shown to be composed of 34% biotype 1, 46% biotype 2, 11% biotype 3 and 9% biotype 4. Subsequent observations during 2002 recorded 44.4%, 25%, 16.7% & 13.9% of biotypes 1, 2, 3 and 4, respectively, at Warangal (DRR, 2003). Such a heterogeneous population at Warangal is to be expected since it can be considered to be a randomly mating mix of biotype 1 and 3 insects.

We anticipate that this population will stabilize in the course of time but its ultimate biotype status may again be influenced by varietal coverage in the region in times to come. An equal exposure to rice varieties with both *Gm1* and *Gm2* genes would drive the selection towards the biotype 4 population. Alternatively, if only the *Gm2* gene is predominantly deployed in the region, biotype 3 may be uniformly spread all over north-Telangana. However, recent evaluation of differentials here suggests virulence against other genes like *gm3* (DRR, 2003).

The susceptible response of MR1523, one of the differentials of group 3, in the North Telangana zone further suggests that the gall midge population here may have already acquired virulence against the unknown gene(s) in this differential. Hence varieties such as *Suraksha* and *Shakti* which have the same source of resistance should not be introduced as alternatives to the existing resistant varieties. Virulence against the resistance conferred by the MR1523 gene is the characteristic of gall midge biotype 5, which is now confined in its distribution to Kerala State (Nair & Ambika Devi, 1994).

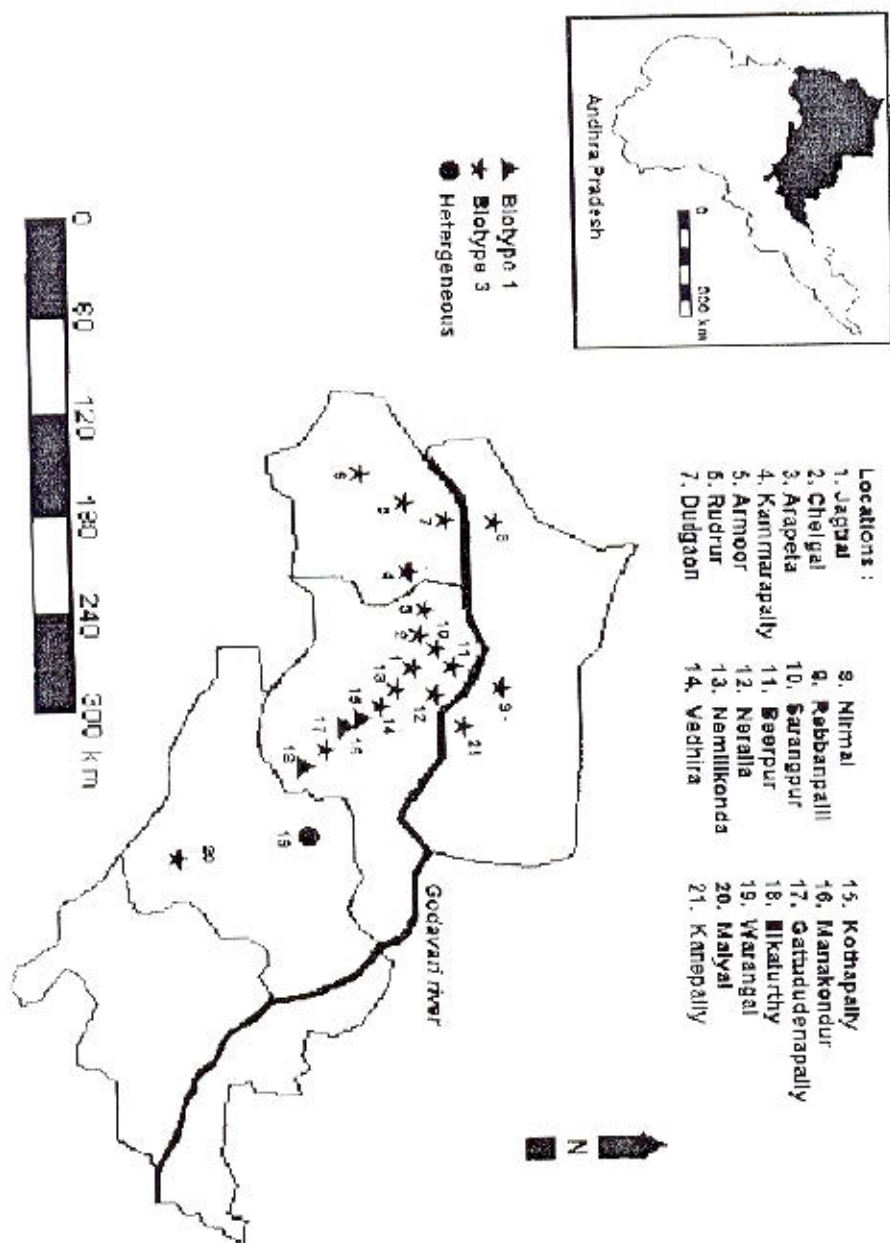


Figure 2. Distribution of gall midge biotypes within Telangana region of the Andhra Pradesh State of India

Porter et al. (1997) concluded that there was no relationship between the use of resistant crop varieties and development of new pest biotypes in the case of wheat/sorghum and the greenbug, *Schizaphis graminum*. There is evidence now that gall midge biotypes may sometime arise in the absence of selection by resistant varieties. The existence of three distinct gall midge biotypes in India in the 1970s (Kalode & Bentur 1989), prior to the release and cultivation of gall midge resistant rice varieties, suggests that there was no influence of resistant varieties on the evolution of those biotypes.

Likewise, the evolution of biotype 6 in Manipur state during 1990 (Singh, 1992) could not be linked to resistant varieties in that region. Based on the AFLP analysis of gall midge populations from five Asian countries, Katiyar et al. (2000) suggested that this new biotype in Manipur could be the result of mass migration of the pest population from the adjoining regions of Myanmar or China.

On the other hand, reports of biotype 4 in north costal Andhra Pradesh (Bentur et al., 1987), Maharastra (Prakasa Rao and Khandalkar, 1992); of biotype 3 in northern Telengana (Srinivas et al., 1994) were preceded by introduction and extensive cultivation of gall midge resistant varieties in the region. The appearance of biotype 5 in Kerala (Nair & Ambika Devi, 1992) was also preceded by extensive cultivation of locally bred rice varieties that were resistant to gall midge. The present study in Andhra Pradesh strongly supports the view that extensive cultivation of gall midge resistant varieties with a single gene for resistance will result in the selection of virulent biotypes.

Thus these studies helped to conclude that i) wild population of gall midge, designated as biotype 1 continues to prevail in other regions of Andhra Pradesh where this is not an important pest, ii) distribution of biotype 1 and 3 within the Telangana region presents a mosaic pattern and iii) rice varieties popularly grown in the area govern the evolution of new biotypes in the State of Andhra Pradesh.

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EFFECT OF DIFFERENT CROPPING SEQUENCES AND FERTILITY LEVELS ON THE WINTER DUAL PURPOSE FOOD AND FODDER CROPS

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ABSTRACT

Six crop rotations [Soybean and maize in kharif followed by wheat, barley and mustard in rabi at three fertility levels ($F_1=10$ t FYM ha^{-1} , $F_2=100\%$ of recommended NPK and $F_3= 50\%$ of F_2+F_1) in Randomized Block Design, replicated thrice were assessed for dual purpose rabi crops and for grain production from kharif crops at 1250 m AMSL of Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR), Almora U.P., India for three consecutive years from 1991-92 to 1993-94. For green forage purpose, wheat and barley were cut at 75-80 days after sowing, while green forage from mustard was obtained by initially growing at 22.5 cm row apart and finally thinned to recommended spacing of 45 cm from 25 to 45 days after sowing by complete removal of alternate rows. The green forage obtained after soybean was 29% more than after maize (0.71 t ha^{-1}). The mean green forage increase by 36% as the fertility level was increased from F_1 to F_2 and 25% from F_2 to F_3 . Barley yielded the highest quantity of NPK (70.9, 5.0 and 38.8 g kg^{-1} DM, respectively) followed by wheat. Grain yield of soybean did not differ significantly among F_1 and F_2 . F_3 produced significantly higher grain yield over F_1 and F_2 , while grain yield of wheat, barley and mustard increased significantly as the fertility level increased to F_2 or F_3 over F_1 . Linear regression analysis indicated that higher dry matter produced in the form of green forage at higher fertility level did not adversely affect the grain yield. From green forage yield point of view barley is more appropriate than wheat and mustard. Soybean followed by dual-purpose wheat is the effect crop rotation.

Keywords: Food crops; Fodder crops; Cropping system; Crop rotation; Fertility management; Winter crops; Uttar Pradesh; India.

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INTRODUCTION

In the hills of northern India, poor availability of fodder is the main factor responsible for poor health and low productivity of cattle. The problem is further aggravated during the lean winter months, when growth of natural grassland is severely hampered because of the extremely unfavorable climatic condition. In the hills, farmers are not able to produce enough food grains even for their domestic consumption from the existing land. Hence the question of putting this land under forage does not arise. Under these circumstances, dual-purpose crops are the only option, which can also provide a good quantity of fodder as well as grain yield. The use of cereals for the dual purpose of winter forage and grain is a common production system in the Southern great plains of USA (Dumpy et al., 1985; Carver et al., 1991) and to a lesser extent, in some areas of Canada (Poysa, 1985), North Africa (Anderson, 1985) and Australia (Dann et al., 1977). Holiday (1956) reported common and deliberate use of winter sown wheat as a dual purpose crop throughout the Southern great plains.

The wheat variety VL 616 developed by VPKAS, Almora is dual purpose; cutting for green forage is done at 75 days after sowing (Jagshoran et al., 1995). A green forage yield (0.93 t ha^{-1}) and grain yield (0.60 t ha^{-1}) was obtained with cutting, compared with a grain yield (0.65 t ha^{-1}) without cutting. The barley variety VLB-1, also has the ability to regenerate profusely after the cutting.

Fertility management in a cropping system plays an important role for its sustainability, owing to variable nature of the crops. Legumes have been found superior over cereals, by virtue of their ability to improve the soil condition and also benefit the following crop. In the hills, FYM is the major source of plant nutrients applied by the farmers. Therefore, it is pertinent to study the impact of conjoint use of organic and inorganic sources of plant nutrients, to make it more relevant in the context of hill farmers.

MATERIALS AND METHODS

Experiment site and management

A field study was conducted at the Research Farm, Hawalbagh ($29^{\circ} 36' \text{ N}$ longitude and $79^{\circ} 40' \text{ latitude}$) at 1250 m AMSL of Vivekananda Parvatiya Krishi Anusandhan Samsthan (ICAR), Almora, for three consecutive years, from 1991-1992 to 1993-94. Six crop rotations [soybean and maize in kharif (June to September) each followed by wheat, barley and mustard during rabi (October to May)] at 3 fertility levels ($F_1=10 \text{ t FYM ha}^{-1}$, $F_2=100\%$ of recommended NPK ha^{-1} and $F_3=F_1 + 50\% \text{ of } F_2$), in a Randomized Block Design, replicated thrice were grown in a plot of 3.6m 3.0m.

The recommended doses of fertilizers of respective crop was used and applied as per treatment (Table 1). Total FYM was applied before last ploughing and P and K were mixed into soil, before sowing, in all the crops. Pre-sowing irrigation was given to ensure proper germination to all crops. For all purpose, the depth of irrigation was 5 cm. For green forage purpose, wheat and barley were cut at 75-80 days after sowing at 5 cm. above from soil surface. While green forage from mustard was obtained by initially sowing it at 22.5 cm. row apart and finally thinned to recommended spacing of 45 cm by removing alternate rows from 25 to 45 days after sowing. Except fertility treatments, all the crops were raised according to the recommended package of practices (Table 1). Crops raised for dual purpose, were supplied with the additional 20 kg N ha⁻¹ by top dressing just after cutting (75-80 days after sowing).

The soil of the experimental site was silty clay loam, having pH 6.3 and a low available nitrogen (180- kg ha⁻¹) and a medium level of available phosphorus (22.0 kg ha⁻¹) and potash (183.0 kg ha⁻¹).

Dry matter yield was determined by sub sampling methods. Then the samples were dried at 70°C ± 1°C for 48 hours in oven and dry weight was recorded. The nitrogen estimated by the Micro-Kjeldahl method, phosphorus by the Vanadomolybdo phosphoric acid yellow colour method in nitric acid system, and potassium determined by Flame Photometrically (Jackson, 1969). Standard combined analysis of variance was used to analyze the data obtained (Gomez & Gomez, 1976). Regression and correlation techniques were used to assess the relationship between dry weight and grain yield after cutting.

Table 1 Crop Management Practices

Crop	Variety	Seed (kg ha ⁻¹)	Row spacing (cm)	Sowing	Crop harvesting	NPK (kg ha ⁻¹)	Application of nitrogen	Irrigation
Wheat (<i>Triticum aestivum</i>)	VL 616	100	22.5	2nd week of October	180-190 days after sowing	80:26:33	50% at sowing 25% at 30-35 days after sowing 25% at 65-70 days after sowing	IW:CPE 0.80
Barley (<i>Hordeum vulgare</i>)	VLB-2	100	22.5	2nd week of October	160-170 days after sowing	80:26:33	50% sowing 25% at 30-35 days after sowing 25% at 65-70 days after sowing	IW:CPE 0.80
Mustard (<i>Brassica campestris</i>)	T-59	10	22.5	2nd week of October	150-160 days after sowing	80:26:33	50% sowing 25% at 30-35 days after sowing 25% at 65-70 days after sowing	IW:CPE 0.80
Maize (<i>Zea mays</i>)	VL-42	20	60.0	3rd week of June	80-90 days after sowing	100:35:33	50% sowing 25% at 30-35 days after sowing 25% at 60-70 days after sowing	Pre-sowing
Soybean (<i>Glycine max</i>)	VLS-2	80	45.0	3rd week of June	100-110 days after sowing	20:35:33	100% At sowing	Pre-sowing

Weather

Figure 1 shows the monthly mean maximum and minimum temperatures in the cropping seasons. Minimum temperature was below 0°C for a part of winter period, during which the growth of natural vegetation as well as of cultivated forages crops almost, stops. Temperature starts to rise from March onwards as a result the growth of the crops.

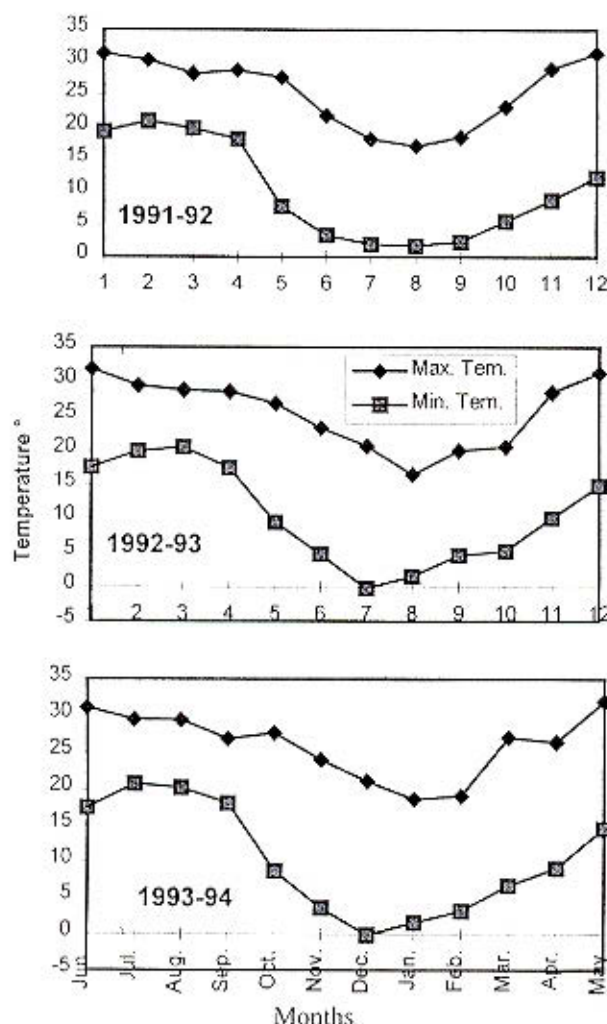


Fig. 1 Monthly mean maximum and minimum temperature during crop growing season

RESULTS AND DISCUSSION

Green and dry forage yield from wheat, barley and mustard crops

The green forage yield obtained from wheat, barley and mustard crops after soybean was 29% more than after maize (0.71 t ha^{-1}) and increased with increase in fertility levels (Table 2). Barley produced the highest green forage yield at all the fertility levels, while wheat produced the lowest. The mean yield increased by 36% as the fertility level increased from 10 t FYM ha^{-1} to 100% of recommended NPK ha^{-1} and by 25%, from 100% of recommended NPK ha^{-1} to $10 \text{ t FYM} + 50\%$ of recommended NPK ha^{-1} recording higher yield following soybean than maize.

The dual purpose crops were tried in order to produce green forage (during the season of scarce supply in the region) and in order to compensate the negative effects of cutting on the production of grain yield, by supporting it through a balanced supply of mineral nutrients. Grazing winter wheat during the fall, winter and spring may have a minimal effect on subsequent yield of grain if the soil moisture at sowing and the subsequent precipitation and soil fertility levels are satisfactory during the growing season (Larry et al., 1995). Although these crops have been recommended for dual purpose, cutting adversely affects the harvest index.

The agronomic manipulation involved in making mustard dual purpose had been taken from the farmer's practice of thinning the broadcast sown mustard for green forage. The higher green forage production from barley was result of its initial faster growth and higher dry matter accumulation. Although mustard produced higher green forage yield, it could not keep pace in dry matter production but because of its high water content.

The soybean was compared with maize because of the farmer's ability to fix atmospheric nitrogen (Bisht & Chandel, 1996) and increase the soil fertility, particularly soil nitrogen and consequently enhance the productivity of the succeeding cereal crops (Chandel et al., 1989). This in term benefited the initial growth of the next crop, provided more green forage production and eventually the grain and straw yield. The main objective of testing 50% of recommended NPK ha^{-1} dose along with 10 t FYM ha^{-1} was to make more balanced application of nutrients and also to make the best utilization of the farmers' available nutrient source to sustain the soil conditions.

The differential response of sole organic source, and sole inorganic source and their combination was obvious due to slow release of nutrients from sole organic source, while inorganic could not sustain supply of nutrients during the entire crop growth period. On the other hand their combination probably fulfilled both the conditions as discussed here.

The dry matter yield of green forage behaved in an almost similar fashion, as did the green forage yield at different fertility levels. Among the crops providing green forage yield, wheat yielded more dry matter than mustard when grown after soybean, but less when grown after maize (Table 2).

Table 2 Green forage and dry matter yield of dual purpose crops under different fertility levels and cropping sequences

Treatments	Yield (t ha ⁻¹)					
	Green forage yield			Dry matter yield		
	After soybean	After maize	Mean	After soybean	After maize	Mean
Winter crops						
Wheat	0.74	0.49	0.62	0.14	0.16	0.15
Barley	1.10	0.80	0.95	0.20	0.15	0.17
Mustard	0.92	0.84	0.88	0.11	0.61	0.11
P> 0.05	0.62	0.90		0.73	0.61	-
Fertility						
	0.64	0.57	0.60	0.10	0.16	0.13
F ₁ =10 t FYM ha ⁻¹	0.97	0.67	0.82	0.14	0.11	0.13
F ₂ =100% recommended NPK ha ⁻¹	1.16	0.89	1.02	0.20	0.15	0.18
F ₃ =50% F ₂ + F ₁	0.62	0.90	-	0.73	0.61	-
P>0.05						

NPK yield of green forage

The barley provided the highest quantity of NPK, followed by wheat and lowest by mustard. The mean NPK yield was higher after soybean than after maize (Table 3). The application of 100% of recommended NPK gave the highest nutrients (g Kg⁻¹ of DM followed by FYM @ 10 t ha⁻¹).

Table 3. NPK yield of wheat, barley and mustard crops through green forage under different fertility levels and cropping sequences

Treatments	Nutrient yield (g kg ⁻¹ dry matter)								
	N			P			K		
	After soybean	After maize	Mean	After soybean	After maize	Mean	After soybean	After maize	Mean
Winter crops									
Wheat	46.5	42.1	44.3	3.1	2.9	3.0	26.4	26.4	26.4
Barley	78.3	63.4	70.9	5.4	4.5	5.0	46.6	30.9	38.8
Mustard	20.3	22.7	21.5	1.6	1.8	1.7	14.0	27.0	20.5
Fertility levels									
F ₁ =10t FYM ha ⁻¹	41.3	37.7	39.5	2.9	2.8	2.9	25.7	25.5	25.6
F ₂ = 100% recommended NPK ha ⁻¹	45.8	41.9	43.9	3.2	3.1	3.2	27.5	27.5	27.5
F ₃ =50%F ₂ +F ₁	37.2	39.0	38.1	3.0	2.7	2.9	25.3	23.1	24.2

Grain yield of maize and soybean crops

The grain yield of soybean (Table 4) did not differ significantly between 100% of recommended NPK and 10 t FYM ha⁻¹, whereas maize grain yield increased significantly with 100% of recommended NPK and 50% of recommended NPK+10 t FYM ha⁻¹ over 10 t FYM ha⁻¹ alone (5.0 t ha⁻¹). The straw yield of maize increased significantly with 100% of recommended NPK ha⁻¹ over 10 t FYM ha⁻¹ and with 50% of recommended NPK + 10 t FYM ha⁻¹ over 100% of recommended NPK ha⁻¹. The straw yield of soybean increased significantly with 100% of recommended NPK ha⁻¹ and 50% of recommended NPK + 10 t FYM ha⁻¹ over 10 to FYM ha⁻¹ alone.

Table 4 Grain and straw yield of maize and soybean crops at different fertility levels

Fertility levels	Yield (t ha ⁻¹)			
	Soybean		Maize	
	Grain	Straw	Grain	Straw
F ₁ =10 t FYM ha ⁻¹	2.47	2.86	5.00	7.90
F ₂ =100% recommended NPK ha ⁻¹	2.50	3.51	5.66	9.04
F ₃ =50% F ₂ + F ₁	2.66	3.67	5.87	9.66
C.D. (P=0.05)	0.08	0.10	0.23	0.23

Grain yield of wheat, barley and mustard crops

The mean yield of rabi crops (Table 5) was considerably higher after soybean than after maize. Only mustard yield increased significantly. The extent of increase was 4.3%, 2.9% and 22.6%, for wheat, barley and mustard respectively.

The grain yield of wheat, barley and mustard increased significantly as the fertility level was increased to 100% of recommended NPK ha⁻¹ or 50% of recommended NPK + 10 t FYM ha⁻¹ over 10 t FYM ha⁻¹ alone. In mustard highest grain yield was obtained with 50% of recommended NPK + 10 t FYM ha⁻¹ (1.57 t ha⁻¹), while in case of wheat and barley grain yield did not vary significantly between 100% of recommended NPK ha⁻¹ and 50% of recommended NPK + 10 t FYM ha⁻¹. The straw yield of all the crops was the highest with 50% of recommended NPK + 10 t FYM ha⁻¹, which was also significantly more than 100% of recommended NPK ha⁻¹ and 10 t FYM ha⁻¹ alone treatments.

Table 5. Grain and straw yield of wheat, barley & mustard soybean crops at different fertility levels

Treatments	Yield (t ha ⁻¹)					
	Wheat		Barley		Mustard	
	Grain	Straw	Grain	Straw	Grain	Straw
<u>Proceeding crop</u>						
Soybean	3.86	13.42	4.24	10.02	1.41	7.28
Maize	3.70	12.53	4.12	9.57	1.15	6.22
P> 0.05	NS	0.36	NS	0.31	0.05	0.22
<u>Fertility</u>						
F ₁ =10 t FYM ha ⁻¹	3.37	9.98	3.51	8.54	1.12	5.83
F ₂ =100% recommended NPK ha ⁻¹	3.88	13.72	4.38	9.69	1.15	6.71
F ₃ =50% F ₂ + F ₁	4.09	15.22	4.66	11.17	1.57	8.31
P>0.05	2.2	7.1	2.2	5.3	0.6	5.3

The relationships between dry forage yields (cutting in the case of wheat and barley and removal in case of mustard) and grain yield of rabi crops is shown in Figure 2, 3 and 4. The relationship has been worked out at 3 fertility levels, taking the data of each year into consideration. Linear regression analysis indicated that higher dry matter production in the form of green forage at higher fertility level did not adversely affect the grain yield. The highest recovery after cutting was observed in barley ($r = 0.85^{**}$), followed by wheat ($r=0.78^{**}$) and mustard ($r = 0.64^{**}$).

The correlation studies between dry matter production in the form of green forage and grain yield of rabi crops indicates, that in spite of more dry matter production/harvesting in the initial phase of growth, they still maintained the higher yields. The trend was more linear in wheat and barley than mustard, indicating no adverse effect more dry matter harvesting on the grain yield and was supported by conjoint use of organic and inorganic fertilizer. The poor relationship in the case of mustard suggests that the crop suffered in terms of grain yield, because of higher initial dry matter production.

CONCLUSION

From the point of view of green forage yield, barley is more appropriate than wheat and mustard. Soybean, followed by dual purpose wheat is the efficient crop rotation. Application of 10 t FYM + 50% recommended NPK dose can be advocated over 100% recommended NPK.

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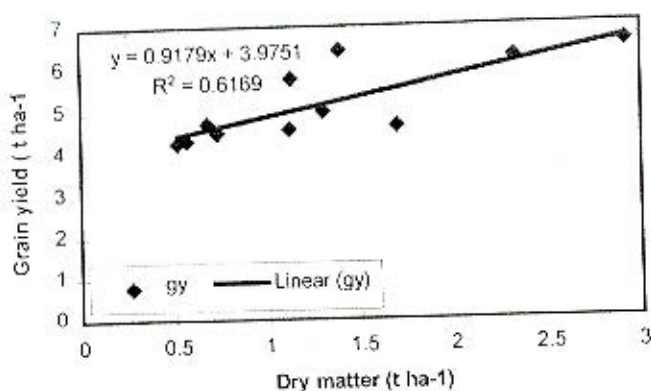


Figure 2 Relationship between dry matter and grain yield of Wheat

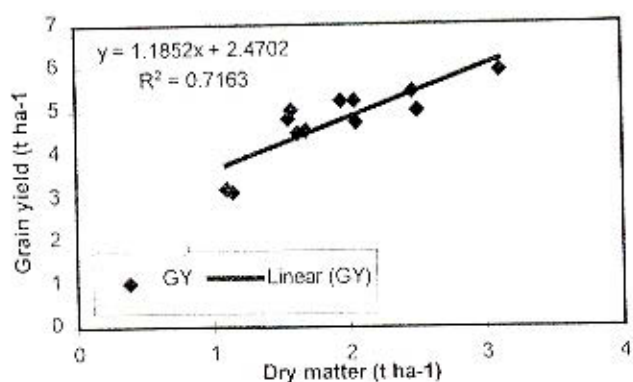


Figure 3 Relationship between dry matter and grain yield of Barley

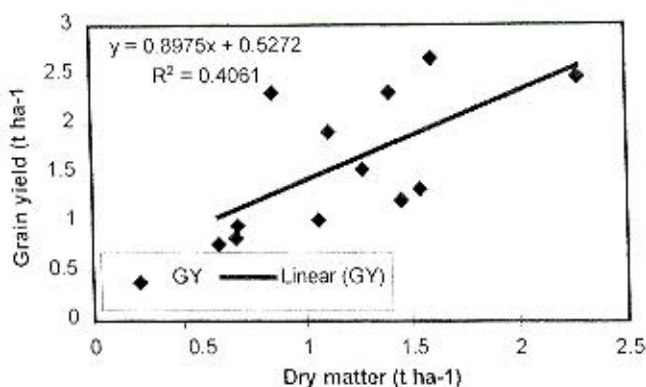


Figure 4 Relationship between dry matter and grain yield of Mustard

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ESTIMATION OF RICE STINKBUG, *Leptocorisa acuta* (THUNBERG) POPULATION FOR MAKING MANAGEMENT DECISION

MO MU THEIN¹, SUBHASH CHANDER¹ AND NAVEEN KALRA¹

ABSTRACT

Taylor's power law and Iwao's patchiness regression were fitted to rice stinkbug population counts on rice cultivar 'Pusa 834'. Sampling factor (a) and aggregation parameter (b) of Taylor's power law for the pooled data of two experiments were found to be 1.094 and 1.5573 respectively while index of basic contagion (α) and density contagiousness coefficient (β) of Iwao's regression were -0.7464 and 1.7691 respectively. These parameters revealed aggregated distribution of the pest on the crop. Simple random sampling plans were formulated with a precision of 10 and 20% coefficient of variation (CV) using both the methods. Optimum sample size was inversely related to mean population density. The Taylor's power law required more sample size at lower bug densities and less sample size at higher densities than Iwao's regression method. Population estimates with a precision of 10% CV needed 4 times the sample size compared with 20% CV and thus seemed uneconomical. Sequential sampling plan was devised using parameters of Taylor's power law, economic injury level (2 bugs/m²) and error probability (20%). The maximum sample size with the sequential sampling was observed to be 12 sample units. The use of sequential sampling could reduce sampling effort appreciably compared to simple random sampling.

Keywords: Pest management, *Leptocorisa acuta*, Iwao's regression, Taylor's power law, sequential sampling.

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INTRODUCTION

India is the largest producer of rice in the world after China. However rice productivity in India is 4.2 tonnes of paddy per hectare as against 6.1 and 8.3 tonnes in China and Egypt, respectively (Siddiq, 2000). Concerted efforts are being made for raising productivity through cultivation of high yielding varieties or hybrids with concomitant use of high levels of fertilizers and irrigation. However, such intensive cultivation also aggravates the problems of various biotic constraints like insects, disease and weeds. The stinkbug, *Leptocoris acuta* (Thunberg) is one of the major pests, which is widely distributed in India, Orient and Australia (Atwal & Dhaliwal, 1997).

The pest has been observed to inflict up to 44 per cent yield loss in different varieties (Rai *et al.*, 1990; Sugimoto & Nugaliyadde, 1995). The insecticides have been recommended against the rice stinkbug in order to prevent high yield losses (Atwal & Dhaliwal, 1997; Verma & Gupta, 2001). Pest management philosophy stresses that the insecticides should only be applied when pest population reaches economic threshold level (ETL). An efficient sampling plan is indispensable for estimating pest density on the crop. The formulation of a reliable sampling plan requires information on the spatial distribution of the pest. Random sampling has been widely used for estimating pest populations in the field (Dent, 1991). However, random sampling generally proves very time consuming as far as decision making in pest management is concerned. On the other hand, sequential sampling has been observed to be very useful in deciding the need for control of pests (Pieters, 1978; Shepard *et al.*, 1988; Chander & Singh 2001). The present study was undertaken considering the economic importance and the need for proper sampling procedure of stingbug in rice pest management.

MATERIALS AND METHODS

Two experiments were conducted during the rainy season of 2001 with rice crop variety Pusa-834 at Indian Agricultural Research Institute, New Delhi. The nursery was sown on 17 June and 30 days old seedlings were transplanted in well puddled field on 18 July 2001 in 2.0 m x 1.5 m quadrates. The hill to hill and row to row spacing was maintained at 15 cm x 20 cm. A quadrate contained 10 rows with 10 hills each and there were a total of 40 quadrates in each experiment. The fertilizer N: P: K were applied at the rate of 120:60:40 kg/ha.

The required amount of P and K and 1/3 nitrogen were applied as a basal dose at the time of transplanting, whereas remaining 2/3 nitrogen was applied in two equal doses at maximum tillering stage (35 days after transplanting) and at flowering (55 days after transplanting). The N, P and K were applied in the form of urea, single super phosphate and muriate of potash, respectively. The crop was irrigated regularly to ensure sufficient availability of water. The weeds were removed manually. No insecticides were applied to the crop.

The population counts of stinkbug, *L. acuta* were recorded at 5-day interval in 40 quadrates after flowering of the crop until the population became very low. In each quadrate the population of nymphs and adults was recorded in 10 consecutive hills in the middle of the quadrate. The population counts so obtained were multiplied by three in order to have population counts on 1 m² basis because with the adopted spacing in the experiment, 1 m x 1 m plot contained about 30 hills. (Ruesink & Kogan, 1982).

Pooled counts of nymphs and adults were arranged in a discrete frequency distribution and population mean ($\bar{X}$) and variance (S^2) were determined. Taylor's power law (Taylor, 1961) and Iwao's regression method (Iwao, 1968) were fitted to stinkbug population mean and variance data. For fitting Taylor's power law to the stinkbug counts, the variance and mean values of each observation were transformed by logarithms. The $\log S^2$ was regressed upon $\log \bar{X}$ to estimate sampling factor (a) and aggregation parameter (b) in each experiment as well as for pooled data of two experiments. The $b > 1$ shows an aggregated distribution, $b=1$, random and $b<1$ regular distribution.

To fit Iwao's regression method mean crowding (X^*) was regressed upon mean ($\bar{X}$) population and index of basic contagion (α) and density contagiousness coefficient (β) were determined for each experiment as well as for the pooled data of two experiments. The values of $\beta > 1$ represent aggregated distribution, $\beta=1$ random distribution and $\beta < 1$ regular distribution.

Simple random sampling plans for rice stinkbug

The optimum sample size for simple random sampling was computed from the formula $n = S^2 / (CV)^2 \bar{X}^2$ (Karandinos, 1976) where, $\bar{X}$ = mean density of the bug, S^2 = variance of the bug population and CV is coefficient of variation taken as the precision criteria. The value of CV used was 10 and 20 per cent. The variance (S^2) in above formula was substituted by $S^2 = a\bar{X}b$ for Taylor's power law and $S^2 = (\alpha + 1)\bar{X} + (\beta - 1)\bar{X}^2$ for Iwao's regression method (Ekholm, 1985). The a and b and α and β values obtained from the pooled data were used.

Precision of population estimates

The precision level (CV%) for population estimates with a fixed number of sample units was worked out based on the following formula.

$$CV = S / \bar{X} \sqrt{n}$$

Where, S = standard deviation of the sample, $\bar{X}$ = mean population, and n = number of sample units in the sample.

In the present study, the stinkbug population was estimated with a uniform sample size of 40 sample units throughout the crop season and therefore $n=40$ was used.

Sequential sampling plans for the rice stinkbug

Sequential sampling plans were formulated using Taylor's power law parameters for stinkbug. By substituting the variance as expressed by Taylor's power law, the decision lines for sequential sampling are expressed as:

$$d = nmo \pm t \sqrt{n(amob)} \quad (\text{Ekbohm, 1985})$$

such that

$$d1 = nmo + t \sqrt{n(amob)} \quad \text{Upper decision line}$$

$$d0 = nmo - t \sqrt{n(amob)} \quad \text{Lower decision line}$$

Where,

$d0$ = Lower limit of the confidence interval for the cumulative number of rice bugs collected (treatment not required)

$d1$ = Upper limit of the confidence interval for the cumulative number of rice bugs collected (treatment required)

n = Number of sample units observed

mo = Economic injury level of the stink bug

t = Student's 't' test at 20 per cent probability level (1.28)

a & b = Parameters of Taylor's power law

The economic injury level of the stinkbug on rice was used as 2 bugs per m^2 (Dhaliwal & Arora, 2001). The values of aggregation parameter (b) and sampling parameter (a) for the pooled data i.e. 1.5573 and 1.1094 respectively were applied. The tolerable level of error was kept as 20 per cent.

The maximum number of sample units (n_{max}) in sequential sampling was worked out as follows:

$$n_{max} = t^2 * (amob)/p^2$$

Where, 't' is the value of normal deviate and $p = t * SE$. A standard error (SE) equal to 25 per cent of mean was deemed as acceptable (Southwood and Henderson, 2000) and for 20 per cent probability level, the value of 't' used was 1.28.

RESULTS AND DISCUSSION

The parameters of Taylor's power law viz., sampling factor (a) and aggregation parameter were found to be 1.1429 and 1.5048 respectively in first experiment and 1.1542 and 1.4168 respectively in second experiment (Fig 1 a & b). The a and b values for the pooled data were found to be 1.094 and 1.5573 respectively (Fig. 1 c). The Taylor's power law provided a good fit to the stinkbug counts as coefficient of determination (R^2) was very high. The aggregation parameter greater than 1.0 revealed aggregated nature of the distribution of the pest on the crop. The Taylor's power relationship for rice stinkbug based on a and b values for the pooled data could be expressed as follows:

$$S^2 = 1.1094 X^{1.5573}$$

Southwood and Henderson (2000) opined that aggregation parameter (b) is considered constant for a species while "a" is related to environment, sampling procedure and sample unit employed. However there has been considerable controversy on this over the years (Taylor, 1984; Trumble et al., 1989).

Parameters of Iwao's regression i.e. index of basic contagion (α) and density contagiousness coefficient (β) were found to be -0.8419 and 1.8404 respectively in first experiment and -0.6406 and 1.6861 respectively in the second experiment while their values for the pooled data were -0.7464 and 1.7691 respectively (Fig. 2 a, b & c). The model provided good fit to the stinkbug mean crowding and mean data, as R^2 values were very high. The negative value of index of basic contagion indicated repulsive tendency among the bugs and it also showed that the unit of spatial distribution of the pest on the crop was a single bug. The value of density contagiousness coefficient greater than 1.0 revealed aggregated distribution of the pest on the crop. Based on α and β values for the pooled data, the equation for estimation of population variance, $S^2 = (\alpha + 1) X + (\beta - 1) X^2$ could be expressed as follows:

$$S^2 = 0.2536X + 0.7691 X^2$$

The equations based on Taylor's power law parameters and Iwao's regression parameters can be used for predicting variance if mean population density of the bug is known. Several workers have used the Taylor's power law and the Iwao's regression method to investigate spatial distribution of rice pests (Wada & Kabasaki, 1985; Foster et al., 1989; Chander & Singh, 2001).

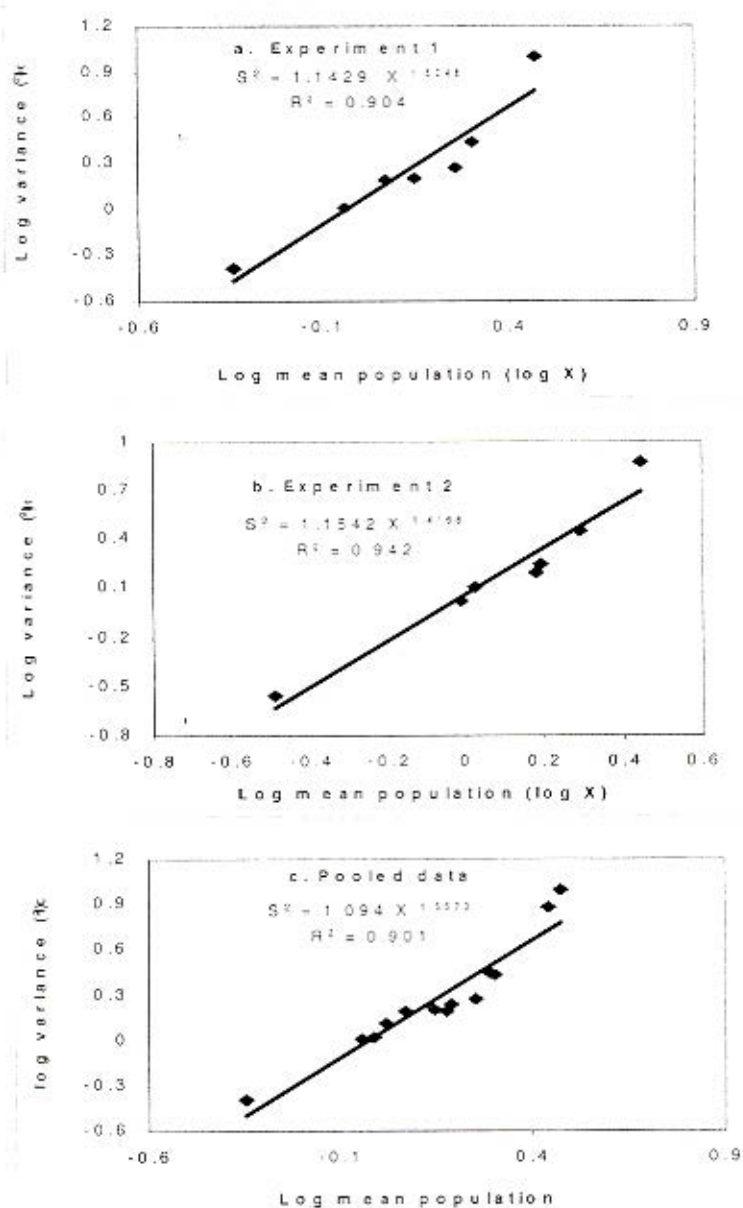


Fig. 1. Relationship between mean population and variance of rice stinkbug, *Leptocorisca acuta* infesting rice

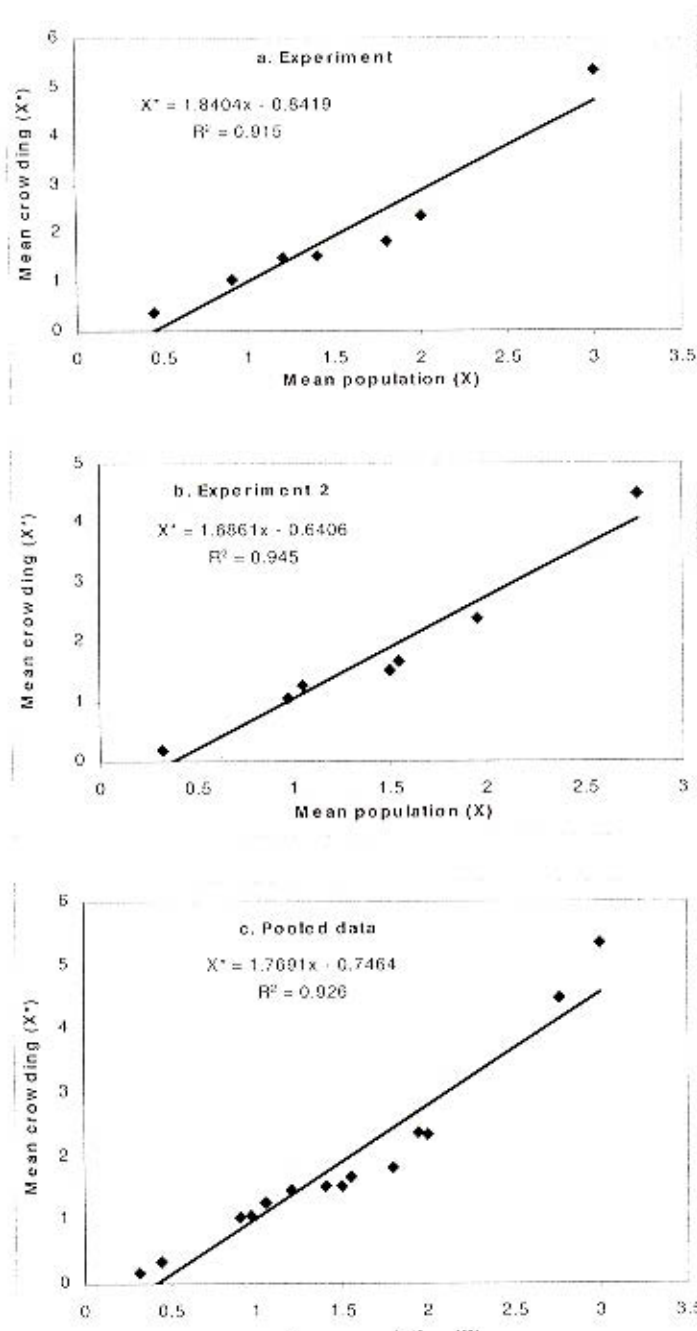


Fig. 2. Relationship between mean population and mean crowding of rice stinkbug *Leptocorisca acuta* infesting rice

Formulation of sampling plans with simple random sampling

The optimum sample size at various pest densities over the two experiments ranged from 70-189 and 11-47 with a precision of 10 and 20 per cent CV, respectively with Taylor's power law, while with Iwao's regression method it varied from 84-156 and 21-39 sample units with a precision of 10 and 20 per cent CV, respectively (Table 1). The optimum sample size with a precision of 10 per cent CV was thus found to be about four times more than the 20 per cent CV with both the methods. The sample size with 10 per cent CV, therefore seemed extremely large. The optimum sample size was inversely related to the stinkbug population density

Table 1. Optimum sample size and precision of sample estimates of *Leptocoris acuta* infesting rice Pusa-834 during rainy season 2001

Crop age (DAT) ^{&}	Population mean and variance*	Sample size with Taylor's power law (a= 1.094, b=1.5573)		Sample size with IRM*** (α = -0.7464, β = 1.7691)		Precision (CV) of Sample estimate
		10% CV**	20% CV	10% CV	20% CV	
Experiment 1						
60	0.9 (1.015)	120	30	105	26	0.18
65	1.4 (1.579)	98	25	95	23	0.14
70	2.0 (2.692)	84 [†]	21	89	22	0.13
75	3.0 (9.974)	70	17	85	21	0.17
80	1.2 (1.533)	105	26	98	24	0.16
85	1.8 (1.856)	88	22	91	23	0.12
90	0.45 (0.408)	163	41	133	33	0.22
Experiment 2						
60	0.97 (1.056)	116	29	103	26	0.17
65	1.5 (1.538)	95	24	94	23	0.13
70	1.95 (2.767)	85	21	90	22	0.13
75	2.77 (7.513)	73	18	84	21	0.16
80	1.55 (1.741)	94	23	93	23	0.13
85	1.05 (1.279)	112	28	101	25	0.17
90	0.32 (0.277)	189	47	156	39	0.24

* mean population/m² and variance (in parentheses) based on 40 sample units

** CV= coefficient of variation *** IRM-Iwao's regression & DAT-Days after transplanting

The Taylor's power law required more sample size at lower densities and less sample size at higher densities than Iwao's regression (Table 1). This happened because it overestimated the variance at low bug densities and underestimated it at higher densities as compared to Iwao's method. The Taylor's power law thus showed more sensitivity for sample size in relation to various pest densities. For this reason, it was preferred over Iwao's method for formulating sequential sampling plans for the stinkbug in present study.

Precision of sample estimates

The precision of sample estimates must be known before these can be used in meaningful way for different applications. The precision achieved in the stinkbug estimates with 40 sample units ranged from 0.13-0.24 at different bug densities. The higher CV value meant lower precision and vice-versa. With a sample size of 40 sample units, the stinkbug population could never be estimated with a precision of 10 per cent CV. On the other hand, the sample size of 40 sample was sufficient to estimate the bug population with a precision of either 25 per cent or even less CV.

Taylor et al. (1988) suggested that for fitting Taylor's power law, mean and variance values should be based on at least 40 sample units. The range of population used for fitting the power law must cover the critical density and densities, which might occur in management practice. Kamai and Dyck (1994) observed a sample size of 40 sample units to be adequate for estimating one or more *Sogatella furcifera* per hill. Likewise Kamal et al. (1995) found that a sample size of 35-40 sample units was sufficient for sampling of rice hispa, brown plant hopper, green leafhopper and some predators when the mean density was at least one per hill or more.

The population estimates of the stinkbug with 40 sample units were not accurate enough for applications such as life table studies, where a precision of 10 per cent CV is required. However, these were suitable for decision making with regard to pest management, where a precision of 25 per cent CV is deemed sufficient (Southwood, 1978).

Formulation of sequential sampling plans for the rice stinkbug

The decision lines of the sequential sampling were found to be as follows:

$$d_0 = 2n - 2.3129\sqrt{n}$$

$$d_1 = 2n + 2.3129\sqrt{n}$$

The above two equations can be used to determine the upper and lower limits of bug population for a number of sample units (Table 2, Fig. 3). These decision lines can be used for decision making with respect to adoption of control measures against the pest. For example, if after inspecting 5 sample units (5 quadrates), the bug population is found to be less than 5.0, then application of control measure is not to be recommended. On the other hand if the bug population is observed to be 15 or more, then application of control measure is to be recommended against the bug. However, if population is found to be between 5.0 and 15, then decision will be arrived at after inspecting next sample unit.

In the event of continuous indecisiveness, the sampling has to be continued until maximum required number of sample units has been examined. The maximum number of sample with sequential sampling was found to be 12. If decision is not arrived at even after inspecting the maximum sample size, then sampling should be stopped and be carried out after waiting for a few days (Ekbom, 1985).

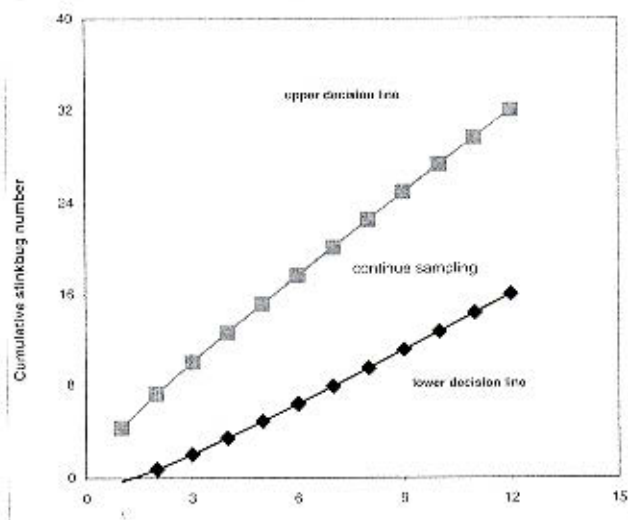
In sequential sampling at low or high pest densities decision could be arrived at with fewer sample units, where as at medium pest densities, comparatively more sample units were needed. A meaningful cumulative bug population count under lower decision line was obtained only after inspecting three sample units (Table 2). Therefore, under very low bug incidence on rice, a minimum sample size of three sample units was found to be necessary.

The sequential sampling plan for the rice bug was compared with the simple random sampling. In sequential sampling, the minimum necessary sample size required to detect very low population was observed to be 3 while maximum sample size was found to be 12 sample units. On the other hand, the optimum sample size with simple random sampling ranged from 17-47 and 21-39 with 20 per cent CV with Taylor's power law and Iwao's regression method (Table 1, Fig. 3). The minimum sample size with simple random sampling was thus more than the maximum sample size with sequential sampling.

Therefore, appreciable reduction in sampling effort could be achieved with sequential sampling in comparison to simple random sampling. Pieters (1978) opined that sequential sampling would attain significance with adoption of sophisticated pest management programmes as decision making and cost reduction are vital in pest management.

Table 2. Sequential sampling table for treatment decisions against rice stinkbug, *Leptocorisca acuta*

Sample unit number (N)	Cumulative number of stinkbugs	
	Lower decision line $d_0=2n-2.3129 (n)^{1/2}$	Upper decision line $D_0=2n+2.3129 (n)^{1/2}$
1	-0.3	4.3
2	0.7	7.3
3	2.0	10.0
4	3.4	12.6
5	4.8	15.2
6	6.3	17.7
7	7.9	20.1
8	9.4	22.5
9	11.1	24.9
10	12.7	27.3
11	14.3	29.6
12	16	32

**Fig. 3.** Sequential sampling decision lines for estimating stinkbug population on rice

CONCLUSION

In simple random sampling the optimum sample size was inversely related to population density. The optimum sample size with a precision of 10% CV was observed to be very high and thus cost prohibitive. Sequential sampling based on spatial distribution and economic threshold level of the stinkbug could reduce the sampling effort appreciably as compared to simple random sampling. The sequential sampling would help to avoid unwarranted pesticide application thereby conserving natural enemies of the pest and reducing environmental contamination.

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EVALUATION OF DIFFERENT CULTIVARS OF BER (*Zizyphus mauritiana* Lamk) UNDER SEMI-ARID CONDITIONS

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ABSTRACT

Four cultivars of Ber viz; Umran, Gola, Kaithli and Chomu-local grown successfully under semi-arid conditions were evaluated with respect to their vegetative growth, yield and fruit quality. Results revealed that inter-variatal differences were highly significant for all the parameters. Cultivar Kaithli attained maximum plant height (4.29 m). The heaviest fruit weight (17.77 g), TSS (21.15%) and pulp stone ratio (14.32) was recorded in Umran whereas maximum stem girth (71.73cm) was noticed in cultivar Chomu local. Cultivar Gola exhibited maximum canopy spread (54.36 m²), and yield (81.62 kg/plant) with strong fruit acidity (0.301%). Gola is earliest to mature (1st week of Jan.) and Umran is late season (4th week of February) cultivar. Kaithli and Chomu local are mid-season (3rd and 4th week of January) cultivars. In view of yield and fruit quality, commercial cultivation of Ber cultivars Gola, Umran and Kaithli (in descending order) are recommended for the semi-arid conditions.

Keywords: Ber, *Zizyphus mauritiana* Lamk, Cultivars, Semi-arid conditions, Vegetative growth.

INTRODUCTION

Vitamin packed Ber (*Zizyphus mauritiana* Lamk.) is popularly known as the apple of desert in India and nearly 22000 hectares area is used for cultivating Ber, mostly in north Indian plains, central India and peninsular India (Chadha, 1990). Arid and semi-arid regions

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are spread over nearly 12 per cent of the total land surface of this country. Out of which 61 per cent is lying only in Rajasthan (Pareek & Nath, 1996). Ber cultivation in arid and semi-arid region of Rajasthan has gained popularity during past 10-12 years with the introduction of various cultivars grown in the sub-tropical plains of north India and also due to successfully grown in adverse soil and climatic conditions without proper care and management (Pareek & Sharma, 1993).

Various cultivars, which have given better performance on one locality, may not necessarily behave in a similar way under different agro-climatic conditions. Only few experiments have so far been conducted in the different parts of India to find the suitable variety for a particularly locality. Considering this in view four cultivars of Ber, which gave better performance under different localities of the country, were collected and studied to find the potentiality in terms of growth yield and quality in this region.

MATERIALS AND METHODS

With the objectives to assess the relative performance, four cultivars viz., Umran, Gola, Kaithli and Chomu local were budded on *Zyziphus rotundifolia* root stocks (planted in July, 1985) at experimental farm of All India Co-ordinated Research Project on Arid Fruits, S.K.N. College of Agriculture, Jobner (Rajasthan) in July, 1986.

After 4 years, bearing was started. The observations were recorded during 1997-98, 1998-99 and 1999-2000 for this study. The cultural practices were maintained uniformly in all cultivars. The pruning up to 6th secondary was done in the 3rd week of April every year. About 20 kg of well rotten farmyard manure was applied per plant. 400 g nitrogen, 400 g phosphorus and 100 g potassium were also applied in the form of urea, single super phosphate and muriate of potash. Full dose of phosphorus and potassium and half dose of nitrogen were applied in the month of June and remaining half dose of nitrogen was applied in September and November in two split doses. Plants were irrigated just after application of manures and fertilizers.

At the time of harvesting, stem girth (15 cm above the ground level), plant height and plant spread were recorded. Five pickings were done and total yield was recorded accordingly. A random sample of 500 g fruits at colour turning stage was collected from each replication for physico-chemical studies. For physical parameters weight of fruits (g) and pulp/stone ratio were recorded. Similarly for chemical parameters TSS and acidity were recorded.

The TSS was measured with the help of 'Zeiss' hand refractometer. Titrable acidity in terms of total organic acids was determined by diluting the known quantity of juice and titrating the same against N/10 Sodium hydroxide solution using phenolphthalein as an indicator (Ranganna, 1977). The trial was laid out in randomized block design with six

replication having a plant unit of five trees per replication. Data of all the three years were pooled and statistically analyzed according to the methods suggested by Panse and Sukhatme (1985) using PC Excels software.

RESULTS AND DISCUSSION

Vegetative growth

The inter-varietal differences with respect to vegetative growth were significant (Table 1). Data revealed that maximum plant height (4.29 m) was attained by cultivar Kaithli and minimum (2.97m) by Chomu local, the maximum plant spread (54.36 m^2) was attained by Gola and minimum (33.48 m^2) by Umran. The maximum stem girth (71.73 cm) was recorded in Chomu local as compared to minimum (61.44 cm) in Umran. Thus the plant height of Kaithli was 44.44 per cent more than Chomu local, the plant spread of Gola was 62.36 per cent more than Umran and the stem girth of Chomu local was 16.75 per cent more than Umran.

Physical parameters

Fruit weight

It was obvious from the data (Table 1) that the fruit weight of different cultivars differed significantly. The fruit weight ranged from the lowest of 11.31 g in cultivar Chomu local to the highest of 17.77 g in cultivar Umran.

Pulp/stone ratio

The data (Table 1) show that the inter-varietal differences with respect to pulp/stone ratio were significant. The pulp stone ratio ranged from the lowest of 8.75 in the fruits of cultivar Goal to the highest of 14.32 in the fruits of cultivar Umran. These findings are with the close conformity of the results of Pareek and Sharma (1993).

Chemical parameters

Total Soluble Solids (TSS)

The TSS content in the juice of different cultivars differed significantly (Table-1) and ranged from 15.32 per cent in the fruits of cultivar Chomu local to 21.15 per cent in the fruits of cultivar Umran. Hence cultivar Umran produced the sweetest fruits with the maximum total soluble solids.

Acidity

It is apparent from the data presented in Table 1 that the total organic acid (as citric acid) content of different cultivars differed significantly and ranged from 0.118 per cent in the fruits of cultivar Umran to 0.302 per cent in the fruits of cultivar Gola. Hence cultivar Gola produced the most sour fruits with maximum acidity. Similar results were also reported by Lal *et al.* (2002) in pomegranate.

Yield

It is revealed from the data (Table 1) that inter-varietal differences with respect to yield were highly significant. Cultivar Gola is the highest yielder (81.62 kg/plant) followed by Kaithli (57.95 kg/plant) and Umran (47.38 kg/plant) however, the lowest yield (32.13 kg/plant) was recorded in cultivar Chomu local. Hence, the yield of cultivar Gola (154.03%), Kaithli (80.36%) and Umran (47.46%) was more than the yield of Chomu local. These results are in agreement with the findings of Pareek and Nath (1996).

Table 1. Growth, yield and quality parameters of different cultivars of Ber

Cultivars	Plant Height (m)	Plant spread (m ²)	Sterm girth (cm)	Fruit weight (g)	Pulp stone ratio	TSS (%)	Acidity (%)	Yield (kg/plant)
Umran	3.13	33.48	61.44	17.77	14.32	21.15	0.118	47.38
Gola	3.56	54.36	70.69	11.46	8.75	16.87	0.301	81.62
Kaithli	4.29	35.85	69.68	12.24	11.01	18.30	0.130	57.95
Chomu local	2.97	41.13	71.73	11.31	10.27	15.32	0.141	32.13
SEm±	0.07	1.70	1.91	0.36	0.40	0.37	0.0024	2.98
CD (P=0.05)	0.20	4.80	5.41	1.30	1.16	1.05	0.0067	8.44

These differences in the vegetative growth, yield and physico-chemical characteristics of the fruits might be mainly due to genotypic variation of the cultivars (Mahajan & Dhillon, 2000), though the agro-climatic condition could not be overlooked. Wide variation in different cultivars of Ber was also recorded by Pareek and Nath (1996) and of pomegranate by Lal *et al.* (2002).

On the basis of yield, physico-chemical characteristics of fruits and ripening period, Gola (early), Umran (late) and Kaithli (mid season) cultivars of Ber in descending order are recommended for commercial cultivation in the semi-arid areas of India.

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EVALUATION OF *Pseudomonas fluorescens* STRAINS ISOLATED FROM COTTON RHIZOSPHERE AGAINST *Rotylenchulus reniformis*

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ABSTRACT

Pseudomonas fluorescens strains isolated from cotton rhizosphere and strain of PF1 were evaluated for the management of reniform nematode in cotton. Significant reduction in soil and root population of *R. reniformis* and subsequent increase in cotton plant growth characteristics were observed in *P. fluorescens* treated plants. Strain PF1 effected maximum population reduction of nematode to the extent of 70.4 % in root and 44.8 % in soils. It was followed by isolates viz., PFSP1, PFTH and PFCO3, which were at par with each other in reducing reniform nematode population in soil and roots of cotton.

Keywords : *Pseudomonas fluorescens*, *Rotylenchulus reniformis*, Cotton.

INTRODUCTION

World wide, the reniform nematode, *Rotylenchulus reniformis* is a serious bottle-neck for cotton production. It causes delayed maturity, stunting growth, reduction in boll size resulting in yield loss to the extent of 10 to 15 % in India (Palanisamy Balasubramanian, 1983). Chemical nematicides are used in large scale for controlling the nematode menace but their indiscriminate use causes serious environmental problems by polluting ground water and leaving chemical residues in soil. Besides, the chemicals are costly. Fluorescent *Pseudomonas* is a potential and most promising plant growth promoting rhizobacteria involved in the bio-control of phyto-nematodes (Oostendrop Sikora, 1989). Hence attempts were made to isolate native strains of *Pseudomonas* strains from cotton rhizosphere from major cotton growing

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areas of Tamil Nadu. The isolates viz., PFCO1, PFCO2, PFCO3, PFSP1, PFSP2, PFRP, PFTH, PFER, PFER, PFTBN from cotton rhizosphere and PF1 strain were evaluated for *R. reniformis* management in cotton.

MATERIALS AND METHODS

Soil samples from cotton rhizosphere were collected from different cotton growing areas of Tamil Nadu. One-gram representative soil from each location was transferred to 10 ml sterile distilled water. The antagonist bacterial population in the suspension was isolated after shaking by serial dilution plate technique. From the dilution of 10^{-5} and 10^{-6} , one ml aliquot was pipetted out in sterile petridishes containing King's B medium and incubated at room temperature for 24 hr. Colonies formed were viewed under UV light at 366 nm for identification of *P. fluorescens*.

King's B broth was prepared without addition of agar and a loopful of the above isolates were inoculated aseptically to the broth in Erlenmeyer flasks and allowed to multiply in a rotary shaker for 48 hr at room temperature. The cultures were centrifuged at 6000 rpm for 10 minutes and bacterial cells were resuspended in phosphate buffer and concentration adjusted to 6×10^8 cfu/ml and used as bacterial inoculum for screening against *R. reniformis* in cotton.

Surface sterilized cotton seeds cv. MCU 5 were treated with *P. fluorescens* isolates @ 10 ml of inoculum and strain PF1 in talc based formulation @ 10 g/kg seeds. Two per cent carboxyl methyl cellulose was mixed in case of *P. fluorescens* isolates with the inoculum as sticky agent. Treated seeds incubated for 24 hr were sown @ five per pot and at 10 days after sowing (DAS), plants were thinned to one per pot. Untreated seeds served as control. At 15 DAS, *R. reniformis* was inoculated @ two per gram of soil.

At 90 DAS, plants were removed with roots intact and cotton plant growth characteristics, final nematode population in soil and roots were recorded.

RESULTS AND DISCUSSION

Varying degree of antagonistic potential against *R. reniformis* was exhibited by different *P. fluorescens* isolates from cotton rhizosphere.

Strain PF1 registered maximum increase in plant height to the tune of 48.3, 36.1 and 14.39 percent at 45, 60 and 90 DAS respectively over untreated control. Other plant growth parameters like root weight, root length and shoot weight were also significantly improved in plants treated with isolates/strain of *P. fluorescens*. Similar increased plant growth parameters in *P. fluorescens* treated plants were reported by various investigators in crops such as potato (Burr *et al.*, 1978), citrus fruits (Gardner *et al.*, 1984) and tomato (Gamliel

Katan, 1991). Such increase in plant growth may be due to production of gibberellins, cytokinin and IAA by growth promoting rhizosphere bacteria as reported by Lifshits *et al.* (1987).

Among eleven isolates tested, PF1, PFSP1 and PFTH were found promising in reducing the reniform nematode population in cotton (Table 1). Strain PF1 effected maximum reduction in root and soil nematode population to the level of 70.4 and 44.8 % respectively and significantly differed from other isolates, which were at par with each other in reducing nematode populations. Zavelta-Mejia and Van Gundy (1982) also reported similar antagonistic potential of various strains of *P. fluorescens* against *Meloidogyne incognita* in tomato. Misaghi *et al.* (1982) had attributed production of antibiotics and iron chelating agents (Siderophores) to such suppression of plant pathogens. Oostendorp and Sikora (1990) reported that the mechanism responsible for such reduction in nematode population may be related to the ability of the bacterium to envelop or bind lectins in the root surface which thereby interferes with normal host recognition by nematodes.

Table 1. Bio-efficacy of *P. fluorescens* strains isolated from cotton rhizosphere against *R. reniformis* in cotton (90 DAS)

Treatment (@ 10 ml / kg seed)	Plant height (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	No. of female nematode root (g)	No. of female nematode/ 200 ml soil
PF1 @10g /kg of seed	76.3	54.7	20.6	7.21	6.0	442.3
PFTH	71.2	48.4	18.7	6.46	10.6	586.3
PEPBR	69.8	44.3	16.9	6.01	17.3	710.6
PFTBN	70.4	46.3	18.1	6.23	10.0	568.3
PFCO3	70.8	46.2	18.2	6.21	12.3	616.0
PFRP	68.9	41.9	16.7	5.80	16.0	692.3
PFSP2	69.3	44.1	17.4	5.91	14.3	649.0
PFCO1	68.4	41.7	16.6	5.73	15.0	723.3
PFER	70.2	42.7	17.0	5.77	13.3	684.63
PFCO2	69.1	44.3	17.3	5.92	14.0	648.3
PFSP1	72.6	50.2	19.4	6.8	10.0	561.3
Control	66.7	39.3	16.2	5.61	20.3	802.0
CD 5%	3.49	3.52	0.71	0.15	5.783	31.68

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INDUCTION OF OESTRUS AND FERTILITY IN FRIESWAL HEIFERS

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ABSTRACT

Forty-two Frieswal heifers (Holstein Friesian x Sahiwal) showing anoestrus were randomly divided into four groups (I-IV). Heifers of group I were fed Norgestrel at the rate of 1.2 mg combined with Ethinylestradiol 0.12 mg per animal per day for 6 days. Animals of group II were administered GnRH 0.02 mg single injection. Group III animals were given two injections of vitamin A at a dose of @ 6 lac IU/animal at weekly interval along with five alternate day injection of Tonophosphan at a dose of @ 2.0 g/animal where as, animals of group IV were kept as controls. Induction of oestrus was observed in 66.7, 80.0 and 80 percent heifers at an average interval of 23.7, 19.4 and 10.2 days post treatment in group I, II and III, respectively. In control group only 20% animals exhibited oestrus after 47.5 days. Animals from all the three treated groups took significantly ($p<0.01$) lesser time to exhibit oestrus as compared to controls. However, heifers from group III took significantly least time (10.2 days significance level) to exhibit oestrus after treatment. The conception rate was also higher (100%) in this group as compared to others. Higher response resulted into group III may be attributed to the sub optimal level of these nutrients available to these animals at farm. These results indicate that oestrus may be induced in heifers by any of the three treatments schedule successfully. However, oral feeding of combined progesterone and oestrogen emerged as most economical and convenient way for the treatment of anoestrus in heifers.

Keywords: Frieswal heifers, fertility, anoestrus.

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INTRODUCTION

Delayed sexual maturity and prolonged anoestrus resulting in low fertility are the most frustrating problem in crossbred cattle and buffaloes. This condition occurs due to temporary suppression of optimum endocrine secretion needed to activate the folliculogenesis and ovulation. The deficiency of certain minerals, vitamins and gonadotropins may aggravate the condition. Oestrus may be induced in cyclic animals employing progesterone (Kordts et. al, 1974; Wilthbank & Spitzer, 1978; Willemse et. al, 1982), progesterone with oestrogen (Foote & Hunter, 1964; Britt et. al, 1974; Shanker et. al 1996), GnRH (Fernandes et. al, 1978; Mauer & Rippel, 1972) and by administering essential minerals and vitamins (Swensson et. al, 1988). It has been observed that at farm in spite of better health, optimum body weight and age for attainment of sexual maturity a large number of heifers remains anoestrus for more than 20 months of age. Accordingly, this experiment was conducted to know the efficacy of various treatments on anoestrus Frieswal heifers.

MATERIALS AND METHODS

Frieswal heifers (Holstein Friesian x Sahiwal) maintained at Military Farm, Meerut under same management and feeding practices were taken for the experimentation. All the heifers were examined per rectum twice at an interval of 11 days to know the status of genital organs. Forty-two animals showing true anoestrus (smooth and inactive ovaries) were divided into four groups.

- Group I: Twelve heifers with mean age 20.83 ± 1.86 month and body weight 334.15 ± 8.54 kg were fed Norgestrel @ 1.2 mg and Ethinylestradiol 0.12 mg per day for 6 days
- Group II: Ten animals with mean age 24.6 ± 1.47 months and body weight 319.7 ± 10.91 kg were administered with GnRH single injection of 0.02 mg.
- Group III: Ten animals with mean age 27.5 ± 0.57 months and body weight 241.0 ± 5.62 kg were administered with two injections of vitamin-A (Glaxosmithkline) 6 lac I.U. per animal at weekly interval along with five injections of Tonophosphan (Intervet @ 2.0 g per animal at alternate days.
- Group IV: Ten animals with mean age 22.2 ± 1.12 months and body weight 308.0 ± 8.07 kg were injected with normal saline and were considered as control.

All the heifers were regularly observed for oestrus after the treatment at 12 hour interval using a vasectomized teaser bull. Animals detected in oestrus were inseminated using frozen-thawed semen twice (i.e. morning and in evening). Pregnancy diagnosis was done by per rectal examination after 60 days of A.I. Data was analysed using chi-square test as mentioned by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Oestrus response was observed in 66.7, 80 and 80 per cent heifers at a mean interval of 23.7, 19.4 and 10.2 days post treatment in group I, II and III, respectively. Two heifers out of 10 (20%) exhibited oestrus after 47.5 days in group IV (control). The oestrus response was significantly higher ($p < 0.01$) in treated animals of group I, II and III as compared to control. Further more, these animals took significantly ($p < 0.01$) lesser time to exhibit oestrus than control animals (table 1).

Progesterone treatment associated with oestrogen had also been used to induce ovarian activity in post-partum cows (Foote & Hunter, 1964; Britt et al., 1974; Kumar et. al, 2000). In our study treatment with progesterone along with oestrogen had resulted in exhibition of oestrus in 66.7% and conception in 87.5% anoestrus heifers. These results confirm the earlier reports of induction of oestrus in heifers using combined progesterone and oestrogen therapy. (Gonzaliz-Padilla et al., 1975; Faure et. al., 1981; Dantre et al., 1998; Srivastava et. al, 1999).

Perusal of available literature did not revealed any report of oral feeding of combination of progesterone and oestrogen in heifers. However there are reports of oral feeding of progesterone along with injection of oestrogen to induce oestrus (Shanker et al., 1996; Pant & Gupta 1996). Mehta & Mehta (1999) had also reported early revival of oestrus in post-partum cows treated with PRID and oestradiol. Our results indicate that oral feeding of Norgestrel in combination with Ethinylestradiol is very effective, convenient and comparatively economical than parenteral administration of other progesterone and oestrogen preparations.

Gonadotropin releasing hormone (GnRH) is known to initiate cyclical ovarian activity in cattle (Webb et al., 1977; Fernandes et al., 1978; Leslie, 1983; Pattabhiraman et. al, 1986; Majumdar 1989; Tamuli et al., 2000). In our animals, oestrus response (80%) and conception rate (75%) after GnRH treatment were significantly higher ($p < 0.01$) than control animals (Table 1). These findings are in agreement with those of Gonzaliz-Padilla et. al, 1975; Shams et al., 1991; Sonwane et al., 1995; Dantre et. al, 1998; Thakur & Bhatt, 1999 in crossbreds and Nautiyal et. al, 1997 in buffalo heifers. In our study oestrus response in GnRH treated animals was 80% with conception rate of 75% as compared to heifers in group I where 66.6% animals exhibited oestrus with a conception rate of 87.5%. These observations also

confirm the report of precise and higher conception rate by oestrogen and progesterone combination than GnRH treated crossbred heifers by Thakur & Bhatt (1999).

The response of administration of phosphorus and vitamin A on the induction of oestrus and conception is given in table - I. It indicates that 80% heifers exhibited oestrus after 10.25 day of treatment. Further, the animals of this group showed significantly ($p < 0.01$) quicker response in exhibition of oestrus and higher conception rates as compared to other two treatment groups. It has been reported that phosphorus is the mineral most frequently associated with reproductive abnormalities in cattle, and its deficiency induces delayed onset of puberty (Gerloft Morrow, 1986), lowered conception rate, irregular oestrus and depressed fertility in cows (Maynard et. al, 1979; Morrow, 1980).

Salisbury and Vandanmark (1961) had observed that most prevalent deficiency affecting reproduction was lack of phosphorus. Lower levels of phosphorus in anoestrus condition as compared to normal cycling animals had reported by Ali et. al, (1991) had also pointed that low phosphorus level in serum was responsible for infertility in buffaloes. Hurley and Done (1989) had also reported that involvement of phosphorus in phospholipid and cAMP synthesis may be a key to its effect on reproduction.

Vitamin A is extremely important for good health and reproduction especially in young replacements (Guthrie West, 1994). Gerloft and Morrow (1986) reported that onset of puberty in females may be delayed due to deficiency of vitamin A, further this deficiency may also develop in animals fed all corn silage. Vitamin A and phosphorus plays a vital role to overcome the problem of anoestrus, sub oestrus and delayed sexual maturity in cattle (Blood et. al, 1989). In an effort to induce oestrus in crossbred heifers under field conditions Dutta and Misra et. al, (2001) reported that most of the cases responded to the administration of vitamin A & phosphorus.

Our study indicates that oestrus may be initiated with acceptable fertility in Frieswal heifers by any of the three treatments given. However, higher response in group III heifers may be attributed to the administration of required minerals and vitamins at optimum levels, which might have enhanced the functioning of genital tract and ovary. The deficiency of vitamin A in our animals may be due to feeding of corn silage at the farm, which is known to cause deficiency of vitamin A in stall fed animals. Although we could not estimate various hormonal and mineral profiles of the animals, however, the results of present investigation indicated that the availability of vitamin A and phosphorus to these animals were at sub optimal levels.

Table 1. Effect of various treatments on induction of cyclicity and fertility in heifers

Group	Treatment	No. of Animal	Age (Months $\pm$ SE)	Body weight (kg $\pm$ SE)	Oestrus Response No (%)	Post treatment oestrus exhibitics (days $\pm$ SE)	Animal Pregnant (at 60 days post AI) No (%)
I	Oestrogen-Progesterone combination	12	20.83 $\pm$ 1.86	334.15 $\pm$ 8.54	8** (66.66)	23.7 ^B $\pm$ 2.84	7 (87.5)
II	GnRH	10	24.6 $\pm$ 1.47	319.7 $\pm$ 10.91	8** (80.00)	19.4 ^B $\pm$ 4.02	6 (75.00)
III	Tonophosphone + Vitamin A	10	27.50 $\pm$ 0.57	341.00 $\pm$ 5.62	8** (80.00)	10.25 ^A $\pm$ 3.95	8 (100.00)
IV	Control	10	22.2 $\pm$ 1.12	308.0 $\pm$ 8.07	2 (20.00)	47.5 ^C $\pm$ 4.48	1 (50.00)

* Significant at P<0.01; different superscript shows significant difference at p<0.05.

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INDUCED TWINING AND BOLL ABNORMALITIES IN *Gossypium hirsutum* L.

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ABSTRACT

Attempts were made to induce improved variants in cotton through the treatment with both physical and chemical mutagens. Seeds of the varieties MCU-5 and MCU-11 were treated with 100-500 Grey ⁶⁰Co gamma rays as well as 10-50 mM of ethyl methane sulphonate and sodium azide. M₂ plants derived from seeds of selfed M₁ plants showed many variations including twin-bolls without other abnormalities and twin-bolls with abnormalities. Frequency of these variants was higher among the M₂ population following gamma ray treatments than those from chemical treatments. The twin-bolled variants were fully fertile and the doubling-tendency without abnormalities was inherited in subsequent M₃, M₄ and M₅ generations. However, these variants exhibited segregation in each generation and the twin bolls with abnormalities were not inherited even in the next generation (M₃). The double-bolled variants have potential in the development of improved varieties of cotton.

Keywords : Cotton seed, *Gossypium hirsutum* L. Mutagenic treatments, Induced mutation, Twin boll,

INTRODUCTION

Induced mutations have successfully been utilized in genetic improvement of many crops including both sexually and asexually propagated species. Induced mutagenesis can increase frequency of mutations, thus allowing the breeder to select useful mutants within a relatively shorter period. Many useful mutants have been released for commercial cultivation

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across the world (Shaikh, 1981; Shaikh, 1983; Kharkwal, 1998). About 2,252 mutants have been officially registered in the FAO/IAEA mutant varieties database (Maluszynski *et al.*, 2000). Cotton varieties and hybrids are more stable in performance over wide range of growing conditions but their potential performance is often challenged by aberrant rainfall, pest and disease incidence with inherent deficiencies for one or other fibre characters (Narayanan *et al.*, 1984). To overcome these problems, mutation breeding was expected to be effective in generating high magnitude of variability for these characters, so that elite lines which are resistant to biotic and abiotic stresses, high yielding with improved fibre qualities can be isolated.

The potentialities of mutation breeding in cotton seem not to have been explored to the extent as in cereals apparently due to the fact that most of the economically useful characters in cotton are under polygenic control (Bahavandoss & Madhava Menon, 1970) and the resultant low frequency of induced mutations. Even though some improvements in a few characters of cotton have been made, quality and yield need further improvement (Shamsuzzaman *et al.*, 1997). Thus further work on this plant is needed to improve its existing features, particularly high yield, ginning out turn and oil content of the seed.

The twin boll character of cotton is of economic interest because one could expect almost double the yield if it turns out to be heritable. The present investigation of biological effects of various mutagens in cotton, a mutant with twining-tendency was observed in M_2 generation. A study was made to determine whether this twining-tendency is heritable. The results of the twining tendency and twining with boll abnormalities are reported in this paper.

MATERIALS AND METHODS

Seeds of MCU 5 and MCU 11 varieties of cotton were irradiated with 100, 200, 300, 400 and 500 Gy ^{60}Co gamma rays and two other sets of seeds were treated with 10, 20, 30, 40 and 50 mM of ethyl methane sulphonate (EMS) and sodium azide (SA) for 4 h. M_1 plants were grown at pre-irrigated field in Bharathidasan University, Tiruchirappalli, India in 1997 whereas M_2 , M_3 , M_4 and M_5 generations were grown in the same field in 1998, 1999 and 2000 respectively. During the time of flowering the plants were selfed, bolls were harvested separately and the seeds were collected separately from individual boll. The mutants were selected in M_4 generation, since the characters for which they were noted in the M_2 were transmitted through to the M_3 generation.

RESULTS AND DISCUSSION

In M_2 several plants showed changes in plant height, number of branch, length of branch, number of nodes, number of bolls, boll weight etc. The number of morphological variants increased with increase in dose/concentrations of the mutagens. Among the morphological variations, twin boll formation in one of the plants was noted. The twin boll was formed from a single flower on one plant (Fig. a, b) following treatment with 100 Gy of gamma rays. The twin boll was formed from the nodes of a sympodial branch (Fig a, b). In this mutant, twin bolls developed from two separate ovaries formed within a single flower. The twin bolls were distinctly heavier and bolder than the normal ones.

The changes in twin boll, boll weight, weight of seed cotton/boll, number of locule/boll, seeds/locule, mean number of seeds, number of seeds/boll (mature and immature) are presented in Table 1. All these changes occurred in both physical and chemical mutagenic treatments, but the twin boll mutants were obtained following 100 Gy of gamma rays treatments. The frequency of these variants following gamma ray treatments was higher than chemical mutagens.

The twining tendency characters were easily scorable and were fully fertile. The twin bolls differed from one another in respective characters and one boll is large and the other one is small (Table 1). The twining tendency character was inherited in M_3 , M_4 and M_5 generations exhibiting segregation during every generation. The plants with twining tendency showed distinct variations in boll characters than normal control plant (Table 1).

The twin bolls with abnormalities were obtained in the M_2 following 400 and 500 Gy of gamma rays treatment (Fig c-i). Three types of twin boll with boll abnormalities were noted in three plants that showed differences both externally and internally. The twin boll with abnormalities observed in M_2 generation was not inherited in the M_3 generation.

Chemical mutagens induced morphological changes were observed in M_2 generation. The twin boll with regular morphological characters was inherited in the M_3 and M_4 generations. The twining tendency characters were inherited and have the segregation in the subsequent generations. In this mutant with twin boll developed from two separate ovaries formed within a single flower. One interesting feature observed in this mutant was that all of the remaining bolls on the same plant did not have twining tendency (Fig. a).

The present report is the first instance of induced twining in cotton where the bolls were developed, the functional carpels matured to produce seeds within a single flower which germinated and produced normal tetraploid plants. Kump (1953) reported heritable nature of

double spike in winter barley and he assumed that the trait was determined by different genetic factors. Mehta *et al.* (1961) obtained a double spike chimera in F_2 generation of wheat cross, E. 771 $\times$ Pb.C. 591. They suggested that this character might have arisen through mutation. The results of the subsequent generations were not published to confirm this observation.

Since all the M_2 aberrants resulting from chemical mutagen treatment were fully fertile, their non-recurrence in the subsequent generations because of the elimination process was also ruled out. The other possible basis of these non-heritable variants could not be confirmed in the present study. Reviewing the effects of ionizing radiation on plant growth, Gunckel (1962) indicated that, although the genetic materials of the cells were sensitive to radiation damage, both primary and secondary physiological effects could be responsible for many morphological changes.

Thus, the twining tendency with abnormalities recorded in the present study seems to be a physiological disorder belonging to the class 'radiomorphs' (Dubinin, 1964) induced by a change in the gene environment rather than a change in the gene itself (Gunckel, 1962). The phenomenon of radiomorphosis is quite interesting and further investigations into the causal nature of the mutagen-induced twining tendencies are needed.

Fig1. Twin boll and boll abnormalities in cotton

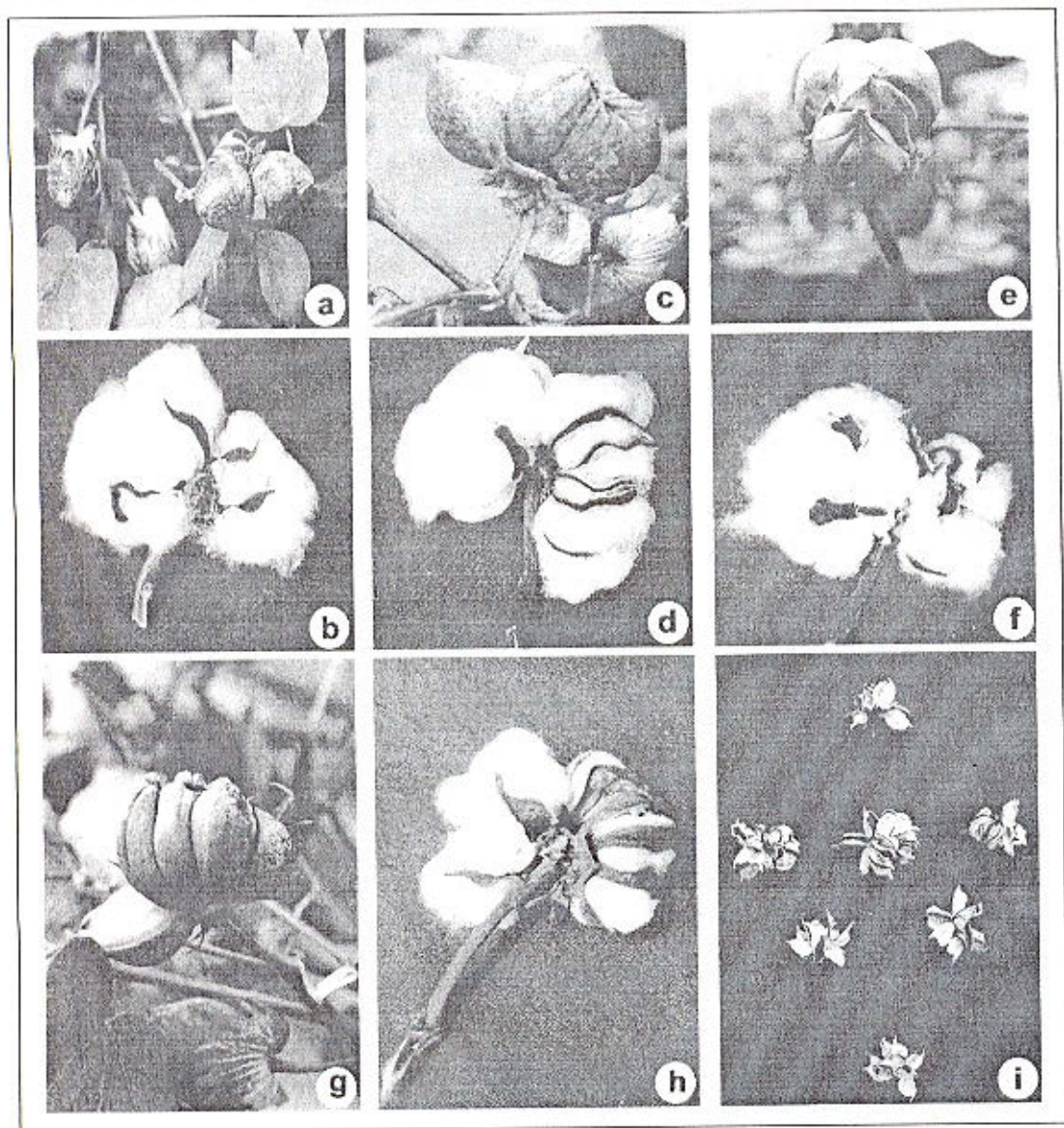


Fig 1. a, b - Twin boll and matured open boll; c - b - Twin boll with abnormalities and respective matured boll; i - Capsule wall of the boll with abnormalities

Table 1. Gamma rays induced Twin boll and boll abnormalities of M₂ plants in the cultivar MCU 5

Character/ Treatment	Boll weight (g)	Weight of seed cotton/boll (g)	No. of locule/ Boll	Seeds/locule	Mean	Number of seeds / boll		Total
						Mature	Immature	
Twin boll At 100 Gy	8.5334	5.3864	6	7, 7, 6, 3, 4, 4	5.16	25	6	31
		2.3100	5	4, 4, 3, 2, 3	3.20	13	3	16
Twin boll With boll Abnormalities At 400 Gy	14.2235	3.8360	4	5, 7, 4, 5	5.25	17	4	21
		5.9982	10	6, 4, 6, 1, 4, 4, 2, 4, 3, 2	3.60	28	8	36
	5.5086	2.2753	5	5, 2, 4, 6, 3	4.00	14	6	20
		1.8123	4	3, 2, 3, 2	2.50	7	3	10
At 500 Gy	11.3246	3.9871	10	1, 7, 6, 3, 3, 2, 1, 1, 1, 3	2.80	21	7	28
		3.3050	4	5, 6, 4, 6	5.25	16	5	21
	7.0769	2.6829	6	4, 4, 2, 1, 2, 3	2.66	11	5	16
		1.8716	4	3, 5, 4, 1	3.25	10	3	13
	6.9227	1.3915	8	2, 1, 3, 2, 1, 2, 1, 1	1.62	9	4	13
		1.3132	4	2, 3, 3, 1	2.25	6	3	9
	4.7623	1.8640	7	3, 2, 3, 3, 1, 3, 4	2.71	13	6	19
		1.0041	4	2, 6, 4, 6	4.50	13	5	18

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NORTH CAROLINA DESIGN II ANALYSIS IN INDIAN RAPESEED (*Brassica campestris* L.)

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ABSTRACT

*A composite derived from ten intervarietal hybrid populations involving toria, yellow sarson and brown sarson of Indian rapeseed (*Brassica campestris* L. ssp. *oleifera* (Metzg.) Sinsk) was subjected to North Carolina design II analysis. Model II analysis of variance of 252 full-sib progenies for 17 characters revealed significant variation among the progenies. Variation for seed and biological yield, siliquae/plant, harvest index and seed weight was predominantly non-additive. The developmental characters namely, days to flower, maturity and plant height showed primarily additive genetic variation. Both additive and non-additive genetic variations were important for the component of branches and the siliqua characters. All the characters except seed density exhibited complete to overdominance gene expression. Maternal effects and repulsion linkages presumably with epistasis were indicated for most of the characters. Sufficient additive genetic variation for yield and its determinants like branches/plant, siliquae on main shoot and seeds/siliqua was present for effective selection in the composite population.*

Keywords : Rapeseed (*Brassica campestris* L.), Oilseed, North Carolina design II analysis, Genetic variance.

INTRODUCTION

The oilseed crops *Brassicas* are the third most important edible oil source after soybean and palm, accounting for over 13.2 per cent of the world's edible oil supply (Ram & Singh, 1994). In India, rapeseed and mustard are the second most important oilseed crops

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after groundnut contributing about 30 per cent of the total oilseed production (Saksena, 2001). However, the productivity of these *Brassicas* in India is low as compared to the world average of 1333 kg per ha (Ganga Rao & Gulati, 2001). Among these mustard (*B. juncea* L.) is the most important accounting for more than 75 per cent of the area under rapeseed and mustard followed by Indian rapeseed (Ram & Singh, 1994). Indian rapeseed (*B. campestris*) has three agro-morphologically distinct ecotypes namely, brown *sarson*, yellow *sarson* and *toria* (Prakash & Hinata, 1980). Yellow *sarson* and *toria* type brown *sarson* are autogamous, whereas *toria* and *lotni* type brown *sarson* are allogamous.

Toria is the predominant oilseed crop in Assam and adjoining States. However, the present plant type of *toria* with weak and pithy stem, spreading branches, lax siliqua density, wide siliqua angle and non synchronous maturity (Rai, 1983), is not conducive for high yield under optimum agronomic environment. Many desirable features of a high yielding plant type are scattered in the three ecotypes of Indian rapeseed. *Toria* has generally high harvest index; but low biological yield limits economic yield (Bhargava *et al.*, 1984). Both brown *sarson* and yellow *sarson* are characterised by high biological yield potential and deep root system. Yellow *sarson* has erect growth habit and generally high oil content. Studies have shown that these desirable traits can be recombined (Barua, 1992).

Genetically diverse *toria* x *toria* and *sarson* x *toria* crosses exhibit higher frequency and magnitude of heterosis for yield (Barua, 1992). A composite of such hybrid populations can be developed to initiate a population improvement programme. The extent of genotypic differences consequent upon recombination through random mating in such composite population determines the extent of gain from such selection.

The effectiveness of selection in different population improvement methods is based on the utilization of additive gene effects (Sprague, 1966). Comparable estimates of genetic variance components can be made in a composite population using suitable mating designs. The diallel mating design has been used more extensively than any other design for genetic analysis in Indian rapeseed. Genetic analysis using North Carolina designs of Comstock and Robinson (1948, 1952) are lacking, if not at all, in Indian rapeseed. Line x tester analysis, a factorial mating design similar to North Carolina Design II (NCD II), has been used to a limited extent in this crop. Model II analysis of NCD II experiment provides estimates of genetic variance component in a composite population for comparing gains from different methods of selection. In the present study, a composite derived from ten intervarietal hybrid populations involving five diverse parents of *toria*, yellow *sarson* and brown *sarson* was subjected to NCD II analysis for understanding the nature and magnitude of gene action involved in the inheritance of yield and its attributes.

MATERIALS AND METHODS

The composite base was a largely random mating population built up by mixing equal quantity of F_2 seeds of ten intervarietal hybrids derived from one way crosses involving five diverse parents namely, 'M 27' and 'PT 303' of *toria*, 'B9' of yellow *sarson*, and 'BSH 1' of *toria* type and 'Pusa Kalyani' of *lotni* type brown *sarson*. The intervarietal crosses were made during winter, 1989-90 (Barua, 1992) as per diallel mating design excluding reciprocals. The composite thus derived was advanced through open pollination and mild phenotypic selection upto F_7 generation. The composite in F_8 generation was used for development of NCD II progenies.

The investigation was carried out at the experimental farm of the Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat during winter season of 1997-98 and 1998-99. The site was located at 26°46' North latitude and 94°16' East longitude having an elevation of 86.6 m above the mean sea level. The soils of the experimental site belonged to the order Inceptisols and sandy loam texture with pH of 4.8. The status of organic matter and available potash was medium, and available nitrogen and phosphate were low.

The crop season of 1997-98 received the highest rainfall of 84.4 mm followed by 46.6 mm during 1998-99. The period of bright sunshine was less due to overcast sky during winter, 1997-98. Low evening relative humidity and warm day temperature characterized both the crop seasons. Similarly, high morning relative humidity and low night temperature also featured the weather.

The base population was raised during winter, 1997-98 in a crossing block of 5 m x 31.5 m with a row spacing of 30 cm and plant spacing of 15 cm. The extent of self-incompatibility of the population was assessed using a random sample of 100 plants tagged before flowering. Self-incompatibility was computed as per Doloi and Rai (1982).

Two hundred and fifty two full-sib progenies were generated in the composite population. The full-sibs were grouped in 21 sets, and a set was developed in every 5 rows of the crossing block. In each set, four plants were used as males and three as females to develop 12 full-sibs, 4 paternal half-sib families and 3 maternal half-sib families. The full-sibs were evaluated in a Randomized Complete Block Design with two replications followed by randomization of the 12 progenies in each of 21 sets. New randomization was followed in each of the two replications. Progenies were raised in single rows of 2 m long spaced 45 cm apart. In each row, thinning was done to keep an approximate spacing of 10 cm between the plants.

Fertilizers were applied at the rate of 60N:25P:35K kg/ha along with Borax 10 kg/ha. Irrigation was done on need basis with manual sprinkling of water. Manual weeding and thinning were done twice during vegetative growth period.

Malathion 5% dust was applied one week after germination to protect the seedlings from sawfly larvae. At later stage of crop growth Rogor 30EC was sprayed twice to keep aphid population under control.

Seventeen characters were observed for genetic analysis (Table 1). The maturity indices were recorded on plot basis. The remaining 15 characters were based on a random sample of five plants. Siliqua characters were recorded on two mature siliquae collected from the middle portion of the main shoot of each sampled plant. Siliqua density was derived as the number of siliquae per unit length of the main shoot. Similarly, seed density was worked out as the number of seeds per unit length of the siliqua. Biological yield was recorded on well dried sampled plants harvested by cutting at the ground level.

Statistical analyses were performed on plot mean basis using the sets in replications arrangement (Hallauer & Miranda, 1981) of North Carolina design II (Comstock and Robinson, 1948, 1952). Analyses of variance were based on model II considering sets, replications, males and females as random effects. The model for one environment is:

$$Y_{ijkl} = \mu + r_i + s_{ij} + m_{jk} + f_{jl} + mf_{jk,l} + e_{ijkl}$$

Estimates of variance components were calculated by equating terms comprising the expected mean squares to the corresponding observed mean square and solving by appropriate algebraic manipulation (Comstock & Robinson, 1948; Hallauer & Miranda, 1981). The components of genetic variance were estimated according to the following expectations under the assumptions of no epistasis and no inbreeding ($F = 0$):

$$\sigma_m^2 = \sigma_e^2 = \text{Cov HS} = (1/4) \sigma_A^2, \sigma_A^2 \text{ is the additive genetic variance, and}$$

$$\sigma_{mf}^2 = \text{Cov FS} - \text{Cov HS}_m - \text{Cov HS}_f = (1/4) \sigma_D^2, \sigma_D^2 \text{ is the dominance variance}$$

Assuming a population in linkage equilibrium at $p = q = 0.5$ and no epistasis, the average degree of dominance of the genes for a trait was estimated as

$$\hat{d} = \left[\frac{2\hat{\sigma}_D^2}{\hat{\sigma}_A^2} \right]^{1/2}$$

Significance of deviation of $\hat{d}$ from unity (in either direction) was tested by F-test (Comstock & Robinson, 1948). Narrow sense heritability was estimated on plot basis from the genetic components of variance values as

$$\hat{h}_N^2 = \frac{\hat{\sigma}_A^2}{\hat{\sigma}_A^2 + \hat{\sigma}_D^2 + \hat{\sigma}^2}$$

The additive genetic coefficient of variability for i th character was estimated as

$$AGCV = \frac{\hat{\sigma}_A}{\bar{X}_i}$$

RESULTS AND DISCUSSION

The composite population possessed a high level of self incompatibility (91 %) and a genetic background of all the three ecotypes of Indian rapeseed. To assess the extent of genetic variation in the composite, the model II analysis of variance of North Carolina design II progenies was carried out for yield and 16 yield attributing characters. The analysis involved the following assumptions in the derivation of expected mean squares as stated by Comstock and Robinson (1952): (1) random choice of individual mated for production of experimental progenies; (2) random distribution of genotypes relative to variation in environment; and (3) absence of non-genic maternal effects.

The first assumption was assured by choosing random parents before flowering to be used as males and females to generate the full-sib progenies in the experimental population. Thus, the estimates of components of variance would characterize the population from which the parents were a random sample (Hallauer & Miranda, 1981). Because the analysis of variance was based on single environment, the mean square due to variation among progenies (genetic variance) would contain genotype-environment interaction variance, which might result in upward bias in genetic variance estimates. The bias due to genotype-environment interaction would, however, be less because the full-sib progenies developed from random non-inbred parents of the composite population were genetically heterogeneous consequent upon random mating and thus endowed with homeostatic device (Allard, 1960). Maternal effects contribute only to mean square due to females/sets in design II analysis.

Table 1. Analysis of variance of North Carolina design II progenies of a composite population of Indian rapeseed

Source of variation	Df	Days to 50% flowering	Days to 75% maturity	Plant height (cm)	Primary branches/plant	Secondary branches/plant	Total branches/plant	Silique/plant	Main shoot length (cm)
Replications	1	1.79	60.77*	831.86**	29.24**	15.23*	90.02**	165687.90*	1266.03**
Sets	20	49.13**	90.90**	749.75**	4.82**	11.67**	24.55**	12184.45**	335.98**
Males(M)/sets	63	10.78	16.50	115.77	2.77*	4.44	9.95	3617.49	84.92
Females(F)/sets	42	24.42**	38.84**	318.48**	3.72**	12.37**	25.24**	9074.71*	184.98*
M x F / sets	126	11.87**	14.26**	91.50*	1.83*	5.32**	10.05**	6069.23**	70.45*
Pooled error	251	7.36	9.59	70.52	1.42	2.67	5.99	1880.34	54.97
Experimental CV (%)		6.67	3.04	7.91	20.95	32.57	22.84	21.84	13.31
Mean :	Progenies	41 ± 2	102 ± 2	106 ± 6	5.7 ± .8	5.0 ± 1.2	10.7 ± 1.7	199 ± 31	56 ± 5
Range :	Progenies	33-46	92-108	83-130	2.9-9.8	1.0-10.1	4.3-21.7	67-437	37-77
	Males	37-45	96-107	92-123	4.1-7.4	2.9-7.6	7.4-14.3	120-276	44-67
	Females	36-44	96-106	87-122	4.2-7.7	2.9-9.4	6.5-17.0	134-291	40-70
Contribution (%) to sum of squares due to crosses:									
	Males	21	2	23	31	19	21	17	24
	Females	32	3	41	28	35	36	28	35
	Males x females	47	4	36	41	46	43	55	41
			0						

Table 1 (continued)

Source of variance	df	Siliquae on main shoot	Siliqua density (No./cm)	Siliqua length (cm)	Seeds / siliqua	Seed density (No./cm)	Biological yield (g/plant)	Seed yield (g/plant)	Harvest index (%)	1000 seed weight (g)
Replications	1	4252.57**	0.6014**	0.6429*	8.41	0.0001	1308.54**	325.45**	494.82**	0.0217
Sets	20	393.24**	0.1044**	1.1410**	37.29**	1.2454**	389.45**	45.21**	106.49**	0.6680**
Males(M)/ sets	63	67.93	0.0190	0.3353**	15.09**	0.7617**	114.86	15.58	24.76	0.2964
Females(F)/ sets	42	142.69**	0.0321*	0.2843*	18.36**	2.2345**	205.68*	24.19*	34.11	0.3302*
M x F / sets	126	59.02**	0.0191**	0.1872**	8.25*	0.3769*	139.95**	16.10**	32.54**	0.2298**
Pooled error	251	34.15	0.0071	0.1175	5.82	0.3274	88.33	9.43	18.66	0.1296
Experimental CV (%)		14.26	11.39	9.22	16.45	14.86	35.70	34.11	12.48	11.38
Mean : Progenies		41 ± 4	0.74 ± .06	3.7 ± 0.2	14 ± 2	3.9 ± 0.4	26 ± 7	9.0 ± 2.2	35 ± 3	3.2 ± 0.3
Range : Progenies		25-66	0.49-1.25	2.8-5.1	6-21	1.6-5.8	8-61	4.1-23.1	25-50	2.1-4.2
Males		30-56	0.57-1.06	3.1-4.7	9-19	2.9-4.6	17-39	5.7-13.6	31-41	2.5-3.6
Females		31-56	0.57-0.96	3.2-4.6	9-18	2.6-4.8	18-40	5.6-16.0	29-42	2.7-3.7
Contribution (%) to sum of squares due to crosses:										
Males		24	24	37	34	25	22	23	22	30
Females		34	27	21	28	50	26	26	20	23
M x F		42	49	42	38	25	52	51	58	47

*, ** Significant at P = 0.05 and 0.01, respectively.

The analysis of variance of NCD II progenies for various quantitative characters is presented in Table I, along with mean, range and per cent contribution of males, females and males x females sources of variation to sum of squares due to progenies. The mean squares due to sets were highly significant for all the characters. Thus there were significant differences among the sets indicating efficient sampling of the reference population.

Significant differences among males/sets were observed for primary branches/plant, siliqua length, seeds/siliqua and seed density. Thus, significant genetic differences exist among the plants chosen as pollen parents with respect to these characters. Significant genetic differences among the female parents were evident for all the characters except harvest index. Except for siliqua length the mean squares for females/sets were larger than for males/sets. The differences between the two mean squares reflected the variability for characters among the parents *per se* and suggested significant maternal and non-maternal reciprocal influences on character expression (Cockerham, 1963). Presence of significant maternal effects for yield and yield attributes in Indian rapeseed was reported by Singh (1991) and Barua (1992).

The range of variation among the full-sib progenies was always greater than their half-sib parents. Thus the two groups of parents (males and females) showed considerable variability for different sets of characters, and upon random mating generated progenies with high range of variation for yield and important yield attributes such as siliquae/plant, biological yield and harvest index as a result of recombination, transgression and heterotic expression with better complementation of genes in the hybrids.

Considerable bi-directional shift in ranges of maternal half-sib means for total branches, main shoot length, seed density and seed yield / plant also indicated greater diversity of the parents chosen as females than that of the males. The ranges of maternal half-sib progenies shifted considerably and unidirectionally from the paternal half-sib means for plant height, secondary branches and siliquae/plant. Thus the greater mean squares due to females/sets observed for these characters might thus result from inflation due to maternal effects apart from sampling error.

The genetic model developed for estimation of genetic variances using North Carolina designs involves several assumptions in addition to those mentioned earlier. Comstock and Robinson (1952) made the following assumptions in order to derive genetic interpretation of the variance components : (1) regular diploid behaviour at meiosis; (2) population gene frequencies of one-half at all loci where there is segregation; (3) no multiple allelism; (4) no linkage except where equilibrium between coupling and repulsion phases exists; and (5) no epistasis.

Indian rapeseed being a diploid species, the composite population of intervarietal hybrids would be expected to show regular diploid inheritance. The constituent intervarietal hybrids of the composite involved all the three ecotypes in different cross combinations. The three ecotypes of Indian rapeseed are genetically diverse (Hinata & Prakash, 1984; Langthasa, 1991) and they are interfertile (Hinata & Prakash, 1984; Singh, 1991).

The estimates of components of variance and related parameters for various characters in the NCD II analysis of the composite population are presented in Table 2. There was large differences between the two estimates of additive genetic variance obtained from paternal and maternal half-sibs for all the characters except seeds/silique, the estimates being smaller in case of paternal half-sibs. Additive genetic variance among paternal half-sibs ($\hat{\sigma}_{A_m}^2$) was significant for primary branches, silique length, seeds/silique and seed density, whereas among maternal half-sibs significant additive variance ($\hat{\sigma}_{A_f}^2$) was recorded for all the characters except harvest index.

Negative additive variances among paternal half-sibs were observed for days to flower, secondary branches, total branches, silique/plant, silique density, biological yield, seed yield and harvest index. All the non-significant estimates of additive variance among paternal half-sibs were associated with large standard errors indicating negative bias in these estimates. The higher estimates of additive variance among maternal half-sibs for all the characters except silique length indicated the presence of maternal effects. The presence of maternal effects causes inflation in the covariances of half-sibs of maternal parents (Mather & Jinks, 1982). Nevertheless, among the significant estimates, maternal effects were less pronounced for seeds/silique, primary branches and seed density in descending order of their magnitude of difference between the two estimates of additive genetic variance. Standard errors for these estimates were also comparable.

The dominance variance ($\hat{\sigma}_D^2$) was significant for all the characters. These estimates were much greater in magnitude than their respective additive variances for days to flower, secondary branches, silique/plant, silique density, silique length, biological yield, seed yield and 1000 seed weight, apparently showing greater importance of dominance variance for these characters. It was, however, noted that eight characters namely, days to flower, secondary branches, total branches, silique/plant, silique density, biological yield, seed yield and harvest index with negative estimates of $\hat{\sigma}_{A_m}^2$ showed very high estimates of $\hat{\sigma}_D^2$ which were also highly significant. Sampling variation was low for these estimates of $\hat{\sigma}_D^2$ as revealed by their relatively small standard errors, 18.5 to 37.6 per cent as large as the estimates. Thus, repulsion phase linkages were most likely to cause upward bias in the estimates of $\hat{\sigma}_D^2$ and downward bias in the estimates of $\hat{\sigma}_{A_m}^2$ for these characters. Although non-significant, positive estimates of $\hat{\sigma}_{A_m}^2$ for days to maturity, plant height, main shoot

length, siliquae on main shoot and 1000 seed weight would suggest that these characters were less affected by linkage bias as compared to those with negative estimates. The estimates of $\hat{\sigma}_D^2$ for plant height, primary branches, main shoot length and seed density with large standard errors of 62.2 to 110.0 per cent of the estimates implicated high sampling variation accrued to these estimates.

The ratios of $\hat{\sigma}_D^2/\hat{\sigma}_A^2$ was less than unity for seed density, main shoot length, plant height and days to maturity in ascending order of magnitude, indicating preponderance of additive variance in the inheritance of these characters. Several earlier studies reported variation of predominantly additive type for days to maturity (Barua, 1992; Hatibaruah *et al.*, 1997) and for plant height (Singh, 1991; Barua, 1992; Hatibaruah *et al.*, 1997). The contribution of males x females interaction component accounted for 25 to 41 per cent of the hybrid sum of squares for these characters.

Although maternal effects were important for these characters, the estimates of $\hat{\sigma}_D^2$ were overestimated due to linkage bias while $\hat{\sigma}_{A_m}^2$ being underestimated. The average degree of dominance for plant height, main shoot length and days to maturity did not show any significant difference from unity, indicating complete dominance in the expression of genes for these characters. The average degree of dominance for seed density showed partial dominance. Assuming equilibrium gene frequencies and with complete dominance, the ratio of $\hat{\sigma}_D^2/\hat{\sigma}_A^2$ for main shoot length was reasonably within the limit of sampling variation. Distribution of genes for days to maturity and plant height might lack symmetry among the random parents sampled in the composite population.

As evident from highly inflated ratio of $\hat{\sigma}_D^2/\hat{\sigma}_A^2$ for siliquae/plant, siliqua density, biological yield, seed yield, harvest index and 1000 seed weight, dominance variance was more important for these characters. In several earlier reports, dominant role of non-additive component was indicated for siliquae/plant (Barua, 1992); biological yield (Varshney *et al.*, 1990; Singh, 1991; Barua, 1992); seed yield (Varshney *et al.*, 1990; Singh, 1991; Yadav *et al.*, 1991; Barua, 1992) harvest index (Barua, 1992) and 1000 seed weight (Yadav *et al.*, 1991; Hatibaruah *et al.*, 1997). The estimates of average degree of dominance were significantly higher than unity, indicating overdominance gene effects in the expression of these characters. As the estimates of $\hat{d}$ were highly significant, maximum upward bias due to repulsion linkages was indicated in the overdominance expression of genes for these characters.

According to Comstock and Robinson (1948), the net effects of genes tightly linked in repulsion could be the same as for overdominance in the action of independently segregating genes even though none of the linked genes were individually more than partially dominant to their alleles. For harvest index, the estimate of dominance variance was highly

significant, whereas the additive variance was non-significant. The apparent overdominance for harvest index could occur as a result of epistasis of tightly linked genes in the repulsion phase leading to inflated dominance variance (Mather and Jinks, 1982).

The ratios of $\hat{\sigma}_D^2/\hat{\sigma}_A^2$ were also greater than unity for days to flower, secondary branches and siliqua length. For siliqua length, dominance variance was predominant with overdominance expression of genes. The estimates of average level of dominance in the overdominance range for days to flower and secondary branches suggested pseudo-overdominance expression because of linkage bias in estimates of $\hat{\sigma}_{A_w}^2$ and $\hat{\sigma}_D^2$. Both additive and dominance variances were found to be equally important for primary branches, total branches, siliquae on main shoot and seeds/siliqua as the ratios $\hat{\sigma}_D^2/\hat{\sigma}_A^2$ being around unity. Complete dominance was evident in the expression of genes for these characters. The effect of linkage bias in the estimates of $\hat{\sigma}_{A_w}^2$ and $\hat{\sigma}_D^2$ was maximum for total branches and minimum for primary branches.

The parental intervarietal hybrids of the composite comprising a half-diallel populations excluding reciprocals were studied for their combining ability and heterosis over two environments by Barua (1992). The inferences on genetic variance estimates through NCD II analysis of the composite population, however, indicated differences from the results of Barua (1992) especially with respect to days to flower, secondary branches, total branches, main shoot length, seeds/siliqua, harvest index and 1000 seed weight.

The changes in pattern of genetic variation might be due to difference in genetic make-up between the composite at F_8 generation and the variety crosses in F_1 generation influenced as much by frequency of segregating loci as by the number of segregating loci (Hallauer and Miranda, 1981). Further, genotype-environment interaction causes positive bias in the estimates of genetic variance component for various characters with varying degrees. However, the non-additive component was more sensitive to environmental variation than the additive components (Barua, 1992).

The magnitude of additive genetic variation in the composite population was assessed through estimation of narrow sense heritability ($\hat{h}_N^2$) on plot basis and additive genetic coefficient of variability (AGCV) in respect of the various characters studied (Table 2). The narrow sense heritabilities were high (>50%) for seed density and plant height; moderate (30–50%) for main shoot length, days to maturity, total branches, siliquae on main shoot, seeds/siliqua and secondary branches; and low for the remaining characters. The characters with low heritabilities (<30%) had, in general, relatively large proportions of the total variance accounted for by $\hat{\sigma}_D^2$. The estimates of $\hat{\sigma}_D^2$ accounted for maximum variation in siliquae / plant (71.2%) followed by siliqua density (63.8%), 1000 seed weight (52.6%), seed yield (49.7%) and biological yield (46.0%). The proportion of plot to plot environmental

variance ($\hat{\sigma}^2$) was maximum for biological yield and 1000 seed weight (39.4%) followed by seed yield (35.2%), siliqua density (18.9%) and siliquae/plant (16.0%). These proportions seem reasonable because the effects of environmental conditions in different stages of ontogeny of the genotype determine the phenotypic expression for various characters. Yield results from the total expression of the genotype from seedling to harvesting, and thus yield itself is the combined expression of genotype and environment throughout the whole growing period (Hallauer and Miranda, 1981).

Yield components, however, are determined during certain stages of the ontogeny of the genotype, so their expression depends on just a portion of the growing season. The heritability estimates for 1000 seed weight, biological yield, siliquae/plant, seed yield, siliqua density, siliqua length, primary branches, days to flower and seeds/siliqua were associated with large standard errors indicating sampling variation in descending order of their magnitudes.

The additive genetic coefficient of variability was high (>20%) for secondary branches, total branches, seed yield, biological yield and seed density; and moderate (10-20%) for siliquae on main shoot, primary branches and seeds/siliqua indicating sufficient variability in the composite population to expect significant progress from selection. Direct selection for characters with low heritability like seed yield and biological yield, however, requires special consideration with respect to selection methods capitalizing on additive genetic variation with allowance for genotype-environment interaction.

Sufficient additive genetic variability for seed yield and dry matter yield, and their components like branches/plant, siliquae on main shoot and seeds/siliqua was present to expect sufficient progress from selection. Further, the non-additive nature of genetic variation for yield and its determinants, mostly with dominance and overdominance expression of genes, suggest that hybrids and synthetics could be developed from the composite population.

Table 2. Component of variance estimates, heritabilities and additive genetic coefficients of variability for the composite population of Indian rapeseed from NCD II experiment

Character	Variance component estimates					$\hat{\sigma}_D^2 / \hat{\sigma}_A^2$	$\hat{d}$	$\hat{h}_N^2$ (%)	AG CV (%)
	$\hat{\sigma}_{Am}^2$	$\hat{\sigma}_{Af}^2$	$\hat{\sigma}_{A pool}^2$	$\hat{\sigma}_D^2$	$\hat{\sigma}_B^2$				
Days to 50% flowering	-0.73±1.60	6.27** ± 2.71	-	9.01** ± 3.24	7.36±0.66	1.44	1.69*	27.7±1 2.0	6.1
Days to 75% maturity	1.49±2.27	12.29** ± 4.21	-	9.34** ± 3.95	9.59±0.86	0.76	1.23	39.4±1 3.5	3.4
Plant height (cm)	16.18±15.54	113.58** ± 34.43	-	41.95* ± 26.09	70.52±6.29	0.36	0.58	50.2±1 5.2	10.1
Primary branches/plant	0.63* ± 0.36	0.95** ± 0.41	0.78±0.39	0.81* ± 0.52	1.42±0.12	1.04	1.44	25.9±1 2.9	15.5
Secondary branches/plant	0.59±0.68	3.52** ± 1.36	-	5.30** ± 1.41	2.67±0.24	1.50	1.73*	30.9±1 1.8	37.5
Total branches/plant	-0.07±1.43	7.59** ± 2.76	-	8.13** ± 2.73	5.99±0.54	1.07	1.46	35.0±1 2.7	25.7
Siliquae / plant	-1634.49 ± 659.36	1502.74* ± 1039.08	-	8377.79** ± 1553.71	1880.34 ± 167.18	5.58	3.34**	12.8±8 .8	19.5
Main shoot length (cm)	9.64±11.54	57.26** ± 20.20	-	30.97* ± 20.14	54.97±4.88	0.54	1.04	40.0±1 4.1	13.5
Siliquae on main shoot	5.94±9.34	41.83** ± 15.65	-	49.75** ± 15.96	34.15±3.04	1.19	1.54	33.3±1 2.4	15.8

Table 2 (continued)

Character	Variance component estimates						$\hat{h}_N^2$ (%)	AG CV (%)
	$\hat{\sigma}_{A_m}^2$	$\hat{\sigma}_{A_f}^2$	$\hat{\sigma}_{A_{pool}}^2$	$\hat{\sigma}_D^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_D^2 / \hat{\sigma}_e^2$		
Siliqua density (No. cm ⁻¹) x 10 ⁻²	-0.01±0.27	0.65 ^{**} ±0.36	-	2.40 ^{**} ±0.49	0.71±0.06	3.71	2.72 ^{**}	17.2±9.6
Siliqua length (cm)	0.10 ^{**} ±0.04	0.05 [*] ±0.03	0.08±0.04	0.14 ^{**} ±0.05	0.12±0.02	1.75	1.93 [*]	22.6±12.1
Seeds/siliqua	4.56 ^{**} ±1.89	5.05 ^{**} ±2.02	4.79±1.98	4.86 [*] ±2.31	5.82±0.52	1.01	1.42	31.0±12.8
Seed density (No. cm ⁻¹)	0.28 ^{**} ±0.09	0.96 ^{**} ±0.24	0.59±0.16	0.10 [*] ±0.11	0.33±0.02	0.17	0.58 [*]	58.1±15.7
Biological yield/plant (g)	-	32.86 [*] ±23.61	-	103.24 ^{**} ±38.85	88.33±7.86	3.14	2.51 ^{**}	14.6±10.5
Seed yield / plant (g)	-1.01±2.17	4.04 [*] ±2.77	-	13.33 ^{**} ±4.36	9.43±0.84	3.30	2.57 ^{**}	15.1±10.3
Harvest index (%)	-5.18±3.97	0.79±4.17	-	27.77 ^{**} ±8.79	18.66±1.66	-	-	-
1000 seed weight (g)	0.04±0.04	0.05 [*] ±0.04	-	0.20 ^{**} ±0.06	0.13±0.02	3.99	2.83 ^{**}	13.2±10.0
								7.1

¹ $\hat{\sigma}_{A_{pool}}^2$ was estimated only when mean squares for males and females were significant ; non-significant and negative estimates were assumed to be zero.

*, ** Significant at P = 0.05 and 0.01, respectively.

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OPTIMAL LAND USE PLANNING MODEL FOR A WATERSHED IN KUMAON HILLS, UTTRANCHAL, INDIA

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ABSTRACT

In present study, a land use-planning model to minimize the soil loss has been developed by using Linear Programming technique. In model formulation, the land, labour employment and the return generated under existing condition have been accounted as model constraints. In addition, seven alternative plans have also been developed based on various possible alterations that could be made in existing cropping system, with the objective to minimize soil loss. All alternative plans were operated by using computer programme to see the variations in reduction of soil loss and increase in net return & human labour employment under each plan as compared to the existing level. Amongst all alternative plans, the plan-5 was found most suitable to reduce maximum soil loss i.e. about 96.25% of existing level. The plan-3 generated highest net return i.e. about 150.43% of current level, and plan-7 generated highest employment opportunities equal to 36.11% of the existing level. On comparison, it was also observed that the alternative plan-7 is most suitable, as under it, the soil loss reduction is about 85.59 % and increase in net return & employment opportunities was 101.62 and 36.11% of existing level, respectively.

Keywords: Land use planning, Watershed management, Soil conservation, Water conservation, labour employment, India.

INTRODUCTION

The soil, minerals and forest constitute the principal natural resource of a watershed. The protection of these resources is essential for the benefit of present generation without

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eroding the ecological assets and productivity of life supporting system of future generation. In hilly areas, the soil loss is occurring at an alarming rate because of over exploitation of land resources to meet out the various requirements of human and live stock population. The tremendous soil loss from precious topsoil is resulting in reduction of the soil potential for sustainable crop yield, national income and employment opportunities. In Himalayan hills, where subsistence agriculture exists, population pressure is high; topography is not suitable for cultivation, over exploitation of unsuitable lands for cultivation, overgrazing of grasslands etc. cause severe soil loss from the watershed and lead to reduction of productive potential of land, there is emergent need to minimize the problem of soil erosion / loss and thus to increase the productive potential of the available land or indirectly to uplift the level of living standards of the population living on the watershed.

The minimization of soil loss from a watershed by using models, is the task of optimization, for which the most versatile technique is the Linear Programming Technique (L.P.T.). The research works on optimization aspects, especially by using linear programming techniques, have been done to a lot, world wide, but in different modes as per requirement of the area concerned. In agriculture sector, the development of model mainly for resource management (Hernandez Batista, 1990; Kenneth *et al.*, 1976; Cheung & Auger, 1979), development of alternative policies for crop planning (Sirohi & Gangwar, 1968; Mann *et al.*, 1968; Guglani & Smith, 1972) and very few on development of optimal land use planning model to minimize the soil erosion and sedimentation (Sands, 1987; Chochrane *et al.*, 1987; Singh, 1991) are the main.

With the concept of optimization by using L.P.T., in present study, an attempt has been made to develop an Optimal Land use Planning Model for a watershed with the objective to minimize the soil loss from the watershed.

MATERIALS AND METHODS

Study Area

The Naurar watershed, which is located in Kumaon range of N-W-Uttranchal (a part of Himalaya) hills, was selected to develop such a model. The total geographical area of watershed is about 6284.25 ha, distributed under five major land use systems, namely: (1) Agricultural land; (2) Orchard lands; (3) Forest lands; (4) Grass lands and (5) Waste lands on 48.25, 4.0, 41.65, 3.05 and 3.05 % area of the watershed respectively. The topography of the watershed is undulate ranging from minimum 5% to maximum greater than 75% slope (Anonymous, 1982). Generally, the soil of the watershed shows a large variation with types of parent materials, vegetation, land use, slope gradient etc. The soil texture varies from cherty

gravelly loamy sand to silt loam. The mean annual rainfall is about 1500mm and maximum mean temperature is about 23 °C.

Data collection

The primary and secondary data were collected from different sources. The watershed was divided into three altitudes i.e. low (up to 600m elevation), medium (600 to 1200 m elevation) and high (more than 1200m elevation). Two villages at each altitude were selected, thus in total six villages were selected. Finally, 40, 30 and 30 farmers were selected at low, medium and high altitude villages, respectively. From these selected farmers, the primary data, such as area allocated under various types of food and vegetable crops, orchards, forests, grass lands and waste lands; the level of application of inputs, such as quantities of seeds, fertilizer, manures, irrigation water, human & bullock labours used, were recorded through personal interviews. The input-output prices used in the study were that on which farmers had actually purchased the inputs or sold their output, were collected from the farmers. The secondary data, such as aggregate acreage allocation of the area under different cultivated crops, orchard of various fruits, forest trees, grass species and waste land bushes was collected from Community Development Block Center, Bhikhiasen, Soil Conservation Office (Ranikhet) and Divisional Forest Office (Soil Conservation), Ranikhet. Agricultural labour statistics of the study area was obtained from the population census report-1991 for Almora district. The land use map of the watershed was procured from Indian Photo Interpretation Institute, Dehra Dun (Uttaranchal).

Model development

The Linear Programming technique was employed for development of land use planning model with the objective to minimize soil loss, based on various constraints such as land, labour employment, net return and predetermined activity. The form of land use model is expressed as:

$$\text{Minimize } Z (\text{soil loss}) = \sum_{j=1}^n C_j X_j \quad \dots(1)$$

$$(j = 1, 2, \dots, n)$$

Subject to

$$\sum_{j=1}^n a_{ij} \cdot X_j \leq b_i \quad \dots(2)$$

$$(i=1,2,\dots,m)$$

$$\sum_{j=1}^n a_{ij}X_j = b_i \quad \dots(3)$$

$$(i=m+1,\dots,p)$$

$$\sum_j^n a_{ij}X_j \geq b_i \quad \dots(4)$$

$$(i=p+1,\dots,q)$$

$$\text{and} \quad X_j \geq 0 \quad \dots(5)$$

where,

Z = total soil loss (t/y) from the optimum crop activities

C_j = soil loss (t/ha/y) of the J -th crop activity

X_j = units of J -th activity

a_{ij} = requirement or contribution of J -th activity for the i -th constraint.

In model, the equation (1) represents the objective function to minimize the soil loss from all possible land use activities in practice on the watershed during Kharif season, only. The equations 2 to 5 represent the constraint structure of the model.

Model activity (X_j)

In model, the types of food grain and vegetable crops being grown during Kharif season, orchard trees, forest trees, grass species and bush species occurring on different categories of land in the watershed, are considered as model activities, viz, in the valley part of the watershed, where irrigation facilities are available, the crops such as local Paddy, Paddy (HYV), Mandua, Capsicum, Chillies and Soybean are grown on improved and traditionally terraced lands under single cropping system. In rainfed areas of valley, the crops like, local Paddy, Paddy (HYV), Soybean, French bean, Mandua, Jhungra, Bhat and Urad are also grown under single cropping system.

In the areas, other than valley i.e. at medium and high hills where rainfed farming is practiced, the mixed cropping system is popular, in which the crops like Paddy (local),

Jhungra, Mandua, Gauhat and Bhat are grown in mixed form. The popular crop combinations are: Paddy + Jhungra, Mandua + Bhat, Mandua + Gauhat and Mandua + Urad (Anonymous, 1995).

In orchard cultivation, a varieties of fruit species are found in the watershed, their occurrence varies depending on elevation and land facing aspect, viz. in the valley (i.e. elevation up to 600m), the Mango, Guava, Citrus, and Peaches are more common; at 600 to 1200m elevation, the Mango, Guava, Apple, Pear, Plum and Apricots are common on the north-east & west facing lands and Mango, Guava, Papaya and Banana on the south facing lands. At the elevations ranging from 1200 to 1800m, the Apple, Pear, Walnut and Plums are found on north-east & west facing lands and on south facing lands, the presence of Apricot and Plum are dominant.

In forest areas, the occurrence of forest trees varied depending on land elevation and facing direction, viz, in the valley areas the Chirpine and Sal; at 600 to 1200m elevation, the Sal and oak on north-east and west facing lands and Chirpine only on south facing lands; at 1200 to 1800m elevation, the Oak, Deodar and Cyprus on north-east & west facing lands and Chirpine and mixed Oak on the south facing lands; at 1800 to less than 3600m, the Oak, Deodar and Cyprus on north east & west facing lands and mixed Oak, Cyprus and Deodar on south facing lands are commonly found. The occurrence of these forest trees is found in all types of forests in the watershed.

The occurrence of grass species is also found different depending on elevation and facing direction viz; upto 600m (i.e. in valley) the Dub, Dallis, Giant star, Love grass and Rhode are more common; at the elevation from 600 to 1200m the Dub, Love grass Dallis, Rhode and Spear are found on north east & west facing lands, while on south facing lands the Dub, Love grass, Giant star, Rhode and Spear are common; at 1200 to 1800m elevation on south facing lands the Dub, Love grass, Rhode, Kikuyi and Spear grasses are common. In wasteland areas, the xerophytic bushes such as, Kilmora, Hisalu and Lantana are found at all the elevations and facing directions. In this way, total 173 land use activities (i.e. variables) were identified from all existing land use systems for model formulation (Suresh, 2002).

Constraints

The resource constraints and predetermined activity constraints were accounted for model development. Under resource constraints, three basic resources namely: (1) Land; (2) Labour and (3) Capital are considered.

Land constraints

Various land categories based on land uses, types of terraces, land slopes, facing directions and altitudes prevailing in the watershed were considered as the land constraints. In current situation the whole area of watershed is grouped into cultivated crop lands, orchards, forests, grass lands and waste lands, which are further sub-divided into different sub-groups viz., the cultivated crop lands are divided into four main categories i.e. (1) Single cropped lands; (2) Mixed cropped rainfed terraced lands; (3) Mixed cropped rainfed untterraced lands with trees; and (4) Mixed cropped rainfed untterraced lands without trees. The sub-groups of cultivated croplands are further sub-divided into different categories based on slope steepness.

The orchard lands are grouped into different categories based on elevations. Since occurrence of orchard fruit trees differs considerably with respect to land facing directions, therefore orchard lands are further sub-divided into north - east & west and south facing slope directions.

The forest lands are grouped into three main classes as per Remote Sensing Centre Dehra Dun (Uttanchal) viz; 'the notified & unnotified forests and forest blank, which are further sub-divided into closed and open canopy forests. All kinds of forests are sub-divided into sub categories based on altitudes and slope facing directions i.e. north- east & west facing and south facing directions (Suresh, 1998).

In Naurar watershed, the grasslands are found at all the altitudes in form of patches and occurrence of grass species on them varies depending on elevations and slope facing directions, therefore, grasslands are also classified similar to the orchard and forest lands.

Wastelands are found in scattered way throughout the watershed. Few parts of it are stony or exposed rock surfaces that are not suitable for cultivation and are termed as uncultivable wastelands. These types of wastelands are not included in formulation of the model. However, some areas of wastelands have some soil depth ranging from poor (less than 5cm) to medium (10 to 15cm) and are covered with natural bushes in Kharif season. These bushes invariably cover the ground surface pretty densely and reduce the soil erosion significantly. These types of wastelands are divided into different categories based on elevation and slope facing direction similar to the forest, orchard and grasslands (Suresh, 1998).

Labour constraint

The constraint on human labour employment was included to make the model socially acceptable. In study watershed, it was observed that the availability of labour becomes limiting during peak period, i.e. sowing / transplanting and harvesting operations in Kharif period, therefore on an average a peak period of 1.5 month was considered to estimate

the requirement of total laboures to be employed under different cultivation activities i.e. agricultural crops, orchards and grasslands. For this period, the total number of labour days to be available was thus estimated as 216075. The crop wise labour employment during Kharif period was obtained by farmers' interview (Suresh, 1998).

Return constraint

To make the land use model economically viable, the return constraint was included. The cultivated croplands, orchard lands and grasslands were considered under this constraint, as these are the main source of farm income for the farmers. The forestlands were not included because these are not owned by the farmers but under the state forest department and returns due to the forests are realized by the government only. Similarly, the wastelands also do not provide any economic return to the farmers, therefore, return constraint for this land use system was also not considered.

Predetermined activities constraints

These constraints are the restrictions imposed on some essential production activities (crops) for minimum area allocation at some predetermined level under them to meet the population requirement. In study watershed, the farmers have preferences for two crops i.e. Mandua and Paddy amongst food grain crops to satisfy their food habits and for generating cash income they have desire to grow Capsicum and Chillies. To allot a minimum area under these crops, restriction was imposed on them.

Alternative plan

Seven alternative plans were developed based on various possible alterations that could be made in the existing land use practices, keeping in view to satisfy various requirements of population and physical features of the watershed, as:

- Alternative plan-1** : Existing cropping system with predetermined activity constraint on crops preferred by the farmers i.e. Paddy, Mandua, Chillies and Capsicum.
- Alternative plan-2** : Existing cropping system with predetermined activity constraint on food grain crops only.
- Alternative plan-3** : Existing cropping system with predetermined activity constraint on cash crop only.

- Alternative plan-4** : Existing cropping system without any predetermined activity constraint on any crop.
- Alternative plan-5** : Assuming all untterraced lands up to 35% slope as terraced lands for cultivation adopting existing cropping system and remaining lands to be used as per Land Use Capability Classification
- Alternative plan-6** : Grouping of cultivated croplands into various classes based on Land Use Capability Classification and considering existing cropping systems on them
- Alternative plan-7** : Grouping of cultivated croplands into various classes based on Land Use Capability Classification and considering recommended cropping practices on them.

For all alternative plans, the model described by eq. 1 to 5 was modified based on their constraints and were operated by using computer programme to find the results on reduction in soil loss and increase in level of net returns & human labour employment as compared to the existing level under each alternative plan.

Model coefficients

The rate of soil loss, net return and human labour employments likely to be generated by various land use activities under current situation of the watershed were accounted as the model coefficients. The possible soil loss rates under various land use activities were borrowed from Suresh et al (1999), Suresh et al (2000), Suresh et al (2001) and Suresh et.al. (2002). The level of net returns and human labour employment from different land use activities were taken from Suresh (1998).

RESULTS AND DISCUSSION

Soil loss under existing condition

The soil loss likely to be generated from different land use systems under existing condition in Naurar watershed is shown in Table-1, which revealed that amongst various land uses, the cultivated crop land generated highest rate of soil loss to the tune of about 79.66 t/ha/y, while forest land noticed lowest rate of soil loss as 0.89 t/ha/y. The other land uses, such as grasslands, orchard lands and wastelands generated the soil loss at the rate of 8.66, 3.78 and 1.96 t/ha/y, respectively in the watershed.

Net return under existing condition.

At watershed level, the amount of net returns likely to be generated from different land uses under existing condition is shown in Table-1. On comparison, it was observed that amongst all five land uses, the orchard land returned highest net return per unit area i.e. Rs. 3370/- per ha, while grassland generated the lowest net return to the tune of Rs.1537/- per ha. The cultivated cropland generated the net return at the rate of Rs.2033 /-per ha.

Human labour employment under existing condition

The level of human labour employment generated under different land use systems in the watershed is shown in Table-1, which noticed that a sum of Rs.376889/- man days were employed during Kharif season under cultivated crops, horticultural crops and grasses. Of the total number of man-days employed in the watershed the cultivated crop lands contributed 320057 man days, (i.e. 105 man days per ha), orchard lands 48149 man days (i.e.192 man days per ha) and grasses 8683 man days (i.e. 45 man days per ha)

Table 1. Average rate of soil loss, net return and human labour employment under existing condition from watershed

Land use	Average soil loss rate, t/ha/h	Average net return rate, Rs /ha	Average labour employment rate, man days /ha
Cultivated crop lands	79.66	2033/-	105
Orchard lands	3.78	3370/-	192
Forest lands	0.89	_*	_*
Grass lands	8.66	1537/-	45
Waste lands	1.96	_*	_*

* The constraints on net return and human labour employment for forestlands and wastelands were not included for development of optimal land use plan, because data on these two aspects were not availabl.

Evaluation of alternative plans

All seven alternative plans were evaluated in respect of reduction in soil loss, increase in net returns and generation of employment opportunities as given below:

Soil loss

The minimized rates of soil loss likely to be occurred from the watershed under different alternative plans are shown in Table-2.

On comparison, it was found that amongst all seven alternative plans, the plans-1, -2, -3 and -6 minimized the soil loss to a lowest limit and almost by the same level from the watershed, which is 10.23, 10.11, 10.16 and 10.43%, respectively less to that of the existing rate. The poor reduction in soil loss is mainly due to consideration of existing cropping system as one of the model constraints. Also, the optimal land use model selected less soil loss generating crop activities and simultaneously allocated greater cultivable acreage under them, which caused insignificant variation in the rates of soil loss amongst four alternative plans. The land use wise reduction in soil loss was found to be 10.12, 10.14, 10.10 & 10.33% in cultivated crop lands; 17.72, (-) 3.70, 8.73 & 20.11% from orchard lands; 28.10% from forest lands and 6.12, 5.00, 12.82 & 6.12% from grasslands under alternative plans-1, -2, -3 and -6, respectively. The wastelands could not appear in the optimal land use model. Overall, the forest land use activities noticed highest reduction in soil loss from the watershed.

In alternative plan-4 (i.e. considering the existing cropping system without any predetermined activity constraint on any crop), the rate of soil loss likely to be generated from watershed was to the tune of 30.28 t/ha/y, which is about 24% less as compared to the existing rate. This alternative plan was found better than the plans -1, -2 and -3 to minimize the soil loss, because of not consideration of predetermined activity constraint on any crops, causing the model counted only those crop activities which have less soil loss generating potential. Amongst different land uses, the highest reduction in soil loss was found from forestlands i.e. 28.10%, followed by cultivated croplands 24.18%, orchard lands 20.11% and grass lands 6.12%.

On using alternative plan-5, the minimized rate of soil loss from watershed was found to the tune of 1.5 t/ha/y, which is about 96.25% less over existing rate. The reduction in soil loss under this plan was maximum amongst all seven alternative plans, because of consideration of all untterraced lands up to 35% slope as terraced lands and remaining lands are used as per L.U.C.C. for cultivation under existing cropping system. The soil loss from terraced lands is being very less as compared to the untterraced lands.

The alternative plan-7, in which grouping of cultivated croplands was done based on L.U.C.C and recommended cropping practices were considered to follow on them, minimized the soil loss to an appreciable level i.e. 5.76 t/ha/y, which is about 85.59% less to that of the existing rate of soil loss from watershed. Under this plan, the highest reduction in soil loss (69.24%) was generated from cultivated croplands, followed by forestlands 22.47% and orchard lands 10.85% while from grasslands, the soil loss was not reduced.

Table 2. Percent reduction in level of soil loss under different alternative plans from different categories of land uses in the watershed

Plan	Cultivated cropland				Orchardland				land			
	Area (ha)	S.L.R.*	Percent reduction	Area (ha)	S.L.R.	Percent reduction	Area (ha)	S.L.R.	Percent reduction	Area (ha)	S.L.R.	Percent reduction
Existing	3035.71	79.66	-	251.25	3.76	-	2620.6	0.89	-	2620.6	0.89	-
Alternative plan-1	3035.71	71.60	10.12	320.50	3.11	17.72	2620.6	0.64	28.10	2620.6	0.64	28.10
Alternative plan-2	3035.71	71.58	10.14	320.50	3.92	-3.70	2620.6	0.64	28.10	2620.6	0.64	28.10
Alternative plan-3	3035.71	71.64	10.10	320.50	3.45	8.73	2620.6	0.64	28.10	2620.6	0.64	28.10
Alternative plan-4	3035.71	60.40	24.18	320.50	3.02	20.11	2620.6	0.64	28.10	2620.6	0.64	28.10
Alternative plan-5	2774.71	0.80	99.00	320.50	3.96	-4.76	2620.6	0.64	27.00	2620.6	0.64	27.00
Alternative plan-6	3035.71	71.43	10.33	320.50	3.02	20.11	2620.6	0.64	28.10	2620.6	0.64	28.10
Alternative plan-7	930.99	24.50	69.24	2613.22	3.37	10.85	2430.85	0.69	22.47	2430.85	0.69	22.47
Column contd.												
Grasslands	Wastelands				Total				Total soil loss from watershed			
	Area, ha	S.L.R.	Percent reduction	Area (ha)	Area (ha)	Percent reduction	area(ha)	Percent reduction	Average soil loss rate (t/ha/y)	Percent reduction	Percent reduction	Percent reduction
191.97	8066	-	-	78.0	1.96	-	6177.53	-	39.97	-	-	-
200.72	8.13	6.12	-	-	-	-	6177.53	-	35.88	10.23	10.23	10.23
200.72	8.23	5.00	-	-	-	-	6177.53	-	35.93	10.11	10.11	10.11
200.72	7.55	12.82	-	-	-	-	6177.53	-	35.91	10.16	10.16	10.16
200.72	8.13	6.12	-	-	-	-	6177.53	-	30.28	24.00	24.00	24.00
424.25	10.46	11.43	-	-	-	-	6177.53	-	1.50	96.25	96.25	96.25
200.72	8.13	6.12	-	-	-	-	6177.53	-	35.80	10.43	10.43	10.43
196.97	11.87	-37.07	-	-	-	-	6177.53	-	5.76	85.59	85.59	85.59

* Soil loss rate, t/ha/y

Net return

The net returns that could be generated from different alternative plans, are given in Table-3, which noticed that from most of the alternative plans, a higher net return was generated as compared to the existing level. However, in case of alternative plan-1, the net return likely to be generated from the watershed was about Rs.2375 per ha, which is about 12.98% higher than the existing level. Overall, this increase in net return is not appreciable. It may be due to consideration of existing cropping pattern and using the predetermined activity constraint on those crops, which are preferred by the farmers (i.e. Paddy, Mandua, Chillies and Capsicum) to satisfy their food habits. Also, the optimal land use planning model selected these crops on priority and allocated greater acreage under them for cultivation. Under this plan, the increase in net return was found to be highest from orchard lands equal to 15.2%, followed by cultivated crop lands 13.4%, while from grass lands about 32.75% reduction in net return was realized.

In alternative plan-2, which was developed by considering the existing cropping system along with predetermined activity constraint on food grain crops, only, generated the net return to the tune of Rs.2151/- per ha from the watershed, which is about 2.33% higher than the current level. Overall, this alternative plan generated lowest net return to the watershed amongst all seven alternative plans, mainly due to consideration of existing cropping system along with predetermined activity constraint on food grain crops. Furthermore, due to consideration of food grain crops under predetermined activity constraint, the optimal land use-planning model selected them for maximum allocation of land acreage for cultivation, which also caused poor net return to the watershed. However, amongst various categories of land use system, the highest increase in net return equal to 51.62% was generated from orchard lands. On contrast, from grasslands and cultivated croplands about 25.73 and 6.3% reduction in net return was obtained, respectively.

Amongst various alternative plans, the plan-3 (i.e. by considering the existing cropping system with predetermined activity constraint on cash crop only) was found to generate highest net return for the watershed, which was about 150.43% higher than the existing level; it is because of allocation of maximum area to the cash crops for cultivation due to restrictions on them under predetermined activity constraint. However, amongst different categories of land use system, the cultivated croplands resulted highest increase in net return i.e. about 179.53% of existing level and from grasslands, it was about 59.26%. On the otherhand, the orchard lands resulted 9.37% less net return.

Alternative plan-4 (i.e. by considering the existing cropping system without any predetermined activity constraint on any crop) generated about 94.05% higher net return as compared to the current level, which is quite good. This is mainly due to allocation of greater acreage to the cash crops for cultivation, because of not consideration of predetermined activity constraint on any crop in the model for this plan. Also, the cash crops relatively generate high net return per unit area as compared to the grain crops. Out of total increase in net return, the cultivated croplands shared about 122.67%, while orchard and grasslands showed reduction in net return to the watershed.

Under alternative plan-5, about 56.8% higher net return was generated as compared to the existing level. In this plan, the entire land area up to 35% slope were considered as the terraced land for cultivation with existing cropping system and rests were used as per L.U.C.C. Since up to 35% slope, a large area of the watershed is available for crop cultivation on terraced land, therefore, total production per unit area becomes more, which, overall, increased the net return to an appreciable level. However, from cultivated croplands about 65.76%, orchard lands 26.18% and from grasslands about 35.87% higher net return was realized.

In alternative plane-6, which was formulated by grouping the entire cropped lands into various L.U.C.C classes and existing cropping system was followed on them for cultivation, generated about 8.37% higher net return which is not sufficient. It is because of allocation of maximum land acreage to those crop activities, which generated high level of net return and human labour employment along with less soil loss. Amongst various categories of land use system, only from cultivated crop lands a higher return equal to 16.87% was noticed, while from orchard and grasslands about 36.28 and 32.75% lesser net return were found, respectively.

The alternative plan-7 generated quite appreciable net return i.e. about 101.62% higher than the existing level of the watershed might be due to grouping of entire crop lands into various L.U.C.C. classes and considering the recommended cropping system on them for cultivation. Amongst different land use systems, the cultivated croplands and orchard lands generated about 120.91 and 30.28% higher net return as compared to the existing level, respectively, while from grasslands about 32.88% less net return was realized under this alternative plan.

Table 3. Percent increase in level of net return under different alternative plans from different categories of land uses in the watershed

Plan	Cultivated crop land			Orchard land		
	Area (ha)	Net return rate(Rs./ha)	Percent increase	Area (ha)	Net return rate (Rs./ha)	Percent increase
Existing	3035.71	2033.0	-	251.25	3369.0	-
Alternative plan-1	3035.71	2305.0	13.40	320.50	3881.0	15.20
Alternative plan-2	3035.71	1905.0	-6.30	320.50	5108.0	51.62
Alternative plan-3	3035.71	5683.0	179.53	320.50	3053.0	-9.37
Alternative plan-4	3035.71	4527.0	122.67	320.50	1737.0	-48.44
Alternative plan-5	2774.71	3370.0	65.76	320.50	4251.0	26.18
Alternative plan-6	3035.71	2376.0	16.87	320.50	2130.0	-36.28
Alternative plan-7	930.99	4491.0	120.91	2613.22	4389.0	30.28

Column contd.

Area, ha	Grasslands		Total area (ha)	Average net return (Rs./ha)	Percent increase in net return
	Net return rate, Rs./ha	Percent increase			
191.5	1539.0	-	3478.71	2102.0	-
200.50	1035.0	-32.75	3556.71	2375.0	12.98
200.50	1143.0	-25.73	3556.71	2151.0	2.33
200.50	2451.0	59.26	3556.71	5264.0	150.43
200.50	1035.0	-32.75	3556.71	4079.0	94.05
424.25	2091.0	35.87	3519.46	3296.0	56.80
200.50	1035.0	-32.75	3556.71	2278.0	8.37
196.97	1033.0	-32.88	3741.18	4238.0	101.62

Human labour employment

The human labour employment that could possibly be created under all seven alternative plans, is given in Table-4, which noticed that on application of alternative plan-1 about 2.78% higher employment opportunities were generated than the present level, which is very less. It is because of consideration of existing cropping system along with restriction on food grain crops only, causing allocation of greater land acreage under them for cultivation. Since, employment of labourer is relatively less in cultivation of food grain crops as compared to the cash crops; therefore, there is overall reduction in the level of human labour employment under this plan.

However, amongst various categories of land use system, about 0.023 and 6.25% higher employment was created from cultivated croplands and orchard lands, respectively, while from grasslands about 11.10% reduction in employments were predicted.

Under alternative plan-2 about 1.85% less employment opportunity was generated as compared to the existing level, might be due to allocation of total cultivated crop lands to the food-grain crops, only for cultivation, which involves less engagement of labourers . However, from orchard lands slightly higher employment i.e. 2.6% greater than the existing level was generated, while from grass lands about 8.89% reduction in level of employment was noticed under this plan.

In alternative plan-3, about 26.85% higher employment was generated to that of the current level, which is quite appreciable. It might be due to consideration of cash crops as the predetermined activity constraint in the model, as the result, the model allocated greater land acreage to the cash crops for cultivation. Since, cash crops require comparatively greater man-days per unit area for cultural operation, therefore, in this alternative plan, greater percentage of human labour employment opportunity was generated to the watershed. Amongst various land use systems, from cultivated croplands about 28.57% higher employment was created, followed by 15.56% from grasslands and 8.85% from orchard lands than their current levels.

The alternative plan-4 generated about 15.74% higher employment opportunity for the watershed as compared to the existing level, which was solely, contributed by cultivated croplands and orchard lands which are about 16.19 and 8.33%, respectively, while from grass lands about 11.0% lesser employment was generated under this plan.

Since, under this plan, there was no restriction on any crop under predetermined activity constraint, causing the model selected to the cash crops on priority and allocated

greater land acreage under them for cultivation. It also created greater human labour employment opportunities for the watershed.

In alternative plan-5, the employment opportunity likely to be generated in the watershed was about 0.92% less than the existing level, which is mainly due to greater allocation of cultivated cropland areas to the food-grain crops for cultivation, where employment scope was relatively very less; and at the same time due to allocation of very steep cultivated crop lands to the forest area. However, from the grasslands about 17.78% higher employment was found to generate in the watershed.

In case of alternative plan-6, the generated employment was about 2.78% higher than the current level, which is same as the alternative plan-1. The poor increment in level of human labour employment opportunity under this plan was mainly due to consideration of existing cropping system and accordingly selection and allocation of maximum land acreage under them for cultivation, by the optimal land use model. However, from cultivated croplands and orchard lands about 0.95 and 8.33% higher employment was created, respectively as compared to their current levels. On the other hand, from grasslands about 11.10% lesser employment was generated.

On application of alternative plan-7 about 36.11% higher employment was generated in the watershed than the existing level, which is the highest amongst all alternative plans, i. e. 32.43% higher than the plan-1, 38.68% from plan-2, 7.23% from plan-3, 17.6% from plan-4, 37.38% from plan-5 and 32.43% from plan-6. The reason may be due to consideration of recommended cropping system in the model.

The optimal land use model selected those crop activities, which generated comparatively greater number of man-days per unit area for cultural operations along with reduction in soil loss and increase in net return from the watershed. However, amongst various categories of land use systems, about 6.67% higher employment was noticed from cultivated croplands, while it was 13.02% less from orchard lands. From grasslands, the additional employment could not be generated under this plan.

Table 4. Percent increase in level of human labour employment under different alternative plans from different categories of land uses in the watershed

Plan	Cultivated crop land			Orchard land		
	Area (ha)	Employment rate, man (days/ha)	Percent increase	Area (ha)	Employment rate, man (days/ha)	Percent increase
Existing	3035.71	105.0	-	251.25	192.0	-
Alternative plan-1	3035.71	105.0	0.023	320.50	204.0	6.25
Alternative plan-2	3035.71	100.0	-4.74	320.50	197.0	2.60
Alternative plan-3	3035.71	135.0	28.57	320.50	209.0	8.85
Alternative plan-4	3035.71	122.0	16.19	320.50	208.0	8.33
Alternative plan-5	2774.71	106.0	0.95	320.50	188.0	-2.08
Alternative plan-6	3035.71	106.0	0.95	320.50	208.0	8.33
Alternative plan-7	930.99	112.0	6.67	2613.22	167.0	-13.02
Column contd.						
Area, ha	Grasslands		Total area (ha)	Average employment rate	Percent increase in employment	
	Employment rate, man (days/ha)	Percent increase				
191.5	45.0	-	3478.71	108.0	-	-
200.50	40.0	-11.1	3556.71	111.0	2.78	2.78
200.50	41.0	-8.89	3556.71	106.0	-1.85	-1.85
200.50	52.0	15.56	3556.71	137.0	26.85	26.85
200.50	40.0	-11.0	3556.71	125.0	15.74	15.74
424.25	53.0	17.78	3519.46	107.0	-0.92	-0.92
200.50	40.0	-11.1	3556.71	111.0	2.78	2.78
196.97	45.0	0.00	3741.18	147.0	36.11	36.11

CONCLUSIONS

The optimal land use planning model, whose objective was to minimize the soil loss along with to increase the level of net return and human labour employment opportunities to the watershed was applied to evaluate its effect on soil loss reduction and increase in net return and human labour employment under different alternative plans. On application, it was found that amongst all seven alternative plans, the plan-5 (i.e. when terraced lands up to 35% slope were considered as terraced lands for cultivation under existing cropping system and remaining lands were used as per Land Use Capability Classification), was found better to minimize the soil loss as compared to the other alternative plans, because of the fact that a large area up to 35 per cent slope was taken as the terraced lands along with adoption of existing cropping system from where the occurrence of soil loss is very less to that of the unterraced lands.

Regarding increase in level of net return and human labour employment, the alternatives plan-3 (i.e. by considering the existing cropping system with predetermined activity constraint on cash crop, only) and plan-7 were found to be the best, respectively. In alternative plan -3, the generation of maximum net returns was mainly due to consideration of predetermined activity constraint on cash crops only, which yield good returns to that of the food grain crops. The alternative plan -7, in which whole cultivated crop lands were grouped as per L.U.C.C and recommended cropping system was followed on them, generated highest level of human labour employment because of employment of greater man power per unit area under cultural operations.

Comparatively, to minimize the soil loss, which is the objective of model, the alternative plan-5 was found better; but due to involvement of heavy expenditure of money for constructing the terraces, this plan is not economically viable to implement. However, this finding could be communicated to the department of Soil Conservation for its implementation to reduce the soil loss from watershed.

Although, the alternative plan-3 generated highest level of net return amongst different plans but did not able to minimize the soil loss to an appreciable level, and this plan is not a good one. Overall, the alternative plan-7 was found better in all the respect i.e. to minimize the soil loss (85.59%), to generate high net return (101.62%) and labour employment opportunities (36.11%) to the watershed.

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POTENTIALS OF TERRESTRIAL WEEDS FOR THE PRODUCTION OF GRASS CARP *Ctenopharyngodon idella* (VAL.) IN MEGHALAYA, NORTH EASTERN INDIA

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ABSTRACT

The weeds like *Ageratum conyzoides* L., *Bidens pilosa* L., *Galinsoga parviflora* Cav. and *Crassocephalum crepidioides* (Benth) are very common and abundantly available in North Eastern India. These weeds were fed to the grass carp, *Ctenopharyngodon idella* (Val.) as a step towards integrated weed management including solving the problem of weed infestation on the pond dykes and fallow areas of the fish farm. Among the four tested weeds, *G. parviflora* was found to be the most preferred feed and the order of feed preference was *G. parviflora* > *C. crepidioides* > *A. conyzoides* > *B. pilosa*. The weight gain (72.53%) and FCR (36.66) were also high with *G. parviflora*. The weight gain with *C. crepidioides*, *A. conyzoides* and *B. pilosa* were 47.34%, 19.83% and 10.06% respectively, while the FCR were 48.46, 75.26 and 144.61 for the same. The results indicated that *G. parviflora* is an excellent feed for the grass carp among the four tested weeds. The utilization of unwanted weeds through biological agent i.e. *C. idella* is one of the best options for production of flesh biomass from the aquatic habitat. This would also pave way for producing organic fish and helps in minimizing the problem of household food and nutritional security in NEH Region.

Keywords : Weed management, Grass carp, Biological control, Feed, Weed Fish System, *Ctenopharyngodon idella* (Val.)

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INTRODUCTION

The menace of aquatic weeds had been serious in many countries and long-term economical solutions were worked out to alleviate this problem. Biological control of weeds, particularly using grass carp, was viewed as the best option for an environment-friendly approach of weed control. The grass carp, *Ctenopharyngodon idella* (Val.), commonly called the white amur, a native of Russian and Chinese rivers, has been thus introduced in many countries, primarily for aquatic weed control, owing to their inherent ability to consume the plant materials. In India, *C. idella* was introduced in the year 1959 and since then it is widely used not only for aquatic weed control, but also as a food fish, and cultured as an important component species in polyculture system. Composite fish culture with grass carp as a major component would help to reduce the supplementary feeding to a considerable extent (Grygierik, 1973; Manissery & Varghese, 1988). This species was found to be highly compatible with the Indian Major Carps viz. *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and the exotic carps like *Hypophthalmichthys molitrix* and *Cyprinus carpio* in the polyculture system.

In the North Eastern Hill Region of India, grass carp is a widely preferred species in a composite fish culture system as they are cold tolerant and found to perform very well, attaining about 1.0 to 1.2 kg in a year. There is a good market demand for this fish, fetching about Rs.50 to Rs.80 per kg. The preference for grass carp among the local people of the region is good, as the flesh of this fish is firm and flaky having a good flavour.

Aquaculture is one of the important enterprises in the North Eastern Hills and many rural farmers have been found to have at least one or two ponds within their farm area for fish culture. This part of the country receives rainfall during most part of the year and is susceptible to prolific growth of terrestrial weeds. The fish farms are infested with terrestrial weeds almost throughout the year and this affects the farm operations adversely. The weeds also become a shelter for many undesired animals including poisonous snakes.

Since, grass carp is a suitable fish species for the hills, some of the terrestrial weeds can be utilized as feed for this fish. A consistent cropping of weeds from within the farm area for feeding grass carp would enable the farmer to keep clean the pond dykes and other fallow areas of the fish farm, besides getting the protein-rich food from the pond. Earlier attempts to use terrestrial grass as feed for grass carp by Venkatesh and Shetty, (1978); Devaraj *et al.*, (1986) and Suresh and Mandal,(200) have shown encouraging results. Azad and Gupta (1990), Azad (1992) and Azad (1996) reported better conversion ratio in grass carp when fed with terrestrial weeds when compared to aquatic weeds.

The present study is therefore focused to utilize the farm weed as feed for the grass carp with a view to minimize the problem of weed infestation and to produce valuable fish protein in a very economical way through integration of Weed-Fish management system.

MATERIALS AND METHODS

Four different terrestrial weeds namely *Ageratum conyzoides* L., *Bidens pilosa* L., *Galinsoga parviflora* Cav. and *Crassocephalum crepidioides* (Benth) which are very common in Meghalaya, North East India, were screened for their acceptance and growth performance by grass carp *C. idella*. The four experimental weeds were collected and analyzed for their proximate composition in respect of moisture, crude protein, ether extract, crude fibre, nitrogen free extract and ash contents following the methods outlined in AOAC (1990).

The experiment was conducted for a period of 90 days during June to September 2003. The fishes were collected from the culture ponds of ICAR Complex research farm and were acclimatized in cement cisterns for a period of one week, by feeding them with the designated feed. Prior to the experiment, the fishes were starved for 48 hours to void off the faecal matter. The feeding experiment was conducted in cement cisterns of dimension 2.0 x 1.5 x 0.75 m. The water for the experimental cisterns were drawn from a nearby culture pond and a water level of 50 cm was maintained in each tank. Ten healthy grass carps (29.30 to 31.60 gms) were introduced into each of the cisterns and the experiment was conducted with four treatments (T₁ to T₄) with two replications for each treatment. The individual fishes were weighed at the commencement of the experiment.

The four different experimental weeds were collected daily from within the research farm area, chopped into small pieces, considering the mouth size of the fishes, weighed and were fed *ad libitum* to the fishes. The chopped feeds were placed on bamboo-made rectangular floating feeding trays. The left over feed was removed and weighed daily.

The water quality of the experimental cisterns was monitored fortnightly and the samples were analyzed following the standard methods (APHA, 1998). A partial replenishment of water was done once in a fortnight, when the fishes were sampled for recording their growth. The acceptability of the tested weeds by grass carp and their growth and Food Conversion Ratio (FCR) were calculated.

The data on the weight gain of fishes, average growth, food consumption and FCR were subjected to Analysis of Variance (ANOVA) to determine the statistical significance between the different means of various treatments.

RESULTS AND DISCUSSION

The range of variations in water temperature, pH, dissolved oxygen and total alkalinity during the experiment was 19 to 24°C, 7.9 to 8.2, 7.0 to 8.5 ml/l and 38 to 46 ppm respectively.

All the experimental weeds fed for grass carp during the study viz., the billy goat weed, *A. conyzoides* (T₁); cobbler's pegs, *B. pilosa* (T₂); little flower quick weed, *G. parviflora* (T₃) and the iron weed *C. crepidioides* (T₄) belonged to the family Asteraceae. The proximate composition of the weeds is presented in Table 1. The crude protein content was found to be the highest in T₄ (6.60%), followed by T₃ (5.95%), T₁ (4.49%) and T₂ (4.11%). However, the lipid content was found to be the highest in T₃ (12.75%), followed by T₂ (9.06%), T₄ (8.92%) and T₁ (5.81%).

Table 1. Biochemical composition of the terrestrial weeds fed to grass carp (Percentage dry matter basis)

Parameters (%)	Weeds			
	<i>A. conyzoides</i> (T ₁)	<i>B. pilosa</i> (T ₂)	<i>G. parviflora</i> (T ₃)	<i>C. crepidioides</i> (T ₄)
Dry matter	19.39	18.62	12.37	11.49
Crude protein	4.49	4.11	5.95	6.60
Ether extract (lipid)	5.81	9.06	12.75	8.92
Total ash	10.76	8.34	13.26	14.64
Crude fibre	35.47	33.28	29.79	28.10
Nitrogen free extract	43.47	45.21	38.25	41.74

During the present study, all the four terrestrial weeds (T₁ to T₄) were found to be consumed by grass carp; although the preference varied from one weed to the other to a considerable degree (Table 3). In the case of *A. conyzoides* and *B. pilosa*, the tender leaves were preferred while in case of *G. parviflora* and *C. crepidioides*, both tender and matured leaves were found to have equal acceptability by the fishes. The acceptance of T₃ (817.19 g) and T₄ (724.14 g) were found to be exceptionally good when compared to T₁ (437.30 g) and T₂ (459.89 g). There was a significant difference among all the treatments at 1% level with a

Critical Difference (CD) of 13.57. The preference to T_3 and T_4 has also reflected on the growth performance of fishes.

The weight gain and the average growth of fishes fed with different terrestrial weeds are presented in Table 2. The individual wet weight gain was the highest in T_3 (22.29 ± 0.43 g) when compared to all other treatments and registered a growth measured in terms of weight gain of 72.53%. The performance of grass carp fed T_4 was also good with a growth of 47.34% and a weight gain of 14.94 ± 0.37 g. Comparatively the weight gain of grass carp was found to be poor in T_1 (5.81 ± 0.17 g) and T_2 (3.18 ± 0.66 g), which recorded a growth of only 19.83% and 10.06% respectively. The results of ANOVA for individual wet weight gain observed a significant difference among all the tested treatments ($P < 0.01$), except between T_1 and T_2 and the CD at 1% level for weight gain was 3.3893.

Table 2. Growth and survival of grass carp fed on different terrestrial weeds

Parameters	Weeds			
	<i>A. conyzoides</i> (T_1)	<i>B. pilosa</i> (T_2)	<i>G. parviflora</i> (T_3)	<i>C. crepidioides</i> (T_4)
No. of fish	10	10	10	10
Duration (days)	90	90	90	90
Initial weight (g)*	29.30 ± 1.48	31.60 ± 1.10	30.73 ± 1.68	31.56 ± 1.43
Final weight (g)*	35.11 ± 1.65	34.78 ± 1.76	53.02 ± 1.25	46.50 ± 1.80
Weight gain (g)*	5.81 ± 0.17^a	3.18 ± 0.66^a	22.29 ± 0.43^b	14.94 ± 0.37^c
Percentage weight gain	19.83	10.06	72.53	47.34
Average growth (g/day/fish)	0.0646 ^a	0.0354 ^b	0.2476 ^c	0.166 ^d
Survival (%)	100	100	100	100

* Average wet weight/individual

Values having different superscripts (a, b, c, d) differ significantly ($P < 0.01$)

C.D. at 1% for weight gain = 3.38

C.D. at 1% for average growth = 0.00

The highest average growth (g/day/fish) was recorded in T_3 (0.2476g). The treatments T_4 , T_1 and T_2 recorded an average growth of 0.166, 0.0646 and 0.0354g respectively. Significant difference was observed among all the treatments ($P < 0.01$) with a CD value of 0.00743. The growth pattern during every 15 days interval is illustrated in Fig 1. The growth increment in T_1 and T_2 was less and the trend was almost similar in these two treatments from the 60th day of culture, while in T_3 and T_4 , there was a remarkable increase in growth after 15 days of culture.

In general, the FCR values were very high (Table 3) and the best FCR was recorded in T_3 (36.66). T_4 also recorded a comparatively better FCR value (48.46) than T_1 (75.26) and T_2 (144.61). ANOVA revealed significant difference among all the four tested treatments ($P < 0.01$) with a CD value of 4.7927. The higher FCR values may be owing to the fact that the grass carp consumes large quantity of feed in a day. However, as the weeds are available plenty in the wild and the farmer does not have to invest on these weeds, large quantities can be chopped and provided on feeding trays as per the requirement of the fishes. Moreover, the large quantity of faeces eliminated by the fishes may serve as feed for the bottom feeders in a polyculture system.

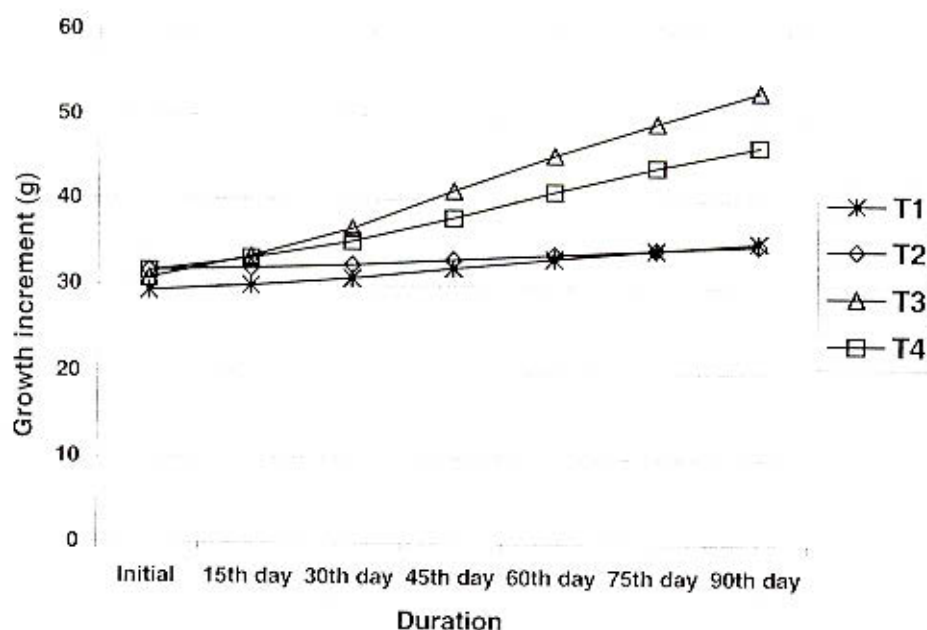


Fig.1. Growth pattern of grass carp *Ctenopharyngodon idella* fed with four different terrestrial weeds (T_1 - T_4)

Thus, it is evident from the present study that some of the terrestrial weeds can serve as potential feed for grass carp. Among the four tested weeds, *G. parviflora* had a better acceptance by grass carp and registered the highest weight gain and average daily growth and also the best conversion.

Azad (1996) found that the grass carp fingerlings showed a better growth performance (0.0712g/day/fish) when fed with *A. conyzoides* when compared to the aquatic weeds *Azolla* and *Lemna* and attributed the tender nature of leaves of *A. conyzoides* as the probable reason for high acceptance. On contrary, in the present study, growth of grass carp fed with *A. conyzoides* was less (0.0646g/day/fish) and the growth performance was remarkably high when fed with *G. parviflora* and *C. crepidioides*.

The North Eastern Region of India receives very high rainfall and consequently there is a prolific growth of weeds. These weeds have always been a menace to the farmers, hampering the overall farm activities. Dense growth of terrestrial weeds are often encountered on the pond dykes and other fallow areas of a fish farm. Tomar (2001) has reported a plant density of 107, 97, 89 and 68 number of plants in 4m² for *A. conyzoides*, *B. pilosa*, *G. parviflora* and *C. crepidioides* respectively in the Khasi hills of Meghalaya. The present study has revealed that the problem of weed infestation in a fish farm can be minimized by utilizing them as feed for the grass carp, which would be a step towards Integrated Terrestrial Weed-Fish Management.

In North-East India, fish culture using conventional feeds like rice polish and oil cakes are not widely acceptable to the farmers owing to the high cost. Hence, utilization of the unwanted weeds for fish production would be a viable proposition to the farming community and moreover the grass carp is well preferred by the local people and has become an integral component of their polyculture ponds.

CONCLUSION

The utilization of unwanted terrestrial weeds as fish feed could be one of the cheaper ways to increase the flesh biomass production from the aquatic habitat and to narrow the wide gap between the fish production and demand in North-East India. This would also pave way for producing organic fish and helps in minimizing the problem of household food and nutritional security in the North Eastern Hill Region of the country.

Table 3. Feed utilization and food conversion ratio of grass carp fed on different terrestrial weeds

Weeds	Parameters		
	Food consumed (g)	Wet Weight gain (g)	FCR
<i>A. conyzoides</i> (T ₁)	437.30 ^a	5.81 ± 0.17 ^a	75.26 ^a
<i>B. pilosa</i> (T ₂)	459.89 ^b	3.18 ± 0.66 ^a	144.61 ^b
<i>G. parviflora</i> (T ₃)	817.19 ^c	22.29 ± 0.43 ^b	36.66 ^c
<i>C. crepidioides</i> (T ₄)	724.14 ^d	14.94 ± 0.37 ^c	48.46 ^d

Values in each column having different superscripts (a, b, c, d) differ significantly

(P<0.01); C.D. at 1% for food consumption = 13.5735

C.D. at 1% for weight gain = 3.3893; C.D. at 1% for FCR = 4.7927

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POTENTIALS OF TERRESTRIAL WEEDS FOR THE PRODUCTION OF GRASS CARP *Ctenopharyngodon idella* (VAL.) IN MEGHALAYA, NORTH EASTERN INDIA

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ABSTRACT

The weeds like *Ageratum conyzoides* L., *Bidens pilosa* L., *Galinsoga parviflora* Cav. and *Crassocephalum crepidioides* (Benth) are very common and abundantly available in North Eastern India. These weeds were fed to the grass carp, *Ctenopharyngodon idella* (Val.) as a step towards integrated weed management including solving the problem of weed infestation on the pond dykes and fallow areas of the fish farm. Among the four tested weeds, *G. parviflora* was found to be the most preferred feed and the order of feed preference was *G. parviflora* > *C. crepidioides* > *A. conyzoides* > *B. pilosa*. The weight gain (72.53%) and FCR (36.66) were also high with *G. parviflora*. The weight gain with *C. crepidioides*, *A. conyzoides* and *B. pilosa* were 47.34%, 19.83% and 10.06% respectively, while the FCR were 48.46, 75.26 and 144.61 for the same. The results indicated that *G. parviflora* is an excellent feed for the grass carp among the four tested weeds. The utilization of unwanted weeds through biological agent i.e. *C. idella* is one of the best options for production of flesh biomass from the aquatic habitat. This would also pave way for producing organic fish and helps in minimizing the problem of household food and nutritional security in NEH Region.

Keywords : Weed management, Grass carp, Biological control, Feed, Weed Fish System, *Ctenopharyngodon idella* (Val.)

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INTRODUCTION

The menace of aquatic weeds had been serious in many countries and long-term economical solutions were worked out to alleviate this problem. Biological control of weeds, particularly using grass carp, was viewed as the best option for an environment-friendly approach of weed control. The grass carp, *Ctenopharyngodon idella* (Val.), commonly called the white amur, a native of Russian and Chinese rivers, has been thus introduced in many countries, primarily for aquatic weed control, owing to their inherent ability to consume the plant materials. In India, *C. idella* was introduced in the year 1959 and since then it is widely used not only for aquatic weed control, but also as a food fish, and cultured as an important component species in polyculture system. Composite fish culture with grass carp as a major component would help to reduce the supplementary feeding to a considerable extent (Grygierik, 1973; Manissery & Varghese, 1988). This species was found to be highly compatible with the Indian Major Carps viz. *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and the exotic carps like *Hypophthalmichthys molitrix* and *Cyprinus carpio* in the polyculture system.

In the North Eastern Hill Region of India, grass carp is a widely preferred species in a composite fish culture system as they are cold tolerant and found to perform very well, attaining about 1.0 to 1.2 kg in a year. There is a good market demand for this fish, fetching about Rs.50 to Rs.80 per kg. The preference for grass carp among the local people of the region is good, as the flesh of this fish is firm and flaky having a good flavour.

Aquaculture is one of the important enterprises in the North Eastern Hills and many rural farmers have been found to have at least one or two ponds within their farm area for fish culture. This part of the country receives rainfall during most part of the year and is susceptible to prolific growth of terrestrial weeds. The fish farms are infested with terrestrial weeds almost throughout the year and this affects the farm operations adversely. The weeds also become a shelter for many undesired animals including poisonous snakes.

Since, grass carp is a suitable fish species for the hills, some of the terrestrial weeds can be utilized as feed for this fish. A consistent cropping of weeds from within the farm area for feeding grass carp would enable the farmer to keep clean the pond dykes and other fallow areas of the fish farm, besides getting the protein-rich food from the pond. Earlier attempts to use terrestrial grass as feed for grass carp by Venkatesh and Shetty, (1978); Devaraj *et al.*, (1986) and Suresh and Mandal,(200) have shown encouraging results. Azad and Gupta (1990), Azad (1992) and Azad (1996) reported better conversion ratio in grass carp when fed with terrestrial weeds when compared to aquatic weeds.

The present study is therefore focused to utilize the farm weed as feed for the grass carp with a view to minimize the problem of weed infestation and to produce valuable fish protein in a very economical way through integration of Weed-Fish management system.

MATERIALS AND METHODS

Four different terrestrial weeds namely *Ageratum conyzoides* L., *Bidens pilosa* L., *Galinsoga parviflora* Cav. and *Crassocephalum crepidioides* (Benth) which are very common in Meghalaya, North East India, were screened for their acceptance and growth performance by grass carp *C. idella*. The four experimental weeds were collected and analyzed for their proximate composition in respect of moisture, crude protein, ether extract, crude fibre, nitrogen free extract and ash contents following the methods outlined in AOAC (1990).

The experiment was conducted for a period of 90 days during June to September 2003. The fishes were collected from the culture ponds of ICAR Complex research farm and were acclimatized in cement cisterns for a period of one week, by feeding them with the designated feed. Prior to the experiment, the fishes were starved for 48 hours to void off the faecal matter. The feeding experiment was conducted in cement cisterns of dimension 2.0 x 1.5 x 0.75 m. The water for the experimental cisterns were drawn from a nearby culture pond and a water level of 50 cm was maintained in each tank. Ten healthy grass carps (29.30 to 31.60 gms) were introduced into each of the cisterns and the experiment was conducted with four treatments (T₁ to T₄) with two replications for each treatment. The individual fishes were weighed at the commencement of the experiment.

The four different experimental weeds were collected daily from within the research farm area, chopped into small pieces, considering the mouth size of the fishes, weighed and were fed *ad libitum* to the fishes. The chopped feeds were placed on bamboo-made rectangular floating feeding trays. The left over feed was removed and weighed daily.

The water quality of the experimental cisterns was monitored fortnightly and the samples were analyzed following the standard methods (APHA, 1998). A partial replenishment of water was done once in a fortnight, when the fishes were sampled for recording their growth. The acceptability of the tested weeds by grass carp and their growth and Food Conversion Ratio (FCR) were calculated.

The data on the weight gain of fishes, average growth, food consumption and FCR were subjected to Analysis of Variance (ANOVA) to determine the statistical significance between the different means of various treatments.

RESULTS AND DISCUSSION

The range of variations in water temperature, pH, dissolved oxygen and total alkalinity during the experiment was 19 to 24°C, 7.9 to 8.2, 7.0 to 8.5 ml/l and 38 to 46 ppm respectively.

All the experimental weeds fed for grass carp during the study viz., the billy goat weed, *A. conyzoides* (T₁); cobbler's pegs, *B. pilosa* (T₂); little flower quick weed, *G. parviflora* (T₃) and the iron weed *C. crepidioides* (T₄) belonged to the family Asteraceae. The proximate composition of the weeds is presented in Table 1. The crude protein content was found to be the highest in T₄ (6.60%), followed by T₃ (5.95%), T₁ (4.49%) and T₂ (4.11%). However, the lipid content was found to be the highest in T₃ (12.75%), followed by T₂ (9.06%), T₄ (8.92%) and T₁ (5.81%).

Table 1. Biochemical composition of the terrestrial weeds fed to grass carp (Percentage dry matter basis)

Parameters (%)	Weeds			
	<i>A. conyzoides</i> (T ₁)	<i>B. pilosa</i> (T ₂)	<i>G. parviflora</i> (T ₃)	<i>C. crepidioides</i> (T ₄)
Dry matter	19.39	18.62	12.37	11.49
Crude protein	4.49	4.11	5.95	6.60
Ether extract (lipid)	5.81	9.06	12.75	8.92
Total ash	10.76	8.34	13.26	14.64
Crude fibre	35.47	33.28	29.79	28.10
Nitrogen free extract	43.47	45.21	38.25	41.74

During the present study, all the four terrestrial weeds (T₁ to T₄) were found to be consumed by grass carp; although the preference varied from one weed to the other to a considerable degree (Table 3). In the case of *A. conyzoides* and *B. pilosa*, the tender leaves were preferred while in case of *G. parviflora* and *C. crepidioides*, both tender and matured leaves were found to have equal acceptability by the fishes. The acceptance of T₃ (817.19 g) and T₄ (724.14 g) were found to be exceptionally good when compared to T₁ (437.30 g) and T₂ (459.89 g). There was a significant difference among all the treatments at 1% level with a

Critical Difference (CD) of 13.57. The preference to T_3 and T_4 has also reflected on the growth performance of fishes.

The weight gain and the average growth of fishes fed with different terrestrial weeds are presented in Table 2. The individual wet weight gain was the highest in T_3 (22.29 ± 0.43 g) when compared to all other treatments and registered a growth measured in terms of weight gain of 72.53%. The performance of grass carp fed T_4 was also good with a growth of 47.34% and a weight gain of 14.94 ± 0.37 g. Comparatively the weight gain of grass carp was found to be poor in T_1 (5.81 ± 0.17 g) and T_2 (3.18 ± 0.66 g), which recorded a growth of only 19.83% and 10.06% respectively. The results of ANOVA for individual wet weight gain observed a significant difference among all the tested treatments ($P < 0.01$), except between T_1 and T_2 and the CD at 1% level for weight gain was 3.3893.

Table 2. Growth and survival of grass carp fed on different terrestrial weeds

Parameters	Weeds			
	<i>A. conyzoides</i> (T_1)	<i>B. pilosa</i> (T_2)	<i>G. parviflora</i> (T_3)	<i>C. crepidioides</i> (T_4)
No. of fish	10	10	10	10
Duration (days)	90	90	90	90
Initial weight (g)*	29.30 ± 1.48	31.60 ± 1.10	30.73 ± 1.68	31.56 ± 1.43
Final weight (g)*	35.11 ± 1.65	34.78 ± 1.76	53.02 ± 1.25	46.50 ± 1.80
Weight gain (g)*	5.81 ± 0.17^a	3.18 ± 0.66^a	22.29 ± 0.43^b	14.94 ± 0.37^c
Percentage weight gain	19.83	10.06	72.53	47.34
Average growth (g/day/fish)	0.0646 ^a	0.0354 ^b	0.2476 ^c	0.166 ^d
Survival (%)	100	100	100	100

* Average wet weight/individual

Values having different superscripts (a, b, c, d) differ significantly ($P < 0.01$)

C.D. at 1% for weight gain = 3.38

C.D. at 1% for average growth = 0.00

The highest average growth (g/day/fish) was recorded in T_3 (0.2476g). The treatments T_4 , T_1 and T_2 recorded an average growth of 0.166, 0.0646 and 0.0354g respectively. Significant difference was observed among all the treatments ($P < 0.01$) with a CD value of 0.00743. The growth pattern during every 15 days interval is illustrated in Fig 1. The growth increment in T_1 and T_2 was less and the trend was almost similar in these two treatments from the 60th day of culture, while in T_3 and T_4 , there was a remarkable increase in growth after 15 days of culture.

In general, the FCR values were very high (Table 3) and the best FCR was recorded in T_3 (36.66). T_4 also recorded a comparatively better FCR value (48.46) than T_1 (75.26) and T_2 (144.61). ANOVA revealed significant difference among all the four tested treatments ($P < 0.01$) with a CD value of 4.7927. The higher FCR values may be owing to the fact that the grass carp consumes large quantity of feed in a day. However, as the weeds are available plenty in the wild and the farmer does not have to invest on these weeds, large quantities can be chopped and provided on feeding trays as per the requirement of the fishes. Moreover, the large quantity of faeces eliminated by the fishes may serve as feed for the bottom feeders in a polyculture system.

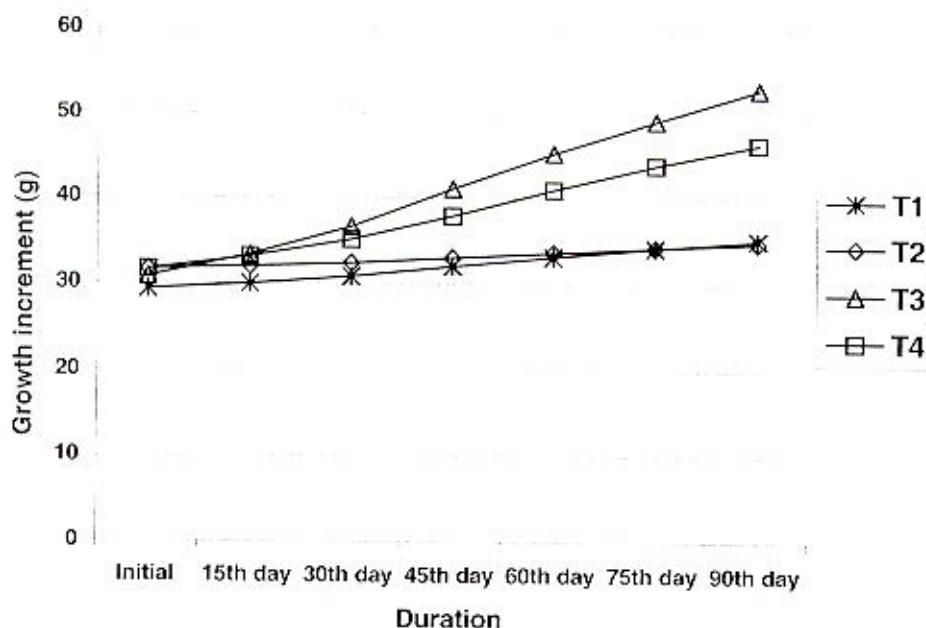


Fig.1. Growth pattern of grass carp *Ctenopharyngodon idella* fed with four different terrestrial weeds (T_1 - T_4)

Thus, it is evident from the present study that some of the terrestrial weeds can serve as potential feed for grass carp. Among the four tested weeds, *G. parviflora* had a better acceptance by grass carp and registered the highest weight gain and average daily growth and also the best conversion.

Azad (1996) found that the grass carp fingerlings showed a better growth performance (0.0712g/day/fish) when fed with *A. conyzoides* when compared to the aquatic weeds *Azolla* and *Lemna* and attributed the tender nature of leaves of *A. conyzoides* as the probable reason for high acceptance. On contrary, in the present study, growth of grass carp fed with *A. conyzoides* was less (0.0646g/day/fish) and the growth performance was remarkably high when fed with *G. parviflora* and *C. crepidioides*.

The North Eastern Region of India receives very high rainfall and consequently there is a prolific growth of weeds. These weeds have always been a menace to the farmers, hampering the overall farm activities. Dense growth of terrestrial weeds are often encountered on the pond dykes and other fallow areas of a fish farm. Tomar (2001) has reported a plant density of 107, 97, 89 and 68 number of plants in 4m² for *A. conyzoides*, *B. pilosa*, *G. parviflora* and *C. crepidioides* respectively in the Khasi hills of Meghalaya. The present study has revealed that the problem of weed infestation in a fish farm can be minimized by utilizing them as feed for the grass carp, which would be a step towards Integrated Terrestrial Weed-Fish Management.

In North-East India, fish culture using conventional feeds like rice polish and oil cakes are not widely acceptable to the farmers owing to the high cost. Hence, utilization of the unwanted weeds for fish production would be a viable proposition to the farming community and moreover the grass carp is well preferred by the local people and has become an integral component of their polyculture ponds.

CONCLUSION

The utilization of unwanted terrestrial weeds as fish feed could be one of the cheaper ways to increase the flesh biomass production from the aquatic habitat and to narrow the wide gap between the fish production and demand in North-East India. This would also pave way for producing organic fish and helps in minimizing the problem of household food and nutritional security in the North Eastern Hill Region of the country.

Table 3. Feed utilization and food conversion ratio of grass carp fed on different terrestrial weeds

Weeds	Parameters		
	Food consumed (g)	Wet Weight gain (g)	FCR
<i>A. conyzoides</i> (T ₁)	437.30 ^a	5.81 ± 0.17 ^a	75.26 ^a
<i>B. pilosa</i> (T ₂)	459.89 ^b	3.18 ± 0.66 ^a	144.61 ^b
<i>G. parviflora</i> (T ₃)	817.19 ^c	22.29 ± 0.43 ^b	36.66 ^c
<i>C. crepidioides</i> (T ₄)	724.14 ^d	14.94 ± 0.37 ^c	48.46 ^d

Values in each column having different superscripts (a, b, c, d) differ significantly

(P<0.01); C.D. at 1% for food consumption = 13.5735

C.D. at 1% for weight gain = 3.3893; C.D. at 1% for FCR = 4.7927

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PROFILE DISTRIBUTION AND LEACHING LOSSES OF NITROGEN APPLIED TO SANDY LOAM AND CLAY LOAM SOILS UNDER UPLAND AND WETLAND MOISTURE REGIMES

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ABSTRACT

Under assured irrigated conditions, coarse textured soils can be very productive provided distribution and leaching losses of applied N can be adequately managed under different moisture regimes. Distribution and movement of applied urea-N was studied in lysimeters filled with sandy loam and clay loam soils at bulk densities close to those under field situations and under wetland and upland moisture regimes encountered under rice and wheat crops, respectively. Under upland moisture regime (4 irrigations of 7.5 cm depth each to wheat), no leaching losses of N occurred beyond 75 cm in both the sandy loam and clay loam soils. In the sandy loam soil under wetland rice (235 cm water applied in 47 irrigations), more than 8 per cent of applied-N was leached beyond 75 cm. Major leaching losses of N occurred during first 10 days after application of each split dose. The losses were more from first split dose as compared to second and third split dose. No leachate was obtained beneath 75 cm depth of clay loam receiving 120 cm of water in 24 irrigation events. Leaching losses of N under rice-wheat rotation can thus be effectively alleviated by applying less fertilizer N in the first split dose to rice in coarse textured soils. In fine textured soils leaching of N does not constitute a major loss mechanism.

Keywords : Nitrogen, Sandy loam, Clay loam, Leaching losses, Moisture regime.

INTRODUCTION

Depending upon availability of water and nutrients, coarse textured soils can be as productive as fine textured soils (Aulakh & Bijay Singh, 1997) and can be used for growing both upland (wheat-*Triticum aestivum* L.) and wetland (rice-*Oryza sativa* L.) crops. The

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sequentially grown rice and wheat constitute a dominant cropping system in the Indo-Gangetic plains spread over 13 M ha in India, Pakistan, Nepal and Bangladesh. Soils in a substantial portion of this area are loamy sand to sandy loam in texture. Urea, the major source of N in rice-wheat cropping system, once applied to soils is subjected to a number of transformations before it is taken up by crops. Under upland conditions, native and applied N may be readily nitrified so that NO_3 form may dominate the mineral N fractions. This form of N may be lost primarily via leaching and to some extent via denitrification depending upon the intensity of irrigation and rainfall events. Urea placed on surface of the soil may be more prone to losses via ammonia volatilization.

In fine textured flooded rice soils, there exists a pan at a depth of few cm which restricts downward percolation (Moorman & Breeman, 1978), so that possibility of leaching NO_3 -N beyond root zone is small. When a sandy soil is brought under wetland rice cultivation, the situation is far from ideal rice soil. High permeability of water through the soil profile may result in leaching of significant amounts of soil and applied N beyond the root zone. Due to alternate wetting and drying conditions, oxidized zone is relatively thick, resulting in extensive nitrification of N, which can be subsequently lost via leaching or denitrification (Shibu & Ghuman, 2001).

Farmers in northwestern India use high amounts of N fertilizers in rice-wheat cropping system and there is already a growing concern of NO_3 pollution of ground water (Bijay Singh *et al.*, 1995). Thus, management especially of coarse soils, is facing a grave challenge - to maximize crop yields and minimize pollution of soil and water. The fertilizer efficiency issue alone deserves careful attention. Recovery of fertilizer N by rice and wheat is often no higher than 30% and 50%, respectively (Aulakh & Bijay Singh, 1997, Bijay Singh *et al.*, 2001). Even if these low recoveries can be tolerated from an economic standpoint, these cannot be tolerated from an environmental pollution point of view. The present investigation was carried out to study distribution and leaching of applied urea-N as these are influenced by soil texture and water regimes for wheat and rice crops grown in lysimeters.

MATERIALS AND METHODS

Lysimeter study

Bulk soil samples of sandy loam and clay loam soils were collected, air dried and ground to pass through 2 mm sieve. Sand, silt, clay, pH, electrical conductivity, organic carbon, available P, available K, cation exchanger capacity, urease activity, NH_4^+ -N, NO_3^- -N were 31.2%, 38.1%, 30.6%, 8.4, 0.6 ds m^{-1} , 0.46%, 13 kg ha^{-1} , 417 kg ha^{-1} , 15 cmol kg^{-1} , 24.5 $\mu\text{g urea-N gm}^{-1}$ soil, 7 mg kg^{-1} and 10 mg kg^{-1} respectively for clay loam soil and 71.4%,

14.8%, 13.8%, 7.8, 0.2 ds m^{-1} , 0.33%, 14 kg ha^{-1} , 81 kg ha^{-1} , 10 cmol kg^{-1} , 16 $\mu\text{g urea-N gm}^{-1}$ soil, 8 mg kg^{-1} and 11 mg kg^{-1} , respectively for sandy loam soil.

Investigations on distribution and leaching of different N species under wheat (upland) and rice (wetland) ecosystems were carried out in sandy loam and clay loam soils packed in 35 cm ID and 85 cm deep lysimeters, in three replicates. At the bottom of the lysimeters an opening of 1 cm diameter was made on one side and an iron tube of 5 cm length was fixed on the opening to make an outlet for collection of leachate.

To obtain clear leachate, a 3 cm thick layer of gravels was placed at the bottom of lysimeter prior to filling of soil and a layer of glass wool was fixed in the opening at the bottom of the lysimeter. Air-dry soil was filled in each lysimeter upto 75 cm depth. Soil was filled in small increments and packing was done with a wooden plunger to achieve bulk densities 1.5 Mg m^{-3} and 1.3 Mg m^{-3} for sandy loam and clay loam soils, respectively. Total amount of soil packed in lysimeters was 108 kg for sandy loam and 94 kg for clay loam soils. After taking a crop of wheat, the lysimeters were refilled in the same way for growing rice under wetland moisture regime.

Irrigation, fertilization and planting: Before sowing of wheat, soils were brought to field capacity by applying 15 L water per lysimeter for sandy loam soil and 20 L water per lysimeter for clay loam soil. Urea, single super phosphate, and muriate of potash were used to supply 200 kg N ha^{-1} , 44 kg P ha^{-1} , and 83 kg K ha^{-1} . A dose of 25 $\text{kg ZnSO}_4 \cdot 7\text{H}_2\text{O ha}^{-1}$ was also given. Half N and all P, K and Zn were applied as basal dose immediately before sowing of wheat. Remaining half dose of N was applied along with first irrigation at 21 days after sowing of wheat. Basal dose of fertilizers was broadcasted and mixed in the surface 0-10 cm soil depth manually.

On the following day, seeds of wheat variety HD-2329 were sown at a depth of about 4 cm in rows 20 cm apart. After germination of the seeds, 25 plants were kept in all the lysimeters. For both the soils, lysimeters with no-N control treatment were also maintained. Both the treatments (no-N and 200 kg N ha^{-1}) were replicated thrice. Irrigations of 7.5 cm depth each were given 3, 8, 14 and 16 weeks after sowing wheat. Tube-well water was used for irrigation and measured quantity of water was applied on surface area basis. Total amount of water applied in 4 irrigations was 28.8 liters.

Before transplanting four 45-day old rice (variety PR 111) seedlings (at row to row and plant to plant distance of 20 cm), lysimeters filled with sandy loam soil were irrigated thrice with 10 cm depth of water daily to make a puddle up to 10 cm depth. In lysimeters

filled with clay loam soil, puddling was done once after applying 10 cm depth of water. On the 4th day, one third N, all P, K and Zn were applied at last puddling with 5 cm depth of water. Remaining N was applied in two equal split doses at 21 and 42 days after transplanting of rice.

Thus source, amount and method of fertilizer application were similar to field grown rice in northwestern India. Lysimeters filled with sandy loam soil were irrigated with 5 cm of water daily upto 3 weeks after transplanting. Irrigation water usually infiltrated in to the soil in 5 to 7 h. Afterwards, irrigations of 5 cm depth each were applied 2 days after the ponded water had infiltrated in to soil. In case of lysimeters filled with clay loam soil, irrigations of 5 cm depth were applied in such a way that standing water was maintained for first 3 weeks after transplanting.

All the applied water used to infiltrate in 3-5 days (depending on weather conditions). Afterwards irrigations of 5 cm depth were applied one day after the ponded water had infiltrated in to the soil. In sandy loam soil lysimeters, a total amount of 226.18 L (equivalent to 235 cm depth) water was applied to rice in 47 irrigations, whereas total amount of water applied to rice grown in clay loam soil was 120 cm (115.5 L) in 24 irrigations. Leachates were collected daily. Quantity of leachates was measured and leachates were analyzed for urea (Mulvaney & Bremner, 1979), NH_4^+ and NO_3^- (Keeney & Nelsen, 1982) forms of N immediately after sampling.

Harvesting of crop, soil sampling and chemical analysis: At maturity, plants of both rice and wheat crops were harvested close to the ground and grain and straw yield were recorded. Nitrogen content in grain and straw was determined by digesting the samples in sulfuric acid (H_2SO_4), followed by analysis for total N by a micro-Kjeldahl method (Yoshida et al., 1976). Soil samples from 0-15, 15-30, 30-45, 45-60 and 60-75 cm depths were obtained immediately after harvest of each crop.

Fresh soil samples (10 g) were extracted with 50 ml of 2 M KCl solution. Simultaneously, 100 gm of fresh soil sample were dried at 105°C for determination of moisture content. Soil extracts in KCl were analyzed for $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ by steam distillation method using MgO and Devarda's alloy (Keeney & Nelsen, 1982), respectively, and results were expressed on a dry weight basis.

RESULTS AND DISCUSSION

Upland moisture regime

Wheat yield and N uptake: Grain and straw yield and total N uptake by wheat were higher when grown in the sandy loam soil rather than in clay loam soil (Table 1). Conditions for growth and proliferation of plant roots were possibly more favorable in sandy loam soil as compared to the clay loam soil. However, apparent N recovery by wheat from the applied urea (N uptake more than in the no-N control and expressed as percentage of applied fertilizer N) was 68.4 per cent in the clay loam soil as compared to 57.8 per cent in sandy loam soil. It could be due to restricted movement of applied fertilizer-N to deeper soil layers thereby resulting in higher uptake of fertilizer-N from clay loam soil as compared to that from the sandy loam soil. During initial growth stages of the crop, roots of wheat are limited to surface 30 cm soil depth (Gajri *et al.*, 1989), so that N moved to deeper layer in sandy loam soil could not be absorbed by young roots of wheat crop resulting in low apparent N recovery. On the other hand, contribution of inherent soil N to total N uptake by wheat grown in clay loam soil also resulted in high apparent-N recovery of applied fertilizer-N. It was supported by the fact that 300 and 190 mg of residual mineral N from applied fertilizer-N ($\text{NH}_4^+ + \text{NO}_3^-$ in fertilized lysimeter minus that in no-N control) in the sandy loam and clay loam soil, respectively, was recovered at the harvest of wheat crop (Table 2).

Table 1. Grain yield, straw yield, total N uptake and recovery efficiency of applied N by wheat in sandy loam and clay loam soils

Treatment	Grain yield (g lysimeter ⁻¹)	Straw yield (g lysimeter ⁻¹)	Total N uptake (g)	Recovery efficiency % applied N
<i>Sandy loam soil</i>				
No-N control	35	42	2.2	-
200 kg N/ha	61	77	3.3	57.8
<i>Clay loam soil</i>				
No-N control	33	39	1.7	-
200kg N/ha	44	57	3.0	68.4
LSD (5%)	4.7	3.0	0.1	9.4

Distribution and movement NH_4^+ and NO_3^- -N: Data on distribution of NH_4^+ and NO_3^- -N in no-N control and fertilized lysimeters after harvest of wheat crop are given in Table 2. In no-N control lysimeters of the sandy loam soil, NH_4^+ -N content showed increase with depth in 0-30 cm soil layers. Thereafter, it decreased with depth upto 60-75 cm soil layer. But NO_3^- -N concentration in the soil showed increase with depth. Higher concentration of NH_4^+ -N in surface 0-30 cm layers may be ascribed to more proliferation of roots and better biological activity thereby increasing mineralization of inherent organic soil-N. Increase in soil NO_3^- -N with depth was due to preferential downward movement of NO_3^- -N with percolating water. Distribution of NH_4^+ -N in no-N control lysimeters filled with clay loam soil showed a trend similar to that in sandy loam soil, but NO_3^- -N content increased considerably with depth upto 30-45 cm soil layer and sharply decreased thereafter. Accumulation of NO_3^- -N at 30-45 cm soil depth should be due to slow percolation of water in fine textured soil that results in NO_3^- -N peak at shallow depth as compared to in the coarse textured soil.

Data on NH_4^+ and NO_3^- -N distribution of applied fertilizer-N in lysimeter showed that NH_4^+ -N accumulated in 30-60 cm soil depth in the sandy loam soil and 0-30 cm soil depth in the clay loam soil (Table 2). Movement of NO_3^- -N also showed a similar trend but NO_3^- -N was accumulated in deeper depths (60-75 cm in the sandy loam and 30-45 cm in the clay loam soil). These results were expected in view of slow movement of water in the clay loam soil as compared to in the sandy loam soil (Singh and Singh, 1988). In a highly percolating soil under rice-wheat system, Katyal et al. (1987) studied distribution of ^{15}N in soil profiles under wheat and found that leaching of applied N was not found to be significant. Applied nitrate was fully recovered between the plant and soil, reflecting little or no leaching of N.

Wet land moisture regime

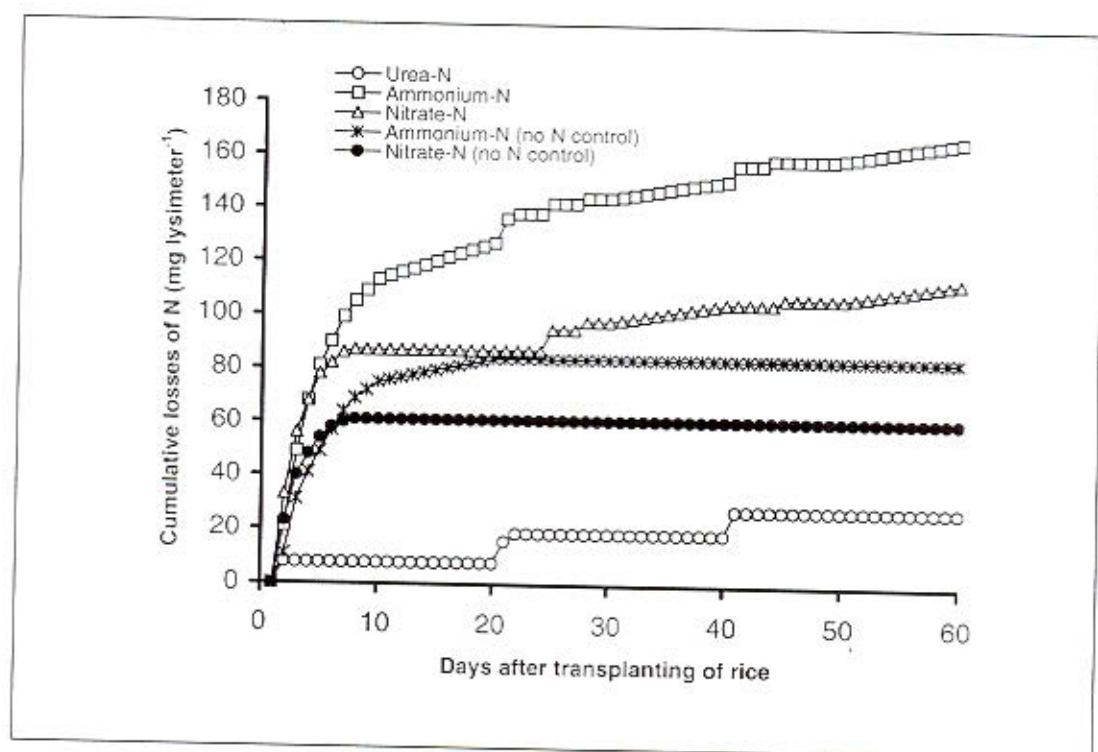
Rice yield and N-uptake: Data in Table 3 show that straw and grain yield and N uptake of rice were higher in the clay loam soil as compared to in the sandy loam soil. Finer texture of the clay loam soil should have helped in creating highly reduced soil environments favorable for growth of rice. Apparent N recovery by rice from the applied urea was about 52 per cent from sandy loam soil as compared to 47 per cent from clay loam soil. It may be due to less contribution of inherent soil N in uptake from sandy loam soil in which leaching losses of mineralized N were expected to be substantial (Fig. 1)

Table 2. Distribution of $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ (mg) after harvesting wheat in sandy loam and clay loam soils

Soil depth depth (cm)	Sandy loam soil						Clay loam soil					
	No-N		200 kg N ha ⁻¹		Fertilized treatment minus no-N control		No-N		200 kg N ha ⁻¹		Fertilized treatment minus no-N control	
	NH ₄ ⁺ -N	NO ₃ ⁻ -N	NH ₄ ⁺ -N	NO ₃ ⁻ -N	NH ₄ ⁺ -N	NO ₃ ⁻ -N	NH ₄ ⁺ -N	NO ₃ ⁻ -N	NH ₄ ⁺ -N	NO ₃ ⁻ -N	NH ₄ ⁺ -N	NO ₃ ⁻ -N
0-15	210	120	220	130	10	10	140	170	158	180	18	10
15-30	240	130	250	162	10	32	170	290	194	303	24	13
30-45	170	174	190	209	20	35	150	320	166	370	16	50
45-60	150	280	175	328	25	46	130	150	142	170	12	20
60-75	140	400	154	496	14	96	122	100	132	117	10	17
Total	910	1104	989	1325	79	221	712	1030	792	1140	80	110

Table 3. Grain yield, straw yield, total N uptake and recovery efficiency of applied N by rice in sandy loam and clay loam soils

Treatment	Grain yield (g lysimeter ⁻¹)	Straw yield (g lysimeter ⁻¹)	Total N uptake (g)	Recovery efficiency % applied N
<i>Sandy loam soil</i>				
No-N control	47	66	0.9	-
200 kg N/ha	93	118	1.9	52.6
<i>Clay loam soil</i>				
No-N control	93	120	1.5	-
200kg N/ha	121	143	2.4	47.3
LSD (5%)	3.0	4.2	0.3	NS

Fig. 1. Cumulative leaching losses of NH_4^+ and NO_3^- N from sandy loam soil lysimeters in which wetland rice was grown with (200 kg N ha^{-1}) and without fertilizer N application

Distribution and movement of NH_4^+ and NO_3^- -N : Data on distribution of NH_4^+ and NO_3^- -N in no-N control and fertilized lysimeters after harvest of rice crop is given in Table 4. In the no-N control lysimeters of sandy-loam soil, NH_4^+ -N and NO_3^- -N contents were almost uniform in different depths. But data on distribution of applied fertilizer-N show that both NH_4^+ and NO_3^- -N content increased with depth up to 60-75 cm soil depth. The NH_4^+ -N content at surface (0-15 cm) layer was 17 mg over that in no-N control and increased to 29 mg at 60-75 cm soil depth, whereas NO_3^- -N content increased from 9 mg (at 0-15 cm soil depth) to 19 mg (at 60-75 cm soil depth). Peak NH_4^+ and NO_3^- -N contents in the 60-75 cm soil layer in the sandy loam soil were due to downward movement of both NH_4^+ -N and NO_3^- -N with frequent irrigations applied under wetland moisture regime.

In no-N control lysimeter filled with the clay loam soil NH_4^+ -N content increased up to 45-60 cm soil layer; it declined in 60-75 cm soil layer. On the other hand NO_3^- -N concentration continued to increase up to 60-75 cm soil layer. Accumulation of more NO_3^- -N in deeper soil layers as compared to NH_4^+ -N indicates slow movement of NH_4^+ -N with percolating water in fine textured soil. Similar trend for distribution of NH_4^+ and NO_3^- -N was observed in lysimeters receiving fertilizer-N.

More residual NH_4^+ -N rather than NO_3^- -N after harvest of rice was observed in lysimeters packed with both sandy loam and clay loam soil (Table 4). Residual N (NH_4^+ + NO_3^- -N) was 543 mg in the clay loam soil as compared to 170 mg in sandy loam soil. Higher apparent N recovery and more leaching losses of N from the sandy loam soil rather than in the clay loam soil are in line with data for residual N.

Leaching losses: No leachate was obtained from clay loam soil. Cumulative leaching losses of N as urea, NH_4^+ and NO_3^- beneath 75 cm from lysimeters filled with sandy loam soil are shown in Fig 1. To each of these lysimeters, 1900 mg N was applied in three equal splits doses at transplanting, 3 weeks and 6 weeks after transplanting. First leachate was collected 2 days after initiation of study and it contained 7.7 mg urea-N. No urea-N was detected in subsequent leachates. Leachate collected a day after the application of 2nd split dose of fertilizer N contained 8 mg urea-N.

Another 3 mg of urea-N was found in leachate obtained on the following day as 36 mm rainfall was received on 22nd day. After application of the third split dose of fertilizer, leachate collected on the following day contained 8 mg urea-N. Leachates collected subsequently did not contain urea-N. Thus from three equal split applications, 26.7 mg of applied urea was leached as urea-N beyond 75 cm soil depth and it was 1.4 per cent of the total fertilizer N applied to rice.

Table 4. Distribution of $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^+\text{-N}$ (mg) after harvesting rice in sandy loam and clay loam soils

Soil depth (cm)	Sandy loam soil						Clay loam soil					
	No-N		200 kg N ha ⁻¹		Fertilized treatment minus No-N control		No-N		200 kg N ha ⁻¹		Fertilized treatment minus No-N control	
	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^+\text{-N}$
0-15	120	104	137	113	17	9	180	114	232	151	52	37
15-30	125	103	143	113	18	10	189	123	247	162	58	39
30-45	130	102	150	112	20	10	223	190	285	232	62	42
45-60	125	107	149	121	24	14	290	210	367	258	77	48
60-75	125	99	154	118	29	19	198	297	267	356	69	59
Total	625	515	733	577	108	62	1080	934	1398	1159	318	225

Due to low CEC and coarse texture of the sandy loam soil, substantial leaching losses of N as NH_4^+ were observed. In the no-N control treatment leaching of NH_4^+ -N beneath 75 cm was higher initially and it steadily decreased to negligible value after 10 days of rice growth. Initial leaching from no-N control should be due to presence of NH_4^+ -N in soil solution from mineralization of soil organic matter. Thereafter, leaching losses decreased due to increased uptake of N by rice, and depressing effect of soil saturation on mineralization of soil organic-N (Gambrell & Patrick, 1978).

Similarly, leaching of NH_4^+ -N beyond 75 cm from applied fertilizer showed decline with time. Leaching of substantial amounts of NH_4^+ -N was detected upto 10 days, 8 days and 4 days after application of first, second and third split dose, respectively. More leaching losses from first split dose of N than from second and third dose was due to limited root growth of rice crop, immediately after transplanting and thus low utilization of applied fertilizer-N (Meelu & Gupta, 1980). Total NH_4^+ -N leaching throughout the study period was 84 mg and 166.5 mg from no-N control and fertilizer-N treatment, respectively. Thus about 82.5 mg NH_4^+ -N in leachate was from applied fertilizer-N alone, which constituted about 4.3 per cent of applied fertilizer-N.

Leaching losses of NO_3^- -N in no-N control lysimeters were also observed beyond 75 cm. Losses were substantial in initial stages and steadily decreased to a negligible level 8 days after initiation of the study. In N treated lysimeters, leaching of NO_3^- -N was observed up to first 8 days after first and second split dose and upto 4 days after third split dose. Afterwards, losses were negligible. The leachates obtained after 2 days contained maximum amount of NO_3^- -N (23 mg from no-N control and 33 mg from fertilizer-N treatments).

It was due to mineralization of soil organic-N and oxidation of urea-N in favorable soil moisture conditions during the initiation of study. Thus NO_3^- -N in the solution moved with percolating water and considerable amount of it was leached with first flush of leachate. Thereafter there was declined in NO_3^- -N content in leachate from day 3 to day 8. Subsequently there was no NO_3^- -N in the leachate. It may be due to continuous irrigation up to 21 days; nearly saturated conditions should have proved unfavorable for microbes to grow leading to reduced N mineralization (Gambrell & Patrick, 1978) and nitrification.

After 21 days, lysimeters were irrigated 2 day after infiltration of ponded water so that conditions were favorable for oxidation of NH_4^+ -N. Thus leaching of NO_3^- on 5 and 8 days after second split dose and on 5 days after 3rd split dose were observed. Losses were 8, 3 and 2 mg, respectively. Total NO_3^- -N lost by leaching during crop growth period were 61 mg

and 113.5 mg from no-N control and fertilizer-N treatments, respectively. Thus about 52.5 mg $\text{NO}_3\text{-N}$ in the leachate came from applied fertilizer N. It was about 2.76 per cent of applied fertilizer-N.

The cumulative leaching of nitrogen (urea+ NH_4^+ + NO_3^-) during the growth season of rice crop was 145 mg and 307 mg from no-N control and fertilizer-N treatment, respectively. Thus about 161.7 mg N in the leachate was from applied urea alone, which was 8.5 per cent of the applied fertilizer-N.

CONCLUSION

In fine textured soils under rice-wheat cropping system, there hardly exists any possibility that applied N will be lost by leaching beyond 75 cm depth. Even in sandy loam soils nitrogen applied to wheat is not prone to losses through leaching. Only when wetland rice is grown on coarse textured soils, substantial leaching of nitrogen is expected. However, losses are reduced with growth of the crop. Losses from third split dose of nitrogen applied around 6 weeks after transplanting of rice are substantially less than those observed from the dose applied at transplanting of rice.

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PRODUCTION OF ACTIVATED CARBON FROM KILUVAI (*Commiphora berryi* (Arn.) Engl.)

T. ARIMUGANATHAN¹, R. KAILAPPAN² AND C. INDU RANI³

ABSTRACT

Activated carbon, a carbonaceous material with porous structure capable of adsorbing organic compounds, contributing colour, odour, taste etc., in the food, pharmaceutical and allied products, can be produced from Kiluvai (*Commiphora berryi* (Arn.) Engl.), a highly drought resistant, spreading shrub, growing well under all soil conditions and wastelands. The Kiluvai stems were cut into pieces, dried and powdered in a burr mill. The powder was sieved through a 500 µm sieve. To this sieved powder, 100, 125 and 150% (by weight of powder taken) zinc chloride, a chemical was added and then activated at 400, 500 and 600°C for 60, 75 and 90 minutes duration. The activated carbon produced was washed with hydrochloric acid, neutralized with sodium hydroxide and finally washed with distilled water. The washed sample was dried, powdered and passed through 75µm sieve. The resulted sample was titrated against the methylene blue solution to determine its quality in terms of decolourizing value. The activated carbon thus produced was tested following the Bureau of Indian Standards (BIS) procedure and reported. The quality of activated carbon produced was better than the requirements prescribed in BIS and hence they can be used in the oil, food and pharmaceutical industries. The approximate cost of production of one Kg. activated carbon from Kiluvai was about Rs. 690/- whereas the cost of similar quality (AR grade) activated carbon in the market was Rs. 1700/- per Kg.

Keywords: Kiluvai, *Commiphora berryi*, Activated Carbon.

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INTRODUCTION

Activated carbon is a carbonaceous material with porous structure capable of adsorbing organic compounds contributing colour, odour, taste, etc., in the food pharmaceutical and allied products. It may be either in powder or granular form.

Activated carbons are characterized by a large specific surface area of 300 to 2500 square meters per gram, which adsorbs organic compounds responsible for colour, odour, taste, etc., Activated carbon is mainly used to purify water by adsorbing insecticides, herbicides and other chemicals present in the drinking water (Hassler, 1974). It has many applications in food and pharmaceutical industries. In the food industries, it is used for purification and odour removal during processing of fruit juices, honey, syrup, candy, soft drinks and alcoholic beverages. In the pharmaceutical industries, activated carbon is used for the removal of pyrogens from the solutions prepared for injections, decolourizing and deodourizing of vitamins and purification of insulin (Dhungat, 1987). Such a highly useful activated carbon is presently produced from peat deposits, lime impregnated lignite, coal and low temperature derived brown coal (Dhungat, 1987). Since they are non-renewable in nature and are going to be exhausted soon, it is necessary to find out a suitable raw material of renewable source.

A number of farm wastes and residues, which are lignocellulosic and carbonaceous in nature, are available in plenty and are suitable for the production of activated carbon (Kailappan *et al.*, 2000). Among the various materials available in the farm, Kiluvai (*Commiphora bettysi* (Arn.) Engl.) is available in plenty and do not find any other use except as a fuel in rural areas of south India. Kiluvai is a highly drought resistant, spreading shrub, growing well under all soil conditions and waste lands. It is grown as live fence shrub around the periphery of most of the farm holdings in many parts of Tamil Nadu in India. The sticks of well grown tree is used as fuel and also converted into charcoal by the method of pyrolysis in the rural areas. Hence this material could be more effectively used as a source for the production of activated carbon. The process for the production of activated carbon from Kiluvai and qualities of activated carbon produced are discussed and reported in this paper.

MATERIALS AND METHODS

(i) Production of activated carbon

Stems of about 100 mm diameter were cut from Kiluvai and made in to chips of 2.5 mm thick size and sun dried to 5-7 per cent moisture content (w.b). The dried pieces were grounded in a burr mill and sieved through 500 μ m sieve to get uniform size powder.

Samples of 10 gram Kiluvai powder was mixed with 100, 125 and 150% zinc chloride (by weight of powder taken) and a paste was prepared by adding required quantity of water. The mixture was kept for 24 hours with occasional stirring to complete the reaction (Capareda, 1990). Then the samples were activated at 400, 500 and 600°C for 60, 75 and 90 minutes duration. To avoid the interference caused by the inorganic materials, the activated carbon samples were initially washed with 25 per cent (W/V) hydrochloric acid. After acid washing, the activated materials were neutralized by washing with dilute sodium hydroxide solution (10 per cent) and finally with distilled water till they were free of chloride. The washed samples were oven dried at 150°C $\pm$ 1°C for three hours and cooled in a desiccator (Hassler, 1974). The experiments were replicated thrice and the average value was worked out. The samples were powdered and sieved through 75 μ m sieve and stored in air tight container for further quality analysis.

(ii) Quality of activated carbon

The quality of the activated carbon produced was assessed based on the volume of methylene blue (150 mg of methylene blue dissolved in 100 ml of distilled water) adsorbed by 100 mg of activated carbon sample and expressed as volume of methylene blue adsorbed in ml (IS 877: 1989). Hence, all the activated carbon samples produced were tested for their methylene blue adsorption values to optimize the different parameters involved in the process of production of activated carbon from Kiluvai.

The quality characteristics of the activated carbon produced from Kiluvai powder was analysed for the best treatment by following the Indian Standard, IS 8366: 1989.

(iii) Cost of production

The cost of production of one Kg of activated carbon from Kiluvai was estimated by calculating the fixed and operating costs of different equipment viz., muffle furnace, vacuum pump, hot air oven, sieve, pestle and mortar, cost of chemicals, labour charges and miscellaneous expenses (Palanisami et al., 1997).

Production of activated carbon

The activated carbon produced during different combinations of activation temperature, activation period and percent zinc chloride mixed are given in Table 1. It is depicted from the Table 1 that the parameter namely level of zinc chloride mixed, exhibited a direct proportional relationship with activated carbon production, whereas the parameters namely, activation period and temperature exhibited an inverse relationship with quantity of activated carbon production. It is seen from the Table 1 that, maximum quantity of 62 per cent

of activated carbon produced by the power mixed with 150 per cent of zinc chloride and activated at 400°C for 60 minutes and the Kiluvai powder mixed with 100% zinc chloride and activated at 600°C for 90 minutes yielded lowest quantity of activated carbon (34.4%).

Table. 1. Effect of activation temperature, zinc chloride addition and duration of activation on quantity of activated carbon produced from Kiluvai

Sl. No.	Activation temperature (°C)	Activation period (min)	Activated carbon produced (%)		
			Zinc chloride mixed		(%)
			100	125	150
1	400	60	54	58.4	62
2	400	75	49	55.6	58
3	400	90	46	50	52.4
4	500	60	49.6	54	59.4
5	500	75	44.8	48	52
6	500	90	38.4	44.4	46.6
7	600	60	46	50.6	54.8
8	600	75	39.2	44.2	46.4
9	600	90	34.4	38	43.2

When the sample was activated for longer duration, irrespective of activation temperature, the decreasing trend in activated carbon production was observed and that could be due to the loss of carbon by oxidation at longer duration of activation. The increasing trend in activated carbon recovery was observed incase of lower duration of activation period. This may be due to the fact that, at lower duration of activation period, partial carbonization of raw material might have taken place and hence it recorded a higher quantity of activated carbon recovery.

Quality of activated carbon

The quality of activated carbon produced was estimated in terms of methylene blue adsorption (IS 877: 1989). The results of methylene blue adsorption by the activated carbon produced by different combinations of activation temperature, per cent zinc chloride mixed and at different periods of activation are shown in Table 2.

From Table 2, it is seen that at all levels of activation temperature, the methylene blue adsorption value increased upto 75 minutes of activation and decreased during further increase in the period of activation. This may be due to the fact that at longer duration, a part of zinc chloride may dissociate as zinc and chloride. The heavy metal, zinc, may be adsorbed on the activated surface resulting in low methylene blue adsorption. Kailappan et. al., (1988) also reported similar results.

In all the treatments conducted, methylene blue adsorption values were higher in the samples activated with 125% zinc chloride for 75 minutes duration. Another trend observed was the samples mixed with 125% per cent zinc chloride recorded high methylene blue adsorption values and further increase in zinc chloride mixing yielded less adsorption values for all the level of activation temperature.

It is observed from the Table 2 that, low methylene blue adsorption value of 4.5 ml was recorded by the activated carbon produced at 400°C with 100 per cent zinc chloride activated for 60 minutes where as the sample mixed with 125 per cent of zinc chloride and activated for 75 minutes at 500°C recorded the highest methylene blue adsorption value of 17.1 ml.

Table 2. Effect of activation temperature, zinc chloride addition and duration of activation on quality of activated carbon produced from Kiluvai

Sl. No.	Activation temperature (°C)	Activation period (min)	Methylene blue adsorbed (ml)		
			Zinc chloride mixed (per cent)		
			100	125	150
1	400	60	5.4	10.6	9.2
2	400	75	7	12.7	10.4
3	400	90	6.9	11.1	8.5
4	500	60	6.4	12.3	11.3
5	500	75	9.1	17.1	14.3
6	500	90	7.6	14.2	9.5
7	600	60	6	9	8.5
8	600	75	8.7	13.5	12
9	600	90	7.2	12	10.5

For the purpose of optimization of production process, the total quantity of methylene blue adsorbed obtained by multiplying quantity of activated carbon produced taken was considered. Among all the treatment the Kiluvai powder mixed with 125 per cent zinc chloride, activated at 500°C for 75 minutes recorded the maximum volume of methylene blue adsorption value of 82.1 ml.

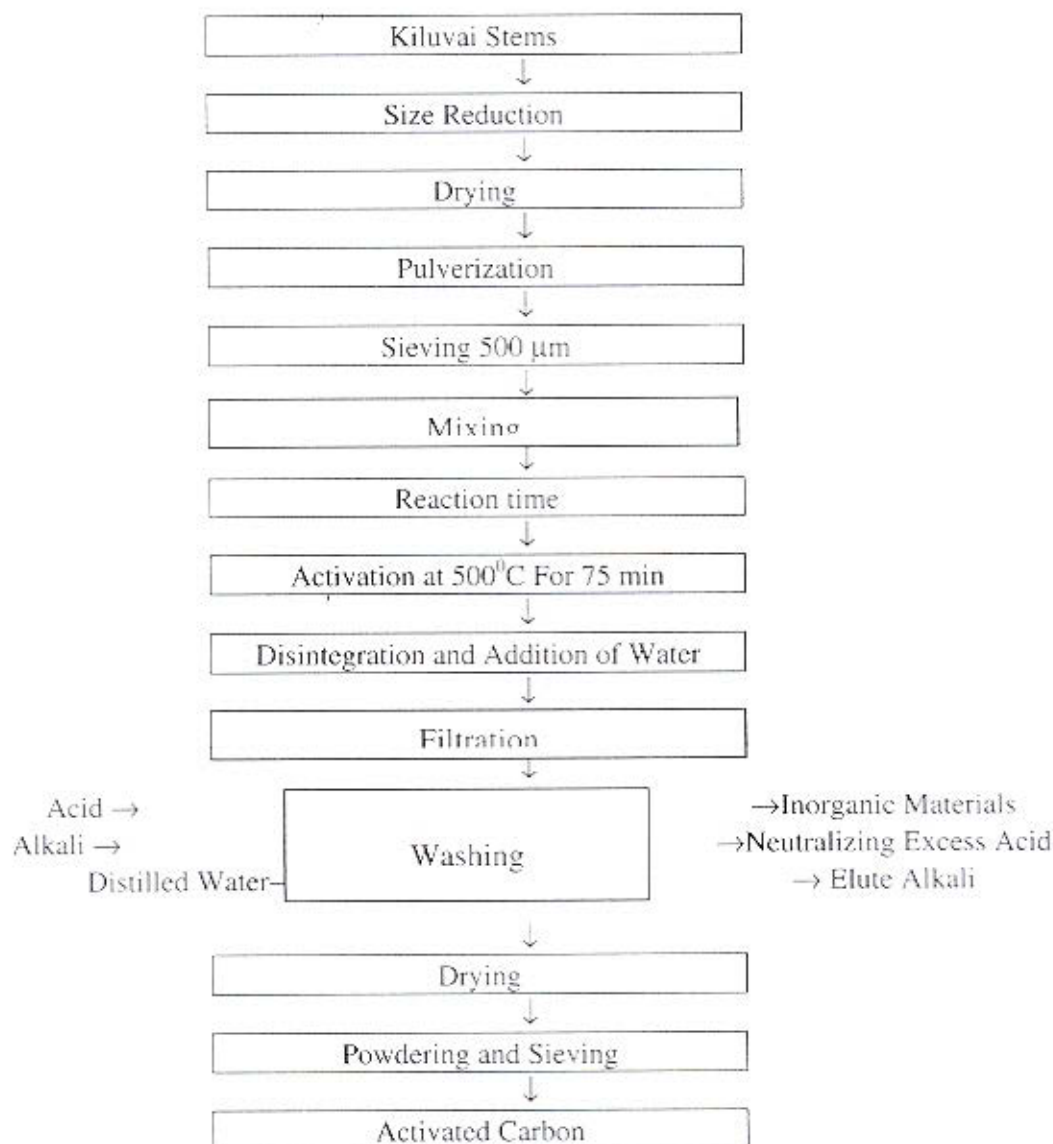


Fig. 1. Flow diagram for the production of activated carbon from Kiluvai

Hence, Kiluvai powder mixed with 125 per cent zinc chloride and activated at 500°C for 75 minutes is considered as the best treatment in which all the activation parameters were involved at optimum level and produced quality activated carbon having the maximum methylene blue adsorption value. The flow diagram describing different unit operations involved in the optimized processes for the production of activated carbon from Kiluvai is shown in Fig. 1.

Table 3. Quality characteristics of the activated carbon produced from Kiluvai

Sl. No.	Characteristics	Activated carbon produced from Kiluvai	Requirements (as per IS 8366: 1989)		
			Type 1 (oil industry)	Type 2 (Food industry)	Type 3 (Pharmaceutical)
1	Moisture (per cent, w.b)	9	15 (max)	15 (max)	15 (max)
2	Ash (per cent by mass)	10.98	60 (max)	40 (max)	20 (max)
3	Matter soluble in water (per cent by mass)	0.22	-	1.5 (max)	0.5 (max)
4	Matter soluble in acid (percent by mass)	2.19	6 (max)	6 (max)	2.5 (max)
5	pH	7.5	5-8	5-8	6.5-7.5
6	Decolourizing power (mg/g)	256.5	50(min)	70 (min)	205 (min)
7	Filterability (minutes)	14 Minutes & 52 seconds	46 (max)	-	-
8	Oil retention (per cent by mass)	26	30 (max)	-	-
9	Particle size	Powdered & sieved through 75 µm sieve. Hence, powder size is 75 µm & less.	Passing through 150 micron- 100% 125 micron – 95% 75 micron – 80%	100% 95% 80%	95% 95% 80%

The results of quality analysis carried out on the activated carbon produced by the best treatment is given in Table 3. The quality characteristics evaluated and presented in the Table 3 clearly indicates the suitability of activated carbon produced from Kiluvai in oil, food and pharmaceutical industries.

Cost of production

Estimation on cost of production of activated carbon from Kiluvai revealed that the cost of one kg of activated carbon was found to be Rs. 690/- where as the cost of one kg of activated carbon of equal quality (AR grade) in the market was about Rs. 1700/-

CONCLUSION

From this study, Kiluvai, a high drought resistance shrub, mostly used as fire wood in rural areas, was found suitable for the production of activated carbon. Good quality activated carbon confirming the requirements as per IS 8366: 1989 could be produced from Kiluvai powder, by mixing it with 125 per cent zinc chloride (by weight of powder taken) and activating it at 500°C for 75 minutes.

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The results of quality analysis carried out on the activated carbon produced by the best treatment is given in Table 3. The quality characteristics evaluated and presented in the Table 3 clearly indicates the suitability of activated carbon produced from Kiluvai in oil, food and pharmaceutical industries.

Cost of production

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LONG-TERM EFFECT OF DIFFERENT SOURCES OF ORGANIC MANURES ON WHEAT SOYBEAN ROTATION

S.L. MASKEY¹, S. BHATTARAI AND K.B. KARKI

ABSTRACT

A long term experiment was conducted at Agronomy Farm (Khumaltar) upland site in RCBD with 3 replications and 9 treatments. Different sources of organic manures like FYM, compost biogas slurry, poultry manure, city waste compost and waste from mushroom cultivation were tested. All organic sources were equally effective and increased grain and straw yield of wheat and soybean in wheat soybean rotation. These treatments also increased the numbers of root nodules and nodule weight. The tested organic manures increased C, N, P, K, B, Zn, Ca and Mn content of soil. Different sources of organic manures on test increased porosity, maximum water holding capacity and hydraulic conductivity of soil but decreased bulk density.

Keywords: Organic farming, Crop rotation, Soybean, Wheat, Soil fertility, Nepal

INTRODUCTION

Nepalese agriculture is based in organic manure and much emphasis is laid on the role of organic matter in soil productivity because of its beneficial effects in supplying plant nutrients, enhancing cation exchange capacity, improving soil aggregation, water retention and supporting soil biological activity (Dudal & Deckers, 1993; Badamur et al, 1990). In addition, organic soil amendments control some root pathogens (Buruchara, 1992). Depending on the availability of manure and crops to be grown, the amount of manure used varies from 10 to 60 tons per hectare per year. In Nepalese condition normally 15 t/ha of organic manure is recommended. In many of the cases farmers apply manure for every crop in

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succession. Since highly erosive power of torrential monsoon rains wash away fertile surface soil and applied organic manure Nepalese farmers are forced to apply the equal amount of compost or Farm Yard Manure to every crop in succession to maintain soil fertility.

Gardner (1977) explained the beneficial effect of organic matter on crop production. Application of organic manures increased efficiency of chemical fertilizer and nitrogen, phosphorus and potassium uptake by different crops (Dixit & Gupta 2000). Applied organic manure also increased micronutrient uptake in crops (Badamur *et al.*, 1990; Singh *et al.* 1999). Use of organic manure on terraced farms increases infiltration rate, reduces surface run off and less soil erosion (Carson, 1985). However, use of organic manures in Nepalese agriculture is reduced significantly after the introduction of chemical fertilizer since mid-sixties.

Different types of organic manures and their effect on crops and soil were studied extensively. Positive effect of poultry manure on crops were studied by Toor *et al.* (2001); and Dosani *et al.* (1999); effect of FYM and Vermin-compost by Srikanth *et al.* (2000). Similarly, the effect of biogas slurry was tested by Gupta *et al.* (2000); Karki (2003). Considering the importance of long-term effect of these organic manures on crop production and soil fertility, a long term experiment was conducted on wheat/soybean rotation to study the effect of different locally available organic manures, at Khumaltar in Lalitpur, Nepal from 1991 to 2002 for ten years in the same field.

MATERIALS AND METHODS

This experiment was conducted on soil belonging to Haplustalf (great group-USDA soil Taxonomy). Texture was loam with total N content of 0.131%. Organic matter content was medium (2.68%) and high in available phosphorus (13.45 mg P/kg) and available potassium (184.3 mg/kg). Soil reaction was acidic (pH 5.6). A long-term experiment was started at Khumal Agronomy Farm, Lalitpur, Nepal, and upland condition in November 1991 to April 2002 for 10 years and was designed in RCBD with 9 Treatments and 3 replications. Locally available organic manures like, farmyard manure, compost, bio-gas slurry, poultry manure, waste from mushroom cultivation and city waste compost were applied to wheat and soybean crops and their effect on crop production were compared to that of NPK fertilizer. The amount of FYM, compost and city waste compost was taken for study was 15t/ha. Because of higher content of total nitrogen in chicken manure and biogas slurry 5t/ha of poultry manure and 10t/ha of biogas slurry were applied. Recommended dose of NPK fertilizers (100:40:30) and one kg of inoculums was supplied to wheat of variety NL 297 and soybean variety Ransom.

The treatments in the experiment were as follows:

<u>SN.</u>	<u>Treatments</u>	<u>Rate of application</u>
1.	T ₁	Control
2.	T ₂ Azotobacter/Rhizobium	1 kg inoculums/ha
3.	T ₃ Compost *	15t/ha
4.	T ₄ FYM	15t/ha
5.	T ₅ Poultry manure	5t/ha
6.	T ₆ Biogas slurry	15t/ha
7.	T ₇ City waste compost	100:40:30 NPK
8.	T ₈ Chemical fertilizer	15t/ha
9.	T ₉ Mushroom Waste Compost	

* Compost is a mixture of dung and dry matter

Nutrient content of the different organic manure is presented in Table 1. Chicken manure contained highest amount of total nitrogen followed by city waste compost, mushroom waste and biogas slurry. Although, P and K played significant role in plant nutrition and varied amounts were present in the different organic manure only N content of these manures were considered.

Table 1. Nutrient Content of Organic Manures Used in the Experiment

<u>S.N.</u>	<u>Organic manures</u>	<u>Nitrogen (%)</u>	<u>Phosphorus(%)</u>	<u>Potassium(%)</u>
1	Compost	0.99	1.24	2.39
2	Farm Yard Manure	0.65	1.00	1.40
3	Poultry manure	3.00	3.56	3.03
4	City waste compost	1.90	3.36	2.39
5	Mushroom Waste compost	1.83	2.30	2.92
6	Dry biogas slurry	1.65	0.85	1.61

Procedure of Soil Analysis

Composite soil samples from 0-10 cm depth were collected before planting and after harvest of each crop, dried, sieved and analysed for pH in soil and water paste (1:1); organic matter (Walkley and Black method); total nitrogen (Kjeldhal method) available P (Bray II), available K by flame ignition after extracting with 1 N, neutral ammonium acetate. Soil texture was analysed following procedure outlined by Day (1965). Water holding capacity, bulk density and infiltration rate were measured following procedure mentioned in PCARRD (1980). Exchangeable cations were extracted by 1 N neutral ammonium acetate whereas micronutrients were analysed according to method explained by Lindsay and Norvel (1978) and detected by ICP. Boron was analysed by Hot water extraction method as outlined by Berger and Troug (1939).

RESULTS AND DISCUSSION

Grain yield of wheat and soybean

Ten years pooled data of grain yield of wheat obtained due to different treatments showed that all organic manures increased wheat yield significantly over control (Table 2). Maximum grain yield of 1.9 t/ha was observed in recommended dose of NPK (T8) treatment followed by 1.78 t/ha produced by FYM (T4) and then compost (T3) which was 1.63 t/ha. Though 1/3 amount (5 t/ha) was applied, poultry manure (T5) produced (1.67 t/ha) at par results to other organic manure. Likewise 2/3 amount of biogas slurry (10 t/ha) produced almost equal amount of wheat grain yield (1.54 t/ha). But none of the treatment results were significantly different from one another i.e. application of different sources of organic manures. Yield response by these sources of organic manures were equally effective.

With regards to the grain yield of soybean mushroom waste compost (T9) produced the highest yield results (1.55 t/ha) followed by city waste compost (T7) that are presented in table 3. Likewise the yield results were 1.4 t/ha as affected by the application of city waste compost by poultry manure (1.38 t/ha) and FYM (1.35 t/ha). Unlike wheat grain yield the results of poultry manure and biogas slurry were inferior to city waste compost and FYM. The soybean grain yields produced by other treatments were much lower but were at par to one another indicating indifference in the nutritive value of these organic manure.

Table 2. Grain yield of wheat (kg/ha)

Treatment	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Pooled 10 years
T1	2271	958	813	979	667	667	1063	1063	1417	1000	1090
T2	2625	1163	1021	854	625	604	1750	1375	1958	1104	1308
T3	2792	1388	1342	1396	938	854	1854	1938	2250	1500	1625
T4	3104	1915	1396	1333	1104	917	2104	1978	2375	1583	1781
T5	3125	1771	1188	1354	1313	750	1813	1396	2000	1938	1665
T6	3292	1592	1438	1333	1042	813	917	1292	1958	1729	1540
T7	2792	1250	1271	2354	1375	1146	1208	1417	1898	1125	1584
T8	3667	1500	1646	2125	1438	875	1938	1750	2458	1583	1898
T9	3021	1429	1750	1313	1333	875	1604	1979	1917	1563	1678
Mean	2965	1441	1318	1449	1093	833	1583	1577	2026	1458	1574
P value	0.16	0.260	<0.001	<0.001	0.015	0.254	0.002	0.315	0.063	0.032	<0.001
CV%	17	30.0	15.3	19.9	25.4	27.1	19.5	33	17	21.8	22.9
LSD (T)	911	748.1	349.4	498.8	480.5	391.1	533.5	899.7	596.8	551	186.9
LSD (Y)											243.8
LSD (YXT)											594.5
LSD (Except wheat comparing means with the same level/s of year)											581.6

Pannerselvam and Lourduraj (2000) conducted similar experiment and reported that FYM, Sheep manure and biogas slurry increased production but not high as compared to mineral fertilizer (120:40:30 NPK kg/ha). Since organic manures contain small amount of nutrients, to supply required amount of plant nutrient it should be applied in larger amount.

Table 3. Grain yield of soybean (kg/ha)

Treatment	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Pooled 10 years
T1	3083	1504	1708	708	813	688	458	458	354	678	1045
T2	3083	1792	1933	937	979	667	375	917	365	703	1175
T3	3083	1354	2063	1083	1021	833	625	1167	458	756	1244
T4	3229	1563	2104	1063	1146	1000	604	1313	708	782	1351
T5	2948	1604	2042	937	1313	958	458	1000	698	703	1266
T6	2958	1896	2563	958	1083	646	625	813	656	1563	1376
T7	3198	1313	2333	1031	1438	1229	625	1021	896	833	1392
T8	3073	1488	1517	792	896	750	458	521	552	443	1049
T9	3000	1729	2542	1167	1417	1333	750	1688	888	964	1548
Mean	3073	1582	2089	964	1123	900	553	988	619	825	1272
P value	0.99	0.318	0.001	0.008	0.105	0.008	0.02	0.005	<0.001	<0.001	<0.001
CV%	12.8	18.9	12	12.8	24.1	23.7	20.7	31.2	20.1	21.9	19.2
LSD (T)	683	516.3	433.6	214	469.2	370.1	198.6	533.7	215.1	312.2	124.7
LSD (Y)											223.2
LSD (YXT)											427.8
LSD (Except wheat comparing means with the same level/s of year)											394.4

However, to get maximum yield, combination of organic and inorganic fertilizer is the best option (Babhulkar *et al.* 2000). Among different sources of organic manures poultry manure is recognized as a valuable fertilizer for crop production. Because of higher amount of NPK present in poultry manure even 5 t/ha resulted at par results with 15 t/ha of other organic manures. It is because nutrients in poultry manure are readily available to crops and has

noteworthy residual effect (Singh et al., 1999; Dosani, et al. Guu et al., 1997; and Singh et al 1999). Brar, et al (1999), Khalel et al. (2000) and Pannerselvam and Lourduraj (2000) reported similar results of biogas slurry. Results of city waste compost were reported by Maskey and Bhattarai (1994); and Karki (1995); effect of mushroom waste by Ranganathan and Selvaccelan (1997); and that of FYM by Kumar and Yadav (1995) and Karki (1995). In this study all types of organic manures increased the yield of wheat as well as soybean.

Straw and Biomass Yield of Wheat and Soybean (kg/ha)

All types of organic manures increased straw yield of wheat significantly different, which was comparable to the straw yield obtained due to recommended dose of NPK application (Table: 4). Maximum straw weight of 2.6 t/ha was obtained in plots receiving poultry manure indicating vigorous growth of the plants. Though not the highest, wheat grain yield was also next to highest as an effect of poultry manure.

Unlike the experimental result published by Brar et al. (1999) where biogas slurry produced outstanding results to that of FYM and mineral P application, the straw yield of wheat and soybean, in this case, was inferior to that of results as affected by poultry manures compost, FYM and mineral fertilizers. Effect of poultry manure in the higher production of grain as well as strew yield, could be due to other elements present in the poultry feeds since all the nutrients additive in the feeds are not absorbed in the physiology of the birds and most them are dropped in the form of excreta which proved to be a better manure.

In soybean too stubble yield was increased significantly due to different sources of organic manure. Chemical fertilizer application did not increase stubble yield of soybean. Effect of chemical fertilizer was lowest among all the treatment (0.75 t/ha). This could be due to the effect of mineral nitrogen applied to the leguminous crops, which inhibited the nitrogen fixing ability of the microorganisms. Additionally, this could be due to physiological characteristics of soybean. In soybean leaves senesced before maturity, which also explains by low stubble yield of soybean.

Table 4. Straw weight of wheat, stubble wt, biomass and root wt of soybean (Average of 10 years)

Treatment	Wheat Straw (kg/ha)	Soybean		
		Stubble (kg/ha)	Biomass wt. (gm/4 plants)	Root wt. (gm/4 plants)
1	1318.0	823	642	17.8
2	1667.0	951.0	676	18.0
3	2229.0	1207.0	838	18.7
4	2078.0	1352.0	763	15.6
5	2589.0	1303.0	757	19.2
6	1604.0	1373.0	813	18.7
7	1839.0	1199.0	754	16.2
8	2037.0	753.0	677	16.9
9	1901.0	1292.0	851	20.5
Mean	1918.00	1139.00	75.0	17.95
P Value	<0.001	<0.001	00.770	0.3770
LSD	339.70	315.40	310.0	4.15
CV%	21.70	34.00	154.3	31.80
LSD (Y)	368.30	181.00	201.6	4.07
LSD (Y.T)	715.10	614.00	400.7	9.46

Biomass (shoot/root) weight of soybean

The weight of soybean sampled at early flowering stage also showed positive effect due to different sources of organic manures, compost, digested biogas slurry and mushroom waste compost gave significantly higher yield than other treatments (Table 4). Among the

application of different sources of manure and fertilizer highest shoot yield is recorded by the application of mushroom compost (85 gm/4 plants) followed by compost, biogas slurry and city waste compost. Shoot yield as resulted by the chemical fertilizers was much lower as compared to organic manure (67.7 gm/4 plants).

Corresponding result of root growth as affected by the different treatments is similar to the shoot weight. Highest root yield was recorded with the mushroom compost treatment followed by compost biogas slurry and poultry manure. But the ratio of shoot and root differed. Highest ratio is observed in FYM treatment followed by city waste compost, compost, biogas slurry and chemical fertilizer. Likewise the lowest ratio was recorded in case of control and then micro-organisms treatments.

Rhizobium fixes nitrogen, which is directly related to the weight of nodules in legumes root. Nodules are the houses of microorganisms, where they fix atmospheric nitrogen and store for their own future use or contribute to other crops symbiotically. Since Rhizobium bacteria derive their energy from carbon source, the effect of organic manure has direct impact on soil C increment which increased nodule weight and hence positive effect on nitrogen fixation.

Ultimately it increases the biomass as well as grain yield of legumes. Nodules were collected from the experimented plants at 50% flowering stage they were dried and weighed. All sources of organic manure increased nodule weight (Table 5.). Highest weight of nodule was recorded in the mushroom waste compost treatment followed by biogas slurry treatment. As usual control treatment had the lowest nodule number.

All the organic manure treatments increased root nodules over control. Highest numbers of nodules were found in the mushroom waste compost treated plots (1358) followed by biogas slurry treatments (1274) and compost treatments (1268). Lowest numbers of nodules were found in the control that was 857 nodules (Table 5). Rest of the treatments produced almost similar results. Organic manure produced different Types of enzymes that helps produce higher numbers of nodules. Muller et al. (2000), and Pantalone et al. (1999) reported similar results.

Table 5. Number and weight of soybean nodules as affected by different treatments

Treat ment	Nodules numbers and weight							
	No./4 plants	Wt. (Kg/ha)	No./4 plants	Wt. (Kg/ha)	No./4 plants	Wt. (Kg/ha)	No./4 plants	Wt. (Kg/ha)
	1994-95		1995-96		1996-97		Mean	
1	1371	1792	813	289	388	529	857	652.8
2	1634	1500	850	409	413	633	1066	636.0
3	2246	1542	800	451	759	471	1268	616.8
4	1671	2042	813	363	683	425	1056	708.5
5	1929	1667	384	366	584	958	1066	749.0
6	2267	2042	500	374	1054	742	1274	791.0
7	1775	1917	784	363	534	984	1031	817.8
8	2042	1542	696	450	429	571	1056	642.8
9	2400	1667	738	424	938	621	1358	680.3
Mean	1959	1745	742	387	642	659	11500	699.4

Effect of organic manures on Nutrient Content of Soil

Major nutrients (pH, NPK and organic matter) as well as micro-nutrients B, Mg, Fe, Cu, Zn and Mn were increased due to application of different sources of organic manure (Table 6). Soil organic matter content was increased from 1.29% in control to 1.83% due to manure application, which is 45% higher. This increment was due to continuous application of organic manure for 10 years. Similarly total nitrogen, phosphorus, potassium and micronutrients like B, Fe, Cu, Zn, and Mn were also increased in soil.

Organic manure are not only sources of major nutrients but also contain micronutrients, which is evident from the increase in macro and micronutrients in soil due to application of organic manures. Organic manures like compost and biogas slurry are also good sources of phosphorus. Brar *et al* (1999) reported increment on dry matter yield and total P uptake of wheat due to FYM and Biogas slurry applications. Triboi and Gauchan (1988)

also reported enhanced P nutrient and increment of P nutrient in soil due to addition of organic manures. Carbon content of soil is very important for soil health and increase in production and productivity of crops and even for increase and multiplication of useful microorganisms in soil. This experiment shows the importance of organic manures in increasing nutrient status of the soil

Impact on soil physical Properties

Organic matter content plays an important role in building soil physical properties such as bulk density, porosity percentage, water holding capacity and aggregate stability. In this long-term experiment, there has been noteworthy improvement on bulk density. Surprisingly, addition of organic manure decreased bulk density to some extent, which could not be explained. In chemical fertilizer treatment with recommended dose of NPK, bulk density has decreased by 0.02 unit (Table 7).

Although application of chemical fertilizer increases total root biomass (Table 4), bulk density was decreased. Unpredictable decrease in bulk density as affected by the application of micro-organisms could be due to increase in the microbial population which was not counted. All the other treatments have positive effect on the bulk density. Similar effects have been noticed on the porosity percentage as well. The implication of decrease in bulk density is positive in soil. It increase aeration and also tillage becomes easy.

Water holding capacity as an impact of organic matter treatments has been apparent. No change has been observed in the micro organisms and chemical fertilizer treatments over control. All the other treatments have some increase on the water holding capacity. It is obvious that addition of organic matter would absorb water equal to its volume (Allison, 1973; Sharma et al. 2000). Similar results have been reported by Badamur et. al (1990) and Dudal and Decker (1993).

As mentioned by Carson (1985) infiltration rate has also been positively affected by the addition of the different organic matter (data not shown). Large differences have been observed with the addition of compost, FYM, and poultry manure. Application of micro organisms also increases infiltration rate by 1 mm/hr.

Table 7. Impact of experiment on the physical properties of soil after 10 years

Treatments	Bulk density (g/cc)	Porosity (%)	Water Holding Capacity % (Max.)
Control	1.17	57.4	65.7
Micro organisms	0.98	58.7	65.7
Compost	1.0	57.5	68.3
FYM	1.08	59.2	69.0
Poultry manure	1.14	59.4	66.0
Biogas Slurry	1.09	58.1	66.1
City waste compost	1.18	58.0	68.2
Chemical fertilizer (NPK)	1.19	58.6	65.7
Mushroom compost	1.07	59.2	66.5

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GAMMA IRRADIATION INDUCED CHLOROPHYLL MUTATIONS IN RICE (*Oryza sativa* L.)

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T. MOHAMMED¹ AND N. N. MASTOI¹

ABSTRACT

Air-dried grains of three local rice varieties (Sarshar, Shua-92 and IR8) were treated with gamma rays (150, 200 and 250 Gy) for determining their mutagenic effectiveness through the occurrence of chlorophyll mutations. The effective dose was 200 Gy in inducing chlorophyll mutations and the rice variety Sarshar had the maximum number of mutations followed by the varieties Shua-92 and IR8. The highest frequency of chlorophyll mutations was that of albina types followed by striata types. The xantha, viridis and tigrina types of mutations were less frequent. The radiation doses used in the present study were also found appropriate for induction of mutation in rice.

Key words: Radiation, Chlorophyll, Mutants, Rice, *Oryza sativa* L.

INTRODUCTION

Several types of chlorophyll deficiencies occur in seedlings of mutagenic treated plants. Some of these deficiencies like *albina* are lethal, while some others are with partial deficiencies like *virescent* and *chlorina*, which continue to survive, but with reduced vigour. The frequency of occurrence of these chlorophyll deficient seedlings in the treated population is generally considered an appropriate measure for determining the effectiveness of a mutagen. (Bari *et al* 1985, Baloch *et al*, 1999, 2001a, 2001b and 2002). The present studies were undertaken to determine the mutagenic effectiveness of gamma rays for inducing mutations in different rice varieties.

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MATERIALS AND METHODS

Air-dried, unhusked grains of three non-aromatic, semi-dwarf rice (*Oryza sativa* L.) varieties viz. IR8, Shua-92 and Sarshar were treated with different doses of gamma rays. The moisture content of the grains at the time of irradiation was 11% and the doses given were 150, 200 and 250 Gy of gamma rays from the ^{60}Co radiation source from the Nuclear Reactor. The radiation treatments were given at the Seibersdorf Laboratories of the International Atomic Energy Agency, Vienna, Austria. Five hundred grains per treatment were taken from each variety for these studies. The treated grains were sown along with untreated grains in nursery beds, and one month old treated and untreated seedlings were transplanted in the field keeping a uniform distance of 20 cm between plants and rows. At maturity, the five first formed panicles of each M_1 plant from each treatment as well as from the untreated control plants were harvested individually. The M_1 panicles thus harvested were subsequently sown separately, without threshing; in the seedbeds and the M_2 seedlings raised thereafter were scored for chlorophyll deficiencies in the second week after their germination. The non-irradiated grains were also sown along with the irradiated material in the seedbeds for comparative studies.

The chlorophyll deficiencies in the seedlings were classified into five groups viz., *albina*, *xantha*, *viridis*, *striata* and *tigrina*. The *albina* were white seedlings, and the *xantha* had pale yellow leaves. Both of these types survived only for one or two weeks after germination. In the *viridis* type of seedlings, there was some delay in the development of chloroplastid pigments in their leaves. They were pale yellow in colour, but gradually turned green. The *striata* seedlings had white longitudinal streaks on normally green leaves, while the *tigrina* seedlings had variegated green and yellow patches on the leaves. The mutation frequency was expressed as the number of chlorophyll mutants per 100 M_2 seedlings.

RESULTS AND DISCUSSION

The chlorophyll mutations were induced effectively by gamma rays (Table 1). The frequency of albino type mutations was higher as compared to other types of chlorophyll mutations. It was followed by the *striata* types. The remaining three types i.e. *xantha*, *viridis* and *tigrina* were less frequent. The average occurrence of *albina* mutants in all the three varieties of rice was only 2.05%, followed by *striata* mutants (0.7170). The remaining three types i.e. *xantha*, *viridis* and *tigrina* were much less frequent in the present mutagenic. The most effective doses of gamma rays for inducing chlorophyll mutations were 200 Gy for all the varieties (Sarshar, Shua-92 and IR8).

The occurrence of chlorophyll mutations in plants is a complex phenomenon. The chlorophyll mutations could result from the interference in chlorophyll synthesis (Raisinghani & Mahna, 1996; Von Wettstein, 1960), such inference may arise due to obstruction in the formation of accessory pigments (Koski & Smith, 1951; Anderson & Robertson, 1960), due to anomalies in the structural development of chloroplasts and consequently the photosynthetic pigments (Von Wettstein, 1961), and interference in the formation of essential metabolites that are necessary for the development of normal chloroplast structure and chloroplast pigmentation (Walles, 1963; Redei, 1965).

The mechanism of mutability of different varieties of crop plants is considered closely related to their radio sensitivity, and several factors like physiological properties inside the cell and the nucleus (Gustafsson, 1944), nuclear volume and DNA content (Sparrow & Evans, 1961; Sparrow *et al.*, 1961), chromosome size (Bari & Godward, 1969), and ploidy level (Conger *et al.*, 1982) such factors have been shown to influence the radio sensitivity of plants.

Table 1. Spectrum and frequency of chlorophyll mutations induced by gamma rays in rice

Variety	Radiation dose (Gy)	Number of M ₂ seedlings analysed	Types and frequency of chlorophyll mutations (%)					Total frequency of mutations (%)
			<i>Albina</i>	<i>Xantha</i>	<i>Viridis</i>	<i>Striata</i>	<i>Tigrina</i>	
Sarshar	0 (control)	2475	--	--	--	--	--	--
	150	2015	1.57	0.05	0.08	0.63	--	2.33
	200	1650	1.83	0.19	--	0.69	--	2.71
	250	1225	0.35	--	--	0.19	--	0.54
Shua-92	0 (control)	2460	--	--	--	--	--	--
	150	1815	0.88	0.14	0.01	0.05	--	1.08
	200	1210	0.10	--	--	0.08	0.08	0.26
	250	1140	0.26	--	--	0.39	--	0.65
IRS	0 (control)	2485	--	--	--	--	--	--
	150	1945	0.51	--	0.03	0.04	--	0.58
	200	1460	0.36	--	--	--	--	0.36
	250	1100	0.28	--	--	0.04	--	0.32

In the present studies, considerable differences were observed in the response of different varieties of rice to radiation treatments. Earlier workers have found gamma rays, to be more effective in inducing chlorophyll mutation than other rays (Futsuhara *et al.*, 1967; Somoto, 1975; Okuno & Kawai, 1977; Sato 1982 & Min *et al.*, 1989). However, the response of genotypes varied. The variety Sarshar produced more chlorophyll mutations than others (Baloch *et al.*, 2002) different treatments of radiation produced different spectra and frequencies of chlorophyll mutations in different varieties. Such differences in radiation response indicate that several physical and biological factors are involved in the mutational process. Thus, it becomes extremely difficult to predict the occurrence of mutations in different varieties of crop plants. Nevertheless, it can be concluded that radiation doses used in the present studies were, by and large, most appropriate for inducing mutations in rice.

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