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ADOPTION OF COMMERCIAL BROILER AND LAYER PACKAGES OF BANGLADESH: A MEANS OF EMPOWERING WOMEN FOR RURAL DEVELOPMENT

S.M.A. RAHMAN[1], M.A. SAYEED[1], N.R. SARKER[1], J. ALAM[1] AND M. M. RAHMAN[1]

ABSTRACT

This study was conducted on 11 broiler and 11 layer female beneficiaries of commercial broiler and layer packages under the incentive coverage of Poultry Management Improvement Technique Project (PMTIP) in 5 different Agro-ecological Zones of Bangladesh to determine the status of women in family and in society. The results showed that among the beneficiaries, 44% broiler and 31% layer farmers were women. Participation of women labour was 13.14, 16.98, 19.62 man-days/batch in broiler and 34.95, 41.64, 42.31 man-days/batch for layer packages for I, II, III categories of farms, respectively. Participation of women in decision making on household expenditure, children education, marriage of daughter/sons, participation in *salish* (Village- Suits) increased in commercial broiler and layer beneficiary farms. The overall membership of women in Non-Government Organizations (NGOs) increased by 20% in broiler beneficiaries and 33% in layer beneficiaries in post-intervention period compared to pre-intervention period. In layer beneficiary farms, the membership of women in Union Council (UC) and *Gram Sarker* (Village Administration) increased by 67%, and 33%, respectively. All these evidences revealed that introduction of commercial broiler and layer packages enhanced women's status in family and society in those rural areas of Bangladesh.

INTRODUCTION

Women in Bangladesh constitute about a half of the population (51% male and 49% female). An overwhelming majority of the rural women are poor. Most of them neither have ownership over the means of production nor do they have access to institutional credit. They are economically deprived and socially disadvantaged. They are lacking in socio-economic empowerment. They desperately need productive and remunerative employment opportunities (Alam, *et al*. 1997).

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[1] Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka

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Bangladesh being an agricultural country, livestock plays a vital role on crop production. In a family based peasant economy of Bangladesh, though women earn a considerable amount of income from agricultural and non-agricultural sources, they are neither the beneficiaries nor are they owner of the means of production. Their activities are mainly concentrated in taking care of children and other family members, preparing and serving food to family members and taking care of domestic animals and birds. Irrespective of classes, women are involved in almost all management practices of duck and poultry production. However, the job they perform at the household level is almost unpaid (Alam, *et al*., 2003).

Situation of rural women in Bangladesh presents a dismal picture. They are under-privileged and mostly illiterate. Schooling is not always favourable for them. ‘Purdah’ and early marriage usually prevent them from getting education. They are dominated by patrimonial and patriarchal kinship systems which maintain a set of social relations with a material base that enables men to control property, income and enforce dependence of woman on man. Although religion of Islam grants the right of property to women but due to their low socio-economic status, their legal rights can hardly be exercised.

Status of woman is an important factor affecting the socio-economic development of a country. There is no single indicator to measure the status of women in the society. Status of women depends on access to material resources like food, income, land and other assets within the family. The role women in decision making process in livestock and poultry production was directly related with their magnitude of involvement in different management practices. Higher the rate of participation in different management practices for livestock and poultry production, the higher was the rate of participation in decision making process (Alam, *et al*., 2003). Akhter *et al*. (1995) **i**n a study identified the status of rural women in Bangladesh and their role in agriculture, income generating activities and decision making processes. The study revealed observed that the women’s working day varied between nine and thirteen hours. However, the productivity of economic activities such as livestock raising and kitchen gardening were very low mainly due to lack of technical knowledge. They concluded that if women from small, marginal and landless farm households were trained in improved techniques they could raise their income levels. Akhter *et al*. (1984) in another study showed that both livestock and poultry farming are profitable to female entrepreneurs and can help alleviate poverty in rural areas.

Karim *et al*. (1988) reported that there was a negative relationship between women’s literacy level on household s land ownership and their participation in milch cow rearing activities. This indicated that women of small and landless households who are mostly illiterate, would be more responsive to milch cow rearing compared to women of medium and large farm households. Ahmed (1991) found that despite women’s significant contribution to agricultural production and rural households, generally they have less access to and control over such productive resources as land, capital credit, technology, information, seeds, tools, fertilizers, water, fuel and training. The constraints that the rural women faced in gaining access to these resources significantly reduce the productivity of both the rural sector and the entire national economy.

In recent years, a number of NGO’s have been providing loans to rural women for livestock raising. It is the policy of the government to utilize idle women labour for employment and income generating activities, particularly with livestock rearing. During 1996-2003, Poultry Management Technique Improvement Project (PMTIP) came into being as a joint cooperative venture between the Government of Bangladesh and the Government of Japan. Under the dynamic leadership of PMTIP, commercial broiler and layer packages suitable for small-scale poultry farmers were developed and introduced in different Agro-ecological Zones of Bangladesh (Project

Proforma, 2001). Broiler beneficiary was divided into 3 categories of farms. Categories I, II and III farms having flock sizes of 300, 400 and 500 numbers of birds, respectively. Ninety four percent inputs substitutions were provided by PMTIP for commercial broiler packages. Similarly, layer beneficiary was also divided into 3 categories of farms. Categories I, II and III farms having flock sizes of 100, 150 and 200 numbers of birds, respectively. The cost sharing by PMTIP for commercial broiler and layer packages were 94% and 25%, respectively. By the time, when the study was undertaken, broiler beneficiaries completed 4 batches and that of layer beneficiaries completed 1 cycle of rearing (Rahman *et al*., 2004).

In this study an attempt was made to assess the status of women beneficiaries under the incentive coverage of PMTIP for commercial broiler and layer farming. Keeping all these views in consideration, the study was undertaken to assess the women's participation in decision-making on household expenditure, children education, marriage of daughter/sons, participation in salish (Village Suits) and enrollment of membership of women in Union Council, Garm Sarker (Village Administration) and Non-Government Organizations (NGOs).

MATERIALS AND METHODS

A total of 11 broiler and 11 layer women beneficiaries from Dinajpur, Khulna, Bogra, Barisal, Sylhet under the incentive coverage of PMTIP in 5 Agro-ecological Zones of Bangladesh were selected for investigation. Thus, 22 women respondents were interviewed. For collection of data, a preliminary survey schedule was prepared and tested in Dinajpur sub-sites for finalization. After the field test, necessary modifications and rearrangements were made in survey schedule. Data were collected from the records and accounts maintained by the interviewing respondents, covering 4 months (November 2003-February 2004). In analyzing the data, pre- and post-project analysis were followed.

Collected data were processed using Microsoft Excel Programme. The impact of commercial broiler and layer packages on female beneficiaries was assessed by a situation "without" research (Pre-adoption), against an alternative situation "with" research (Post-adoption) comparisons. "With" and "without" method made a meaningful comparison of the baseline data with that of reference year on changes of social status of women in the project areas. Data were tabulated and analyzed for pre- and post-project comparison. The intervention was for a short duration and the effect of intervention can better be measurable in qualitative or descriptive reading rather than quantitative assessment, data were analyzed using descriptive statistical tools like mean and percentages. Data included women's participation in decision making on household expenditure, children education, marriage of daughter /sons, participation in *salish* and membership of women in Union Council, *Gram Sarker* and NGOs.

RESULTS AND DISCUSSIONS

Women Empowerment

Among the beneficiaries, 44% broiler and 31% layer beneficiaries were women. PMTIP facilitated family labour employment opportunities to them and thus their status in family and in society were apparently enhanced. Their relationship with husbands has also been improved and thereby, their participation in decision making on household affairs has also increased.

Women Labour Employment Opportunities in Broiler and Layer Packages

Employment opportunities to female members of broiler beneficiary farmers/batch were 13.14, 16.98, 19.62 and 19.62 man-days/batch for I, II, III categories, respectively. The male and female labour ratios were 56% and 44%, respectively. The adoption of commercial broiler packages made a positive impact on employment of unemployed family labour, especially women in rural areas of Bangladesh (Table 1).

Table 1. Women labour employment in commercial broiler packages/batch

Categories & Number of Birds	Rearing days	Family labour/day (Hours)				Hired lab.	Total		Total Man-days		
		Adult		Children		Adult male	Adult Equivalent/day		Male	Female	Labour
		Male	Female	Male	Female		(Hour)	Man-days			
I (300)	156.18	8.9	7.45	0.9	1 56	0	12.2	1.53	16.73	13.14	29.87
II (400)	157.45	11.38	7.49	0	1 38	0	15.69	1.96	21.60	16.98	38.58
III (500)	159.21	11.52	10.33	1.3	0.79	1.5	17.93	2.24	24.96	19.62	44.58
All farms (average)	**157.61**	**10.61**	**8.39**	**0.71**	**1.26**	**0.48**	**15.28**	**1.91**	**21.07 (56%)**	**16.56 (44%)**	**37.63 (100%)**

Employment opportunities to female members of layer beneficiaries were 34.95, 41.64. 42.31 and 39.83 man-days/batch for farm category I, II and III, respectively (Table 2). The male and female labour ratios were 67.02% and 32.98%, respectively. The adoption of commercial layer packages has made a positive impact on employment of unemployed family labour, especially women in rural areas of Bangladesh. However, before launching the project, the male/female beneficiaries were not engaged in rearing commercial broiler and layer birds.

Table 2. Women labour employment in commercial layer packages/batch

Categories & Number of Birds	Rearing days	Family labour/day (Hours)				Total		Total labour Days		Total Man-days
		Adult		Children		Adult equivalent/day		Male	Female	
		Male	Female	Male	Female	(Hour)	Man-days			
I (100)	539.00	0.98	1.10	0.04	0.00	1.52	0.19	67.46	34.95	102.41
II (150)	556.55	1.41	0.82	0.05	0.09	1.84	0.23	86.37	41.64	128.01
III (200)	552.00	0.83	1.67	0.50	0.13	1.84	0.23	84.65	42.31	126.96
All farms average	**548.97**	**1.06**	**1.21**	**0.20**	**0.07**	**1.76**	**0.22**	**80.94 (67.02)**	**39.83 (32.98%)**	**120.77 (100%)**

Participation in Decision Making in Household Expenditure

The change in decision-making on household expenditure altogether increased by 10.53% in broiler beneficiaries while with layer-beneficiaries it decreased by 8.33% in post intervention period compared to pre-intervention period. It is noticeable that in broiler beneficiaries, the change in decision making in household expenditure by the father decreased by 66.67%. The change in decision-making on household expenditure by father, mother, father and mother jointly increased by 33%, 100% and 150% and while that of husband and wife jointly altogether decreased by 50% and 8% in layer beneficiaries, respectively compared to pre-intervention period (Tables 3 & 4). Thus, earning and employment advantage received from layer and broiler packages, empowered women in decision-making on household expenditure of the respective beneficiaries.

Table 3. Decision making on household expenditure of broiler beneficiary

Sites	Decision Making (Pre-intervention period)					Decision Making (Post-intervention period)				
	Father	Father & Mother	Ben. herself	Husband	All together	Father	Father & mother	Ben. himself	Husband	All together
Khulna	1	1	0	0	6	0	1	1	0	7
Bogra	1	0	0	0	3	0	0	0	0	4
Barisal	1	0	0	0	5	1	0	0	0	5
Sylhet	0	0	0	1	5	0	0	0	1	5
All	**3 (12)**	**1 (4)**	**1 (4)**	**1 (4)**	**19 (76)**	**1 (4)**	**1 (4)**	**1 (4)**	**1 (4)**	**21 (84)**
Change (%)	-	-	-	-	-	**-66.67**	**0**	**0**	**0**	**10.53**

Table 4. Decision on Household expenditure of layer beneficiary at different sites

Sites	Decision Making (Pre-intervention period)						Decision Making (Post-intervention period)					
	Father	Mother	Father & mother jointly	Husband & wife jointly	Male Beneficiary	Altogether	Father	Mother	Father & mother jointly	Husband & wife jointly	Male Beneficiary	Altogether
Dinajpur	1	0	0	2	1	8	1	0	0	2	1	8
Bogra	1	1	1	0	0	8	1	1	3	0	0	7
Barisal	1	0	1	2	0	8	2	1	2	0	0	7
All	**3 (8.57)**	**1 (2.86)**	**2 (5.71)**	**4 (11.43)**	**1 (2.86)**	**24 (68.57)**	**4 (11.43)**	**2 (5.71)**	**5 (14.29)**	**2 (5.71)**	**1 (2.86)**	**22 (62.86)**
Change (%)	-	--	-	-	-	-	**33.33**	**100**	**150**	**-50**	**0**	**-8.33**

Figures in parentheses indicate percentages

Participation in decision making on children education

The percent change in decision making on children education by father, mother and father-mother jointly and altogether were 50, 200, -33.33 and -11.11, respectively in broiler beneficiaries compared to the pre-intervention stage. Dominancy of male labour employment over female labour in commercial broiler rearing might have increased the percentage of participation of father and decreased the participation of beneficiary herself. The percent change in decision making on children education by mother, father and mother jointly and altogether were 200, 50, and 6.66%, respectively in layer beneficiaries in post-intervention period compared to pre-intervention period. Thus, financial advantage received from broiler and layer packages introduced by PMTIP empowered the women in decision-making on children education (Tables 5 & 6).

Table 5. Decision making on children education of broiler beneficiary at different sites

Sites	Decision Making (Pre-intervention period)					Decision Making (Post-intervention period)				
	Father	Mother	Father & mother jointly	Beneficiary herself	Altogether	Father	Mother	Father & mother jointly	Beneficiary herself	Altogether
Khulna	1	1	1	2	4	1	1	3	2	2
Bogra	0	0	0	0	4	0	0	0	0	4
Barisal	1	0	0	0	5	1	0	0	0	5
Sylhet	0	0	0	1	5	1	0	0	0	5
All	**2** (8)	**1** (4)	**1** (4)	**3** (12)	**18** (72)	**3** (12)	**1** (4)	**3** (12)	**2** (8)	**16** (64)
Change (%)	-	-	-	-	-	**50**	**0**	**200**	**-33.33**	**-11.11**

Figures in parentheses indicate percentages

Table 6. Decision making on children education of layer beneficiary at different sites

Sites	Post-intervention period						Pre-intervention period					
	Father	Mother	Father & mother jointly	Husband & wife jointly	Husband	Altogether	Father	Mother	Father & mother jointly	Husband & wife jointly	Husband	Altogether
Dinajpur	1	1	3	2		5	1	1	3	2		4
Bogra	1	1	2	0	1	6	1	0	2	0	1	7
Barisal	1	1	4	1	0	5	1	0	0	0	0	4
All	3 (8 57)	3 (8 57)	9 (25.71)	3 (8 57)	1 (2.86)	16 (45.71)	3 (8.57)	1 (2.86)	6 (17.14)	3 (8.57)	1 (2.86)	15 (42.86)
Change (%)	**0**	**200**	**50**	**0**	**0**	**6.66**	-	-	-	-	-	-

Figures in parentheses indicate percentages

Participation in decision making on marriage of daughters/sons

Participation in decision making on marriage of daughters/sons altogether for broiler beneficiary increased by 17.65% and in layer beneficiary, it was increased by 22.22% in post–intervention period compared to pre-intervention period (Table 7 & 8). This higher percentage in decision making on marriage of daughters/sons in layer beneficiary indicates that higher income earned by the beneficiary and thus facilitated women in deciding marriage of daughters/sons.

Table 7. Decision making on marriage of daughters/sons of broiler beneficiaries

Sites	Post-intervention period					Pre-intervention period				
	Father	Father & mother jointly	Husband & wife jointly	Female beneficiary	Altogether	Father	Father & mother jointly	Husband & wife jointly	Female beneficiary	Altogether
Khulna	0	0	0	0	6	0	0	0	0	6
Bogra	0	0	0	0	6	0	0	0	0	4
Barisal	1	0	0	1	5	1	0	0	1	4
Sylhet	2	0	0	0	0	2	0	0	0	0
All	3	0	0	1	17 (40 00)	3	0	0	1	14 (60 00)
Change (%)	**0**	**0**	**0**	**0**	**17.65**	-	-	-	-	-

Figures in parentheses indicate percentages

Table 8. Decision making on marriage of daughters/sons of layer-beneficiaries

Sites	Post-intervention period					Pre-intervention period				
	Father	Father & mother jointly	Husband & wife jointly	Female beneficiary	Altogether	Father	Father & mother jointly	Husband & wife jointly	Female beneficiary	Altogether
Dinajpur	2	0	3	4	6	2	0	3	1	4
Bogra	1	0	2	2	6	1	0	1	3	4
Barisal	2	2	1	2	6	2	2	1	1	6
All	5 (14 29)	2 (5 71)	6 (17 14)	8 (22 86)	18 (51 43)	5 14 29)	2 (5 71)	5 (14 29)	5 (14 29)	14 (40 00)
Change (%)	**0**	**0**	**20**	**37.50**	**22.22**	-	-	-	-	-

Figures in parentheses indicate percentages

Participation in decision making in *Salish*

Decision making on participation in *salish* by father and mother jointly increased by 40% in post-project than pre-project situation in broiler beneficiaries (Table 9). In layer group, decision making on participation in *salish* by father and mother jointly increased by 11% in post-project than pre-project (Table 10). This implies that PMTIP has increased women's status in the society and helped participating in decision making.

Table 9. Decision making on Participation in *Salish* of broiler and layer beneficiaries

Sites	Post-intervention period			Pre-intervention period		
	Father & Mother Jointly	Male Beneficiary	Altogether	Father & Mother Jointly	Male Beneficiary	Altogether
Khulna	2	3	4	2	3	4
Bogra	2	2	0	2	2	0
Barisal	1	3	2	1	1	4
Sylhet	2	0	1	0	0	2
All	**7 (28)**	**8 (32)**	**7 (28)**	**5 (20)**	**6 (24)**	**10 (40)**
Change (%)	**40.00**	**33.33**	**-30.0**	**-**	**-**	**-**

Figures in parentheses indicate percentages

Table 10. Decision making on participation in S*alish* of layer-beneficiaries

Sites	Post-intervention period			Pre-intervention period		
	Father & Mother Jointly	Male Beneficiary	Altogether	Father & Mother Jointly	Male Beneficiary	Altogether
Dinajpur	2	2	6	3	3	6
Bogra	4	3	4	3	4	3
Barisal	4	5	5	3	5	5
-	-	-	-	-	-	-
All	10 (28.57)	10 (28.57)	15 (46)	9 (25.7)	12 (34)	14 (40)
% Change	**11.11**	**-16.7**	**7.14**	-	-	-

Figures in parentheses indicate percentages

Membership of women in Union Council, *Gram Sarker* and NGOs

In the case of broiler-beneficiary, none was found members of Union Council and *Gram Sarker* in both pre- & post-intervention period but membership of women in NGOs increased by 20% in post-intervention period over pre- intervention period (Table 11). In the case of layer beneficiary, also none was found the members of Union Council and *Gram Sarker* in pre-intervention period. But in post- intervention period, membership of Union Council and *Gram Sarker* increased by 67% and 33% respectively (Table 12). Membership of women in NGOs of layer-beneficiary increased by 33% in post- intervention period than pre- intervention period (Table 12). It could be stated that in this case, broiler beneficiaries were ahead of layer beneficiaries because, higher employment opportunities of women in broiler production leading to higher income and thus facilitated their more involvement in women empowerment. All these evidences suggest that the socio-economic status of women within the household increased after the intervention made by PMTIP in the sub-site areas.

Table 11. Membership of Union Council, *Gram Sarker* & NGOs of broiler –beneficiaries

Sites	Members of Union Council		Members of *Gram Sarker*		Members of NGOs	
	Post-intervention period	Pre-intervention period	Post-intervention period	Pre-intervention period	Post-intervention period	Pre-intervention period
Khulna	0	0	0	0	1	0
Bogra	0	0	0	0	1	1
Barisal	0	0	0	0	0	0
Sylhet	0	0	0	0	3	3
All (average)	0	0	0	0	**1.25**	**1**
Change (%)	0	-	0	-	**20**	**-**

Table 12. Membership of Union Council, *Gram Sarker* & NGOs of layer-beneficiaries

Sites	Members of Union Council		Members of *Gram Sarker*		Members of NGOs	
	Post-intervention period	Pre-intervention period	Post-intervention period	Pre-intervention period	Post-intervention period	Pre-intervention period
Dinajpur	2	0	1	0	3	2
Bogra	0	0	0	0	0	0
Barisal	0	0	0	0	0	0
All (average)	0.67	0	0.33	0	1.00	0.67
Change (%)	67	-	33	-	33	-

CONCLUSIONS AND RECOMMENDATIONS

Among the beneficiaries, 44% broiler and 31% layer beneficiaries were women. PMTIP facilitated women labour employment opportunities and their status in family and in society enhanced. Participation of women in decision making on household expenditure, children education, marriage of daughter/sons, participation in *salish* increased in commercial broiler and layer beneficiary farms. In commercial broiler and layer beneficiary farms, the women memberships of NGOs increased. In layer beneficiary farm, the women membership of Union Council and *Gram Sarker* increased. All these evidences revealed that introduction of commercial broiler and layer packages enhanced women status in those areas. Therefore, for improving livelihood of women through adoption of commercial broiler and layer packages need further expansion covering larger number of female beneficiaries in other parts of the country.

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BUSINESS RATIONALE FOR INVESTMENT ON CLOSED DRUM THRESHER IN BANGLADESH

SWAPAN KUMAR ROY[1], ABDUR ROB[1], MIKE ALBU[2] AND SHAHJAHAN ALI PRAMANIK[1]

ABSTRACT

A study was carried out to investigate the investment of a selected agro-machinery i.e. power operated Closed Drum Thresher in the course of mechanization of Bangladesh to over-come the expensived limited labour during rice threshing season. A power operated Closed Drum Thresher is used to remove rice grains from plant-panicle by means of shearing force while harvested paddy plants move axially over a rotating central spike-drum inside a closed metal structure. The analysis considers different models of Closed Drum Thresher as well as inter-regional differences in agro-economic factors that influence the business rationale for investment. Close-drum threshers look like a wise investment, compared to manual pedal-threshers to wealthier farmers who cultivate at least 5 -10 acres land annually (assuming at least two crops per year). Capital cost is modest (upto Tk[3] 30,000) and can be recouped in a short period. Therefore, power operated Closed Drum Thresher is able to overcome the shortage of labour during peak harvesting season.

Key words: Closed Drum Thresher, business rationale, inter-regional wage rate, pedal thresher, break-even area

INTRODUCTION

Growth in agricultural productivity is essential to promote broad-based economic growth and reduce rural poverty. Productivity growth is based largely on application of technology and information. Investment in agricultural machinery and technology has been critically important to growth performance in agriculture generally, and is likely to become increasingly important for Bangladesh (Albu *et al*., 2006).

During the last 10-15 years, the traditional animal-draught power in agriculture is becoming increasingly unavailable which is due to the increase in the cost of cattle rearing in Bangladesh (Hatch, 2005). Therefore, farmers used to sell cattle before starting the rainy season because of

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[1] Markets and Livelihoods Program; Practical Action-Bangladesh, Dhanmondi, Dhaka, Bangladesh
[2] Markets and Livelihoods Program; Practical Action-U.K.
[3] 1 US$=Tk. 69.00

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unavailability of cattle feed. On the other hand, labour shortage has occurred in rural areas because the young generation is not willing to engage in agriculture and the shifting of local labours or little-educated people to other available jobs avoiding inconsistent income from seasonal agricultural works. The land owners usually hire labour locally or temporarily available labour from other regions with high price. So, the use of agro-machinery is increasing day by day which is relevant and necessary in Bangladesh agriculture due to unavailability of animal-draught power and the expensive limited labour.

The agricultural tillage and irrigation practices are already mechanized in many districts of Bangladesh where about 33% and 40% of the total cultivable land are being liked with more than 350,000 power tillers and irrigated with about 1 million different types of power driven pumps (Anon, 2004; BBS, 1999). At the same time, about 200,000 manually operated pedal threshers are also being practiced in different districts of Bangladesh (Anon, 2004). This study covers of agro-machine like power operated Closed Drum Thresher which can save time and labour to farmers in agricultural crop threshing, besides existing agro-machines (pedal thresher). Regarding payback period of the Closed Drum Thresher, BRRI (2005) reported that it can be covered within one year while considering the traditional manual threshing option. However, the analysis did not consider existing low-cost pedal thresher, inter-regional wage rate variation and also different IRR (internal rates of return) options.

This short study sets out to analyses the business rationale for smallholder farmers to invest in specific types of agro-machinery in Bangladesh. The analysis considers different models of Closed Drum Thresher and inter-regional differences in agro-economic factors that influence the business rationale for investment.

MATERIALS AND METHODS

The field survey was done to collect information on Closed Drum Thresher from farmers and different stakeholders in selected regions of Bangladesh. For this purpose, we developed a questionnaire for farmers to collect the information on types and models, advantageous locations, incurred capital cost, running costs items, expected economic life, usage operating hours and acres, cost savings in terms of labours and other factors. To find the farmers who are using the Closed Drum Thresher, we communicated with agro-machinery manufacturers, repairing workshops, local farmers, research organizations and Department of Agricultural Extension (DAE) in the selected regions. After understanding the locations of farmers, we moved to farmer's house in rural area to get their views/data on agro-machine according to the questionnaire.

Regarding selection of regions, we consulted regional research organizations, the Department of Agricultural Extension, local private institutions and literature about current usage patterns of Closed Drum threshers (BBS, 1999; BRRI, 1997; Hatch, 2005; ITDG, 2003). Initially, we selected eight regions for the field work which cover almost all the typical crops and agricultural practices used in Bangladesh. During field survey, we found 18 users of Closed Drum among which 1, 3, 3, 3, 5 and 3 interviewees were found in Bogra, Comilla, Dinajpur, Kustia, Mymensingh and Sylhet, respectively. However, we were unable to collect information from two regions (Jessore and Dhaka) because of unavailability of selected agro-machine users.

This study examines variations in capital cost and performance characteristics (C) by comparing different types of agro-machinery. It looks at variations in substituted costs (L), by considering inter-regional differences in rural wage rates. And it the examines scale of production (S) or capacity utilisation, i.e. the annual acreages of crop that is covered by the agro-machinery.

A conventional way to assess the investment opportunities is to calculate the internal rates of return (IRR) generated by investments as these factors vary. In mathematical terms we would examine IRR as a function of variations in C, L and S.

However, land-holdings in Bangladesh are very small (mean <2 acres, median <1 acre), the third factor [S] dominates the analysis of IRR (BBS, 2004). We could have arbitrarily selected a range of different land-holding sizes, and calculated the IRR for the agro-machine, but this would not produce very useful results, and would have taken a huge amount of time.

In mathematical terms, therefore, this study is slightly unusual in examining S as a function of variations in IRR, C and L which is derived from break-even concept used for agro-machinery as reported by Bainer *et al.* (1987) and Hunt (1995). The break-even area or scale of production (S) was calculated as below:

$$S = 0.80 \times \left(\frac{C}{GB}\right) \times \left(IRR + \frac{1}{EL}\right) \quad [1]$$

$$GB = (L + VOB) - RC \quad [2]$$

where, C = capital cost in Tk; GB = Gross benefit Tk/acre; EL = Economic life in yrs; VOB = Values of other benefits (reduced in processing loss, crop damage risk, cost of labour logistics) in Tk/acre; RC = Running costs in Tk/acre.

The exact difference in results depends on the interest rate and period of depreciation. However, for the calculations in this study, reducing the “simple” result by 20% gives a result that is more than sufficiently accurate for our purposes (within one or two percent of an IRR calculation).

RESULTS AND DISCUSSIONS

Land holding patterns

Table 1 illustrates inter-regional differences in the areas of cultivated land that fall into various sizes of land-holding categories. It also shows any differences in these patterns for rice compared to other crops and the opportunity of using of Closed Drum Threshers.

Table 1. Land holdings of different regions

Areas with acreage		Size of land holding			
		< 1 acreage	1 - 2.5 acreage	2.5 - 7.5 acreage	> 7.50 acreage
Bogra					
Number of land holdings	335,000	52%	32%	15%	2%
Rice crop acreage (Aus, Aman & Boro)	706,000 ac	15%	32%	39%	13%
Other crops (wheat, oilseeds, pulses, vegetables)	335,000 ac	21%	34%	33%	13%
Average crops per year	2.0	2.1	2.1	2.0	1.9

(Cont...)

Comilla					
Number of land holdings	483,000	60%	31%	9%	0%
Rice crop acreage (Aus, Aman & Boro)	696,000 ac	25%	42%	29%	4%
Other crops (wheat, oilseeds, pulses, vegetables)	426,000 ac	32%	43%	23%	2%
Average crops per year	2.1	2.2	2.1	1.9	1.7
Dinajpur					
Number of land holdings	271,000	36%	32%	27%	5%
Rice crop acres (Aus, Aman & Boro)	810,000 ac	6%	21%	46%	27%
Other crops (wheat, oilseeds, pulses, vegetables)	339,000 ac	10%	25%	42%	22%
Average crops per year	1.8	1.9	1.9	1.8	1.7
Kustia					
Number of land holdings	166,000	53%	29%	16%	2%
Rice crop acreage (Aus, Aman & Boro)	190,000 ac	14%	31%	43%	13%
Other crops (wheat, oilseeds, pulses, vegetables)	298,000 ac	17%	30%	38%	14%
Average crops per year	1.9	2.0	2.0	1.8	1.7
Mymensingh					
Number of land holdings	767,000	14%	31%	39%	16%
Rice crop acres (Aus, Aman & Boro)	1,600,000 ac	13%	33%	40%	14%
Other crops (wheat, oilseeds, pulses, vegetables)	320,000 ac	41%	44%	15%	0%
Average crops per year	1.5	2.0	1.7	1.4	1.1
Sylhet					
Number of land holdings	700,000	9%	21%	43%	27%
Rice crop acreage (Aus, Aman & Boro)	1,559,000 ac	6%	22%	44%	27%
Other crop acres (oilseeds, vegetables)	446,000 ac	22%	27%	35%	16%
Average crops per year	1.3	1.5	1.5	1.3	1.2

Source: BBS, 1999

Labour / Wage Rates

Wage rates for manual labour vary from region to region, and rise to peaks in the main periods of high labour-demand during the Boro and Aman harvest times. During off-seasons, wages are 10 – 30 % below the on-season or peak-season rates (associated with harvesting and planting times). They fall even further during drought (e.g. May-July, before starting of rainy season) (Table 2). This is especially in rural areas where only two rice crops are grown. Inter-regional variations in wage rates are also caused by type of crops handling or cultivation, mentality of farmers or labours, and whether the crop season starts early or late in that region.

Table 2. Seasonal wage rates (Tk/day) of male and female labours by location

Location	Jan / Feb		Mar/Apr		May/Jun		Jul/Aug		Sep/Oct		Nov/Dec	
	M	F	M	F	M	F	M	F	M	F	M	F
Bogra	110	90	100	80	120	100	80	60	80	60	120	100
Comilla	120	100	120	100	140	120	100	80	100	80	140	120
Dhaka	110	90	110	90	120	100	90	70	90	70	120	100
Dinajpur	70	50	60	40	80	60	60	40	50	30	80	60
Jessore	100	80	100	80	110	90	90	70	90	70	110	90
Kustia	90	70	90	70	100	80	70	50	70	50	100	80
Mymensingh	100	80	100	80	120	100	90	70	90	70	120	100
Sylhet	110	100	110	90	120	100	110	90	110	90	120	100

Note: M = Male; F = Female

Wage rates are similar whether labour is used for machine operations or for simple manual work. However the field survey revealed significant variation in wage rates between farmers even in the same district. This is thought to be due to differences in relationships, attitudes and competing labour opportunities in particular villages. For the purposes of calculations in this study, information were gathered from farmers about the costs per acre of the agro-activities which are being substituted by use of the agro-machine.

Costs of Finance / Borrowing for Capital Investment

Table 3 shows available financial opportunities which are accessible all over Bangladesh since the government and private institutions mentioned are available in remote area.

Table 3. Summary of available financial services for farmer investment

Institutions	Max Loan Amount (Tk)	Interest Rate (%)	Duration (year)	Instalments (no.)	Terms and conditions
Bangladesh Krishi Bank	14,500	8	1	1	- lend against one acre crop cultivation and can purchase other inputs (seeds, fertilizer, water) - needs to deposit land titles
Janata Bank	14,500	8	1	1	- lend against one acre crop cultivation and can purchase other inputs (seeds, fertilizer, water) - needs to deposit land titles
BRAC	20,000	15	1	12	- need to deposit land titles - needs proof of income - need to show assets of double the loan
ASA	100,000	12.5	1	12	- need to prepare Tk 150/- of stamp paper - need to pay 0.2% appraisal fees - needs proof of income

The local manufacturers of agro-machines are generally reluctant to provide credit (e.g. payment by instalments) due to poor history of farmers in repayment. The most trusting ones might accept 50% down-payment from well known customers.

Findings on Closed Drum Thresher

Typically, a closed-drum machine (Fig. 1) comprises a closed metal drum structure driven by an 8~12 hp diesel engine. Rice grains are removed from plant-panicle by shearing action while moving axially over a rotating spike-drum inside a cylinder structure. As with closed-drum threshers, the larger prime movers usually have uses in other agricultural processes on the farm. The weight of this movable machine varied from 150 to 200 kg depending on type of feed and outlet mechanisms, cleaning sieve, fan and metal-thickness used in construction. Some machines are mounted on two wheels to assist movement with the help of human or other vehicle means: for example rickshaw-type tricycle.

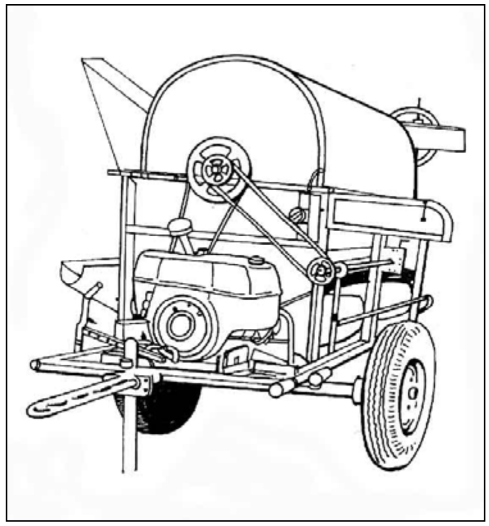

Fig. 1: Power operated Closed Drum Thresher

During field survey, low cost closed-drum threshers were found in Bogra, Sylhet and Mymensingh regions which lacked a shaking-sieve type cleaning mechanism; but instead relied on a fan to clear the machine of husk debris. The reasonable valued closed-drum machines excluding diesel engine is available in Bangladesh at present are probably: Tk 14,500 for TH7 type from Bhai Bhai Engg. (Netrokona), Tk 13,000 for TH7 type from Shoan Engg. (Kishoregonj), Tk 16,000 for TH7 type from Alim Industries (Sylhet), and Tk 24,000 for TH8 type from Uttaran Engg. (Dinajpur), based on information provided by manufacturers.

Advantageous locations for use

The field survey revealed that the Closed Drum type of power thresher is commonly used in Bogra, Dinajpur, Kushtia, Sylhet, Comilla and Mymensingh, but not in Dhaka and Jessore. Big-size farming in Dinajpur, wheat/rice cultivation in Kustia, solvent farmers in Sylhet, three intensive rice seasons in Comilla, available rental-service in Mymensingh have drawn farmer's interest to invest money to use expensive Closed Drum thresher in those regions. On the other hand, we observed that the availability of irrigation scheme existed in Dinajpur, Kushtia, Comilla and Mymensingh has played a role in drawing farmer's interest towards this machine. In the Sylhet region, there is a big low land area which is good for rice growing as the soil remains moist around the year except the winter/dry season. The unavailability of local labour or expensive labour is also one of the reasons to drive farmer in having this machine to perform threshing within a short time to catch up the next planting season. The Sylhet and Mymensingh regions are close to upland or hilly area nearby Indian side get heavy rainfall throughout the year. During beginning of Kharif or rainy season farmers need quick threshing machine to store or pick up their harvested *Boro* rice, to avoid spoilage of piled up harvested paddy plants for a uncertain long time. In Bogra, most farmer expressed that they are reluctant to use Closed Drum thresher as it makes small size straw which is not suitable for storage and the threshed straw is difficult to feed cattle. Farmers in Dhaka and Jessore are not interested in this expensive Closed Drum Thresher because they are habituated with less expensive pedal thresher.

Patterns of use (crops, seasons)

Generally, closed drum thresher is used during paddy harvesting seasons [May/Jun (*Boro*), Jul/Aug (*Aus*), Nov/Dec (*Aman*)] and wheat harvesting season (Mar/Apr). It is also used for threshing oilseeds and pulses. The average operating hours/year and serviced acreage/year for Closed Drum thresher was calculated for three crop seasons in six selected regions. The average operating services, extracted from respondent data, are found to be 145 hr/yr and 53 ac/yr for Closed Drum thresher which included farmers' own-land and land covered on rental service. Figures are higher in Dinajpur (402 hr/yr, 115 ac/yr), because farmers in this region have larger land holdings and / or cultivate contract land (100 ac) for *Aman* and *Boro* seasons. In rental service to neighbours, farmers received around Tk 5-10 per 40 kg rice threshed. However, this opportunity is diminishing day by day as more machines are purchased by farmer's neighbours.

Capital costs

Capital cost of Closed Drum threshers ranges widely, depending on facilities and manufacture, from Tk 17,000 – 30,000. The farmer's carrying cost varied from Tk 500 to Tk 1,000 (due to unavailability of producers nearby). Because, only a few manufacturers have attempted to manufacture this sophisticated machine, farmers in Dinajpur, Kushtia and Comilla regions purchased Closed Drum from long distances - Mymensingh or Sylhet regions based on good personal communication or information. Twenty percent (20%) of Engine capital cost has been counted in the Closed Drum capital cost as the 12-hp engine is used for tilling, irrigation, carrying goods, etc. Most of the farmers in Sylhet and Mymensingh regions used 12-hp diesel engine for tillage and irrigation. We allow 3% of capital costs against insurance, tax and shelter/storage costs (see also Bainer *et al*., 1987; Hunt, 1995; Smith and Wilkes, 1976). Due to the wide range of machines available, we looked at two models of Closed Drum thresher for the purpose of the investment analysis (Table 4).

Table 4. Capital costs of Closed Drum Threshers

Category / Model	Type TH7	Type TH8
Power Source	8-10 hp diesel engine	10-12 hp diesel engine
Effective Throughput	400 kg / hr	700 kg / hr
Manufacturer	Awolad Machineries (Kishoregonj)	Uttaran Eng. (Dinajpur)
Capital Costs (including share of prime-mover)	Tk 16,000	Tk 28,000
Economic Lifetime	10 yrs	10 yrs

Operating costs per acre

The running cost of Closed Drum threshers varied from Tk 100 to Tk 120 per hour which includes repairing of machine and engine, fuel, oil and labour wages. Parts that frequently fail or need replacing are bearings, belts and "wearing spike". The running cost was found to be low in Dinajpur, Mymensingh and Comilla, which was due to longer service hours used. In Dinajpur and Mymensingh, farmers used this machine in own harvested paddy as well as for rental or contract services (402 hr/yr in Dinajpur; 163 hr/yr in Mymensingh). One big advantage of Closed Drum thresher is that it can easily move from field to field or a long distance during rental services. On the other hand, farmers in Comilla used this machine longer period as they covered three successive rice seasons each year (93 hr/yr). Operating costs for different categories are presented in Table 5.

Table 5. Operating costs of closed Drum Thresher

Category / Model	TH7	TH8
Running Cost / Hr	Tk 115	Tk 110
Hours / Acre	4	2.3
Running Cost / Acre	Tk 460	Tk 253

Cost reductions per acre

The principal economic benefit of using a closed-drum thresher comes from replacing the labour involved in manual pedal-threshing. Pedal threshers are widely available in Bangladesh. Farmers variously reported that it takes around 14 hours for two male labourers to manually pedal thresh an acre of rice (estimated 1600 kgs), one labourer pedalling the thresher and the other helping in feeding the crop. In addition, there are some maintenance and repair costs.

Table 6. Substituted Costs of Manual Pedal-Threshing

Location	**Labour cost per acre**
Bogra	Tk 420
Comilla	Tk 490
Dhaka	Tk 420
Dinajpur	Tk 280
Jessore	Tk 385
Kustia	Tk 350
Mymensingh	Tk 420
Sylhet	Tk 420

Other factors (risks and non-financial benefits)

Almost all farmers valued the convenience and time saved by closed-drum thresher during busy harvesting periods: for example a crop can be processed in a single day rather than two or three days.

They have three major benefits:

- It reduces crop losses during processing. BRRI reported that compared to manual threshing, drum threshers cut processing losses from 3.5% to less than 1% (BRRI, 1997).

- It reduces the risks of post-harvest crop damage due to rain. Even if this happens only once every five years, the losses can be very high when it does.
- It reduces the time and mental stress involved in finding and coordinating large inputs of temporary extra labour during busy harvesting periods.

Overall, Closed Drum threshers increase farmer's confidence in taking on a larger cultivated area.

Assuming that the selling price of rice produced from an acre is Tk 10,000 – 15,000 at the farm-gate, preventing post-harvest losses creates significant benefits (e.g. a 5% reduction of losses on average is equivalent to Tk. 500 - 750 per acre). Quantifying these risks and benefits is not easy, but for purposes of this analysis, we have assumed that the total savings are worth Tk 450 per acre.

Break-even calculation of Closed Drum Thresher

The results of the financial analysis are shown in the Table 7. They are shown in terms of both the minimum annual acreage of cultivation, and the minimum hours of operation, needed to achieve internal rates of return (IRR) of 10%, 25% and 40% in each district.

Table 7. Results for closed drum thresher

Closed-Drum Threshers	**TH7**			**TH8**		
Capital Costs	Tk 16,000			Tk 28,000		
Operating Cost	Tk 440 /acre			Tk 310 /acre		
Output	4 hrs/acre			2.3 hrs/acre		
To achieve IRR of:	**10%**	**25%**	**40%**	**10%**	**25%**	**40%**
Minimum production acreage						
Bogra, Dhaka, Mymensingh, Sylhet	6	10	15	8	14	20
Comilla	5	9	13	7	12	18
Dinajpur	9	15	22	11	19	27
Jessore	6	11	16	9	15	21
Kustia	7	12	18	9	16	23
Minimum hours of operation						
Bogra, Dhaka, Mymensingh, Sylhet	24	42	60	18	32	46
Comilla	20	36	51	16	29	41
Dinajpur	35	62	88	25	43	61
Jessore	26	45	65	20	34	49
Kustia	28	50	71	21	37	53

As with closed-drum threshers, inter-regional variations in wage rates cause only a modest difference in results. However the results are heavily dependent on the required IRR. This was also expected, and reveals how influential farmer access to medium-term loans at reasonable rates could be, in order to enable investment.

According to this analysis, the annual acreages required to achieve these internal returns are pretty high by Bangladeshi standards (compare with Table 1). For example, at least 8 acres of land, cropped twice a year, would be needed to generate investment returns at 25% interest rate per year in all districts except Dinajpur for TH8 model (Table 7). This helps explain why closed-drum threshers are much less widespread. Not surprisingly the smallest model of thresher (TH7) appears to be most suitable in terms of returns from smaller acreages (e.g. up to 5 or 10 acres).

Among the 18 interviewed farmers using closed-drum threshers, the area of crops for which the machine was used annually ranged from 10 acres minimum to 220 acres, with an average of 56 acres. These are, of course, quite large land-holdings by Bangladesh standards (see Table 1). In most regions, land-holdings of this size are the privilege of a tiny percentage of farmers. However, when thresher owners are able to operate on larger acreages by renting to their neighbours, then these break-even acreages look more achievable. This helps explain growing interest in closed-drum threshers for rental operations.

The results expressed in hours also give an idea of the scale of operation needed to make the closed-drum thresher a good investment for a rental service business. Note that a rental service business would need higher hours of operation than these results show (e.g. by a factor of perhaps 50%) so as to cover additional management and logistical costs not included in this analysis. In this case, the larger, faster machines (TH8 design) looks like the best option. According to the data collected here, closed-drum threshers are slightly more expensive to run per acre than open-drum threshers. However this disadvantage can be easily outweighed by the better quality of output (less stones and debris) when crop is sold at market.

CONCLUSIONS

This study set out to analyse the business rationale for small-holder investment in specific type of the agro-machinery in Bangladesh, the Closed Drum Thresher. The analysis considers both different types and models of agro-machinery, and inter-regional differences in agro-economic factors that influence the business rationale for investment. Closed-drum thresher is a good investment for farmers cultivating at least 5 - 10 acres land annually (assuming at least two crops per year). This, and the capital cost (up to Tk 30,000) makes it an opportunity for a small minority of wealthier farmers only. However, the technology is well-suited for promotion as a rental service provider and a viable scale of operation for this is very achievable (e.g. 60 – 100 hours a year at Tk 200 per hour).

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COST OF PRODUCTION OF TEA IN SELECTED AREAS OF BANGLADESH

J.K. SAHA[1], A.F.M. BADRUL ALAM[2] AND M. WAHIDUL HAQUE[3]

ABSTRACT

The study was conducted to examine the cost of production of tea in Bangladesh. The average per kilogram cost of made tea was Tk 54.40. The average per kilogram cost of made tea was the highest (Tk 62.69 /kg) at U class while it was the lowest (Tk 53.07 /kg) at A class. Cost of production decreased with an increase in production. The average per kg cost of made tea in greater Sylhet and greater Chittagong was Tk 52.47 and Tk 59.13 respectively. The average per kg cost of made tea was the highest at greater Chittagong irrespective of type of managements and classes. The average per kg cost of made tea was the highest (Tk 57.67 /kg) at the proprietary tea estates while it was the lowest (Tk 47.91/kg) at BTB managed tea estates. On average the cost of labour was the major cost constituting 32.17% of the total cost. The study also showed that a reverse relationship exists between per kilogram cost and per hectare production. This indicates that with an increase of 100 kg yield, per kg cost is reduced by Tk 0.85.

INTRODUCTION

Tea is a major cash crop as well as an important export earner of Bangladesh accounting for about 0.30 % of the total export earning (EPB, 2002). It holds a special place in agriculture as it is the only long established plantation crop of the country. The industry and related trade are providing employment to about 0.35 million people, which are nearly 3.3% of the total industrial employment (BCS, 2000). At present there are 160 tea estates in Bangladesh covering 1,14,047 hectares of grant area of which 50,470 hectares are under tea. Among them, 39.46 % of tea area was cultivated under the management of Sterling Companies, 31.95% by Private Limited Companies, 14.99 % by proprietary tea estates, 10.83 % by National Tea Company and 2.77 % by BTB managed tea estates (Table 2). But on the basis of agro-ecological zone, 92.26% area was

[1] Principal Scientific Officer and Head, Bangladesh Tea Research Institute (BTRI), Srimangal, Maulvibazar
[2] Director, BTRI, Srimangal, Maulvibazar
[3] Chairman, Bangladeshyio Cha Sangsad, Chittagong.

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cultivated in greater Sylhet region whereas only 7.74% of area was cultivated in Greater Chittagong area. As per classification on the basis of annual production, 81 tea estates of A class cultivated about 82.21% of tea area, 19 tea estates belonging to B class cultivated 7.60%, 28 tea estates of C class cultivated 7.17% whereas 32 tea estates of U class cultivated only 3.02 % Table 1). The total production of Bangladesh tea in the year 2005 was 58.60 million kg (ITC, 2005).

Among the total production, 48.62% was produced by Sterling Companies, 29.42% by Private Limited Companies, 9.72 % by Proprietary tea estates, 8.99 % by NTC and 3.25% by BTB managed tea estates (Table 2). The highest production (94.24%) was obtained in greater Sylhet region and it was the lowest (5.76%) at greater Chittagong region. On the other hand, the contribution made by A class gardens was 87.75% followed by 4.82%, 3.54% and 0.43% in B, C and U classes respectively (Table 1).

Table 1. Break up of tea estates, tea area and production according to class and area

Class	Area	No.of Tea Estates	Area		Production	
			(ha)	(%)	(kg)	(%)
A	Sylhet	76	39890	79.04	46.43	87.36
	Chittagong	5	1603	3.18	2.05	3.85
	Sub-Total	**81**	**41493**	**82.21**	**46.63**	**87.75**
B	Sylhet	14	2689	5.33	1.85	3.49
	Chittagong	5	1145	2.27	0.71	1.33
	Sub-Total	**19**	**3834**	**7.60**	**2.56**	**4.82**
C	Sylhet	24	3122	6.19	1.66	3.13
	Chittagong	**4**	**495**	**0.98**	**0.22**	**0.41**
	Sub-Total	28	3617	7.17	1.88	3.54
U	Sylhet	22	862	1.71	0.14	0.27
	Chittagong	10	664	1.32	0.09	0.16
	Sub-Total	**32**	**1526**	**3.02**	**0.23**	**0.43**
	Sylhet	136	46563	92.26	50.08	94.24
	Chittagong	24	3907	7.74	3.06	5.76
Grand Total		**160**	**50470**	**100.00**	**53.14**	**100.00**

Table 2. Types of management-wise area, production and yield of Bangladesh tea

Types of Management	No. of Tea Estates	Area		Production		Yield kg/ha)
		(ha)	(%)	(kg)	(%)	
BTB	3	1396	2.77	1.72	3.25	1425
Sterling	27	19919	39.46	25.84	48.62	1405
NTC	13	5466	10.83	4.78	8.99	962
Private Ltd. Companies	57	16124	31.95	15.63	29.42	1057
Proprietary	60	7565	14.99	5.16	9.72	739
Total	160	50470	100.00	53.13	100.00	1147

The cost of production of a commodity plays an important role in the economy of the industry concerned. It regulates and also indicates the growth of an industry. It furnishes the real base for making a policy decision. It is also an important parameter to determine the economic profitability of a particular tea estate. Inspite of such a role and the fact that tea industry is one of the oldest organized industries of our country, cost has remained as an underdeveloped field of study. Systematic cost accounting is still little known or practised by a large number of tea estates and the costing methods are thus far from being standardized. This makes inter-estate and also intra-estate cost comparisons extremely difficult and unrewarding. In the short run, cost has been classified into prime and overhead category. Accordingly, in Farm Management Study, crop cost for an owner-operated farm is classified into cost A1, Cost B and cost C1. Cost A1 is defined as out of pocket expenses and hence it includes all items of cost paid out by the farmers. Cost B is worked out by adding imputed value of rent of owned land and interest on fixed capital with cost A1. Cost C1 is found out by adding cost of family labour with cost B (Singh, 1992). The concept of prime cost in the short-run for any seasonal crop has been subsequently developed and designed as cost D2, defined as cost A1 exclusive of land revenue and cesses plus imputed value of family labour (Krishinji, 1975). For a perennial crop like tea the concept of short-run cost as adopted in farm management studies has little relevance. It is very difficult to disentangle and classify the various items, which go to make the cost of production. Each estate or company has its own system of allocating the items of expenditure. Tea plantation management is very expensive and it takes more than two lacks taka to bring one hectare of land into cultivation (Gazi, 1996). Thus, finance is the most important constraint factor to bring new areas under tea. The cost of production includes all fixed and variable expenses such as upkeep of mature tea, plucking, manuring, using fertilizers, insecticides and pesticides, tea manufacturing, obtaining tea chest and dispatching, transporting, paying duties and taxes, repairs to building and machinery, providing for labour welfare, establishment and miscellaneous expenses. The objectives of this study purports to find out the cost of production per unit area and per unit of made tea as well as their structural composition of selected tea estates in order to examine the variability of cost and cost structure, if any, among the estates of different size categories and ownership pattern.

MATERIALS AND METHODS

Out of a total seven valley circles in greater Chittagong and greater Sylhet, representative 36 tea estates having 20 from A class, 8 from B class, 4 from C class and the rest 4 tea estates of U class were selected primarily during 2004. Later on, a total of 25 tea estates out of which 19 from

Sylhet region and 6 from Chittagong region were selected randomly. As a matter of fact, 17 tea estates from A class, 3 from B class, 3 from C class while 2 from U class were selected for the study. It is to be mentioned that per kg cost of production in 1993 field level data were taken into consideration as a base year. The present cost of production was calculated keeping in mind regular trend of increase for considered components. That is why present trend of cost for different components increased in terms of percentages as: Labour wage 33%, Labour. Welfare 14%, Establishment 5%, Manures & Fertilizers 34%, Transport 8.75%, Maintenance 10.5%, Manufacturing 10.5%, Tea chest & Dispatch 8.75%, Rent & Taxes 7.00% and Miscellaneous 9.00%, respectively.

RESULTS AND DISCUSSION

In order to have an overall idea on production, the total of 160 tea estates of Bangladesh were divided into four categories namely 'A', 'B', 'C' and 'U' depending on their annual production. On an average per kilogram cost of made tea was Tk.54.40. The highest (Tk 62.69) per kg cost of made tea was found in U class and it was the lowest (Tk 53.07) in A class. The cost per kilogarm was the highest in U class due to lower productivity. On an average per kg cost of labour wage was Tk 17.50 (Table 3). The labour cost was more or less same among A, B & C classes. It was the highest (Tk 22.58 /kg) in U class. The labour cost was the lower (Tk 16.86 / kg) in greater Sylhet while it was the higher (Tk 19.54 /kg) in greater Chittagong. On an average per kg cost of labour welfare was Tk 2.46. The labour welfare cost was the highest (Tk 2.94 /kg) in A class and it was the lowest (Tk 1.23 /kg) in B class. On the otherhand, labour welfare cost was lower (Tk 2.14/ kg) in Chittagong while it was the higher (Tk 2.55 /kg) in Sylhet.

Table 3. Break-up of cost of made tea according to class, area and components

(Tk/kg)

Class & Location		Cost Components										Total
		Labour Wage	Labour Welfare	Establish-ment	Manures & Pesticides	Transpor t& fuel	Main. of Build. & mach.	Manufac-turing	Chest & Dispatch	Rent & Taxes	Misc.	
	Sylhet	16.66	3.06	5.25	4.12	1.37	1.30	7.53	4.56	0.94	6.24	51.03
A	Chittagong	18.27	2.41	6.99	4.26	2.57	1.47	9.35	6.36	1.29	5.33	58.31
	Sub-Total	16.94	2.94	5.55	4.16	1.59	2.06	7.87	4.88	1.01	6.07	53.07
B	Sylhet	14.52	1.24	3.74	5.98	1.59	1.97	8.75	5.89	1.90	7.15	52.74
	Chittagong	21.76	1.19	6.27	5.85	1.61	4.31	5.77	3.18	3.67	4.52	58.12
	Sub-Total	16.93	1.23	4.59	5.93	1.59	2.75	7.79	4.99	2.49	6.28	54.56
C	Sylhet	19.63	1.31	4.31	4.49	0.74	2.41	15.46	2.48	0.88	4.58	56.28
	Chittagong	14.30	1.63	6.20	4.14	0.54	3.65	13.25	8.47	1.61	6.17	59.95
	Sub-Total	17.85	1.40	4.94	4.37	0.69	2.83	14.76	4.49	1.12	5.11	57.55
U	Sylhet	18.85	0.60	3.70	2.24	3.85	0.15	24.60	1.46	2.17	2.82	60.44
	Chittagong	26.31	2.85	11.60	4.31	7.63	0.54	--	--	2.29	9.35	64.89
	Sub-Total	22.58	1.72	7.64	3.28	5.74	0.34	12.40	0.66	2.24	6.08	62.69
Total	Sylhet	16.86	2.55	4.90	4.26	1.47	2.09	9.38	3.88	1.10	5.97	52.47
	Chittagong	19.54	2.14	7.51	4.49	2.91	2.15	7.85	4.61	1.92	6.01	59.13
All Average		17.50	2.46	5.53	4.53	1.81	2.10	9.06	4.06	1.28	6.07	54.40

On an average, establishment cost per kilogram was Tk 5.53. The establishment cost was the lowest (Tk 4.59/ kg) in B class and it was the highest (Tk 7.64 /kg) in U class. The establishment cost was the higher (Tk 11.60/kg) in Chittagong and it was the lower (Tk 3.70 /kg) in Sylhet. The study showed that on an average per kg cost of using manures & insecticides was Tk 4.53. The highest cost for manures and fertilizers (Tk 5.93 /kg) was found in B class whereas it was the lowest (Tk 3.28/kg) in U class. The per kg cost was a little bit higher in Chittagong compared to Sylhet. Per kg cost of transport and fuel was Tk 1.81. The transport cost was the higher (Tk 2.91/kg) in Chittagong while it was the lower in Sylhet (Tk 1.47 /kg). The cost was the highest (Tk 5.74 /kg) in U class and it was the lowest (Tk 0.69 /kg) in C class. The average per kg cost of maintenance was Tk 2.10. The study showed that the highest cost was found in C (Tk 2.83 /kg) class whereas it was the lowest in U (Tk 0.34 /kg) class. It was also found that maintenance cost was a little bit higher in Chittagong compared to the Sylhet region. The study shows on an average manufacturing cost per kg was Tk 9.06. The study indicated that per kg cost of manufacturing decreased with the increase in production. The manufacturing cost was the higher (Tk 9.38 /kg) in Sylhet while it was the lower (Tk 7.85 /kg) in the Chittagong region. It was also found that the highest cost (Tk 12.40 /kg) was found in U class while it was the lowest (Tk 7.87 /kg) in A class.

The per kg cost of using chest and dispatching was found to be Tk 4.06. The study revealed that per kg cost was the highest (Tk 4.99) in B class while the lowest (Tk 0.66 /kg) was in U class. It was also observed that per kg cost was the higher (Tk 4.61 /kg) in Chittagong and it was the lower (Tk 3.88 /kg) in Sylhet. The study showed that per kg cost of rent and taxes was found to be Tk 1.28. The highest cost (Tk 2.24 /kg) was found in U class and it was the lowest (Tk 1.01/kg) in A class. The study also revealed that per kg cost was the higher (Tk 1.92 /kg) in the Chittagong region cpmpared to the Sylhet (Tk 1.10 /kg) region due to lower productivity in Chittagong. On an average miscellaneous cost per kg of made tea was found to be Tk 6.07. It was observed that there was no significant difference in cost among the different classes. But it was observed that miscellaneous cost was the higher (Tk 9.35 /kg) in the Chittagong region and it was the lower in the Sylhet region (Tk 2.17 /kg) in U class. Tea estates in Bangladesh are divided into five diverse management ownership. They are Sterling companies, National Tea Company (NTC), Bangladesh Tea Board managed tea estates, Private Limited Companies and Proprietary tea estates. The labour wage was the lowest (Tk 14.07 /kg) at National tea company and it was the highest (Tk 19.21 /kg) at Proprietary tea estates due to lower per hectare yield obtained by Proprietary tea estates (Table 4). The study showed that labour wage of BTB, Sterling and Private Limited companies ranged from Tk 16.21 to Tk 17.00. Labour welfare cost was the highest (Tk 5.16 /kg) at NTC while it was the lowest (Tk 0.88 /kg) at BTB managed tea estates. The establishment cost was the highest (Tk 6.17 /kg) at Sterling Companies while it was the lowest (Tk 4.55 /kg) at National tea Company Limited. The establishment cost of BTB, Private and Proprietary tea estates were Tk 4.63, 6.04 and 5.29, respectively.

The study showed that per kg cost of using manures & pesticides was Tk 7.28 /kg at National Tea Company Limited which is about double compared with other type of managements. The lowest cost (Tk 3.91 /kg) was found in BTB managed tea estates. The per kg cost of using manures & pesticides at Sterling, Private Limited companies and Proprietary tea estates was Tk 3.03, 4.44, 4.80 respectively.The per kg transport cost was the highest (Tk 2.19 /kg) at proprietary estates and it was the lowest (Tk 0.86 /kg) at Sterling Companies.

The per kg transport costs of BTB, NTC and Private Limited Companies were Tk 0.91, 1.77 and 2.07 respectively. The study showed that per kg maintenance cost was the highest (Tk 2.64/kg) in BTB managed tea estates and it was the lowest (Tk1.82 /kg) at Sterling Companies. The per kg maintenance cost of made tea in NTC and Private Limited Companies and proprietary tea estates were Tk 1.92, 1.89 and 2.28, respectively.

Table 4. Break-up of cost (Tk/kg) of made tea by different types of management

Cost components	Types of management					Average
	BTB	Sterling	NTC	Private	Proprietary	
Labour Wage	16.21	16.53	14.07	17.00	19.21	17.50
Labour Welfare	0.88	3.96	5.16	2.38	1.69	2.46
Establishment	4.63	6.17	4.55	6.04	5.29	5.53
Manures & pesticides	3.91	3.03	7.28	4.44	4.44	4.53
Transport & fuel	0.91	0.86	1.77	2.07	2.19	1.81
Main. of Build. & machinery	2.64	1.82	1.92	1.89	2.28	2.10
Manufacturing	7.75	6.19	9.02	8.68	10.73	9.06
Tea Chest & Dispatch	3.95	4.25	3.66	4.65	3.65	4.06
Rent & Taxes	0.56	0.83	0.48	1.34	1.75	1.28
Miscellaneous	6.47	5.64	6.29	6.13	6.08	6.07
Total	47.91	49.28	54.20	54.62	57.67	54.40

Manufacturing cost is one of the major cost components in the total cost of production. The highest (Tk 10.73 /kg) per kg cost of manufacturing was found in proprietary tea estates. The lowest (Tk 6.19 /kg) per kg cost was found in Sterling Companies. The per kg manufacturing cost at BTB, NTC and Private limited Companies were Tk 7.75, 9.02 and 8.68 respectively. The study also showed that per kg cost of using chest and dispatching was the highest (Tk 4.65 /kg) in private Limited companies and it was the lowest (Tk 3.65 /kg) in proprietary tea estates. The per kg cost of using chest and dispatching at BTB, Sterling Companies and NTC were Tk 3.95, 4.25 and 3.66 respectively. The per kg cost of rent and taxes was almost same among the different types of managements. But it was found higher in Private Company Limited and Proprietary tea estates. On the other hand, the per kg miscellaneous cost was almost same among the different types of managements. The study showed that on an average per kg cost of made tea in greater Sylhet and greater Chittagong were Tk 52.47 and Tk 59.13 respectively (Table 5). The study revealed that per kg cost of made tea at greater Chittagong was about 13% higher when compared with greater Sylhet. It was also observed that per kg cost of production of Private Limited Companies in greater Sylhet region was Tk 52.14 while it was Tk 57.92 at greater Chittagong region. The per kg cost of made tea at Private Limited Companies in Chittagong region was about 11% higher compared to Sylhet region. Similarly, per kg cost of made tea of proprietary tea estates at Chittagong region was about 12 % higher compared to greater Sylhet region. The per kg cost of made tea in different classes in greater Chittagong region was also found higher when compared to greater Sylhet region (Table 6).

Table5. Break-up of cost (Tk/kg) of made tea according to types of management and location

Type of Management	Location		Average
	Greater Sylhet	Greater Chittagong	
BTB	47.91	--	47.91
Sterling	49.28	--	49.28
NTC	54.20	--	54.20
Private Limited Companies	52.14	57.92	54.62
Proprietary	52.65	59.30	57.67
Average	52.47	59.13	54.40

Table 6. Break-up of cost (Tk/kg) of made tea according to location and category

Category	Location		Average
	Greater Sylhet	Greater Chittagong	
A	51.03	58.31	53.07
B	52.74	58.12	54.56
C	56.28	59.95	57.55
U	60.44	64.89	62.69
Average	52.47	59.13	54.40

Table 7 shows the percentage of different items of cost to total cost of production of made tea. The study showed that cost of labour was the major cost item constituting 32.17% of the total cost on the basis of cost estimation. The second major cost incurred is tea manufacturing accounting for 16.65% of the total cost.

Table 7. Cost components as proportion to total cost by different types of management
(in percent)

Cost components	Type of Management					Average
	BTB	Sterling	NTC	Private	Proprietary	
Labour Wage	33.83	33.54	25.96	31.12	33.31	32.17
Labour Welfare	1.84	8.04	9.52	4.36	2.94	4.52
Establishment	9.66	12.53	8.39	11.06	9.17	10.17
Manures & pesticides	8.16	6.15	13.43	8.13	8.32	8.33
Transport & fuel	1.91	1.75	3.27	3.80	3.80	3.33
Main. of Build. & machinery	5.51	3.69	3.54	3.46	3.95	3.86
Manufacturing	16.18	12.56	16.64	15.89	18.61	16.65
Tea Chest & Dispatch	8.24	8.62	6.75	8.51	6.33	7.46
Rent & Taxes	1.17	1.68	0.89	2.45	3.03	2.35
Miscellaeneous	13.50	11.44	11.61	11.22	10.54	11.16
Total	100.00	100.00	100.00	100.00	100.00	100.00

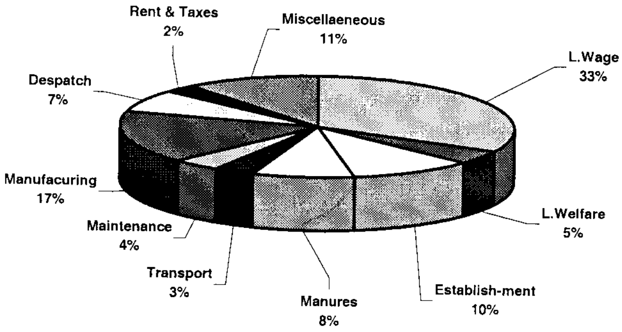

Fig. 1. Proportion of per kg cost of made tea to the total cost

Fig. 2 shows the per kg cost of made tea with per hectare production. The study showed that there exists a reverse relationship between per kg cost of made tea with per hectare production. This indicated that with an increase of 100 kg yield per hectare, the per kg cost is reduced by Tk.0.85

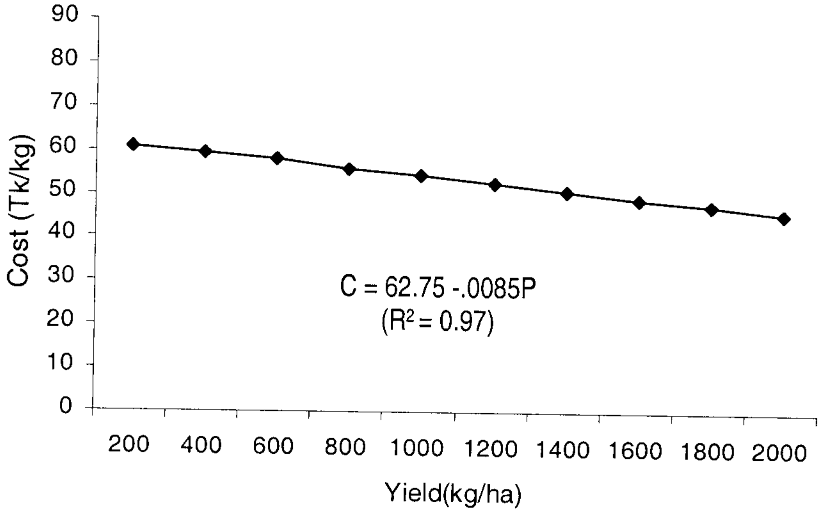

Fig. 2. Relationship between Yield (kg/ha) and cost (Tk/kg)

The figure 3 shows the type of management wise per kg cost of made tea. The study showed that the highest cost (Tk 17.50 /kg) was found in labour wage followed by tea manufacturing (Tk 9.06 /kg) and establishment (Tk 5.53 /kg). The lowest cost (Tk 1.28 /kg) was found for rent and taxes. The study also revealed that the per kg cost was the highest (Tk 57.67 /kg) in proprietary tea estates and the lowest (Tk 47.91 /kg) in BTB managed tea estates.

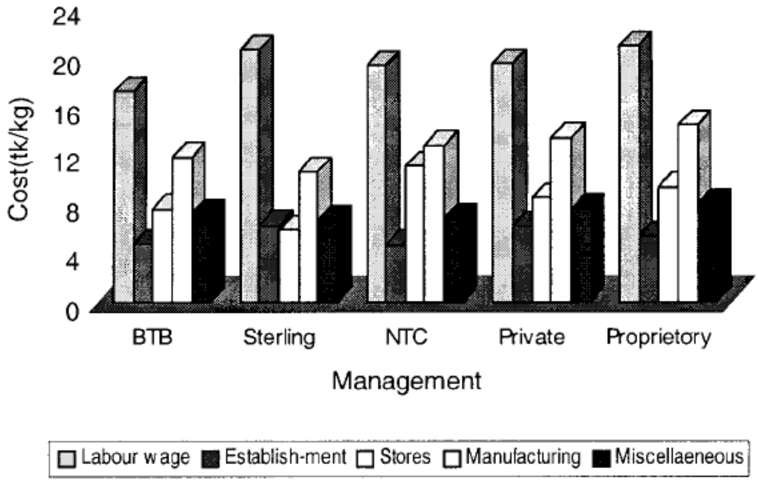

Fig. 3. Type of Management wise per kg cost of made tea

CONCLUSION

Tea cultivation in Bangladesh is economically viable. In order to sustain the industry as viable one, per hectare yield of the proprietary tea estates should be increased and its quality should be improved by introducing BTRI clones and better quality seeds. As a result, cost of production is likely to be reduced and this in turn it will help to make the industry a viable one.

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CROP PRODUCTIVITY AS INFLUENCED BY SOIL TEST BASED FERTILIZER MANAGEMENT IN SIX CROPPING PATTERNS AT FARMERS' FIELD

J.C. BISWAS[1], M.R. ISLAM[2] AND M.J. ISLAM[3]

ABSTRACT

Experiments with six cropping patterns were conducted at farmers' field to minimize yield gap between researcher's and farmers' crop management and to diffuse soil test based (STB) fertilizer packages for growing crops. Grain yield of Boro (dry season irrigated rice) and T. aman (rainfed lowland rice) rice increased by 20-27% and 28-62%, respectively compared to farmers' practice (FP) in Boro-GM-T. aman pattern. Total rice yield was increased by about 28-51 % in Boro- T. aus (premoonsoon rainfed rice) - T. aman pattern with STB fertilizer management compared to FP. In other patterns, grain yield of rice was increased by 28-57% compared to FP. Increase in jute yield was 31-62% in wheat-jute- T. aman pattern; whereas, grain yield of wheat increased by 30-118% compared to FP in the same pattern. The grain yield increase of wheat was 141.2% in Wheat-T. aus-T. aman pattern compared to FP. In comparison to FP, there was about 48% increase in potato yield with high fertilizer management in Potato-jute- T. aman pattern. The Agronomic use-Efficiency (AE) varied from 78-106 and 16-23 kg grains kg^{-1} P and K, respectively. The highest AE was 196 kg grains kg^{-1} added S. Considering high yield goal of crops, the highest added benefit was obtained from Potato-jute-T. aman pattern (\$1020.7 ha^{-1}) followed by Wheat-jute-T. aman (\$567.0 ha^{-1}) and Wheat-T. aus-T. aman (\$512.7 ha-l), respectively because of additional fertilizer use compared to FP. About 42% farmers' adopted STB fertilizer technology in the study area.

Keywords: Soil test based fertilizer management, cropping pattern, and crop productivity.

[1] Agronomy Division, Bangladesh Rich Research Institute (BRRI), Gazipur
[2] Department of Agricultural Extension, Mymensingh, Bangladesh
[3] Department of Agricultural Engineering, Bangladesh Agricultural University (BAU), Mymensingh

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INTRODUCTION

In Bangladesh, farmers are growing more than one rice crop in most of their lands having low organic matter content without balanced fertilizer doses with photo-insensitive modern varieties along with increased irrigation facilities. As a result, not only turnaround period has been narrowed down for rejuvenating soil nutrient supplying capacity, but also higher amount of chemical fertilizers is needed than before to sustain rice yield. However, because of visible influence of N fertilizer most of the farmers use more urea than others for growing rice (Biswas *et al.* 2001).

Organic matter content of most soils in Bangladesh is less than 2% (BARC, 1997), which is further declining because of intensive cropping (Ali *et al.*, 1997) and improper crop management. There are also deficiencies of sulfur in about 4 million ha and zinc in 2 million ha of arable land (Karim, 1999). Although continuous rice growing showed organic matter build up in soil, but N supplying capacity apparently declined (Cassman *et al.*, 1995; Dobermann *et al.*, 2000). This indicated that productivity of N fertilizer for rice is decreasing (Cassman *et al.*, 1997). Moreover, decrease of organic matter content in rice-wheat system (Yadav *et al.*, 2000) is a great concern for sustainable crop production.

Addition of organic manures and use of balanced fertilizers are most likely to increase yields of crops and restore soil productivity at farmers fields. A legume crop after wheat restored soil mineral N which otherwise could be lost upon flooding for growing rice (Buresh *et al.*, 1989). However, farmers generally do not include legume crop in a cropping pattern because of many factors like, lack of knowledge on beneficial effects of legumes, low yield, etc., and seldom use balanced fertilizers for crop production resulting in declining yields in most cases. Moreover, cultivated area in Bangladesh is decreasing day by day because of inftastructure development. This has necessitated increased yield of crops from unit land area by cultural manipulations like fertilizer and water management. Fertilizer management based on soil test significantly improves grain yield of rice (Biswas *et al.*, 2003) but most of the farmers) in Bangladesh do not practice it. Therefore, six cropping patterns together with soil test based fertilizer management were evaluated at farmer's field for determination of crop productivity and farmers' response to new technology.

MATERIALS AND METHODS

Location and soil

The experiment was conducted at farmers' field, Ishwargonj, Mymensingh, Bangladesh, located at 24°35'-24°42' N latitude and 90°28'-90°44' E longitude. The site belongs to Agricultural Ecological Zone 9 having subtropical climate (FAO, 1988). The average annual rainfall is 3000 mm and the lowest mean temperature is observed in January and highest in June. The soils of experimental fields are Ishwargonj silt clay loam of Aeric Haplaquept family.

Cropping pattern, crops, experimental design and treatments

Six cropping patterns viz., Boro (dry season irrigated rice) - GM *(Sesbania* sp.)- T. aman (rainfed lowland rice), Boro - Fallow - T. aman, Boro - T. aus (premonsoon rainfed rice) - T. am an, wheat (dry season irrigated crop) - jute (rainfed upland crop) - T. aman, wheat - T. aus - T.

aman and potato (dry season irrigated crop) - jute - T. aman were evaluated under three fertilizer packages. The crop varieties used were BRI4, Kanchan, Cardinal, CVE3, BR2 and BRll for Boro, wheat, potato, jute, T. aus and T. aman respectively. However, in wheat - T. aus - T. aman pattern BRRI dhan32 was used as T. aman crop. A randomized complete block design was used. The treatments dispersed at farmers' fields were considered as replication.

Crop culture and fertilizer application

Standard production packages were followed for growing the crops. Some of the major cultural operations are listed in Table 1. The fertilizer packages used were farmers' practice, medium yield goal and high yield goal as per BARC (1987) manual. Fertilizer doses for medium and high goals are provided in Table 2. Green biomass of *Sesbania* sp in Boro -GM *(Sesbania* sp) - T. aman pattern was incorporated in situ at 55-60 days after seeding.

Table 1: Schedule of some cultural practices of different crops

Name of crop	Seeding date	Transplanting date	Spacing (cm)	Application schedule of Urea
Aus rice	15-30 May	15-30 June	20 x 20	Basal and 35 DAT
T. aman	20-30 June	25 July - 5 Aug	25 x 15	15-20,30-45,55-65 DAT
Bora rice	2-15 Dec	20-30 Jan	20-25 x 15	20-25, 40-50, 60-70 DAT
Jute	1-15 April	-	10-15 x 25	20-25, 45-50 DAS
Wheat	1-10 Dec	-	Direct seeded	15-20,45-55 DAS
Potato	20-30 Nov	-	55 x 15	10-15,35-40 DAS

Data collection and analyses

Crop yields were recorded from 100 m-2 areas. Grain yields of rice and wheat were adjusted at 14% moisture content. Jute yield was recorded after sun drying for 3-4 days in a traditional way practiced by the farmers'. Potato yield was recorded immediately after harvest. Pre-tested structured questionnaire was used for determination of technology adoption rate by the farmers' in the same experimental site.

Table 2: Amount of fertilizers used in farmers' practice and soil test based dose for cultivation of fidderent crops. Ishwargonj, Mymensingh

	Kg ha-1				
	N	P	K	S	Zn
Boro (BR14)					
Farmers' practice	112.5	15	25	-	-
Medium yield goal	100	15	40	10.8	1.08
High yield goal	132.5	20	52.5	14.4	1.44

Wheat (Kanchan)					
Farmers; practice	34-45	-	-	-	-
Medium yield goal	60	10	30	4	-
High yield goal	78	13	39	5.2	-
Potato (Cardinal)					
Farmers; practice	66	25	-	-	-
Medium yield goal	101.2	20	31.2	10.08	1.08
High yield goal	131	23	40	13.5	1.44
Aus (BR2)					
Farmers' practice	90	-	-	-	-
Medium yield goal	60	10	30	4	-
High yield goal	78	13	39	5.2	-
Jute (CVE3)					
Farmers' practice	45-67	-	-	-	-
Medium yield goal	40	7	20	3	-
High yield goal	52	10	26	4	-
T. aman (BR11)					
Farmers' practice*	60-112	0-10	0-25	0-4	-
Medium yield goal	60	8	30	4	-
High yield goal	78	10.4	39	5.2	-
T. aman (BRRI dhan 32)					
Farmers' practice	45-90	-	-	-	-
Medium yield goal	60	8	30	4	-
High yield goal	78	10.4	39	5.2	-

No fertilizer used, *only a few farmers used TSP, MP and gypsum fertilizers

Analysis of variance of the measured parameters of each crop was performed and treatment means were compared using Duncan's Multiple Range Test at 5% level of probability. Total income was calculated as (average price of produce) x (total yield). Additional profit was calculated as

$$\Pi = \Delta_Y P_p - A_F P_F$$

where Π is the additional profit (US \$ ha^{-1} yr^{-1}); *tly*, change in yield because of additional fertilizers used compared to farmers' dose; Pp, price of produce (US \$ t^{-1}; A_F, additional fertilizer (kg ha^{-1}) and P_F, the price of fertilizer (US \$ kg^{-1}).

Agronomic efficiency (AE) of P (AEp), K (AE_K) and S (AE_S) in T. aman rice was calculated

as

$AE_P = (Y_{NPK} - Y_{NK})$/Fertilizer P applied

$AE_K = (Y_{NPK} - Y_{NP})$/Fertilizer K applied

$AE_S = (Y_{NPKS} - Y_{NPK})$/Fertilizer S applied

where Y is the grain yield with or without N, P, K and S fertilizers (shown. as subscripts). All units are in kg ha^{-1}.

Total rice yield was the summation of rice yield in each growing season together with rice equivalent yield (REY) of non-rice crops over a year. The REY was calculated as

REY = (Total price of non-rice crops in US \$)/(Cost ofrice \$ $^{-1}$)

RESULTS

Treatment differences in yield

The highest total rice yield (24.56 t ha^{-1}) was recorded in potato-jute-T. aman pattern followed by Boro-T. aus-T. aman pattern (11.92 t ha^{-1}) irrespective of fertilizer management packages (Table 3). The response of fertilizer to yield improvement was greater when three crops were grown in a year than two crops in comparison to farmers' practice (FP). The yield improvement in different cropping pattern with medium yield goal (MYG) fertilizer management was 19-38% compared to FP (Table 3). However, this improvement was about 38-76% with high yield goal (HYG) fertilizer management compared to FP. In general, 27.37% and 53.10% higher yield could be obtained following MYG and HYG fertilizer management, respectively (Table 3).

Table 3: Total rice/rice equivalent yield as influenced by cropping pattern, Ishwargonj, Mymensingh, Bangladesh

Pattern	Yield (t ha-1)			Mean (t ha-1)
	FP	MYG	HYG	
Boro-Sesbania- T. aman	7.39	9.14	10.38	8.97
Potato-Jute-T. aman	19.58	24.48	29.62	24.56
Wheat-Jute-T. aman	7.16	9.56	12.56	9.76
Boro-Fallow-T. aman	7.98	9.51	11.07	9.52
Boro-T.aus-T. aman	9.43	12.12	14.20	11.92
Wheat-T.aus-T. aman	7.45	10.30	12.49	10.08
Mean	9.83	12.52	15.05	

Grain yield of Boro rice increased by 20-27% compared to farmers' practice (FP) in Boro-GM-T. aman pattern. The increase in grain yield of T. aman rice in the same cropping pattern was 62% compared to FP. It was possible to obtain a total of 10.38 t ha^{-1} rice from the above mentioned pattern following fertilizer management based on high yield goal (HYG), which was about 40.4% higher than FP. Nasim *et al.*, (1999) reported a total of 10 t ha^{-1} rice from the Boro-GM-T. aman pattern.

In Boro- T. aus- T. aman, total grain yield was 14.25 t ha^{-1} with higher fertilizer dose and it was only 9.43 t ha^{-1} with FP (Fig. 2): In Wheat-T. aus-T. aman and Wheat-jute-T. aman pattern, grain yield of rice increased by 28-57% compared to FP. Increase in jute yield was 31-62% in Wheat-jute- T. aman pattern; whereas, grain yield of wheat increased by 30-118% compared to FP in the same pattern. The highest grain yield increase of wheat was 141.2% in Wheat-T. aus-T. aman pattern compared to FP. In comparison to FP, there was 19% increase in potato yield based on medium yield goal (MYG) fertilizer management; whereas, it was about 48% with HYG fertilizer management in Potato-jute- T. aman cropping pattern. In Boro-fallow-T. aman pattern, total paddy yield varied from 9.51-11.07 t ha^{-1} because of fertilizer management following MYG and HYG; while it was only 7.89 t ha^{-1} with farmers' fertilizer management. Similar paddy yield at farmers' field was reported by Elahi *et al.*, (2001).

Agronomic-economic analysis

Agronomic efficiency in BR11 varied from 16-196 kg grains kg^{-1} nutrient depending on type of nutrients applied during wet season. The highest AE (195.6 kg) was observed when S fertilizer was used in combination with N, P and K fertilizers. The AE of P ranged from 78-106 kg grains kg^{-1} fertilizer P applied; whereas, it was 16-23 for K. These findings are in agreement with Dobermann *et al.*, (1998).

Considering HYG of crops, the highest additional profit was obtained from Potato-jute-T. aman pattern (\$1020.7 ha^{-1}) followed by wheat-jute-T. aman (\$567.0 ha^{-1}) and wheat T. aus- T. aman (\$5 12. 7 ha^{-1}) respectively because of additional fertilizer use compared to FP (Table 4). Almost similar trend was observed when fertilizer was used according to MYG.

Table 4: Total income in a hectare of land as influenced by cropping pattern and fertilizer management. Ishwargonj, Mymensingh

Fertilizer management	Total income ($ ha-1)	Total fertilizer cost ($ ha-1)	Additional fertilizer cost ($ ha-1)	Additional benefit ($ ha-1)
Boro (BR14)-GM (Sesbania sp)-T. aman (BR11)				
Farmer's practice	751.7	59.3	-	-
Medium yield goal	929.5	93.1	33.7	177.8
High yield goal	1055.4	122.6	63.3	303.7
Potato (Cardinal)-Jute (CVE3)- T. aman (BR11)				
Farmer's practice	1990.7	51.9	-	-
Medium yield goal	2488.3	130.6	78.6	497.5
High yield goal	3011.5	166.4	114.5	1020.7

Wheat (Kanchan) – Jute (CVE3) – T. aman (BR11)				
Farmer's practice	758.2	29.7	-	-
Medium yield goal	1010.9	92.2	62.5	252.7
High yield goal	1325.2	118.9	89.3	567.0
Boro (BR14) – Fallow- T. aman (BR11)				
Farmer's practice	811.7	56.2	-	-
Medium yield goal	967.5	97.5	41.4	155.8
High yield goal	1126.0	128.4	72.3	314.2
Boro (BR14) – T. aus (BR2) – T. aman (BR11)				
Farmer's practice	958.8	88.5	-	-
Medium yield goal	1232.7	136.2	47.7	274.0
High yield goal	1449.4	180.1	91.6	490.6
Wheat (Kanchan) – T. aus (BR2)- T. aman (BRRI dhan32)				
Farmer's practice	757.4	52.5	-	-
Medium yield goal	1047.1	110.8	58.3	289.6
High yield goal	1270.2	151.4	98.8	512.7

Price of rice, wheat potato and jute is @ \$101.7, 152.5, 84.7 and 169.5 t^{-1} respectively \$1= Tk. 59.00

Adoption rate of technology

Our post evaluation survey revealed that about 42% farmers who experienced the benefit of soil test based (STB) fertilizer management were using the technology (Table 5). The rest of the demonstration farmers failed to adopt the technology because of lack in cash capital at the right time of cropping season. The STB fertilizer technology was diffused to about 8% of neighboring farmers, although their technical know how with to balanced fertilizer use, choice of right cropping pattern and green manuring was poor compared to demonstration farmers.

Table 5: Adoption and diffusion of fertilizer management concepts at farmers' field, Ishwargonj, Mymensingh, Bangladesh

	Demonstration farmers (%)	Non-demonstration farmers (%)
Soil test based fertilizer management	42.11	7.89
How to keep soil productive?		
Use of balanced fertilizer	36.84	18.42
Choice of right cropping pattern	21.05	13.16
Use of farm manures	29.95	31.20
Incorporation of GM crops	36.84	31.01
Knowledge on balanced fertilizer use	40.47	25.32
Why they don't use balanced fertilizer?		
Lack of capital	35.12	26.32
Lack of knowledge	-	10.89

N.B. Total number of respondents was 40

DISCUSSION

There was a great variation in yield and profit because of fertilizer doses used by the farmers and STB fertilizer management with different cropping patterns. The increase in yield was as high as 118% in wheat and 19% in potato compared to farmers' fertilizer management. These variations clearly indicated that farmers used lower amount of fertilizers in different crops without considering the requirements of crops and nutrient supplying capacity of soils for satisfactory return. Sarker *et al.*, (2003) also reported that land tenure system, lack of cash capital during the crop establishment period, high input price, low product price and lack of modern agricultural knowledge are the bottlenecks in using higher amount and/or balanced fertilizer for crop production.

Although cropping intensity in Mymensingh, Bangladesh is about 240% and Boro- T. aus-T. aman is one of the dominant cropping patterns, farmers' are unable to harvest a good crop from their land because of imbalanced fertilizer use, choice of variety, lack of farmyard manures application and/or no cultivation of legume crops. It was found that fertilizer management based on yield goal was significantly correlated with crop's yield (r = 0.882**).

However, the relationship between yield and pattern was statistically insignificant [$y = 0.491 + 0.9$ (pattern); $R^2 = 0.62$DS].

From the present investigation it was observed that most of the farmers' use only urea because of its visible effect on growth of T. am an, T. aus and jute crops. Biswas *et al.* (2001) also reported that farmers' generally apply large quantities of urea, especially for cultivation of rainfed lowland rice. But these crops are removing large amounts of P, K and S ITom soil (Dobermann et al., 1998; Panaullah et al., 1999). As a result, soil fertility in terms of P, K, S and Zn is declining and in many soils their supplying capacity is below critical level (Fig. 1).

Similar views were expressed by Dobermann et al., (1998). Moreover, Biswas et al., (2003) reported that Ca and Mg are emerging as limiting nutrient elements for crops in light textured soils of Bangladesh. Panaullah et al., (1999) reported that at the present system of cultivation and yield level in Bangladesh, about 1 million tones nutrients year^{-1} are removed by the crops of which partly are replenished by the application of chemical fertilizers. Inadequate supply of these nutrients is widening yield gaps between on station and farmers' management.

In general, AE was higher with fertilizer management based on HYG compared to fertilizer management based on medium yield goal (MYG). The highest AE (196 kg grains kg^{-1} S) with S application indicates that S deficiency is increasing with intensive rice based cropping systems. Although Karim (1999) reported that S deficiency was distributed over 4 million hectares in Bangladesh, the present investigation revealed that S deficiency has been intensified. The deficiency of S needs to be corrected for efficient utilization of other nutrients, especially N. However, blanket recommendation of fertilizer may prevent significant response to added nutrients because interactions among nutrients could be synergistic or antagonistic depending on the nutrient supplying capacity of soil in irrigated culture. Therefore, farmers' training for their skill development in a site specific crop-nutrient management is needed for higher net return.

CONCLUSION

Grain yield of rice, jute, wheat and potato could be increased by about 20-51 %, 3162%, 30-118% and 19-48%, respectively following BARC recommended fertilizer management compared to farmers' fertilizer dose. However, inclusion of a legume crop in a pattern should be considered to sustained soil productivity. The highest agronomic efficiency (195.6 kg) was observed when S fertilizer was used in combination with N, P and K fertilizers indicating that proper care should be taken for S fertilizer application. The highest additional profit was obtained from Potato-Jute-T. aman pattern (\$1020.7 ha^{-1}). However, the price of Potato at the farm gate is very low in many years because of bumper production. Moreover, cold storage facilities are still inadequate in Bangladesh. So, infrastructure development and ensured market policy is needed before greater diffusion of Potato-Jute- T. aman pattern. Although the benefit of STB fertilizer management was high, the technology was diffused to about 8% of neighboring farmers emphasing more concerted efforts to diffuse agricultural technology to increase productivity at national level.

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EFFECT OF LOW NIGHT TEMPERATURE ON THE SPIKELET DEFORMITY, STERILITY AND YIELD OF RICE

A.K.M.R. AMIN[1], N. ISLAM[2], S.M.A. HOSSAIN[2], A.R. SARKAR[2] AND M.A. RAZZAQUE[3]

ABSTRACT

A experiment was conducted at the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during 2000-01. Boro season to evaluate the performance of rice under low night temperature treatments imposed at flower initiation to flowering. Low night temperatures (18^{0}C and 16^{0}C) over varieties, BRRIdhan29 and Sonarbangla1, promoted sterility from 27.24-33.19% by decreasing seed yield from 4.94 to 12.47% compared to that grown under natural condition. Several forms of both hyperplasia and hypoplasia of the reproductive organs of rice spikelets e.g. swollen anthers, elongated and spiral stigma, balloon-shaped stigma, bi-lobed spikelets, deformed glumes, lemma, palea and kernels were identified in both the varieties when low temperature conditions were imposed during night periods.

Key words: Boro rice, Spikelet, Sterility, Low night temperature, Transplanting

INTRODUCTION

In Bangladesh rice crops are grown round the year in Aus, Aman and Boro seasons. Aman rice is the major group of rice crops, although Boro rice has comparatively higher productivity potential. About 75% of the total cropped area of Bangladesh is devoted to rice production with the area and production 10.8 million hectares and 25.2 million tons, respectively (BBS, 2004). In general, the yield of Boro rice is highest as the crop receives more favorable environmental conditions, enjoying relatively the longer growing season extending from November-December to June-July. However, Boro rice crops are sometimes affected by low temperature during flowering, booting to early flash floods and hailstorms (Rashid, 1994). Spikelet sterility is a serious problem in Boro rice and this becomes very acute particularly in the extended cooler seasons. The sterility may occur due to stresses caused by several environmental and production factors such as low temperature (Zhong, 1991) and high temperature (Naidu and Reddy, 1998) during flower initiation to flowering stages. In Bangladesh, flowering in Boro rice occurs in the

[1] Associate Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka
[2] Professor, Department of Agronomy, Bangladesh Agricultural University (BAU), Mymensingh
[3] Member Director, Bangladesh Agricultural Research Council

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months of March–April. This is the transition time of seasonal change from winter to summer. Therefore, high temperatures, at the reproductive phase, are moderate well not cause any substantial difference in deciding flowering behavior and hence yield. On the other hand, low temperatures at night causing meiotic disturbance at reproductive phase will cause severe sterility. Experimental evidences in rice show that a low temperature range of 13.8-16.8 °C prevailing during pre-flowering to early flowering period for about 20 days is detrimental, as this promotes spikelet sterility up to 18% (Reddy *et al*., 1987).

It is not clear as to what per cent of spikelet sterility is caused by low temperature during flowering in Bangladesh and it is not also precisely known what happens exactly in the flowering time of Boro rice due to low temperature stresses in HYV rice. It is, therefore, likely that the development mechanism of spikelet sterility in Boro rice due to low temperature stress is an important area of investigation. This experiment was, therefore, undertaken to evaluate the deformities of spikelets, and the yield performance and spikelet sterility of Boro rice under low night temperature conditions.

MATERIALS AND METHODS

The pot experiment was conducted in the net house and growth chamber of Bangladesh Agricultural University, Mymensingh during 1999-2000 Boro season. The soil belongs to Sonatola soil series of Non-calcareous Dark Grey Floodplain Soil. The soil is silt loam with low organic matter content and slightly acidic in reaction. Two high yielding varieties viz. BRRIDhan29 and Sonarbangla1, popularly being cultivated in the country, were involved to study the morphological disorders under two controlled low night temperature conditions viz. 16^{0}C and 18^{0}C and also in normal atmospheric condition (more than 18^{0}C temperature). The experiment was set up in a completely randomized design. Six treatment combinations (2×3) were replicated 10 times to accommodate extra plant sampling programme for studying spikelet deformities in addition to allowing 5 replications for statistical analysis of yield and yield components. Seedlings of 40 and 30-day old, respectively for BRRIdhan29 and Sonarbangla1 were transplanted on 20 December 2000. Fertilizers were applied as per recommended dose of the crops. Irrigation was given as and when required to maintain 3-5 cm depth of water up to the heading stage of crops. A portion of the net house was modified and renovated to create three chambers. In one of the chambers, normal atmospheric conditions were maintained. The other two chambers were built up to install cooling provisions (growth chambers), in which the specified night temperature conditions were temperature. All pots with rice seedlings were first placed in the net house at normal atmospheric condition. At the time of panicle initiation, ten pots of each variety were transferred to the growth chambers to impose 16^{0}C and 18^{0}C cold stresses at night. Remaining ten pots of each variety experienced normal atmospheric temperature conditions until maturity. When flowering stage was over, pots from the cold chambers were transferred back to the normal atmospheric condition.

After panicle initiation, both the external and internal organs of the spikelets were thoroughly examined by dissecting them with scalpel under a Sterio-Microscope. The abnormal spikelets were then fixed in Formaline-Acetic Acid-Alcohol (FAA) solution and then magnified photographs and Sterio-Microscopic photographs of those abnormal spiket structures were taken. Plants from four hills pot^{-1} were used for assessing yield and yield components. At maturity yield and yield components were assessed from the plants collected from each pot with special attention given to assessing % sterility and seed yield. The data were analyzed following the ANOVA-Technique and means were adjudged with Duncan's Multiple Range Test (Zaman *et al.*, 1992).

RESULTS AND DISCUSSION

Spikelet deformity

Two high yielding varieties, BRRI dhan29 and Sonarbangla1, when examined under night temperature treatments, showed differential response in terms of generating spikelet sterility. The deformities were observed from the very beginning of panicle emergence and these were ultimately transformed into sterile spikelets. Major portion of sterile spikelets were visually found normal but they lacked grains inside. These empty spikelets were probably developed due to the lack of secondary developments following fertilization or due to total failure of fertilization. The actual cause and effect could not be traced under the present set-up of the study. Two kinds of visual deformities as stated by Takeoka *et al.* (1992) were very much evident in the spikelets of both the varieties, especially under the low night temperature conditions. The various kinds of deformities found could likely be grouped as i] Hyperplasia- in which the unusual or abnormal increase in the elements composed the reproductive organ(s) and ii] Hypoplasia- whereby the arrested growth or development of the organ(s) concern resulted in below the normal size or in immature state of the organ(s).

a) Hypoplasia of BRRI dhan29 rice spikelets as influenced by low night temperature stresses (16^0 and 18^0C) at panicle initiation to flowering stage showed following abnormalities of the organs (Plates 1.1-1.2).

i) Poorly developed spikelets, which ultimately dried up (Plate 1.1.1).

ii) Poorly developed rachis and spikelets, which ultimately dried up (Plate 1.1.2).

iii) Spikelets with short and sickle shaped lemma. Palea was large and single glume was found beneath the palea. Spikelet lacked kernel (Plate 1.1.3).

iv) Spikelet with thin and long palea, and short and beak shaped lemma. Single glume was found beneath the palea (Plate 1.1.4).

v) Palea was absent in the spikelet. Kernel was uncovered due to the absence of palea. A glume was found in the place of palea (Plate 1.2.1).

vi) Lemma was absent in the spikelet. Kernel was uncovered due to the absence of lemma. Kernel was curved and looked like sickle shaped. Single glume was found beneath the palea (Plate 1.2.2).

vii) Spikelet with sickle shaped palea and without lemma (Plate 1.2.3).

viii) Spikelet lacked lemma with defused anthers and stigma (Plate 1.2.4).

b) Hyperplasia of BRRI dhan29 rice spikelets as influenced by low temperature stresses (16^0 and 18^0C) at night from panicle initiation to flowering stage showed following abnormalities of the organs (Plate 2).

i) Spikelet with long and spiral glume. Normal sized lemma and palea, but had no reproductive organ inside (Plate 2.1).

ii) Normal shaped spikelet with long glume II (Plate 2.2).

iii) Spikelet with abnormally developed lemma, palea and glumes (Plate 2.3).

iv) Two uneven spikelets generated from a single ovary with three glumes. The spikelets were thin and long. Three glumes were visible in place of two (Plate 2.4).

c) Hypoplasia of BRRI dhan29 rice variety as observed in stamen, anther, lodicule and stigma due to low night temperature (16^0 and 18^0C) stresses from panicle initiation to flowering stage is noted below:

i. Six short stamens with one small anther (Plate 3.1).

ii. Spikelet with both long and short stamen with small stigma (Plate 3.2).

iii. Spikelet with five anthers of which one showed over-growth at the joint of stamen and anther (Plate 3.3).

d) Hyperplasia of BRRI dhan29 rice variety as observed in stamen, anther, lodicule and stigma due to low night temperature (16^0 and 18^0C) stresses from panicle initiation to flowering stage (Plate 4).

i) Spikelet with elongated and needle shaped reproductive organs (Plate 4.1).

ii) Spikelet with six anthers of which one showed over-growth (Plate 4.2).

iii) Anther with over-growth symptom (Plate 4.3).

iv) A curved anther (Plate 4.4).

e) Hypoplasia of Snoarbangla1 rice variety as observed in spikelets and reproductive organs due to low night temperature (16^0 and 18^0C) stresses from panicle initiation to flowering stage (Plate5).

i) Poorly developed spikelet (Plate 5.1).

ii) Spikelet with short palea and single glume (Plate 5.2).

iii) Apical portion of lemma and palea showed bend like modification. Anther was visible in between lemma and palea, and looked like a kernel (Plate 5.3).

iv) Lemma looked like a parrot beak and stigma showed balloon shaped modification. In between lemma and palea, a large lodicule and stigma were visible. The stigma also looked like a balloon shaped structure (Plate 5.4).

f) Hyperplasia of Sonarbangla1 rice variety as observed in spikelet and reproductive organs due to night temperature (16^0 and 18^0C) stresses from panicle initiation to flowering stage (Plate 6).

i) A deformed spikelet with degenerating glumes, lemma, palea, anther and stigma, which showed over growth (Plate 6.1).

ii) Kernel was visible in between lemma and palea. Single glume was found, which was large in size (Plate 6.2).

iii) There was a gap between lemma and palea and apical portion of lemma was modified into beak like structure. A degenerating elongated stigma was visible inside (Plate 6.3).

1.1.1 Panicle with poorly developed spikelets

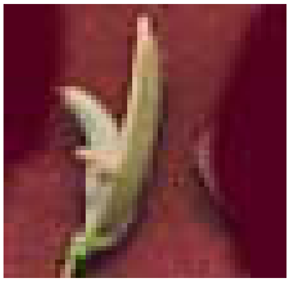
1.1.2 Panicle with poorly developed rachis & spikelet

1.1.3 A short and sickle shaped lemma with single glume

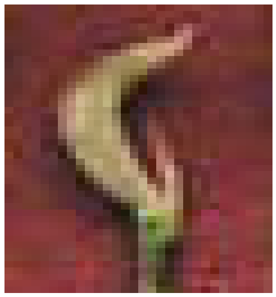
1.1.4 An abnormally thin and elongated lemma with a sickle shaped palea

Plate 1.1. Hypoplasia of BRRI dhan29 found in lemma, palea and glumes as influenced by low night temperatures imposed at panicle initiation to completion of flowering

1.2.1 A short and malformed palea failing to cover the kernel



1.2.2 A sickle shaped palea and kernel with single glume and without lemma



1.2.3 A spikelet with sickle shaped palea

1.2.4 An abnormal spikelet with deformed anthers and stigma

Plate 1.2. Hypoplasia of BRRI dhan29 found in lemma, palea and glumes as influenced by low night temperatures imposed at panicle initiation to completion of flowering

2.1 Mal-positioned and distorted stigma

2.2 A spikelet with abnormally elongate glume-II

2.3 A deformed spikelet with abnormal lemma, palea and glumes

2.4 A bi-lobed spikelet developed from a single ovary

Plate 2. Hyperlasia of BRRI dhan29 found in lemma, palea and glumes as influenced by low night temperatures imposed at panicle initiation to completion of flowering

3.1 Anthers with short stamen

3.2 A short stigma with short and long stamen

3.3 Five anthers, one showed over growth

Plate 3. Hypoplasia of BRRI dhan 29 found in anther and stigma as influenced by low night temperatures imposed at panicle initiation to completion of flowering

4.1 Abnormally elongated and needle shaped stigma

4.2 Normal and abnormal anthers shaped stigma

4.3 Abnormally swollen anther

4.4 A curved anther

Plate 4. Hyperplasia of BRRI dhan29 found in anther and stigma as influenced by low night temperatures imposed at panicle initiation to completion of flowering

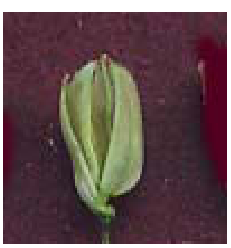
5.1 A poorly developed spikelet

5.2 A spikelet with short palea and single glume

5.3 A deformed spikelet with anthers and stigma coalesced together along with the degenerating palea

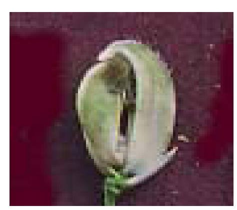
5.4 A short and mal-formed palea failing to cover the kernel

Plate 5. Hypoplasia of Sonarbangla1 found in the glume, lemma, palea and reproductive organs as influenced by low night temperatures imposed at panicle initiation to completion of flowering



6.1 A deformed spikelet

6.2 A large kernel visible in between lemma and plaea



6.3 A beak-like lemma and degenerating palea with elongated modified stigma

Plate 6. Hyperplasia of Sonarbangla1 found in the glume, lemma, palea and reproductive organs as influenced by low night temperatures imposed at panicle initiation to completion of flowering

Agronomic characters

The two rice varieties tested in this experiment were significantly influenced by their genetic variability, low night temperature treatment and also by their interaction (Table 1 and Table 2). The hybrid rice Sonarbangla1 out-yielded BRRIdhan29 by 1.68 t ha^{-1} (26.21%), mainly because of its heavier seeds and markedly lower % spikelet sterility. Low night temperatures decreased seed yields compared to the normal atmospheric condition and the difference in seed yield obtained between 16^0C night temperature and control treatment was significant. The seed yield reduction was 4.94% and 12.47%, respectively in night temperature conditions of 18^0C and 16^0C than in the normal atmospheric condition. This seed yield reduction might be related to similar level of increase in % sterility (23.07, 27.24 and 33.19%) as observed in the treatments of control, 18^0C and 16^0C night temperatures.

The interaction effects show that Sonarbangla1 was a bit resistant to low night temperature and grain yield reduction due to exposure of 18^0C and 16^0C was just marginal (2.5 and 9.4%) and this difference was not significant (Table 2). The increase in % sterility also was not so prominent in this variety with the fall of night temperature, 22.43% and 28.09% in 18^0C and 16^0C compared to 18.90% in the control treatment. The influence of low night temperature was highly marked in BRRIdhan29. The seed yield reduction was 7.9% at 18^0C night temperature compared to normal atmospheric temperature. A further fall in temperature to 16^0C reduced seed yield by 16.2%. The % sterility in these treatments for BRRIdhan29 was 32.05 and 38.42%, respectively compared to the normal atmospheric condition (27.23%) i.e. low night temperatures were associated with more spikelet sterility.

Table 1. Effect of variety and low night temperature on yield, yield components and sterility of BRRI Dhan29 and Sonarbangla1

Treatment	Effective tillers $hill^{-1}$ (no.)	Spikelets $panicles^{-1}$ (no.)	Sterile spikelets $panicles^{-1}$ (no.)	Total spikelets $panicles^{-1}$ (no.)	% Sterility	1000-grain weight (g)	Grain yield (t/ha)
BRRIDhan29 (V_1)	11.72 a	103.13 a	50.77 a	153.91 a	32.53 a	20.35 b	6.41 b
Sonarbangla1 (V_2)	10.17 b	87.43 b	26.73 b	114.16 b	23.13 b	27.96 a	8.09 b
LS	.01	.01	.01	.01	.01	.01	.01
Normal Atmos. Temp. (T_1)	11.17	99.90 a	31.23 b	131.13	23.07 b	24.27	7.70 a
18^0C Night temp. (T_2)	10.92	96.03 ab	37.57 b	131.78	27.24 b	24.15	7.32 ab
16^0C Night temp. (T_3)	10.75	89.92 b	47.45 a	142.76	33.19 a	24.03	6.74 b
LS	NS	.01	.01	NS	.01	NS	.01
CV (%)	10.55	8.02	13.92	11.12	15.17	6.82	9.03

Table 2. Effect of interaction between variety and low night temperature on yield, yield components and sterility of BRRIDhan29 and Sonarbangla1

Treatment	Effective tillers hill^{-1} (no.)	Spikelets panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Total spikelets panicle^{-1} (no.)	% Sterility	1000-grain weight (g)	Grain yield (t ha^{-1})
$V_1 \times T_1$	12.00 a	109.22 a	41.09 bc	150.31 a	27.23 bc	20.42 b	6.97 bc
$V_1 \times T_2$	11.66 ab	104.09 ab	49.35 b	153.45 a	32.05 ab	20.36 b	6.42 cd
$V_1 \times T_3$	11.50 ab	96.08 bc	61.88 a	157.96 a	38.32 a	20.25 b	5.84 d
$V_2 \times T_1$	10.33 b	90.58 cd	21.38 c	111.95 b	18.90 d	28.12 a	8.42 a
$V_2 \times T_2$	10.17 b	87.96 cd	25.79 de	113.75 b	22.43 cd	27.95 a	8.21 a
$V_2 \times T_3$	10.00 b	83.76 d	33.03 cd	116.78 b	28.06 bc	28.80 a	7.63 ab
LS	.05	.05	.01	.05	.01	.05	.05
CV(%)	10.55	8.02	13.92	11.12	15.17	6.82	9.03

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PERFORMANCE OF INTERCROPPING BANANA WITH VEGETABLES

M.I. NAZRUL[1], M.A. RAHMAN[1] AND M.A. QUAYYUM[2]

ABSTRACT

On farm experiment was conducted at Multi Location Testing site, Madhupur, Tangail for consecutive two years (2003-05) to find out the most productive and profitable Banana based intercropping system. The experiment was laid out in randomized complete block design with four replications. Four intercropping combinations viz. Banana (Sole), Banana + Okra, Banana + Sweet Gourd and Banana + Bitter gourd were considered as treatment variables. The result showed that the highest Banana equivalent yield (94.03 t/ha^{-1}) and maximum yield advantage (20%) than sole Banana was recorded from the intercropping combination of Banana + Sweet gourd. This intercropping system also showed the highest benefit cost ratio (2.41) and therefore it might be more economically viable than sole Banana in Tangail region.

Key words: Intercropping system, banana equivalent yield and economics.

INTRODUCTION

Cropping intensity as well as crop production can be increased by multiple cropping practices and this has long been recognized as a very common practice. It is suggested that intercropping can provide substantial yield advantages compared with sole cropping (Singh *et al.*, 1999; Willey, 1979a, b). Banana *(Musa sapientum)* is a nutritional fruit in Bangladesh, which occupies a total of 97,465 acres of land producing 5,61,770 metric ton edible fruit (BBS, 1999). Banana is largely grown in well drained high land, which is also suitable for growing other cash crops. The inter row space of Banana remains under utilized in the early growing period. During this period short duration crops may be grown as intercrops with Banana (Bose. 1990). Intercropping system offers a possibility to grow more than one crop to utilize the space and other resources efficiently (Ahlawat. 1998). Banana is a common crop in Madhupur and Tangail districs and most of the farmers follow intercropping systems. However, the farmers are very reluctant to select the intercrops. The success of intercropping systems depend mostly on selection of component crops and agronomic modification of resource use (Midmore, 1993) Selection of intercrops should be done in such a way that they have no or little adverse effect on the main crop. Therefore, an on-farm trial was conducted to optimize the productivity and the economics of Banana based intercropping system.

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[1] Scientific Officer, OFRD, Bangladesh Agricultural Research Institute (BARI), Tangail
[2] Chief Scientific Officer, OFRD, BARI, Gazipur, Bangladesh

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MATERIALS AND METHODS

The experiment was carried out at Multi Location Testing (MLT) site, Madhupur, Tangail for consecutive two years of 2003-05 in the medium highland under Agro Ecological Zone (AEZ) of 28. The experiment was laid out in randomized complete block design with four replications. The unit plot size was 6 m x 6 m with plant-to-plant spacing 2 m x 2 m. The variety of Banana "Amrit Sagar", Okra "BARI Dherosh-1, Sweet gourd “Local cultivar” and Bitter gourd "Advance line” were used in this trial. The Banana is an annual crop where suckers were planted in 60 cm x 60 cm x 60 cm size of pits. Four treatments viz. Banana (sole), Banana + Okra, Banana + Sweet gourd and Banana + Bitter gourd were considered as treatment variables. Soil samples were collected and its chemical analysis was done before setting the experiment. Fertilizer dose was calculated on the basis of soil test results followed by BARC (1997). Fertilizers were applied at the rate of 749-197-375-57-0.25kg NPKSB and 10 t cowdung ha^{-1}. Fifty percent cowdung was well mixed at the time of final land preparation. Rest 50% cowdung, 50% P and K and all sulphur and borax were applied during pit preparation. Remaining P, K and all N were top dressed in ring method at 30, 60 and 90 cm apart from plant stalk in three successive intervals. No additional fertilizer was applied for intercrops but adequate plant protection and intercultural operations were done as and when necessary. Three irrigations were applied in all treatments before each top dressing of fertilizers. Three weedings and earthing up were also done at 60, 135 days after planting (DAP) and before flowering of Banana. Tilt (0.2%) was sprayed four times for controlling Sigatoga and Fyfanon (0.2%) for control of Banana beetle. Banana equivalent yield (BEY) was calculated by using the following formula by Aujeneyulu *et al*. (1985).

$$\text{BEY} = \text{Yield of Banana} + \frac{\text{Yield of intercrop} \times \text{price of intercrop}}{\text{Price of main crop (Tk./kg)}}$$

Data of two years pooled together for statistical analysis. Economics of each treatment was computed with prevailing market rates of products. Collected data were analyzed statistically using computer package MSTATC (Gomez, 1993).

RESULTS AND DISCUSSIONS

Yield and yield attributes of Banana

The yield and yield contributing characters of Banana showed that highest plant height (2.35m), leaves per plant (20.86) and number of finger per bunch (126.7) were found in Banana + Bitter gourd intercropping system (Table 1). Maximum weight of finger was recorded from intercrop combination of Banana + Sweet gourd which was statistically identical to other intercrop combinations except sole Banana. Intercrop combinations also produced higher weight of bunch than sole Banana. Higher fruit yield was obtained from Banana + Sweet gourd (61.69 t ha^{-1}) but it was statistically similar to Banana + Bitter gourd and Banana + Okra intercrop combinations. Higher yield advantage in Banana + Sweet gourd combination might be due to higher canopy coverage produced by Sweet gourd which helped to retain better soil moisture, lower soil temperature and enhanced the growth and the fruit yield. Better fruit yield of Banana obtained from intercrop than that of from sole crop indicated the complementary effect of Banana based intercropping systems. Similar complementary effects of intercropping systems were also observed by other authors (Haque & Hamid, 1998; Islam *et al.,* 2004).

Table 1. Yield and yield attributes of sole and intercrop Banana at Madhupur, Tangail

Treatment combination	Plant height (m)	No. of leaves/ plant	No. of fingers/ bunch	Weight of fingers (g)	Wt. of bunch (kg)	Fruit yield (t ha^{-1})
Banana (Sole)	2.14	18.46	117.6	175.40	20.48	51.13
Banana + Okra	2.10	19.17	121.1	189.80	23.65	59.13
Banana + Sweet gourd	2.20	19.42	122.1	200.90	24.66	61.69
Banana + Bitter gourd	2.35	20.86	126.7	190.90	24.06	60.19
LSD (0.05)	0.03	0.35	2.25	47.00	1.45	9.30

Intercrop and equivalent yield

Among the intercrops, Sweet gourd showed higher mean yield than the other two vegetable crops. Yield of okra was lower because of viral infection and poor growth due to shade effect by banana leaf. In contrast Sweet gourd yielded significantly better under the intercropping system (at 0.05) and was found more compatible with Banana than other vegetables. Results of equivalent yield revealed that intercropping system is much productive than sole cropping (Table 2). This result confirmed the finding of Islam *et al*. (2004) in maize-bush bean intercropping system.

The highest Banana equivalent yield (94.03 t ha^{-1}) was obtained from Banana + Sweet gourd followed by Banana + Okra intercropping system. The sole crop of Banana gave the lowest equivalent yield (51.13 t ha^{-1}). Crop index of intercropping systems indicated that 20 % yield advantage was found in Banana + Sweet gourd combination compared with sole Banana, followed by Banana + Bitter gourd (17%) and Banana + Okra (15%) intercrop combination. Such yield advantage with intercropping over sole cropping was also reported by Haque *et al*. (2001) and Haque & Hamid (2001) in maize-sweet potato intercropping system.

Table 2. Yield of Banana and intercrops, equivalent yield of Banana and crop index at Madhupur, Tangail

Treatment combination	Banana yield (t/ha)	Intercrop yield (t/ha)	Banana equivalent yield (t/ha)	Crop index (%)
Banana (Sole)	51.13	-	51.13	100
Banana + Okra	59.13	2.20	61.98	115
Banana + Sweet gourd	61.69	24.90	94.03	120
Banana + Bitter gourd	60.19	5.57	76.10	117

Economics of intercropping

The highest gross return was recorded from Banana + Sweet gourd combination followed by Banana + Bitter gourd. All the intercropping systems showed higher gross return with higher cultivation cost than the sole crop (Table 3). Higher cost was involved in intercropping systems due to the additional crop management. Higher cost, however, resulted higher gross return and gross margin in intercropping systems. Cost benefit analysis further showed that highest benefit was found in Banana + Sweet gourd combination. Other two intercrop combinations also showed better benefit cost ratio than sole cropping.

Table 3. Economics of Banana based intercropping systems at Madhupur, Tangail

Treatment combination	Gross return (Tk. ha^{-1})	Total cost of cultivation (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (Tk. ha^{-1})
Banana (Sole)	1,96851	135676	61175	1.45
Banana + Okra	2,38650	139286	99364	1.71
Banana + Sweet gourd	3,62007	150424	211582	2.41
Banana + Bitter gourd	293001	156257	136744	1.87

Market prices:

Input cost (Tk. Kg^{-1})

Urea = 6

TSP = I4

MP = 12

Boric acid = 60

Gypsum = 4

Other cost **(Tk. m^{-1})**

Irrigation 1.67

Insecticides 0.70

Fungicides 1.22

Price of output (Tk. Kg^{-1})

Banana = 3.85

Okra = 5

Sweet gourd = 5

Bitter gourd = 11

CONCLUSION

The result showed that Banana with Sweet Gourd intercropped combination gave higher yield and benefit cost ratio than other combination. So, this combination could be advocated for Banana growing area of Tangail.

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GOAT FARMING: A POTENTIAL RURAL ENTERPRISE FOR ALLEVIATING POVERTY AMOUNG SMALL HOLDER FARMERS IN BHUTAN

N.B. TAINANG[1], D.L. SHERPA[2] AND G. TSHERING[3]

ABSTRACT

In Bhutan goats are used for meat, manure, and for commercial and religious purposes. Goat population is concentrated in Chukha, Samtse, Sarpang, Tsirang and Dagana Dzongkhag (district) of Bhutan. In these Dzongkhags goat farming is an important activity to improve household nutrition and generate income. As of now, no research and development activities have been undertaken on goats in Bhutan and thus its importance is largely unknown. Therefore, this study was undertaken to improve the understanding on present goat husbandry practices and their socio-economics and religious roles to smallholder farming communities. Study was carried out in all goat rearing dzongkhags except Samtse. A stratified two stage sampling technique was adopted. Semi-structured questionnaires were used to collect information from at least 25 households in each dzongkhag. Results indicated that average flock size per household was five goats. The mean age at puberty and age at first kidding were 6.8 ± 0.12 and 12.2 ± 0.14 months, respectively. The kidding interval was about 6.5 ± 0.04 months and number of kids born per year was 2.5 ± 0.08. In mid-altitudes goats were mostly stall-fed while in low-altitudes they were mostly tethered. Goats were stall-fed with weeds. Housing is simple with enclosure made out of bamboo, poles or timber. Roughly an hour of labour is required to take care of four goats.Goats played a significant religious and socio-economic role to rural-commmunities. Quick economic returns helped smallholder farmers to generate income in the shortest period of time. It provided social security to farmers as it can be sold as and when there is urgent need for cash. Farmers used income from goats for schooling of children, overcome food shortage, pay taxes and repair houses helping them to alleviate poverty and improve the quality of life. Training on improved goat husbandry practice and crossbreeding with exotic meat breeds of goat or allowing them to rear more goats under controlled grazing can increase their income.

Key words: Goat farming, prolificacy, smallholders, poverty alleviation.

[1] Deputy Chief Research Officer, RNR Research Centre, Jakar , Bhutan
[2] Offtg. Program Officer, RNR Research Centre, Bajo, Nepal, Bhutan
[3] Sr. Research Assistant, RNR Research Centre, Jakar, Nepal, Bhutan

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INTRODUCTION

Worldwide goats are used for producing milk, meat and fine fibres (mohair and cashmere). Besides, goats are being used for biological control of troublesome weeds in many countries (e.g., in Australia and New Zealand) (Pierce, 1990; RIRDC, 1997) and in USA (Jensen and Williams, 2002).

Goats in Bhutan are used for meat, manure, religious offerings and commercial purposes. They are generally reared along with other livestock. These animals have the ability to utilize and survive on otherwise waste fodder resources such as weeds (Artemisia, Eupatorium and other waste plants) which other livestock do not readily consume. However, because of voracious browsing habits, goat may destroy tender plants/sapling if grazing goes uncontrolled.

The goat population in Bhutan is about 31,000 heads with maximum concentration in sub-tropical belt viz. Chulcha, Samtse, Sarpang, Tsirang and Dagana Dzongkhag (district) (RNR census, 2000). In this belt, goat rearing has been a tradition among the farming communities and is considered as one of the important farming activities to improve household nutrition and generate income to support the farm families. However, because of enviromnental implications it could have, government policy restricts the number of goats per household to four. This undermines the potential the goat farming could have in boosting rural income to alleviate poverty.

During the 10th Five Year Plan (FYP) (2008-2013), alleviating poverty is the major thrusty of Royal Government of Bhutan (RGoB), mainly to reduce the proportion of population living below the poverty line from 38 percent to about 15 percent by the end of the plan period (PCS, 2006). Renewable Natural Resources (RNR) sector can be instrumental in rural poverty reduction as this sector still is the main source of livelihood for the Bhutanese population. Within the RNR sector, livestock sub-sector has ample scope to initiate a number of income generating schemes for the poor.

Experience from developing countries reveals that small livestock such as goats, pig, poultry, fish, bees etc are promoted among poorest of the poor rural segments as well as in areas affected by drought, flood and famine for quick recovery from losses. Women folks traditionally responsible for managing livestock are encouraged to take up this venture through appropriate support.

However, as of now, not much research and development activities have been undertaken on small livestock especially goats in Bhutan and thus its importance is largely unknown. The need was felt by Research and Extension to document the present goat husbandry practices and their socio-economics and religious roles to the farming communities. Therefore, this study was undertaken to improve the understanding on these aspects.

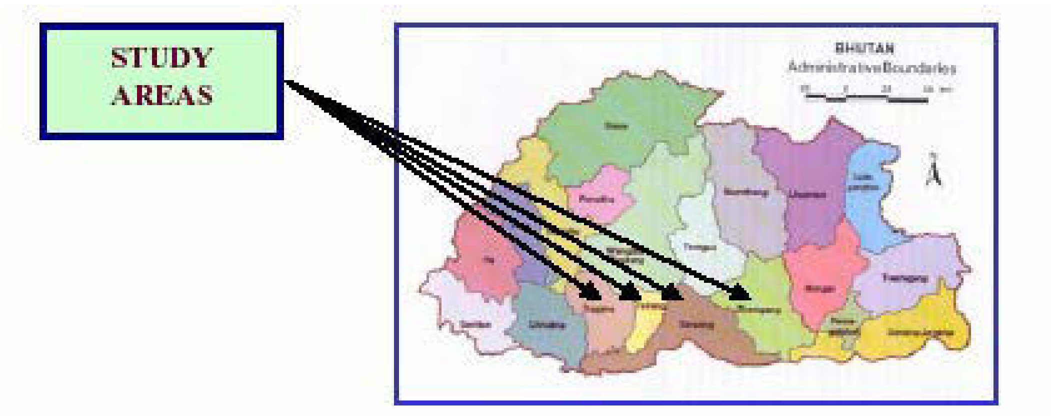
Objectives

- To describe traditional goat husbandry practices in Bhutan
- To understand socio-economic role of goats to farming households
- To understand the extent to which goat farming helps to alleviate rural poverty
- To generate inputs for policy decisions on goat farming

MATERIALS AND METHOD

Study area

The survey was carried out in Jigmechoeling and Gelephu geog (block) under Sarpang dzongkhag, Rangthangling and Tshendagang under Tsirang dzongkhag and Goshi and Tashiding geog under Dagana dzongkhag and Pachu-Sadumadhu under Phuntsholing geog in Chukka dzongkhag. These geogs were selected based on (high) goat population density and large number of farmers involvement in goat rearing.



Sampling techniques and data collection

A stratified two stage sampling techniques was adopted. In the first stage, villages with high goat population within goat rearing dzongkhags of Bhutan were selected. In the second stage, 25 goat rearing households each from Sarpang, Tsirang, Dagana and Chukka were purposively sampled.

Semi-structured questionnaires were used to collect information from selected households on goat husbandry practices and the socio-economics role goat rearing plays. Informal discussion was also held with some of the resourceful farmers to gather additional information.

Data Analysis

- Quantitative variables such as flock size, population distribution, and reproductive parameterss were entered in spread sheet. Mean, Standard Error (SE) for flock size and reproductive parameters and percentage distribution of different categories of goat in a population were calculated.
- Chi squared (x^2) test was used to determine significance level of feeding management by farmers in different agro-ecological zones
- Qualitative data acquired through informal discussion with individual herders were coded and put into spreadsheets. Answers in many cases fell into patterns with the same answer appearing frequently being coded. The frequency of each answer was sorted, counted manually and, when practical, converted to a percentage.
- Simple cost benefit analysis of rearing goats was calculated

RESULT AND DISCUSSION

Origin and population distribution

Origin of goats

There is no history of introduction of exotic breeds of goats from elsewhere. Thus the origin of existing goat population could be from their locality or villages itself. Farmers either maintain their own breeding stock or procure them from neighbouring households or villages.

Flock size

All household surveyed owned goats. The maximum flock size was seven goats and minimum of one goat per household. The average flock size was four goats in Jigmecholing and six goats in other study areas. The latter is despite the policy restrictions to limit goats to four. This could indicate the profitability of goat and farmer's wish to maximize profit from this enterprise.

In most villages surveyed, the proportion of adult female was higher than the male (Fig.1) because males are often castrated and slaughtered for home consumption, sacrificed during the religious festivals and also sold live.

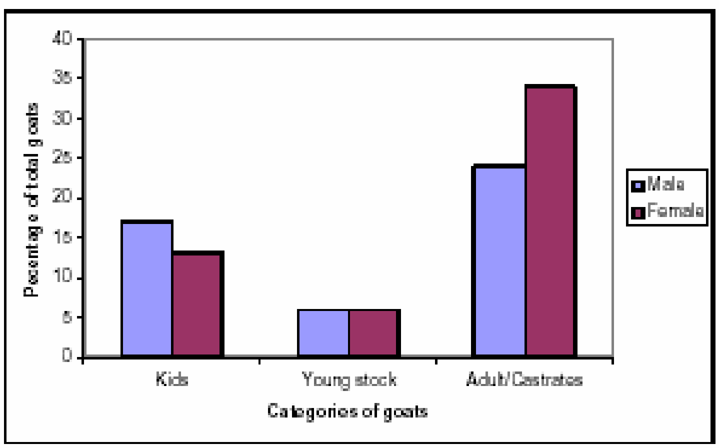


Fig. 1 Population distribution (Percentage) by categories of goats

Reproduction and breeding

The mean age at puberty and age at first kidding were 6.8 ± 0.12 and 12.2 ± 0.14 months respectively. The kidding interval was about 6.5 ± 0.04 months and number of kids born per year was 2.5 ± 0.08. (Table 1). Twin birth is very common. Triplet and even quadruplet birth is also reported. Kids (young ones) are weaned at about four months of age. It is therefore obvious that before a doe (female goat) is three years old, she could have given birth to more than five or six kids. This result is consistent with the finding from Philippines, where a doe is reported to give birth to at least five kids before it attained the age of three years (MBRLC, 1990). Thus, higher prolificacy and ability to give birth a couple of years earlier than cattle and buffaloes would mean that farmers are able get a faster return to their investments.

Table 1. Reproductive parameters of goals

Parameters	n	Mean	SE(±)
Age at puberty (months)	15	6.8	0.12
Age at first kidding (months)	15	12.2	0.14
Kidding interval (months)	15	6.5	0.04
Kids per year (nos.)	I S	2.5	0.08
Life expectancy of Doe (yrs)	15	12.8	0.23
Productive life of Doe (yrs)	15	9.8	0.13
Total kids during lifetime (nos.)	15	19.6	0.51

The breeding stock is selected from within the local population and crossbred among the existing breeds. One or two males are kept in the community for breeding and rest of them are castrated at an early age to fatten for sale. Most mating takes place from September to October and kidding from February to March- April.

Goat management, marketing and price

Feeding management

Chi squared (x^2) test revealed that the feeding management has strong association with geographical location where goats are reared ($p<0.003$). In mid-altitude areas significantly higher numbers of farmers tether their goats while in low-altitude areas more farmers stall-fed them. Farmer's in both areas, however, also open graze goats.

When stall-fed, goats are mostly fed with weeds in low-altitudes. They are fed *Bupatoriuni adenophorum* (kala zhar) in the mid-altitudes while in low-altitudes they are fed with Buhari Jhar, Bayar, (throny plants), *Cromolaena ordorata* (Siam weed), lopped fodder trees, aracanut leaves and grasses. Crop by-products such as maize hull is also fed to adult goats. Compound feed as concentrates are seldom fed but whole cereal grains, bran and salt are fed to fatteners. Kids are generally fed with gruel made out of cereals. Due to docile nature of goat, it can be fed and managed by anyone in a household including women and children.

Fig 2. Goats stall-feed (left) tethered on fallow land (right)

Housing

Most of the farmers sheltered goats in their homestead for manure production as goat and sheep manure are considered best for growing crops. Housing is simple for enclosures made out of bamboo, poles roughly finished timber. The wall is made of solid bamboo or wood and thatched with rice straw (Fig.3). The floor is often slatted for faeces and urine to pass through as goats reportedly love to live on dry shed and often avoid dampness and rain.

Fig. 3. A semi permanent goat house

Health and mortality

Farmers reported occasional death of goats. At times death was due to unknown diseases and debility while at some other time, it was reported to have died all of a sudden, probably because the farmers failed to detect the sickness on time. But in general farmers feel that it is less susceptible to diseases than other livestock.

Goat marketing systems and price

Most farmers in Sarpang traded live goats to local customers and dealers from Thimphu and across the Indian borders. In other study areas, it is sold within the locality. Farmers reported to have no difficulties in selling goats as sale is accomplished at the farmer's doorsteps most of the time. The price per kilogram of meat is about Nu. 150 in the locality, and fetches premium price as compared to other meat (Table-2). Higher market price fetched by chevon (goat meat) in the locality and towns near the Indian border could be because, unlike pork and beef, there are no religious sentiments attached to its consumption. Long tradition of consuming chevon could have helped to develop special taste for it and has become a delicacy over a period of time. Moreover, due to high consumer demand at the urban center such as Thimphu, chevon suppliers to this town are willing to pay the price tagged by farmers. These factors could also have contributed to better market price for chevon.

Table 2: Meat types and their prevailing price at Gelephu

Meat types	Price (Nu)/kg
Beef	55-80
Fish	60-70
Mutton/Chevon	150
Pork	75
Chicken	75

Source: Bhutan Agriculture and Food Regulatory Authority, Gelephu, May, 2006.

The adult castrates fetch between Nu. 2000-4500 depending on the body size /weight and doe fetches around Nu. 1200-1900 depending on pregnancy and kids at foot. Cost of weaned kids/yearlings range from Nu. 300-600. Goat sales timed to coincide with special period of increased demand (such as festivals) is reported to fetch better market price.

Importance of goat rearing

Religious and social role

Among goat rearing communities, goats a play significant religious and social role. They are reared for religious and social purposes apart from meat and manure. They are sacrificed on special occasions such as annual Hindu festivals (e.g., Dasai) to appease local deities, and also during social occasions e.g., New Year celebration and weddings. Similar practice of slaughter and consumption of goat meat at Easter and Christmas and as a substitute for lamb at the various Muslim holidays is reported from western and Middle East countries (MBRLC, 1990). However, for people following these faiths, goats may not be slaughtered for religious reasons.

Socio-economic importance and role in poverty alleviation

Goats have many economic benefits and can contribute to poverty alleviation for following reasons:

Firstly, quick economic return from goat within 1-1.5 year helps farmers to generate income in a short period of time, reduces time lag and avoids accumulation of interest on loans if available. ICIMOD (2005) supplemented the view that goats are of significant advantages to marginal farmers over cows and buffalo because of faster returns. They require small capital investment and, therefore, the risk per animal is less.

Secondly, it provides social security to smallholder resources poor farmers as it can be sold as and when there is urgent need of cash. Because of high demand both for live as well as dressed goats, some farmers believe that keeping goats is as good as having cash in hand. In the words of 76 years B. Daurali, "Goat keeping is as good as having cash in your coffee, unlike sheep, cattle and other livestock it can be instantly sold however you want and whenever you need cash at home" (Daurali, Pers.comm., 2006). His statements were well supported by other goat farmers.

Thirdly, though it is not scientifically proven, local people believe that chevon has medicinal property to cure sub-tropical diseases including Malaria. The preparation of chevon is served to people suffering from this disease with positive results. According to Karma Nidup "Consuming chevon has miraculously saved my life when I critically suffered from Malaria during my tender age" (Nidup, K., Pers.comin., 2006). Medicinal value of goat milk to cure sub-tropical disease (Ragi ohm choepai nye lu phen) which literally means "goat meat can cure sub-tropical disease such as malaria" is well documented in Bhutanese literature. Finally, some of the symptoms of poverty: inability to own decent house, vulnerability to food shortage and lack of funds to send children to school as highlighted in Renewable Natural Resources (RNR) Research System Strategy 2006 (MoA, 2006) is largely addressed by keeping goats. Farmers reportedly use income from goats for schooling of children, overcoming food shortage, paying taxes and repairing houses thus helping them to alleviate poverty and improve the quality of life.

Goat as a biological weed controller

Goats when tethered or grazed are reported to utilize forages and shrubs that are less palatable and not normally utilized by other livestock such as sheep or cattle. Ability of goats to survive on such otherwise wasted vegetation is an advantage as it can make best use of available fodder resources. Thus, goats can be added to sheep or cattle paddocks with little or no loss in production of the latter as their grazing is complementary to both.

When stall-fed, goats are mostly fed with noxious weeds such as *Artemesia vulgaris* (Pati), *Eupatorium adenophorum* (Icala zhar), Buhari Jhar, Bayar, (throny plants), *Cromolaena ordorata* (Siam weed), making effective use of such unwanted plants. Utilization of goat to control different weeds such as Blackberries (*Rubus frzeticostics*), Saffron thistle (*Carthamus lanatus*) have also been reported from Australia and other countries in the West (Pierce, 1990). Therefore, in areas where weeds such as Eupatorium is a problem, its biological control either through controlled grazing or cut and carry to stall feed goats could provide a continuous pressure on these weeds. At the same time, while the weeds are being controlled, farmer is able to derive some economic return.

Investments and return from goats

The investments and return from rearing goat in a period of one year was discussed with farmers. The average cost of housing, feeding, labor, equipment was calculated based on information received from them. The labor cost is calculated based on standard wage rate (Nit. 100/day or 8 hours) and feeding cost per year was calculated for ingredients fed by majority of farmers and cost per kilogram. Amount earned through sale/slaughter of goats (yearlings, castrates, doe with kids etc.) in one year period were also discussed and averaged (section 4.3.4).

In one year period if all stocks are sold, Nu.7,166 is earned (Table.3). This amount is substantial for resource poor households. However, these are not the absolute figures because in a subsistence system, it raises conceptual problem in estimating the actual value of production.

Table 3: Average investment cost and benefits of goat rearing

Inputs	Quantity/ Unit	Cost (Nu.)	Cost/Income per year (Nu.)
A. Investment cost			
Foundation stock (cost of yearlings)	4 (3 ♀,1♂)	500	2000
Average housing cost	1 unit	305	61
Average equipment cost	1 unit	61	12
Average feeding cost	242g/day	2/day	730
Average hours of labour & cost Annual maintenance of barn (10% of housing cost)	1 hr/day	12.5/day	4562 31
Total			**7,396**
B. Returns			
Sale of yearling	6	500	3000
Doe with kids	3	1500	4500
Castrate	1	2500	2500
Gross income from sale of goats			10,000
Net income (B-A)			2604
Net income (if labor cost excluded)			7166

Assumption made were a yearling (foundation stock) gives twin birth twice. The house and utensils last for five years. Goats are taken care of through family labor on a part-time basis and the labor cost is minimal /negligible.

Hindrance to realization of effective economic gain from goat rearing

Though most farmers wish to rear more than four goats, restriction to keep only four goats per households at all time is a hindrance to realization of economic gains. Goats give birth to twins, triplets and even quadruplet and there are usually two crops/births in a year. When there is a second crop; the number of goat in a household can easily exceed four before the first crop of the year matures and attends marketable age. To maintain the number, farmers have to sell them off at an early age, incurring loss as such sales don't fetch food price as matured castrates.

Farmer's vision to increase income from goats

The existing goat breed is not a fast grower nor a prolific breeder. To maximize production and income from goats, 45% of farmers (n=40) wished that their stock should be fast growing and be prolific (Fig. 4). About 20% of farmers felt that training on improved goat husbandry practiced could enhance their income. About 15%, however, thought that crossbreeding with exotic meat breeds of goat or allowing them to keep up to ten heads of goat could increase their income.

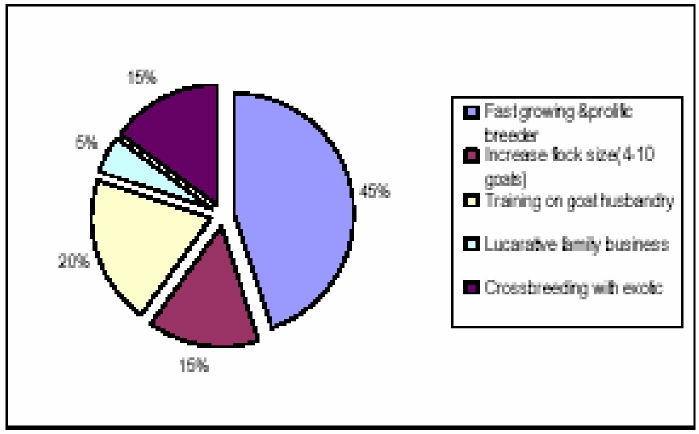


Fig. 4. Farmers vision to increase income from goats

Experiences from Nepal indicate that importing exotic Boer breed of goats for crossing with local breeds have helped farmers to increase their income (ICIMOD, 2005). Further, studies conducted in India suggested that to earn livelihood and profit from goat keeping about 4-10 goats have to be maintained (Gokale, *et al.*, 2002). It is evident, therefore, that there is a need to provide fast growing and prolific breed of goats besides imparting training on improved goat husbandry practices to the farmers. Such initiation shall go a long way in reducing rural poverty, which is the theme of RGoB's 10th FYP.

CONCLUSIONS

Goats are used mainly for meat purpose in goat rearing areas of Bhutan. There is favourable consumer demand for goat meat especially in towns near the Indian border. Thus it fetches premium price compared to meat from other livestock. Provision of fast growing and prolific meat purpose goat breed made available either through selection from existing flock or cross breeding with exotic meat breeds could improve the value of animal and bring higher returns.

Goat rearing is much easier than large ruminants as housing is simple, management is easy and it can survive on feed sources that are not utilized by cattle and sheep. Thus, goat rearing is complementary to other livestock enterprises and provides opportunity for farmer to supplement their income. Support on goat rearing by way of making technologies available and training on improved husbandry practices could help the rural farmers to earn subsidiary income from diversified livestock enterprises.

High prolificacy and short generation interval of goats as compared to large livestock underlines their usefulness in generating family income at the shortest possible time. These help resource poor farm families to overcome financial difficulties and generate income to alleviate poverty.

As goats are stall fed with weeds and other thorny plants, they could be reared to provide a biological (non-chemical) option to suppress these noxious weeds through controlled grazing. Research, however, needs to be carried out to understand and validate the information on use of grazing goats in biological control of weeds.

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EFFECT OF TILLAGE ON SOIL MICROBIOLOGICAL PARAMETER IN MAIZE-WHEAT CROPPING SYSTEM

GEETA SINGH[1], A.K. SINGH[2], T.S. MARWAHA AND B.D. KAUSHIK

ABSTRACT

A field experiment was conducted at Indian Agricultural Research Institute to evaluate the effect of two contrasting tillage systems on soil microbial population in maize-wheat cropping system. Two tillage systems were minimum and conventional where soil microbial population was monitored in upper (0-7.5 cm) and lower (7.5-15 cm) soil depths. Soil respiration and dehydrogenase activity were used to as indices of soil micro-organism population. Soil respiration and dehydrogenase activity influenced greatly by different tillage systems. In general, minimum tillage increased significantly soil respiration and dehydrogenase activity in upper layer while conventional tillage favored in lower soil depth. Conventional tillage accounted for higher soil microflora at lower soil zone because of even distribution of crop residues and other nutrients throughout the whole soil profile. Pattern of microbial distribution revealed that *Azotobacter* spp. and *Pseudomonas* spp. use higher in upper soil layer under minimum tillage. Contrary, population of nitrifiers were higher under conventional tillage over the soil depths.

Key Words: Soil tillage, Respiration, Dehydrogenase activity. Nitrifiers. Plant growth promoting micro-organisms.

INTRODUCTION

In India, Maize-Wheat cropping sequence is an important cereal based cropping system. Many efforts are being made to sustain high productivity of this system. Different cultural techniques affect soil productivity, contrasting tillage practices have been shown to alter the chemical and microbiological properties of soils which is supposed to creat a great impact on agricultural production (Ferreira *et al.,* 2000).

The practice of minimum tillage is important due to its role in protecting the soil from wind and water erosion (Agassi, 1995). Compared to conventional tillage, minimum tillage favours microbial and zoological activities, improve soil structure, and increase infiltration rate of water into the topsoil (Frielinghaus *et al.*, 1997). Crop cultivation is known to diminish the levels of organic matter in soils (Coleman *et al.*, 1984). Conversely, tillage increases rate of organic matter

[1] Dr. Geeta Singh, Sr. Scientist, Division of Microbiology, IARI, New Dellhi -110012
[2] Dr. A.K. Singh, Project Director, Water Technology Centre, IARI, New Delhi-110012

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decomposition and mineralization by aerating soils, breaking soil aggregates, thereby increasing the exposure of soil organic matter to microbial activity (Phillips and Phillips, 1984). It is also reported that soil organic carbon and soil microbial biomass in the surface layer is significantly higher in minimum tillage compared to conventional tillage (Saffigna *et al.*, 1989; Alvarez *et al.*, 1995). The soil microbial biomass comprises only 1 – 3% of the total organic carbon in soil but is a relatively labile fraction of soil organic matter (Jenkinson & Ladd, 1981). The differential distribution of organic matter observed under different tillage systems might possibly affect the micro flora present in the soils. However, pattern of microbial population in different depths of soil in maize-wheat cropping system under different tillage systems was not adequately studied elsewhere. Therefore, in the present study, the influence of minimum and conventional tillage systems on soil microbial populations was evaluated in maize-wheat cropping system.

MATERIALS AND METHODS

Maize-Wheat cropping systems was rotated for five continuous years (1997-2001) at IARI, New Delhi, India using two tillage systems and collecting soil samples from two soil depths. Tillage systems were assigned in main plots and depth in sub plots in a split plot experimental design replicated three times. Characteristics of soils in experimental plots were pH 8.2, EC 0.3 m mho/ cm, organic carbon 0.15%, available P 4.5 Kg/ ha^{-1}, available K 134 Kg/ha^{-1}, total N 0.06% and medium in calcium carbonate. Effects of minimum tillage (cultivation to a depth of 3 – 5 cm) on the microbial population and biological processes in rhizosphere of maize-wheat cropping system were compared to that of conventional tillage (plough furrow to a depth of 23-28 cm). In the minimum tillage system, bed planting for maize and zero tillage for wheat was followed to establish the crops. Soil from rhizosphere was collected from two soil depths (0 -7.5 cm and 7.5-15.0 cm) and from six points per replication plot during each sampling. The soils from six points were pooled together for the purpose of analysis. Soil sampling was done at two weeks after germination and before harvesting of crops. The pooled soil samples of both soil depths were subjected to dilution plating.

Enumeration of bacteria was done on Nutrient Agar, fungi on Rose – Bengal agar (Martin, 1950), actinomycetes on Kenknight and Munaier's medium. For analysis of growth promoting bacteria a specific medium was used for each group. Jensen's nitrogen free (Jensen, 1951) medium for isolation of *Azotobacter spp.*, King's B medium for *Pseudomonas spp.* (King *et al*. 1954), Nitrifiers by MPN method (Alexander and Clark, 1965) using Ammonium calcium carbonate (*Nitrosomonas spp.*) and Nitrite calcium carbonate medium were used (*Nitrobacter spp.*). Nitrifiers were tested as positive / negative for nitrite and nitrate in presence or absence of purplish red colour using Griess – Illosvay reagent. Gram positive *Bacillus spp.* was identified on Methyl red agar (Hagedorn and Holt, 1975) followed by its ability to form spores under aerobic condition.

Dehydrogenase assay was performed by Casida *et al.* (1964) and soil respiration was measured using Warburg's respirometer (Umbreit *et al.*, 1972). Statistical analysis was performed by ANOVA and specific effects were tested by Newman Keul's test (Alpha= 0.05).

RESULTS AND DISCUSSION

Soil microbial status

No qualitative difference was observed in the microbial population colonizing the root system of the studied crops in either of the tillage systems. The order of abundance of fungi was

Aspergillus spp. >, *Penicillium spp.* >, *Fusarium spp.* >, *Trichoderma spp.* >, *Cephalosporium spp.* (data not shown). Upper soil layer (0 – 7.5 cm) in minimum tillage (bed planting of maize and zero tillage of wheat) showed a significant increase in the extent of colonization of bacteria, fungi and actinomycetes over the conventional tillage. However, at lower soil depth (7.5 – 15.0 cm) higher microbial population counts were recorded under conventional tillage in both wheat and maize rhizosphere (Table 1). Among the bacterial genera gram-negative forms were positively stimulated in the rhizosphere as fewer gram positive or gram variable were recorded. Relatively low counts of *Bacillus spp.* a gram positive bacterium was noted in the rhizospheric soils of maize and wheat at two-soil depths under both the tillage systems. No tillage specific effect was observed except that in the upper horizon of soil which had significantly higher population of *Bacillus spp.* than in the lower layers (Table 2). However, Nitrifiers (*Nitrosomonas spp.* and *Nitrobacter spp.*) were exception as both genera were recorded significantly high in number at both the soil depths under conventional tillage. Further, stimulation of nitrifiers was observed under conventional tillage system both at germination as well as at harvesting stage of maize and wheat crop.

Free living nitrogen fixing *Azotobacter spp.* was found to colonize the rhizosphere of maize and wheat more effectively under minimum tillage at upper soil layer. At lower layer, *Azotobacter spp.* counts were insignificantly higher under conventional tillage as compared to minimum tillage in both maize and wheat crop. The distribution pattern of *Pseudomonas spp.* was similar to *Azotobacter spp.* in the upper soil layer as highly significant counts of *Pseudomonas spp.* were recorded under minimum tillage in the rhizosphere of both the crops. At lower soil profile under conventional tillage system *Pseudomonas spp.* were significantly higher than in minimum tillage.

Table 1. Effect of Tillage methods on microbial populations in Maize-Wheat cropping system at different soil depths and crop growth stage

Soil depth

Crops	**0-7.5cm**				**7.5-15.0cm**			
Maize	**Conventional tillage**		**Minimum tillage**		**Conventional tillage**		**Minimum tillage**	
Group of Microorganism	**Germination**	**Harvest**	**Germination**	**Harvest**	**Germination**	**Harvest**	**Germination**	**Harvest**
Bacteria $10^6 g^{-1}$ soil	43.3c	26.8a	155.4d	34.84b	49.67b	13.0a	12.78a	8.45a
Fungi 10^4 g^{-1}soil	21.26	16.67a	47.21b	26.67b	17.0b	8.2b	3.1a	2.9a
Actinomycetes 10^3 g^{-1}soil	27.3a	19.0a	41.49b	23.94a	19.0b	11.4a	10.9a	6.61a
Wheat	**Conventional tillage**		**Minimum tillage**		**Conventional tillage**		**Minimum tillage**	
Bacteria 10^6 g^{-1} soil	56.2c	34.3b	85.3d	48.6b	42.3b	10.67a	18.2a	6.4a
Fungi 10^4 g^{-1}soil	14.0a	11.33a	28.67b	16.9a	9.82b	7.4a	4.71a	2.81a
Actinomycetes 10^3 g^{-1}soil	23.67a	18.42a	46.83b	27.33b	26.0b	22.4b	16.0a	18.67a

Data in column by same letters are not different at 0.05 level of significant.

S-I : Post germination Stage

S-II : Harvesting Stage

Table 2. Influence of tillage on the method on the number of growth promoting bacteria (colony forming unit g^{-1} soil) in the rhizosphere of maize and wheat under maize –wheat cropping

Soil depth and crop growth stage	Nitrobacter **Cfux10^{3}g^{-1}soil**		***Nitrosomonas*** **Cfux10^{3}g^{-1}soil**		Azotobacter **Cfux10^{3}g^{-1}soil**		Pseudomonas **Cfux10^{3}g^{-1}soil**		Bacillus **Cfux10^{3}g^{-1}soil**	
	Conventional Tillage	**Minimum Tillage**	**Conventional Tillage**	**Minimum Tillage**	**Conventional Tillage**	**Minimum Tillage**	**Conventional Tillage**	**Minimum Tillage**	**Conventional Tillage**	**Minimum Tillage**
Maize										
0-7.5										
Post Germination	280d	130b	230c	110b	14.0a	34.2b	48b	187c	21.4b	23.0b
Harvesting	170b	139a	45b	14a	12.7a	26.9b	11a	26b	13.1a	10.80a
7.5-15.0										
Post germination	240c	9a	28b	2a	6.3a	3.15a	54b	23a	8.3a	9.0a
Harvesting	110b	7a	15b	1.7a	5.2a	3.8a	16b	6.4a	8.7a	10.2a
Wheat										
0-7.5										
Post Germination	39.0a	1.4a	88b	11a	16.8a	28.7b	59.0b	193.0c	44.7b	40.9b
Harvesting	12b	0.22a	64b	3.2a	13.0a	15.6a	32b	42.0b	8.4a	9 2a
7.5-15.0										
Post germination	33b	0.14a	62b	8a	9.7a	5.044a	32.0b	15.2a	2.6a	4.8a
Harvesting	5b	0.22a	35b	2a	6.3a	2.835a	11.4a	7.3a	1 9a	1.7a

Data in column by same letters are not different at 0.05 level of significant.

Soil respiration and dehydrogenase activity

Soil respiration and dehydrogenase activity (DHA) were significantly high under minimum tillage. These two parameters were strongly stimulated at post germination stage under minimum tillage condition both under wheat and maize crop. The positive stimulation of these two biological parameters was confined to the upper soil layer only as the rate of soil respiration and dehydrogenase activity were found higher in ploughed soil at lower depth (Table 3).

Table 3. Effect of conventional and minimum tillage on soil respiration and dehydrogenase activity in maize -wheat cropping system

Tillage System	Sampling	Soil respiration µl O2 uptake/4h/4g soil)		Dehydrogenase activity (µg TPF h^{-1} g^{-1} soil)	
		0.-7.5 cm	7.5-15 cm	0-7.5 cm soil depth	7.5-15 cm soil depth
		Maize			
Conventional	Germination	103.43b	95.40b	167.20c	153.60c
	Harvest	33.95a	28.9a	77.04b	75.60b
Minimum tillage (Bed plants)	Germination	126.11c	40.7a	298.07d	74.80b
	Harvest	39.42a	24.6a	64.40a	25.60a
		Wheat			
Conventional	Germination	95.52b	72.07b	116.72b	103.20b
	Harvest	40.2a	22.9a	53.16a	48.59a
Minimum tillage	Germination	110.46b	44.28a	159.30c	78.60c
Zero tillage	Harvest	43.06a	29.07a	43.40a	28.40a

At upper layer soil respiration during maize germination was significantly higher in minimum tillage than under conventional tillage but during wheat germination insignificantly high value was recorded in minimum tillage than under conventional tillage. However, at lower depth soils under conventional tillage were found to show significantly higher respiration at post germination stage of maize and wheat crop. Soil at lower depth showed low respiration rates in terms of oxygen uptake under minimum tillage. At harvesting stage, upper soils of maize and wheat showed high values of respiration than lower soil although it was not statistically significant. Highest DHA was recorded at post germination stage of maize in upper layer soils under minimum tillage. In both crops, post germination stage soils under minimum tillage showed significantly higher DHA values than the corresponding conventional tillage. At harvesting stage of maize and wheat no consistent trend in DHA activity was observed. Only maize at harvesting stage significantly showed high DHA in top layer soil in minimum tillage. A sharp gradient in soil respiration and DHA values was observed at both stages of crop growth under minimum tillage but was absent under conventional tillage.

DISCUSSION

From the results it is apparent that tillage systems influenced profoundly on soil micro flora and biological activities. In this study, two tillage methods, not qualitatively, but quantitatively altered the micro flora distribution over the soil profiles. The microbial biomass and soil organic matter are reported to be influenced by alteration in soil management practices (Powlson *et al.*, 1987; Saffigna *et al.*, 1989). Several reports exist which indicate that minimum or zero tillage system increase the soil microbial biomass and size of microbial population. (Carter, 1986; Follett and Schimel, 1989; Alvarez *et al.*, 1995). In this study, the overall counts of microorganisms was found to be significantly high in the upper soil layer under minimum tillage (bed planting of maize and zero tillage of wheat). It might be because of enhanced carbon and nutrient availability in the upper layer soil. Conventional tillage caused relatively even distribution of soil organic matter. Several workers (Powlson and Jenkinson, 1981; Follett and Schimel 1989; Karlen *et al.*, 1991) also reported that change from conventional to zero tillage only alters the distribution of soil organic matter along the soil profile. Accumulation of organic matter in upper soil profile under minimum tillage is also responsible for the abundance and activity of decomposer organisms (Blumberg and Crossley, 1983; House and Parmele, 1985). In present study, stimulation of gram negative *Azotobacter spp.* and *Pseudomonas spp.* in upper soil layers under minimum tillage may be attributed to enhanced availability of organic substrates as well as plant root exudates. Ferreira et al., (2000) also reported similar observations with regard to *Bradyrhizobium spp.* populations in soybean rhizosphere cultivated under zero tillage system. The reduced soil micro flora in lower layer (7.5-15.0 cm) under minimum tillage had no negative impact on the crop yield. Relatively high availability of soil organic matter at lower soil profile under conventional tillage may be due to even distribution of crop residues and other nutrients throughout the plough zone. This may possibly accounted for observed higher counts of soil microflora at lower (7.5- 15.0 cm) soil zone under conventional tillage than the minimum tillage.

Presence of *Nitrosomonas spp.*, *Nitrobacter spp.* and Nitrifires was exception as their population counts were high at both the two soil depths under conventional tillage (Table 2). Nitrifiers are highly aerobic organisms requiring high fluxes of oxygen which are available under conventional tillage and not under minimum tillage where soil aeration is restricted. The other possibility is that accumulation of crop residues of high C:N ratio at the upper soil layer under minimum tillage may cause immobilization of nitrogen and hence reduce the rates of nitrate formation. Hughes and Herridge (1989) also reported a reduced level of soil nitrifying organisms and consequently low soil nitrate concentrations under minimum tillage conditions.

The pattern of dehydroganase activity and soil respiration can be described on the basis of occurrence of soil carbon pools, the labile pool which undergo microbial attack and the resistant pool. The organic carbon fraction present on the surface layer under minimum tillage is readily degradable than under conventional tillage (Alvarez *et al.,* 1995). The abundance of labile carbon fraction stimulates microbial activity in the topsoil layer under minimum tillage. A high dehydrogenase activity is expected in upper soil profile as dehydrogenases are fundamental to the enzyme system of all microorganisms and play an essential role in the initial stages of oxidation of soil organic matter by transferring electrons or hydrogen from substrates to acceptor (Ross, 1971). The activity of these dehydrogenases serves as an indicator of the microbiological red-ox system in soils and are a good measure of microbial oxidation activity (Tabatabai, 1982). The sharp gradient in dehydrogenase activity from top to lower soil layer under minimum tillage and absence of sharp gradient in dehydrogenase activity at different soil horizons in conventional tillage (Table 3) may be due to differential distribution of micro-organisms (Table 1) and carbon substrate availability. Almost a parallel relationship was noticed in the soil respiration and dehydrogenase activity in both the tillage systems and the soil depths. Although tillage was expected to stimulate soil respiration under conventional tillage but this study indicated greater soil oxygen uptake at germination stages of wheat and maize cultivated under minimum tillage condition.

Tillage affects carbon availability by disturbing soil structure and exposing protected organic materials. After extended periods of cultivation, soil microbial activity may become carbon limited (Hendrix *et al.*, 1987). Therefore which determines the pattern of respiration. Our data is in accordance with that of Doran (1980) where microbial abundance and activity were higher in surface layers of minimum tillage but not over the whole soil profile. Soil microbes are responsible for most heterotrophic soil respiration. Effect of tillage and residue placement on respiration and other soil biotic activity may also vaz. because of variation of other abiotic factors like soil moisture and soil temperature occured in two distinct tillage system (Buyanovsky *et al*., 1986).

CONCLUSION

This work highlights that of tillage system has a profound effect on the soil biological activities. Even during short term experiments the tillage method influenced the distribution pattern of soil microflora. It has indirect effect on the populations colonizing the root system and the crop production. However, a number of techniques including biological and chemical are needed when monitoring soil microbial populations and its impact on crop production.

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MANAGEMENT OF BANDED LEAF AND SHEATH BLIGHT OF MAIZE USING *Pseudomona fluorescens*

G. SIVAKUMAR[1] AND R.C. SHARMA[1]

ABSTRACT

Pseudomonas fluorescens PF-1, isolated from crop rhizosphere, exhibited inhibitory action against *Rhizoctonia solani* f.sp. *sasakii* Exner. causing banded leaf and sheath blight disease in Maize. Among the carriers, peat and talc were noted to maintain the population at 19.5 x 10^7 and 18.3x10^7 colony forming units per gram of the product, respectively after 40 days of storage. The disease was effectively controlled by seed treatment with the peat based formulation @ 16 g/kg or soil application @ 2.5 kg / ha or spraying the liquid formulation twice @ 5g/l of water on maize foliage. Seed treatment with *P. fluorescens* resulted in increased population of fluorescent Pseudomonads in the rhizosphere. Soil application of *P. fluorescens* along with seed treatment resulted in further increase in rhizosphere population of the bacterium in glass house and field conditions. Though the seed treatment alone was quite effective in minimizing disease incidence, the application of the antagonist in combination gave a significant control of the disease in glass house and field conditions. The yield was also increased considerably due to the bacterial treatment.

Key Words: *Pseudomonas fluorescens, Rhizoctonia solani,* maize, biocontrol, banded leaf and sheath blight.

INTRODUCTION

Banded leaf and sheath blight (BSLB) of maize caused by *Rhizoctonia solani f. sp. sasakii* Exner. has attained a wide distribution and become an economically important disease not only in India but the whole of tropical Asia wherever maize is grown. It was first recorded from Sri Lanka (Bertus, 1927). Now the disease is of common occurrence in Nepal, India, Bhutan, Bangladesh, Myanmar, Malaysia, Phillipines, Thailand, Vietnam, Kampuchea, Laos, South China and Taiwan. In 1970, an endemic of this disease occurred in the warm humid hilly regions of Himachal Pradesh in India, particularly in Mandi district (Sharma *et al.*, 1993). Since the pathogen is soil borne, drenching with fungicides is expensive and impractical. Development of resistant cultivars is more ideal to suit the strategy, but it has not been possible due to non-availability of host resistance.

[1] Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi –110012

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Exploitation of biocontrol agents is one of the alternative approaches to manage plant diseases. Isolates of *Pseudomonas fluorescens* were used as biocontrol agents as the bacterium was reported to suppress soil borne diseases caused by fungal pathogens (Weller, 1988).

MATERIALS AND METHODS

Fluorescent pseudomonas species were isolated on King'B medium from fresh roots of maize, pigeon pea, chickpea and rice plants from several geographic areas. The antagonistic potential of *P. fluorescens* isolates against *Rhizoctonia solani* f.sp. *sasakii* was tested by dual culture method on PDA medium. The bacterial antagonists were streaked at one end of the PDA medium placed in sterilized plates 24hr prior to the pathogen inoculation. Just opposite to the bacterial streak, a 9 mm disc of the pathogen was placed. Three replications of each isolate including a control, i.e. without inoculation of the antagonist were maintained. The inhibition zone was measured after 96 hr. Observations were recorded on sclerotial production 10 days after inoculation. The matured sclerotia were harvested from the dual plate with sterile forceps and then counted. Matured sclerotia harvested from the dual plate were tested for germination. The sclerotia of uniform size were taken in a cavity slide and a drop of sterilized distilled water was added. The slides were incubated in a moist chamber for 24 hr. The number of germinated sclerotia in each treatment were counted.

Survival of *P. fluorescens* in different carrier materials and efficacy of different doses of peat based formulation of *P. fluorescens* through various application methods were evaluated under greenhouse studies (Sivakumar *et al.*, 2000).

Preparation of peat formulation

The effective antagonistic isolate (PF-1) was grown in King's B liquid medium for 48 hr in a shake culture (150 rpm) at laboratory temperature $25 \pm {}^{0}C$. The pH of the peat soil was adjusted to 7.0 by adding calcium carbonate. Twenty grams of carboxy methyl cellulose was added to 1 kg of the peat soil and mixed throughly. Then the peat soil was autoclaved at $121^{0}c$ for 2 consecutive days. Four hundred milliliters of bacterial suspension containing $9x10^{8}$ colony forming unit per mililiter was added to 1 kg of the peat soil and mixed thoroughly under sterile conditions. The final product was packed in sealed ploythene bags and incubated at room temperature ($25 \pm {}^{0}C$). This peat formulation was used for seed treatment, soil application and spray application.

Evaluation of *P. fluorescens* (PF-1) against the banded leaf and sheath blight under green house conditions

A pot culture experiment was undertaken at the Directorate of Maize Research greenhouse with the following treatments using Pusa Composite-2 as a test variety of maize. The treatments were as follows: (1) seed treatment, (2) soil application, (3) spray application, (4) seed treatment and soil application, (5) seed treatment and spray application, (6) soil and spray application, (7) seed, (8) soil and spray application. The plants were inoculated with pathogen *R. solani* f.sp. *sasakii* at 45 days after sowing and the biocontrol agent was applied as per the procedures described earlier by Sivakumar *et.al* (2000). Seed treatment was done @ of 20 g of peat based formulation per kilogram of seed. Treated seeds were sown in moist soil kept in pots. Soil application was done @ of 2.5 kg of peat formulation per hactare (25 mg per pot) 25 days after sowing. The peat-based formulation was mixed with the top moist soil. The pots were irrigated after words. The foliar spray @ 6 g of formulation per litre of water was sprayed at late evening over the maize plants (42 and 50 days after sowing). The disease intensity was assessed based on a 1-5 rating scale described by Ahuja and Payak (1983).

Evaluation of *P. fluorescens* (PF-1) under field conditions

Two field experiments were conducted during two seasons in a research farm at Indian Agricultural Research Institute (IARI), Delhi, India. The experiments were laid out in randomized block design with three replications using Pusa Composite –2 as a test maize variety. Field experiment was conducted under pathogen induced condition. Rhizosphere population of *P. fluorescens* was estimated by the procedure described by Papavizas and Davy (1960) both under green house and field conditions.

RESULTS AND DISCUSSION

Among seven isolates of *P. fluorescens*, collected from rhizosphere of various crops, two isolates, PF-1 and PF-6 showed high degree of efficacy in inhibiting *R. solani* f.sp. *sasakii* at *in vitro*, exhibiting inhibition zone of 23.7 mm and 20.3 mm, respectively (Table-1). High degree of *in vitro* antagonism against different kinds of pathogens by fluorescent *Pseudomonads* has been reported (Geels & Schippers, 1983; Sivakumar & Narayanasamy, 1998; Rangeswaran & Prasad, 2000; Sivprasad *et al.*, 2003). Data in Table 1 indicated that all the seven isolates inhibited the sclerotial production *in vitro*. The pathogen produced very less number of sclerotia in the dual plate inoculated with the bacterial isolates PF-1 and PF-6. In these isolates, the number of sclerotia produced were 19.3 and 22.7, respectively. Sclerotial germination (by number) ranged from 2.3 to 8.0 in the antagonistic isolates compared to 0.90 in the control (Table 1). This is possibly due to the production different types of secondary metabolites by the bacterial antagonist.

In both green house and field experiments the antagonist *P. fluorescens* survived well in the rhizosphere of maize crop. When applied to seeds the antagonist multiplied and survived well in the rhizosphere, even 75 days after sowing. All the treatments showed considerable bacterial population even 90 days after sowing. There was an increase in the rhizosphere bacterial population when seed treatment was combined with soil application (Table 2, 4). Seed treatment, followed by root zone application of *P. fluorescens* recorded better rhizosphere bacterial population. Rhozosphere population ranged 15.6-22.6 x 10^8 and 18.4-27x10^4, respectively both under green house and field conditions as compared to untreated plants where it was recorded 1x 10^8 and 8x10^4 respectively. Good establishment of the bacteria in the rhizosphere of plants may be due to an improved capacity of it to compete for root exudates (Loper *et al.*, 985; Gamliel & Katan, 1992). Several reports on good establishment of the bacteria in the rhizosphere in green house studies (Mew & Rosales,1986) and in field trials (Burr *et al.*,1978; Vidyasekaran & Muthamilan, 1995) are available.

The disease was effectively controlled by *P. fluorescens* through different methods of applications. Although a single method was effective in reducing disease incidence under green house and field conditions, the most effective control was attained when the peat based formulation was applied to seed, soil and in combination. A combination of all the three application methods was the most effective approach for the disease control (Table 3, 5). In the combination approach, the percent disease reduction over control was 75.0 as compared to single method of application such as seed treatment, soil application and spray application. In the case of a single method of application, seed treatment was found to be the best in reducing the disease intensity followed by soil and spray application (Table 3, 5). Evaluation of different doses of peat based formulation of *P. fluorescens* through different methods of application for the management of banded leaf and sheath blight of Maize was done by Sivakumar *et al.*, (2000). Seed treatment with the formulation of *P. fluorescens* has been found effective in controlling several diseases (Weller, 1998; Sivakumar and Narayanaswamy, 1998; Sivakumae *et al*., 2000 and Sivaprasad *et al.,* 2003). Control of foliar diseases using fluorescent *Pseudomonads* as foliar spray has been reported by other workers (Mew and Rosales,1986; Sivakumar and Narayanaswamy,1998). Indications of induced disease resistance by seed treatment of this bacteria has been reported by Burr. 1972; Sivakumar and Sharma. 2003.

Highest yield of maize was recorded in the combined method of application as compared to single method of application of the antagonist. In both the trials, the yield was 45 percent more in the combination approach as compared to untreated check (Table 5). There are other reports supporting these findings in other crops such as potato and wheat (Becker & Cook, 1998).

Table 1. *In vitro* effect of *P. fluorescens* on *R. solani* f.sp. *sasakii*

Isolates of *P. fluorescens*	Rhizosphere of crops	Inhibition zone (mm)	No. of sclerotia developed	No. of sclerotia germinated
Isolate-1	Maize	23.7	19.3	2.3
Isolate-2	Maize	7.3	25.0	5.3
Isolate-3	Rice	4.3	30.3	6.3
Iisolate-4	Maize	8.7	26.0	4.7
Isolate-5	Chick pea	10.7	24.7	3.3
Isolate-6	Maize	20.3	22.7	3.3
Isolate-7	Pigeon pea	2.7	25.3	8.0
Control		0.1	40.3	9.7
C.D (P=0.05)		0.90	1.20	0.90

Table 2. Survival of *P. fluorescens* in maize rhozosphere under pot culture conditions

Treatments	Rhizosphere population (10^8cfu/g) at different days after sowing			
	30	**60**	**75**	**90**
Seed treatment	9.0	12.6	14.4	15.6
Soil application	7.6	11.8	12.8	12.6
Seed treatment +Soil application	12.0	18.4	21.2	22.6
Control	1.0	1.0	1.0	1.0
C.D. (P=0.05)	0.9	0.6	0.7	0.6

Table 3. Efficacy of *P. fluorescens* in management of banded leaf and sheath blight of maize under green house condition

Ttreatments	Disease rating
Seed treatment	1.7
Soil application	2.2
Spray application	2.3
Seed treatment +Soil application	1.3
Seed treatment +Spray application	1.3
Soil application+ Spray application	1.5
Seed treatment + Soil application +Spray application	1.0
Control	4.0
C.D. (P=0.05)	0.32

Table 4. *P. fluorescens* population in maize rhizosphere under field conditions

Treatments	Population (10^4 cfu/g) in rhizosphere at different days after sowing							
	Trial 1				Trial II			
	15	30	60	90	15	30	60	90
Seed treatment	4.2	11.8	15.6	18.0	4.0	11.0	10.0	10.4
Soil application	3.0	10.4	14.5	16.6	3.0	10.6	13.2	16.4
Seed treatment+Soil application	4.8	13.4	22.4	27.0	5.0	14.0	22.8	27.0
Control	1.4	3.2	5.2	7.2	16.0	3.2	6.0	8.0
C.D. (P=0.05)	0.87	0.99	.43	0.96	1.04	0.83	0.99	1.23

Table 5. Efficacy of *P. fluorescens* in management of banded leaf and sheath blight of maize under field conditions

Treatments	Trial-1		Trial-II	
	Disease rating	Grain yield (kg/ha)	Disease rating	Grain yield (kg/ha)
Seed treatment	2.66	3938.65	2.71	3941.21
Soil application	2.83	3480.06	2.92	3484.21
Spray application	3.16	3366.88	3.32	3370.91
Seed treatment +Soil application	1.83	4238.65	1.95	4242.71
Seed treatment +Spray application	2.00	4011.92	2.12	4015.68
Soil application+ Spray application	2.33	4010.16	2.45	4014.29
Seed treatment + Soil application +Spray application	1.50	4605.25	1.60	4610.41
Control	4.33	2996.82	4.48	2993.94
C.D. (P=0.05)	0.44	46.69	0.38	32.25

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SEEDLING GROWTH INHIBITION INDEX - A TECHNIQUE FOR IDENTIFYING FOOT-ROT RESISTANCE IN WHEAT

S.G. BORKAR[1] AND K.N. CHAUDHARI[1]

ABSTRACT

Foot-rot of wheat caused by *Sclerotium rolfsii Sacc.* inhibited seedling growth of susceptible wheat cvs upto 20 DAS and by 30-45 DAS the affected seedlings became pale yellow and died ultimately. The wheat cvs which showed less than 11 percent seedling growth at 20 DAS were found to be resistant; whereas more than 11 percent seedling growth were found to be susceptible to foot-rot infection. The seedlings of susceptible cvs became pale-yellow and died by 45 DAS; whereas the resistant cvs remained dark green and vigorous. Thus, seedling growth inhibition percentage (index) can be used as a faster and reliable tool to identify resistant materials against foot-rot pathogen S. *rolfsii* in wheat.

By using seedling growth inhibition index to identify foot-rot resistance in wheat, at least nine elite wheat entries and two released varieties were found resistant; whereas four elite entries and 5 released varieties were-found susceptible to foot-rot infection.

Key Words: Foot-rot, Wheat, Resistance, *Sclerotium rolfsii*

INTRODUCTION

Foot-rot of wheat caused by *Sclerotium rolfsii* Sacc. causes considerable damage to wheat (Mc Rae, 1923). The affected seedling remain stunted with yellowing of leaves which later dries up. The root system of the affected plant starts rotting with root bark peeled having fragmented root fibres (Saxena and Kumar, 1971). The disease is observed to be severe in central provinces viz., Peninsular and Central India (Mc Rae, 1923; Subramanium, 1928; Dastur, 1932). Management of foot-rot of wheat under field condition, as a soil borne disease, is difficult. Development of resistant varieties against it is the only viable alternative in its management. During development of resistant varieties, determination of disease resistance becomes faulty in the absence of a proper evaluation method. Earlier, Chattopadhya (1953) reported 50-60% death of seedlings in S. *rolfsii* inoculated soil after 20 DAS. Similarly, Agarwal and Sindh (1969) distributed resistance pattern in four groups viz., resistant (0-10% mortality), moderately resistant

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[1] Mahatma Phule Agricultural University, Wheat Research Station, Niphod, Dist: Nashik (M.S.), India

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(11-30% mortality), moderately susceptible (31-70% mortality) and susceptible (71-100% mortality). However, it remains a question that in a fully infected soil, how in a given line/variety (i.e. pureline/variety and not segregating material) only 10 percent or 20 percent plants will succumb to infection and rest will show resistance. Therefore, the concept of determining resistance to soil borne diseases particularly S. *rolfsii* needs a viable and well defined technique. Present investigation deals with this technology development aspect to identify foot-rot resistance in wheat.

MATERIALS AND METHOD

The experiment was conducted at Mahatma Phule Agriculture University, Wheat Research Station, Niphad (MS), India during 1999 and 2003 respectively.

A) Isolation of foot-rot pathogen

Plants showing foot-rot symptoms in wheat during 1999 and 2002 under field conditions were used for isolation of the causal organisms. Fungal pathogen from the infected root was isolated on Pototo-Dextrose-Agar medium. Pathogenic cultures were purified by using single sclerotial body. Thus three sclerotium cultures viz., Niphad-99 (isolated in 1999 from Niphad), Niphad-02 (isolated in 2002 from Niphad) and Dharwad (isolated from Dharwad sample) obtained from wheat foot-rot were maintained. These were identified as *Sclerotium rolfsii* with Indian type culture collection No. 5465-02,5466-02 and 5467-02. Pathogenic nature of these cultures i.e. yellowing and mortality of wheat seedling (Saxena and Kumar, 1971) were established under pot culture test. All the three cultures were used for mass production and seedling growth inhibition index studies.

B) Mass production of *S. rolfsii*

Individual *S. rolfsii* culture was grown on wheat-jawar-soybean medium (wheat 500g; jowar 250 g; soybean 250 g; $CaCO_3$ 250 g). Grains of wheat, jawar and soybean were soaked in water for overnight, cooked in boiling water for 20 min, excess water was drenched off and the grains were dried in shed for 30 min. All grains were mixed well with $CaCO_3$ and bottles were filled and autoclaved at 20 lbs pressure for 30 min. These bottles were inoculated with *S. rolfsii* cultures separately and incubated at 28^0C for its growth.

C) Seedling growth inhibition index

Thirty-days old cultures of *S. rolfsii* on wheat-jowar-soybean medium were mixed together. This mixture was mixed well with sterilized soil (1:1) and pots were filled. Thirteen elite Niphad entries and seven released wheat varieties were sown separately in these pots. Proper control was maintained in sterilized soil without *S. rolfsii.* Pots were watered as and when required. Inhibition of germination due to foot-rot pathogen, inhibition of seedling growth and seedling mortality were studied to determine resistant lines to foot-rot infection.

RESULTS AND DISCUSSION

Foot-rot pathogen *S. rolfsii* affected seed germination as well as seedling growth are given in wheat (Table 1). In foot-rot infected soil, seedling growth was affected upto 20 DAS and by 30-

45 DAS the growth affected plants became pale yellow and died ultimately. Chattopadhya (1953) also reported death of seedlings in *S. rolfsii* inoculated soil after 20 DAS. The wheat cvs which showed less than 30 percent inhibition of germination were found to be resistant provided the inhibition of seedling growth was less than 11 percent. More the percentage inhibition of seedling growth, more the variety/cv was susceptible to foot-rot infection.

Wheat variety HD 2189 and elite material Niphad 319 showed more than 50 percent reduction in germination in *S. rolfsii* infected soil. At 20 DAS, seedling growth inhibition showed, marked differences in resistant/susceptible wheat cvs. In 30-45 DAS, the susceptible lines became yellow and died ultimately, while resistant lines remained dark green and vigorous. Wheat cvs showing more than 11 percent inhibition of seedling growth were observed to be susceptible to foot-rot pathogen as these became yellow and died ultimately.

Out of 13 Niphad elite materials, atleast 9 entries viz., NIAW 917, 979, 963, 962, 933, 939 (of Aestivum group) and NIDW 907, 295, 325 (of Durum group) were found resistant. Similarly, out of 7 released varieties, 2 varieties viz., Panchavati and MACS 2496 were found resistant to *S. rolfsii* in seedling growth inhibition test.

S. rolfsii is a destructive plant pathogen causing diseases in more than 500 host species (Punja, 1988). Despite continuous research over the past one century since the report of Rolfs in 1892 (not listed in the reference sec.) of *S. rolfsii* on tomato, management of the pathogen has remained a challenge (Sarma *et al*., 2002). Although various control measures viz., application of soil fungicides (Shahi *et al.*, 1987), soil solarization (Grinstein, *et al.*, 1979), plant products (Shahi *et al.*, 1998; Singh *et al.*, 2000) and biocontrol agents (Mukherjee *et al.*, 1995) to control *S. rolfsii* have been reported. However, the feasibility of use of these methods over large wheat acreage has limitations. Therefore, development of resistant cvs either through transgenic plants (Punja and Raharjo, 1996) or through direct selection are vital alternatives and, therefore, in order to determine resistance/susceptibility of wheat lines/varieties to foot-rot pathogen (*S. rolfsii*), seedling growth inhibition index technique can be used a tool.

Table 1. Varietal reaction of wheat cvs to foot-rot pathogen *S. rolfsii*

Wheat cvs/ Varieties	Germination (%)			Growth (cm) at 20 DAS			Seedling Mortality	Reaction
	Control	*S. rolfsii* treated soil	Inhibit-ion of germi-nation (%)	Control	*S. rolfsii* treated soil	Inhibition of growth (%)		
Elite cvs								
1. NIAW 957	100	90	10	19	10	47.3	+	S
2. NIAW 957	100	80	20	21	11	47.6	+	S
3. NIAW 917	100	90	10	19	17	10		R
4. NIAW 979	100	80	20	26	23	11		R
5. NIAW 963	100	90	10	20	20	00		R
6. NIAW 962	100	100	00	23	23	00		R
7. NIAW 933	100	80	20	29	29	00		R
8. NIAW 939	100	100	00	29	29	00		R
9. NIDW 907	100	90	10	30	28	6.6		R
10. NIDW 319	100	20	80	25	15	40	+	S

(Cont…)

11. NIDW 295	100	70	30	16	15	6.25		R
12. NIDW 325	100	70	30	21	19	9 5		R
13. NIDW 309	100	80	20	26	13	50	+	S
Released varieties								
1. NIAW 34	100	90	10	21	17	19	+	S
2. NIAW 301	100	80	20	22	17	22	+	S
3. NIDW 15	100	70	30	31	29	6.4		R
4. NI 9947	100	100	00	24	18	25	+	S
5. HD 2189	100	50	50	30	16	46	+	S
6. MACS 2496	100	90	10	23	21	8.6		R
7. Lok 45	100	90	10	26	18	30	+	S

+ = Seedling become yellow and die ultimately at 30-45 DAS.

S = Susceptible to S rolfsii infection.

R = Resistant to S rolfsii infection.

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SUPPRESSION OF COTTON RENIFORM NEMATODE *Rotylenchutus reniformis*, WITH *Pseudomonas fluorescence*

J. JAYAKUMAR[1], S. RAMAKRISHNAN[2] AND G. RAJINDRAN[1]

ABSTRACT

Experiments under glasshouse conditions were conducted to evaluate talc formulation of *Pseudomonas fluorescens* by applying as seed treatment, soil application and split application for the management of *Rotylenchulus reniformis* in cotton cv. MCU-5. Treatments viz., 1 Soil application (SA) with *P. fluorescens* @ 2.5 kg/ha before sowing, 2 Seed treatment (ST) with *P. fluorescens* 10g/kg seed ($6x10^8$ cfu/g), 3. *P. fluorescens* as ST (10g/kg seed) and SA (2.5 kg/ha), 4. Split application with *P. fluorescens* @ 1, 0.75 and 0.75 kg/ha at sowing, 30 and 60 days after sowing (DAS) respectively, 5. *P. fluorescens* as ST (10g/kg seed) and split application and 6. Untreated control. Seeds were soaked in water @ 100 ml/kg seed (6×10^8 cfu/g) for 12 hours. Maximum colonization of *rhizobacterium* in root was observed in plants treated with seed + split application of PF1 and followed by split application of PF1 in soil. All the methods of appliction of *P. fluorescens* through seed and soil as single and split application significantly reduced the soil and root population of *R. reniformis* compared to untreated control. The maximum reduction in this reniform nematode population in roots was noticed in the treatment of seed split application of *P. fluorescens* (74.2 %)+ compared to various other application methods.

Key words: *Pseudomonas fluorescens, Rotylenchulus renifermis*, Cotton

INTRODUCTION

Reniform nematode, *Rotylenchulus reniformis*, causes 40-60 per cent yield loss in cotton in tropical and subtropical regions (Sikora & Bridge, 1960). Palanisamy and Balasubramanian (1983) reported cotton yield loss to the tune of 14.8% due to *R. reniformis* infestation and it ranged from 10-15 per cent in Tamil Nadu. At present nematode management proves to be a difficult task in developing countries where nematicides are very costly giving only short term solution. Environmental problems associated with the use of nematicides have forced the evolution of novel nematode management strategies such as use of biocontrol agents which are economical and

[1] Department of Nematology, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
[2] CTRI Research Station, Hunsur 571005, Karnataka, India

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environmentally safer. More over, it does not allow the nematodes to develop into new races or biotypes. Chitinolytic microbes like fluorescent pseudomonads appear frequently isolated from plant rhizosphere which inhibit early root penetration of nematodes (Oostendorp & Sikora, 1989) and their multiplication under invitro conditions was found to be easy. Hence, present investigations were under taken under glass house conditions to study the bio-control potential of fluorescent pseudomonads against *R. reniformis* in cotton.

MATERIALS AND METHODS

Seeds of cotton (cv MCU-5) were sown in earthern pots filled with steam sterilized soil mixture (5 kg capacity) @ 5 seeds/pot and thinned to one seedling per pot at 10 days after sowing followed by inoculation with *R. reniformis* @ 2 juveniles/g soil.

Following treatments were tested with three replications in a randomized block design:

1. Soil application (SA) with *P. fluorescens* @ 2.5 kg/ha before sowing
2. Seed treatment (ST) with *P. fluorescens* @ 10g/kg seed ($6x10^8$ cfu/g)
3. ST with P.fluorescens (10g/kg seed) and SA (2.5 kg/ha)
4. Split application of P. fluorescens @ 1, 0.75 and 0.75 kg/ha at sowing, 30 and 60 days after sowing (DAS) respectively
5. ST with *P. fluorescens* and its split application as in treatments no. 2^4 4 respectively
6. Untreated control

The plants were maintained carefully under glass house conditions and on 180^{th} day after sowing (DAS), observations on their growth parameters and the nematode population, both in soil and root and cotton yield per plant were recorded.

RESULTS AND DISCUSSION

The results of the experiment are summarized in Table 1. Among the various methods of *P. fluorescens* application, seed treatment + split application gave maximum increase in plant height to the tune of 19.6 percent over untreated control. The effect of this treatment was at par with seed treatment alone. Further, seed treatment + split application of *P. fluorescens* registered maximum number of bolls/plant (75.3%). However, this treatment was at par with seed treatment + soil application of *P. fluorescens* as a single dose recording 57.4% increase over control in respect of number of bolls/plant. Similar results were obtained on growth and yield improvement in cotton due to application of *P. fluorescens*, irrespective of methods of application and significant increase in yields of potato (Burr *et al*., 1978) and wheat (Becker and Cook, 1988) were reported earlier due to *P. fluorescens* application.

All the methods of application of *P. fluorescens* through seed and soil as single and split application either singly or in combination reduced the soil and root population of *R. reniformis* compared to untreated control. The treatment with seed and split application of *P. fluorescens* strain effected maximum decrease in soil and root nematode population to the level of 74.2 and 53.9% respectively from control. Effective reduction in nematode population due to split applications at different intervals may be due to maximum building up of bacterial population/root colonization by bacterium inoculum. Similar to the present results obtained, *Ramakrishnan et al*. (1998) have also viewed that the nematode suppressing ability of *P. fluorescens* strains is related mainly to their root colonizing ability.

Table 1: Effect of various application methods of *P. fluorescens* on plant characters and population for *R. reniformis* management in cotton

Treatment	Plant height (cm)	Root length (cm)	Root weight (g)	Boll weight (g/plant)	R. reniformis population	
					Per gram of root	Per 200 c.c of soil
T_1	102.2	32.2	12.0	3.26	10.0	381.3
T_2	107.6	31.7	11.5	2.7	13.3	394
T_3	107.3	34.6	12.4	3.47	7.0	343.0
T_4	104.6	32.4	12.2	3.24	8.60	366.6
T_5	112.7	37.3	13.1	3.83	6.0	335.6
T_6	94.2	28.1	9.2	1.95	23.3	729.3
CD at 5%	4.82	2.61	0.61	0.15	50.4	4.99

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ISOZYME VARIATION IN NEPALESE RICE (*Oryza sative L.*) CULTIVARS

BAL KRISHNA JOSHI[1]

ABSTRACT

Diversity study and classification of large variation within *Oryza sativa* L. have importance for breeders and geneticists. A total of 39 Nepalese rice cultivars were classified and evaluated by eight isozyme systems. These cultivars were analyzed considering first into varietal groups (indica, intermediate and japonica) and second into geographical groups (Tarai, Mid hill and High hill). Multivariate analysis grouped these cultivars into three, indica (22), intermediate (3) (probably javanica) and japonica (14) varietal types. There were sixteen loci coding eight isozyme systems. All loci were found in indica group, 14 loci in intermediate and 15 in japonica. Most of the enzyme systems expressed distinct zymograms for indica and japonica. Loci Mdh-3, Est-2 and Sdh-1 showed highest gene diversity within indica, intermediate and japonica types respectively. Frequency of 48 alleles ranged from 0 to 0.905, 0 to 1 and 0 to 1 in Tarai, Mid hill and High hill populations. Highest heterozygosity was noticed in Tarai population followed by Mid hill population. Nei's genetic distance was highest between Tarai and High hill populations (0.518). Diversity indices were higher in indica than in japonica. Isozymic parameters of indica were similar to Tarai population and that of japonica to High hill population.

Key Words: Isozyme, populations, rice cultivars, varietal classification

INTRODUCTION

The intraspecific variation is very high in *Oryza sativa* L. Rice scientists have shown the existence of three varietal types i.e. indica, japonica and javanica (Kato et al., 1928; Terao & Mizushima, 1942; Mallick, 1981/82; Matsuo, 1952; Oka, 1958; Glaszmann, 1987; Second, 1982). Classification of these large variations is important for breeders and geneticists. For example, rice breeders have used indica and japonica type in crossing program to increase yield. Seven different approaches have been used to classify rice genotypes. These classification are based on i. Geographical distribution (Morinaga, 1954), ii. Morphological traits (Matsuo, 1952), iii. Intervarietal sterility (Terao & Mizushima, 1942), iv. Serological characters (Oka, 1958), v. Biochemical markers (Oka, 1958), vi. Molecular markers (Zhang et al. 1992) and vii. Pedigree (for released cultivars after crossing among landraces) (Joshi, 2004a). A single method may not be

[1] Biotechnology Unit, Nepal Agricultural Research Council, Khumaltar, PO Box 1135, Kathmandu, Nepal

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a good way of confirming varietal types. For example, Taichung-176 is indica based on their ancestors Tsai-Yuanchung and DGWG (Joshi, 2004b). Both these ancestors are indica. But intervarietal sterility between Taichung-176 and indica type indicate it as japonica type. Therefore, combinations of these approaches are better way of classifying rice genotypes.

Considerable variation between the two species indica and japonica at both morphological and molecular levels is observed and considered to be associated with their adaptability to different environments (Glaszmann, 1987; Oka, 1988; Wang et al., 1992). The *Oryza* accessions from the same geographic regions, or near by geographic regions tended to be clustered in the same groups (Lu et al., 2002). The indica rice varieties showed relatively high genetic diversity and were scattered in different groups of their wild relatives but the japonica varieties showed a relatively low variation and formed an independent group. Geographic isolation has played a significant role in the differentiation of the *Oryza* accessions. Cluster analysis using RAPD distance grouped the populations according to their altitudinal habitat and a similar pattern of clustering was observed with respect to morphological distance also. Ecological heterogeneity associated with elevational gradient has a crucial role in the evolution of *Oryza malampuzhaensis* (Thomas et al., 2001).

Many rice genotypes have been studied by biochemical markers especially by isozymes. Shahi *et al*. (1969) surveyed isozyme variations in *Oryza* and found two zymograms of *sativa* varieties representing the indica and japonica types. Second (1982) noticed 25 polymorphic loci within O. *sativa*. The varieties tended to cluster into indica and japonica types. Glaszmann et al. (1987) reported a strong differentiation of the varieties towards the indica and japonica types. They pointed out that the japonica varieties, the typical upland rices from Africa and America and most upland rices from Southeast Asia belonged to the japonica type. Glaszmann (1985) identified 6 groups (I-VI) among 120 Asian varieties based on polymorphism at 21 loci. Group I consisted of the typical indica type and group VI consisted of temperate and tropical japonica type. Joshi and Bimb (2004) classified Nepalese rice cultivars using eight isozyme systems. Rice is being cultivated in three ecological regions i.e. Tarai, Mid hill and High hill in Nepal. Cultivars cultivated in these 3 regions are considered as three geographical (geo) populations i.e. Tarai, Mid hill and High hill. Here we have classified Nepalese rice cultivars (released rice genotypes in Nepal) first in varietal groups i.e. indica, intermediate and japonica types and second in geo populations i.e. Tarai, Mid hill and High hill populations and discussed their characteristics features of isozymes. Isozyme variations within and among populations were also studied.

MATERIAL AND METHODS

Plant materials

Nepal Agricultural Research Council has released 49 rice cultivars in Nepal. A total of 39 Nepalese rice cultivars including one non-released, Fuji-102 was used in this study to classify them on indica/japonica group. Details of these cultivars are given in Table 1. Breeder seeds of these cultivars were collected from National Rice Research Program, Hardinath and Agriculture Botany Division, Khumaltar. Khumal-4 and Fuji-102 were used as standard cultivars, former as indica and second as japonica. All these cultivars were first grouped in indica, intermediate and japonica groups based on literature review and these groups were verified with isozymic markers. Secondly based on their area of adaptation these cultivars were grouped in three populations i.e. Tarai, Mid hill and High hill. Tarai populations consisted of 21 cultivars, Mid hill 12 and High hill 6 cultivars.

Table 1. Populations of rice cultivars used in isozyme study

Code	Genotype	Pedigree	Geo-population	Varietal population
M1	BG-1442	BG 951///79-3348/H 4//BW 288-1-3	Tarai	Indica
M2	Bindesowri	TN 1/Co29	Tarai	Indica
M3	CH-45	Selection at CRRI	Tarai	Indica
M4	Chianung-242	Hsinchu 4/Taichung 150// Taipei7/T45	Mid hill	Japonica
M5	Chaite-2	BG34-8/IR2061-522-6-9	Tarai	Indica
M6	Chaite-4	BG34-8/IR28//IR2071-625-1-252	Tarai	Intermediate
M7	Chaite-6	NR6-5-46-50/IR28	Tarai	Indica
M8	Chandannath-1	Selection from Jinling 78-102	High hill	Japonica
M9	Chandannath-3	Selection from Yunlen-1	High hill	Japonica
M10	Chhommrong	Selection from Ghandruk local	High hill	Japonica
M11	Fuji-102	-	High hill	Japonica
M12	Ghaiya-2	MTU15/Waikakku	Tarai	Indica
M13	Himali	Cica 4/Kulu	Mid hill	
M14	IR-20	IR 262-24-3/TKM6	Tarai	Indica
M15	IR-22	IR 8/Tadukan	Tarai	Indica
M16	IR-24	IR8/// Century Patna/SLO//Sigadis	Tarai	Indica
M17	IR-8	Peta/DGWG	Tarai	Indica
M18	Janaki	Peta*3/TN1//Remadja	Tarai	Indica
M19	Khumal-11	NR 10375-14-2-1	Mid hill	Japonica
M20	Khumal-2	NR 10068-60-3-2	Mid hill	Intermediate
M21	Khumal-3	K 39	Mid hill	Intermediate
M22	Khumal-4	IR 28/Pokhreli Masino	Mid hill	
M23	Khumal-5	Pokhreli Masino/KN-1B-361-BLK-2-8	Mid hill	Japonica
M24	Khumal-6	NR10172-2B-12-4-1-3-2	Mid hill	Japonica
M25	Khumal-7	China 1039-DWF-MUT/KN-1B-361-1-8-6-10	Mid hill	Japonica
M26	Khumal-9	IR 15579-135-2	Mid hill	Japonica
M27	Machhapuchhre-3	Fuji 102/Chhommrong	High hill	Japonica
M28	Makawanpur-1	Ob678/IR20//H4	Tarai	Indica
M29	Manjushree-2	Fuji 102/NR10157-2B-7-1-1	High hill	Japonica
M30	Masuli	Mayang Ebos 80*2/Taichung 65	Tarai	Indica
M31	Palung-2	BG 94-2/Pokhreli Masino	Mid hill	Japonica
M32	Radha-11	Local selection	Tarai	Indica
M33	Radha-12	TNI/T141//Annapurna	Tarai	Indica
M34	Radha-4	BG 34-8/IR 2071-625-1	Tarai	Indica
M35	Radha-7	Janaki/Masuli	Tarai	Indica
M36	Radha-9	IR 42/Masuli	Tarai	Indica
M37	Rampur Masuli	Lal Nakanda/IR30	Tarai	Indica
M38	Sabitri	IR 1561-228-1/IR 1737//CR 94-13	Tarai	Indica
M39	Taichung-176	Tsai-Yuanchung/DGWG	Mid hill	Japonica

Sources: NRRP (1997), Joshi (2004a,b).

Enzyme extraction

Ten seeds of each cultivar were kept in Petri dish containing soaked filter paper. These were incubated in 30^{o}C for 7 days in dark plumules and coleoptiles of 3-5 seedlings of each cultivar were used to extract enzyme using Sodium ascorbate extraction buffer at pH 7.4. The extracts were absorbed with Whatman filter paper wicks of size 1.2 cm × 2 mm. Two weeks per cultivar were used. These enzyme-absorbed wicks were electrophoresed immediately. Details of enzyme extraction are described in GEVES (1993).

Electrophoresis and enzyme detection

A starch gel (12.5%) was prepared using the appropriate gel buffer for the specific enzyme under investigation. Gel preparation (tank and gel buffer), electrophoresis run and enzyme staining were followed as described in GEVEs (1993) and Glaszmann *et al*. (1988). Buffer system E was used. Electrophoresis was run at 4 W over night at 4^{o}C in refrigerator. Bromophenel blue marker was used as a check for electrophoresis run. After electrophoresis run, gels were sliced horizontally and stained in an appropriate staining mixture for isozyme banding patterns (GEVES, 1993). Eight enzyme systems, Alcohol dehydrogenase (ADH), Acid phosphatase (ACP), Esterase (EST), Isocitrate dehydrogenase (IDH), Malate dehydrogenase (MDH), Malic enzyme (ME), Peroxidase (POX) and Shikimate dehydrogenase (SDH) were assessed.

Data analysis

The genetic interpretations are based on Glaszmann *et al*. (1988). Most anodal zone of enzyme activity was assigned as locus 1, the next locus 2 etc. At each locus, most anodal allozyme (allele) was given alphabetical code a, the next b etc. The zone without band was considered as n, null. Bands were scored as 1 for presence and 0 for absence. Binary data matrix was made based on bands vs cultivars. Cluster and principal component analyses were applied on binary data matrix. After grouping these cultivars into varietal types (indica, intermediate and japonica), further isozyme analysis was done on these types and compared. Zymograms were presented separately for each enzyme. Frequency of zymotypes was calculated. The electromorphs were used as isozymic descriptors. Each electromorph (present + absence of bands) was considered as a character. A total of 28, 19 and 23 distinct electromorphs were used as isozymic descriptors for indica, intermediate and japonica varietal types respectively, and if two cultivars were different for at least one electromorph (presence or absence) they were considered to exhibit two different zymotypes. In second time, these cultivars were grouped based on their adaptation into Tarai, Mid hill and High hill populations and analyzed accordingly. A total of 28, 25 and 22 distinct electromorphs were used as isozymic descriptors for Tarai, Mid hill and High hill rice populations respectively. Frequency of alleles, descriptive statistics and gene diversity were calculated using GeneStat software.

RESULTS AND DISCUSSION

A total of 16 loci coding for eight enzyme systems were identified in 39 Nepalese rice cultivars. So far 59 isozymic loci have been identified coding for 23 isozymes. Isozyme variation for more than 40 presumed loci has been used in studies on the genetic structure of cultivated rice and its closest wild relatives in the genus *Oryza* (Second, 1982; Glaszmann, 1987). Fifteen polymorphic loci coding for 8 enzymes were reported by Glaszmann in 1688 rices (1987). Glaszmann *et al*. (1988) reported that at least 36 polymorphic loci could be surveyed during the development of the rice plant.

Based on the total 32 different electromorphs, these cultivars were grouped into 5 clusters (Fig. 1). Indica and japonica types tended to make separate cluster. Morphologically defined japonica types fell in cluster V but morphologically defined indica dispersed in all clusters I-V. Based on the check cultivars Khumal-4 and Fuji-102, cluster II is defined as indica group, cluster V as japonica type and remaining as intermediate (Table 2). Most of the cultivars recommended to Mid and High hills are included in cluster V i.e. japonica group. These isozymic grouping is related with morphological and geographical groupings. All the cultivars suitable to Tarai areas has fallen in clusters I-IV i.e. intermediate and indica types. Whatever the cluster analysis grouped these cultivars, discriminate analysis has confirmed these groupings. In some extent these classification were similar to those as classified by principle component (PC) analysis. Scatter plot of these cultivars considering first two PCs also separated three distinct groups (Fig. 2). For better grouping more than two PCs should be taken into account, because these two PCs has accounted for only 35% variability. All the japonica types have fallen in right two quarters, indica types in left two quarters and intermediate types in the central part. Glaszmann (1985) clustered 120 varieties into six groups and multivariate analysis in 1688 varieties resulted in 6 varietal groups (Glaszmann 1987). Nakagahra (1977) found 11 out of 12 expected zymograms in 1,095 strains of rice.

Zymograms of all isozymes except IDH and SDH are the characteristics features of these three groups, indica, intermediate and japonica. Indica types possess higher number of different zymograms. Among eight isozymes, EST bands traveled faster followed by POX. A total of 19 zymotypes for eight isozymes was observed (Table 3). IDH has expressed only zymotype A. Maximum number of zymotypes was noticed in POX.

There is one zone of ACP activity within 3 alleles including null (silent) (Figure 3). Null allele was observed only in indica and japonica groups. Among 3 zymotypes of ACP in 39 cultivars, B zymotype was not noticed in japonica group. Frequencies of zymotypes are given in Table 2.

ADH has one locus with 3 active alleles. There are three zymotypes in indica group and two in each of intermediate and japonica. B zymotype was the highest in number followed by C. EST has 3 loci Est-1, Est-2 and Est-9 with 3, 4 and 3 alleles including null in all loci respectively. Among 13 zymotypes of EST, 9 zymotypes are found in indica, 3 in intermediate and 7 in japonica groups. G and NA (null allele) zymotypes were common in all these groups. Zymotypes A, D and F were lowest in frequency. A single locus with two alleles (active and silent) was observed in indica and intermediate group for IDH. Japonica group has all active single allele. Zymotype A was common in all three groups. Nakagahra et al. (1975) reported that *O. sativa* show a wide variation in esterase isozymes. Oka (1958) pointed out that no single character distinguishes the two types, but that strong character associations indicate a trend towards differentiation. *Sativa* varieties show a different zymogram of esterase for indica and japonica types (Shahi et al., 1969).

Three loci were detected for MDH. First two loci (Mdh-1 and Mdh-2) have two alleles (active + silent) each and third (Mdh-3) have 4 alleles. There were 10 zymotypes, among which B and G types are common in indica and japonica groups. Two loci coding for ME (Me-1 and Me-2) have 2 and 3 alleles including silent respectively. Among 8 different zymotypes of ME, three zymotypes B, D and NA are common to indica and japonica groups. NA was highest in frequency. SDH was coded by single locus (Sdh-1) with 4 alleles. There were 4 zymotypes, most of which are common to all three groups. B type was highest in frequency. Highest variability among these 8 isozymes was expressed by POX. There were eight different electromorphs in POX. Among the 4 loci of POX, Pox-1 has the highest number of alleles (4) followed by Pox-3 (3), and Pox-1 and Pox-2 with two alleles each. Among 19 zymotypes of POX, 13 are found in indica and 5 in japonica groups. Only C type was common to indica and japonica groups.

The frequency of alleles determined based on different number of individual are presented in Table 3. Frequency of alleles ranged from 0 to 0.86 in indica and 0 to 1 in intermediate and japonica. The expression of number of alleles was more in indica population. No alleles appeared to be fixed in the populations since their frequencies were <98% (Mogaddam et al., 2000). Some alleles of these loci occurred in more than one population with frequency of <10% and could be considered rare and widespread. Null allele was detected in most of the locus. Rare and localized alleles were not found. Most of the alleles could be described as having a common and widespread occurrence (Brown, 1978).

The number of allele per locus was low ranging from 1.8 to 2.75 with a mean of 2.166 across the populations of varietal types (Table 4). Indica populations showed the highest number of alleles per locus followed by japonica. The percentage of polymorphic loci varied from population to population ranging from 0.81 to 0.93 with a mean of 0.85. The expected heterozygosity averaged over all loci and varietal populations was 0.46.

Frequency of 48 alleles ranged from 0 to 0.905, 0 to 1 and 0 to 1 in Tarai, Mid hill and High hill populations. High hill population has either 0 or 1 frequency for most of the alleles. Tarai population has least variation in alleles frequency among these 3 populations. Tarai population had highest mean number of alleles per locus (Table 4) followed by Mid hill. The least number of alleles per polymorphic locus was observed in High hill population. Tarai population had 4 unique alleles. Highest heterozygosity was noticed in Tarai population followed by Mid hill population.

Result indicates that POX was more important isozyme to characterize the intervarietal types. EST was second most important isozyme for expressing variability in varietal types. Bands of EST and POX traveled faster in japonica than indica type. Each cultivar has their own distinct isozyme profile which, can be used to figure out the cultivar easily. However, further research on stability of this profile is necessary. Isozyme profile of *O. sativa* elite line IR31917 was reported by Romero et al. (1993).

Est-9 and Mdh-1 were not expressed in intermediate and Mdh-2 not expressed in japonica type. Null allele was found in all three varietal types for most of the isozyme systems. Gene diversity in Pox-3 and Pox-4 for japonica and intermediate types respectively was zero. Within indica, highest gene diversity was observed in Mdh-3 followed by Est-2. Est-2 and Pox-1 showed highest gene diversity within intermediate types. Within japonica, Sdh-1 possessed highest gene diversity, which was highest within these three varietal types. Total number of alleles for multilocus ranged from 4 to 8. Highest average number of alleles per locus was found in EST and MDH of indica type. Except POX, all multilocus isozymes were polymorphic. Romero *et al.* (1993) found IDH and ADH as monomorphic and SDH, MDH and EST as polymorhphic.

Genetic distance values computed for all possible pairs of population are given in Table 5**.** The distances between pairs of populations were variable ranging from 0.19 to 0.51 for varietal types. The highest genetic divergence value was displayed by pair, indica and japonica. Intermediate and japonica populations displayed the least genetic divergence.

Nei's genetic distance was highest between Tarai and High hill populations (0.518) and lowest between Mid hill and High hill populations (0.1647) (Table 5). Geographically Tarai and High hill populations are most distantly located. Thus the distantly located the population, the highest the Nei's genetic distance. Tarai is the hottest area and High hill is the coolest. Tarai population had the highest genetic diversity i.e. the center of diversity lies in lower belt of Nepal.

The distribution of genetic variation at the various levels of structure for each locus is summarized in Table 6a and 6b. The average total genetic diversity across all varietal populations was 0.587 and the range was from 0.354 to 0.915. Four loci, Est-2, Est-9, Mdh-2 and Shd-1 exhibited marked diversity. The mean within population component of diversity was 0.467 with a range of 0.122 to 0.745. Seven loci have the values above the average. The measure of interpopulations diversity was on average 0.119, ranging from 0.009 to 0.391. The mean relative coefficient of gene differentiation was 0.204 with a range of 0.019 to 0.761. This indicated that the interpopulational component accounted for 20.40% of the total genetic diversity, while 79.60% of the total was due to the within-population component. The highest differentiation coefficient was displayed by the locus Pox-4 followed by Me-2 and Ihd-1.

Highest total genetic diversity was found in locus Sdh-1 followed by Pox-1 and least was in locus Idh-1 among geo populations (Table 6b). Mdh-2 had the highest mean gene diversity within population and Pox-4 had highest mean gene diversity among populations. Highest percentage mean gene diversity was observed in Mdh-1 within population. Coefficient of gene differentiation was highest in Pox-4 followed by Mdh-2. Least diverse locus was Mdh-1 among populations. These results indicated that different geographic regions have distinctly different populations adapted to a particular region.

Variations found within *sativa* was partitioned in terms of their varietal types and their adaptation. Varietal types grouped here in Nepalese rice cultivars may be useful for breeding programme and documentation of genotypes. This varietal grouping was related with geographical distribution. For example japonica group was distributed to High hill. Relationship of classification of rice genotypes among 3 systems, morphological, isozymic and geographical, indicates the high reliability of this classification. Good agreement for classification of indica and japonica types by the three methods, discriminant analysis by Z value, isozyme analysis and PCR analysis for cpDNA was reported by Chen et al. (1994). Isozymic traits used to describe indica, intermediate and japonica types are zymogram, zymotype, allele number and gene diversity. Variation among these isozymic traits between varietal types supports grouping of these rice genotypes and indicates the importance of these traits. Diversity was more in indica than japonica. Isozymic parameters of indica were similar to Tarai populations i.e. indica are adapted to Tarai and japonica to High hill. For documentation and breeding purposes, classification of all Nepalese rice genotypes are necessary and recommended here to use these isozymes for the same.

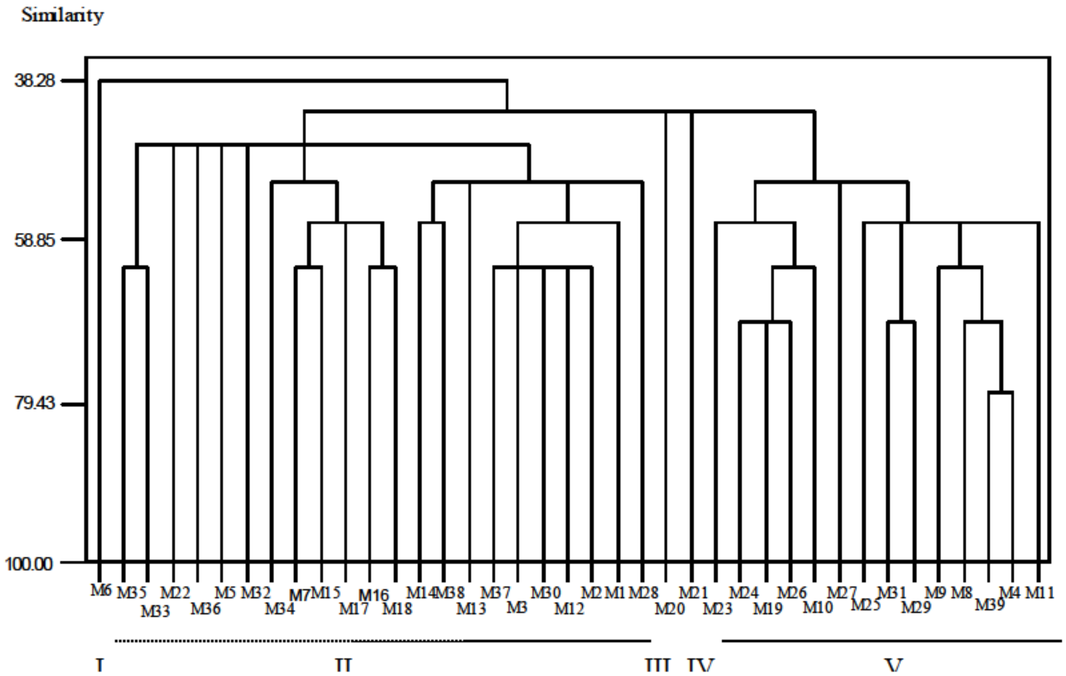

Fig. 1. Dendrogram constructed from Euclidean distance using UPGMA for 8 isozyme systems among 39 Nepalese rice cultivars (See Table 1 for description of varietal code)

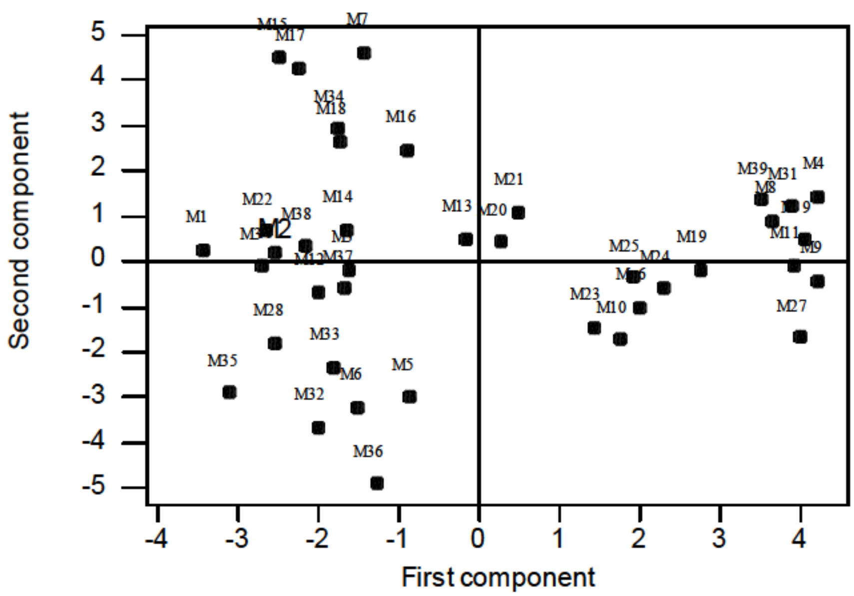

Fig 2. Scatter plot of 39 rice cultivars considering 1st and 2nd principal components (accounting 35% variability) for 8 isozyme systems (See Table 1 for description of varietal code)

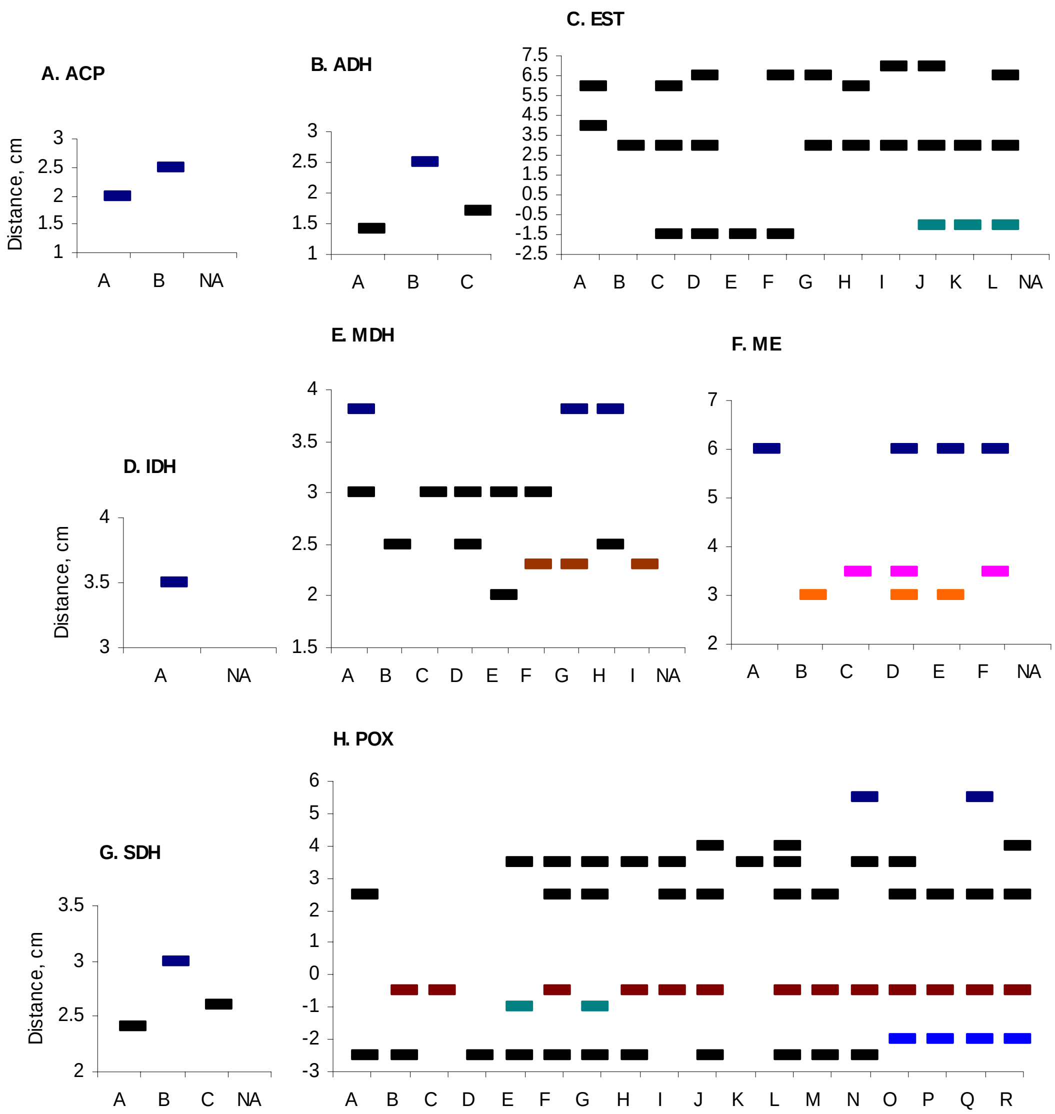

Fig. 3. Zymogram of eight isozymes observed in 39 Nepalese rice cultivars

Table 2 : Frequency of zymotypes observed in 39 Nepalese rice cultivars for eight isozyme systems

Isozyme	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	NA
ACP	69	2.5																	1.3
ADH	28	62	1.3																
EST	2.6	1.3	1.3	2.6	5.1	2.6	15	18	5.1	7.7	2.6	5.1							13
IDH	87																		13
MDH	18	1.3	7.7	13	5.1	5.1	2.5	5.1	1.3										5.1
ME	13	13	2.6	5.1	5.1	2.5	2.6												38
SDH	38	24	24																15
POX	5.1	5.1	5.1	5.1	2.6	13	5.1	7.7	2.6	5.1	2.6	2.6	2.6	2.6	18	7.7	2.6	5.1	

Table 3. Frequencies of alleles of eight isozyme systems in varietal and geo-populations of rice

SN	Isozyme	Locus	Allele	Varietal population			Geo-population		
				Indica	Intermediate	Japonica	Tarai	Mid hill	High hill
1	ACP	Acp-1	a	0.318	0.33	0	0.333	0.083	0
			b	0.545	0.67	0.929	0.571	0.75	1
			n	0.136		0.071	0.095	0.167	0
2	ADH	Adh-1	a	0.455	0.67	0.857	0.381	1	0.667
			b	0.045	0.33	0.143	0.095	0	0.333
			c	0.5		0	0.524	0	0
			n	0.045	0	0	0.048	0	0
3	EST	Est-1	a	0.727	0.67	0.857	0.762	0.667	1
			b	0.227	0.33	0.143	0.19	0.333	0
			n	0	0	0.357	0	0.167	0.5
		Est-2	a	0.227	0.33	0.286	0.238	0.167	0.5
			b	0.5	0.33	0	0.524	0.083	0
			c	0.273	0.34	0.357	0.238	0.583	0
			n	0		0.429	0	0.25	0.5
		Est-9	a	0.364		0	0.333	0.083	0
			b	0.636		0.571	0.667	0.667	0.5
			n	0	0.67	1	0.762	1	1

(Cont...)

4	IDH	Idh-1	a	0	0.33	0	0.238	0	0
			n	0.409	0.33	0.5	0.476	0.417	0.333
5	MDH	Mdh-1	a	0.591	0.67	0.5	0.524	0.583	0.667
			n	0.864		0	0.857	0.083	0
		Mdh-2	a	0.136		0	0.143	0.917	0
			n	0.318	0.33	0.214	0.333	0.25	0.167
		Mdh-3	a	0.136	0.67	0.786	0.143	0.5	0.833
			b	0.091		0	0.048	0.083	0
			c	0.455		0	0.476	0.167	0
			n	0.273	0.67	0.714	0.238	0.667	0.833
6	ME	Me-1	a	0.727	0.33	0.286	0.762	0.333	0.167
			n	0.091	0	0.642	0.095	0.333	0.833
		Me-2	a	0.091	0.67	0.286	0.095	0.417	0.167
			b	0.818	0.33	0.071	0.81	0.25	0
			n	0.045	0.67	0.429	0.095	0.25	0.667
7	SDH	Sdh-1	a	0.182	0.33	0.286	0.19	0.417	0
			b	0.591		0.143	0.571	0.167	0.167
			c	0.182		0.143	0.143	0.167	0.167
			n	0	0.33	0.071	0.048	0	0.167
8	POX	Pox-1	a	0.136	0	0.143	0.143	0	0.333
			b	0.591	0.33	0.571	0.571	0.667	0.333
			c	0.273	0.34	0.214	0.238	0.333	0.167
			n	0.591	0.33	0.857	0.571	0.667	1
		Pox-2	a	0.409	0.67	0.143	0.429	0.333	0
			n	0.682	0.67	1	0.667	0.917	1
		Pox-3	a	0.136	0	0	0.143	0	0
			b	0.182	0.33	0	0.19	0.083	0
			n	0	0	0.929	0	0.583	1
		Pox-4	a	0.864	1	0	0.905	0.25	0
			b	0.136		0.071	0.095	0.167	0

Table 4: Descriptive statistics (sample sizes, polymorphic indices and mean frequencies of private alleles) based on eight isozymes of rice cultivars

Population	N	A	Ap	P	H	Hu	U	P (1)
Varietal population								
Indica	22	2.5625	2.7333	0.9375	0.5041	0.5158	8	0.3239
Intermediate	3	1.8125	2.1538	0.8125	0.5123	0.6148	1	0.3300
Iaponica	14	2.1250	2.4615	0.8125	0.3871	0.4014	3	0.5717
Mean	13	2.1667	2.4496	0.8542	0.4678	0.5107	4	0.4085
SE	5.50	0.2175	0.1674	0.0417	0.0404	0.0616	2.08	0.0816
Geo population								
Tarai	21	2.7500	2.7500	1.0000	0.4599	0.4711	4	0.2382
Mid	12	2.5000	2.7143	0.8750	0.4149	0.4330	0	-
High	6	1.6875	2.3333	0.5625	0.3090	0.3371	0	-
Mean	13	2.3125	2.5992	0.8125	0.3946	0.4137	1.33	0.2382
SE	4.35	0.3207	0.1333	0.1301	0.0447	0.0399	1.33	0.0000

N, Average number of individuals sampled (mean across all loci). A, Mean number of alleles per locus. Ap, Mean number of alleles per polymorphic locus. P, Proportion of polymorphic loci. H, Expected heterozygosity. Hu, Expected heterozygosity unbiased for sample size. U, Number of alleles unique to that population (=private alleles). p(1), Average frequency of private alleles (useful for obtaining indirect estimates of gene flow).

Table 5: Nei's genetic distances based on eight isozymes of rice cultivars

Varietal population			Geo population		
	Indica	Intermediate		Tarai	Mid hill
Intermediate	0.2477		Mid hill	0.2852	
Japonica	0.5109	0.1904	High hill	0.5180	0.1647

Table 6a. Gene diversity of 8 isozymes in rice varietal population

Locus	Hs	Ht	Hs/Ht (%)	Dst	Gst
Acp1	0.3857	0.4378	88.09959	0.0521	0.1189
Adh1	0.4094	0.5059	80.92508	0.0965	0.1908
Est1	0.3683	0.3807	96.74284	0.0124	0.0326
Est2	0.6513	0.7258	89.73546	0.0745	0.1027
Est9	0.6510	0.8030	81.07098	0.1520	0.1893
Idh1	0.4807	0.6780	70.89971	0.1973	0.2910
Mdh1	0.4752	0.4849	97.99959	0.0096	0.0199

(Cont...)

Mdh2	0.7450	0.9150	81.42077	0.1700	0.1858
Mdh3	0.4812	0.6119	78.6403	0.1307	0.2136
Me1	0.4158	0.4945	84.08493	0.0787	0.1591
Me2	0.4187	0.6532	64.09982	0.2345	0.3590
Sdh1	0.5729	0.7125	80.40702	0.1396	0.1959
Pox1	0.6089	0.6501	93.66251	0.0411	0.0633
Pox2	0.3902	0.4828	80.82022	0.0926	0.1917
Pox3	0.3085	0.3542	87.09768	0.0457	0.1290
Pox4	0.1223	0.5133	23.82622	0.3910	0.7617
Mean	0.4678	0.5877	79.59843	0.1199	0.2040
SE	0.0383	0.0391	97.95396	-	-
N	16	16	100		

Ht, Total gene diversity. Hs, Mean gene diversity within population. Dst, Mean gene diversity among populations. Gst, Coefficient of gene differentiation. Hs/Ht, Percentage mean gene diversity within population.

Table 6b. Gene diversity of 8 isozymes in geo population

Locus	Hs	Ht	Hs/Ht, %	Dst	Gst
Acp1	0.3186	0.3741	85.16439	0.0555	0.1484
Adh1	0.3386	0.4832	70.0745	0.1447	0.2994
Est1	0.2751	0.3139	87.63938	0.0388	0.1236
Est2	0.5698	0.7437	76.61692	0.1739	0.2339
Est9	0.4768	0.5446	87.5505	0.0679	0.1246
Idh1	0.1209	0.1461	82.75154	0.0252	0.1723
Mdh1	0.4765	0.4833	98.59301	0.0069	0.0142
Mdh2	0.4659	0.7770	59.96139	0.3110	0.4003
Mdh3	0.5235	0.6476	80.83694	0.1241	0.1917
Me1	0.3617	0.4874	74.21009	0.1258	0.2580
Me2	0.4188	0.6472	64.70952	0.2284	0.3529
Sdh1	0.6052	0.7291	83.00645	0.1239	0.1700
Pox1	0.5871	0.6349	92.47126	0.0479	0.0754
Pox2	0.3114	0.3791	82.14192	0.0676	0.1784
Pox3	0.2171	0.2477	87.64635	0.0306	0.1236
Pox4	0.2471	0.5656	43.68812	0.3185	0.5631
Mean	0.3946	0.5128	76.95008	0.1182	0.2304
SE	0.0358	0.0460	77.82609	-	-
N	16	16	100	-	-

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COMPARATIVE STUDY ON BIOMASS YIELD AND NUTRITIVE VALUE OF THREE CEREAL FODDERS

S. H. KHAN[1], A. G. KHAN[2], M. SARWAR[1] AND A. AZEEM[2]

ABSTRACT

This study was conducted to compare productive potential and nutritional value of maize (Zea mays), sorghum (Sorghum bicolor) and millet (Pennisetum americanum) fodders. These fodders were grown in experimental plots (1.8 x 6m of each) according to Completely Randomized Design. Each fodder was manually harvested at three physiological stages i.e., pre heading (CS1), heading (CS2) and milk stage (CS3). The results showed that Green fodder, dry matter (DM), crude protein (CP) and total digestible nutrient (TDN) yields (ton/ha) increased with the advancement of age for all fodders. The maximum yield of all the three fodders was noticed at milk growth stage. Higher green fodder and DM yield was observed in millet than that of maize and sorghum fodder. Whereas, higher CP yield was noticed in maize than that of sorghum and millet fodders. However, TDN yield was similar in both maize and millet fodders. The DM, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and water soluble carbohydrate (WSC) contents was increased (P<0.05) in all the three fodder with advancing age. However, CP, TDN and metabolizable energy (ME) contents decreased (P<O. 05) in all the three fodders as they grew older. In situ DM, organic matter (OM) and NDF digestibility of the three fodder decreased (P<O. 05) with the increase in of age both at 24 and 48 h of ruminal incubation. The DM, OM and NDF digestibilities of maize, sorghum and millet fodders decreased with advancing age by 11.10, 18.48 and 14.08 %; 10.24, 11.25 and 12.18 % and 12.59, 18.36 and 23.69%, respectively at 48 h of ruminal incubation. Based upon biomass and nutrient yields, the milk growth stage was the best physiological stage of the three fodders.

Key words: Neutral Detergent Fibre, Acid Detergent Fibre, Acid Detergent Lignin, Water Soluble Carbohydrates, Total Digestible Nutrients, Digestibility, Maize, Millet, Sorghum, Yield.

[1] Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, Pakistan
[2] Department of Animal Nutrition, National Agriculture Research Centre, Islamabad, Pakistan

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INTRODUCTION

Production of good quality fodder is of a great importance for economical ruminant production. Both quantity and quality of fodder are influenced due to soil variation (Yar and Waheed, 1991), plant species (Kaiser and Piltz, 2000), climatic conditions (Siefers *et al.*, 1997), water supply (Rashid and Saleem, 1989), stages of growth (Shirma, 2001 and Kim *et al.*, 2001), frequency of cutting (Bilal, 1998) and other agronomic practices (Rehman and Khan, 2003).

Stages of growth is one of the most important factors influencing nutritional quality of fodder (Fariani *et al*., 1994). Sullivan (1973) reported that the nutritive value of a fodder depends upon the morphological and physiological changes. As the fodder matures, the cytoplasmic portion of the cell reduces and the quantity of protein, lipids, soluble carbohydrates and soluble minerals decrease. The protein and lipid contents of forage are negatively correlated to the maturity of fodder (Cleale and Bull, 1986). However, dry matter (DM) content increases with advancing the age of fodder (Azim *et al*., 1989). Similarly, the cell wall contents increase and cell wall become lignified with maturity of fodder (Kim *et al*., 2001). However, the quality of fodder is very high at an early stage of the growth, but yield of DM per unit area remaining low (Fariani *et al*., 1994). Therefore, in order to get more nutrients per unit area, the optimum time, keeping in view nutritive value and DM yield, of harvest must be considered. Firdous and Gilani (1999) suggested that maize fodder should be cut preferably between 8th to 9th week after sowing to obtain maximum nutritious and digestible feed for livestock. Firdous and Gilani (2001) suggested that optimum harvesting for sorghum was at flowering stage. Similarly, Grewal *et al*. (2003) suggested that millet fodder might be harvested at pre-boot stage of maturity. Utley *et al*. (1995) compared the crude protein (CP) yield of spring crop and late summer crop of pearl millet with maize fodder. Crude protein yield of the maize fodder was 30% greater than that of the first crop millet and twice the amount produced by the second crop millet.

Variation in the contents of structural carbohydrate occurred with seasonal changes as well as worth growth stages (Singh, 1976). Digestibility of cell contents and cell wall contents decreased with the maturity of maize and sorghum fodder (Havilah *et al*., (1995); Oda *et al*., (2001). In contrast to the above findings, DeBoever *et al*. (1993) reported that maturity stages (from milk dough to hard dough stages) had no clear effect on organic matter (OM) digestibility when 14 maize fodder samples were investigated.

Little information is available on the yield/ha and nutrient availability of maize (*Zea mays*), sorghum (*Sorghum hieolor*) and millet (*Pennisetum amerieanum*) in Pakistani environment. An attempt was, therefore, made to determine comparative production efficiency (yield/ha) and nutritive value of local maize, sorghum and millet fodders at different physiological stages.

MATERIALS AND METHODS

Fodders

Maize, sorghum and millet fodders were grown in the experimental field of Animal Nutrition Institute, National Agricultural Research Centre (NARC), Islamabad, Pakistan. The soil type at the site was well drained calcareous silt loam. Akbar, Hegari and NARC-5 varieties of maize, sorghum and millet, respectively, were grown for this study. The experiment was conducted according to Completely Randomized Design. The layout of the experiment is given in figure 1.

Millet	Maize	Sorghum
Maize	Sorghum	Millet
Sorghum	Millet	Maize

Figure 1. Plan of cultivation of fodder

Each fodder plot size was 1.8 x 6 m. The meteorological data were recorded by Agro-meteorological Department at NARC, Islamabad, Pakistan during the experimental period (Table 1).

Table 1: Meteorological data* during Kharif season

Altitude 518m		Latitude 33^o 42'	Longitude 73^o 08'	
Month	Rainfall (mm)	Relative Humidity (%)	Temperature (^{o}C)	
			Max.	Min.
April	10.5	42.5	32.6	15.1
May	3.1	33.0	39.1	19.7
June	130.4	46.8	38.4	23.2
July	64.8	52.1	37.9	23.7

Source: Agro Meteorological Department, National Agricultural Research Centre, Islamabad, Pakistan

Seed germination test

To determine the percentage of viable seed, 100 seeds of each experimental fodder were placed on moist filter paper in petri dishes and kept at room temperature following the standard techniques described by Myers (1952). The seed germination rate of each experimental fodder was found to be in the range of 95-97%. The results were very close to the recommendation of fodder section at NARC, Islamabad. Before applying the seeds to field, foreign materials (weed, other seed, stone and soil) were removed from the seed of each fodder.

Cultivation of fodders

Seed of maize, sorghum and millet was sown at the rates of 100, 75 and 15 kg/ha, respectively (Ahmad *et al*., 2003) using a hand drill. The rows were 30 cm apart (Hussain *et al*., 1995). The field was fertilized uniformly at the rate of 60 kg each of N and P/ha in such a way that full dose of phosphorus (diammonium phosphate) and a half of nitrogen (urea) was applied at the time of sowing (Ahmad et al., 2003). The remaining half dose of nitrogen was applied after one month of sowing. During the experimental period, the field was irrigated thrice from dam water with an interval of 15 to 21 days. One hoeing was done before the first irrigation.

Harvesting of fodder

The fodders were manually harvested at three stages of maturity. Maize, sorghum and millet fodders were harvested at pre-heading (CSI), heading (CS2) and milk stage (CS3). Green fodder yield/ha was recorded at all stages of maturity. The DM, CP and total digestible nutrient (TDN) yield/ha were calculated on the basis of chemical analysis. The samples of each fodder cut at three vegetative stages of maturity were chopped in a locally manufactured chopper. Samples were dried at 55°C and ground to particle size of 2mm through a Wiley mill. These samples were analyzed for DM and CP using method described by AOAC (1990), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) was determined by the methods of Goering and Van Soest (1970), and water soluble carbohydrates (WSC) by the procedure of Dubois *et al.* (1956) modified by Johnson *et al.* (1966). Total digestible nutrient and metabolizable energy (ME) contents of each fodder samples cut at the three vegetative stages were calculated by the equations of Wardeh (1981) and Moe and Tyrrell (1976), respectively.

In situ digestibility

Four grams of dried samples in duplicate were weighed into dacron polyester bags having average pore size of 50 μm with dimension of 7" x 4" (Orskov, 1980). These bags were closed and tied with nylon fishing line before placing in the dorsal sac of the rumen of two sheep fitted with permanent ruminal canola (40 mm diameter). The sheep were fed with the same fodder as those were being incubated in their rumens. This was done to avoid the effects of diet on the ruminal fermentation of the feedstuffs (Clark and David, 1990). All bags, including empty bags to act as blank were simultaneously incubated in the rumen for 24 and 48 hour (h) after removal from the rumen, bags were washed in running tap water until the rinse was clear. The bags were then dried in a hot air oven at 60°C for 48 h and then weighed back and the residues were stored for subsequent analyses. The in situ digestibility for DM, OM and NDF at 24 and 48 h of ruminal incubation was calculated according to the procedure described by Sarwar *et al*. (1995).

Statistical analysis

The data on chemical composition and digestibility of fodders at three vegetative stages were statistically analyzed by using Completely Randomized Design. Duncan's Multiple Range tests were used to compare the treatment means (Steel and Tome, 1980).

RESULTS AND DISCUSSION

Green fodder yield

The green fodder yields of millet (19.57 ton/ha) and sorghum (19.77 ton/ha) were higher ($P<0.05$) than that of maize (17.89 ton/ha) harvested at pre heading stage (Figure 2). However, no difference ($P>0.05$) in the yield was noticed between millet and sorghum fodders. The green fodder yield of millet (36.49ton/ha) was higher ($P<0.05$) than that of sorghum (32.45 ton/ha) or maize (31.37 ton/ha) harvested at heading stage. Similarly, the green fodder yield of millet (48.39 ton/ha) was higher ($P<0.05$) than that of sorghum (46.38 ton/ha) or maize (46.06 ton/ha) harvested at milk stage. However, no difference ($P>0.05$) in the yield was observed between sorghum and maize fodders at this stage of maturity.

The results of the present study were consistent with those of Paroda (1976), Bhatti,(1996) and Hinjra (1996) who reported a higher green fodder yield of millet than those of sorghum and maize fodders. They explained that the higher yield of millet was due to its high leaf-to-stem ratio. Yar and Waheed (1991) reported that the range of green fodder yield of six millet fodder varieties harvested at full mature stage ranged from 36.73 to 50.47 ton/ha. These yield values are comparable to the green fodder yield of millet fodder (48.39 tonlha) of the present study.

Figure 2: The comparative green fodder yield (ton/ha) of maize, sorghum and millet fodders at three vegetative stages of growth

Dry matter yield

The DM yield of millet (8.67 and 16.84 ton/ha) was higher ($P<0.05$) than that of maize (7.33 and 15.38 ton/ha) or sorghum (7.30 and 15.80 ton/ha) fodder harvested at heading and milk stages, respectively (Figure 3). However, the DM yield of millet (3.06 ton/ha) was lower ($P<0.05$) than that of sorghum (3.58 ton/ha) or maize (3.47 ton/ha) fodder harvested at pre heading stage. The results of this study were inconcordance to annual report (1998-99), which stated that the DM yield of millet fodder was higher than that of maize fodder. Weiss and Wyatt (2000) reported 15.90 ton/ha DM yield of maize fodder at mature stage, which was comparable to the present study (15.38 ton/ha).

Crude protein yield

The CP yield was higher ($P<0.05$) in maize (0.57, 0.86 and 1.53 ton/ha) than that of sorghum (0.36, 0.69 and 1.16 ton/ha) or millet (0.29, 0.70 and 1.17 ton/ha) fodders when harvested at pre heading, heading and milk stages, respectively (Figure 4). Similar findings were reported by Utley *et al*., (1995) who noticed that CP yield of maize fodder was 30% higher than that of millet fodder at mature stage. In the present study, CP yield of maize fodder was about 31 % higher than that of millet fodder at milk stage. In the present study, CP yield of sorghum fodder (1.16 ton/ha) at milk stage was comparable (1.10 ton/ha) to that reported by Bhatti (1996).

Figure 3. The comparative dry matter yield (ton/ha) of maize, sorghum and millet fodders at three vegetative stages of growth

Figure 4. The comparative crude protein yield (ton/ha) of maize, sorghum and nillet fodders at three vegetative stages of growth

Total digestible nutrient yield

The TDN yield of millet (1.67 ton/ha) was lower (P<0.05) than that of maize (2.16 ton/ha) or sorghum (1.99 ton/ha) fodder harvested at pre heading stage (Figure 5). However, the TDN yield of millet (4.69 ton/ha) was higher (P<0.05) than that of maize (4.29 ton/ha) or sorghum (3.99 ton/ha) fodder harvested at heading stage. Whereas, the TDN yield of millet (8.78 ton/ha) or maize (8.76 ton/ha) were higher (P<0.05) than that of sorghum fodder (8.37 ton/ha) harvested at milk stage. The results of the present study in which TDN yield of maize fodder was 8.76 ton/ha at milk stage are substantiated by the results of Azim *et al*. (2000) and Kim *et al*. (2001).

Figure 5. The comparative total digestible nutrient yield (ton/ha) of maize, sorghum and millet fodders at three vegetative stages of growth

Influence of maturity on nutrient concentration

The DM, NDF, ADF, ADL and WSC contents increased (P<O.05) as the fodders grew in age. However, the CP, TDN and ME contents reduced (P<O.05) as the fodders advanced in age (Table 2). The results of the present study were inconcordance with those of Sarwatt *et al*. (1989) and Church (1991) who reported decreased cell soluble contents and increased NDF and DM contents with advancement in the age of fodders. Schake *et al*. (1982) reported reduced CP content of sorghum as the fodder advanced in age. Church (1991) observed that DM and fibre contents were increased from early bloom to hard dough stage of growth of sorghum fodder, whereas, CP contents decreased with increasing maturity of fodder. Similarly, other workers (Kim and Voigtlaender, 1985; Gupta and Sagar, 1987) reported that the cell wall contents of fodder increased with the increase in their age. However, Hunt *et al*. (1989) and Kohn and Allen (1995) reported that concentration of NDF and ADF in whole plant of maize decreased as maturity proceeded from early one third milk line to late (black lager maturity). This decline in concentration of NDF and ADF might be due to accumulation of starch in grains. Morphological differences in cell wall contents were attributed to differences in the concentration and composition of their lignin and carbohydrate fraction in fodders (Fritz, 1989).

The present study supported the findings of Thomas and Thomas (1985) and Boisen *et al*. (1992) who reported that the WSC increased as the fodder advanced in age. However, Boisen *et al*. (1983) and Havilah and Kaisar (1992) reported that average WSC contents of sorghum, wheat and barley at dough, late dough and hard grain of growth decreased, which might be due to accumulation of starch in grains. In the present study, WSC content in maize fodder at heading stage was 10.25%, which was comparable with the findings of Azim *et al*. (2000). Kim *et al*. (2001) reported that TDN value of maize fodder was higher at an early stage of growth, and it decreased with increasing maturity. The reduced TDN may be because of increased cell wall contents as the plant advanced in age. Thomas and Thomas (1985) also reported that ME value of fodder crop decreased with the advancing maturity of crop.

Table 2. Dry matter, crude protein, cell wall contents, water soluble carbohydrate, total digestible nutrient and metabolizable energy (%DM) of experimental fodders at different stages of maturity

			Fodders	
		Maize	**Sohum**	**Millet**
Dry Matter	CS1	I9.37c	IS.11c	I5.69c
	CS2	23.3Sb	22.4Sb	23.76b
	CS3	33.408	34.068	34.S18
	S.E	2.04	2.38	2.77
Crude Protein	CS1	16.348	10.108	09.508
	CS2	11. 75b	09.42b	OS.OOb
	CS3	09.91 c	07.3 7c	06.94c
	S.E	0.95	0.41	0.38
Neutral Detergent Fibre	CS1	63.73c	65.71c	65.76c
	CS2	65.60b	66.55b	66.S6b
	CS3	6S.728	69.038	69.758
	S.E	0.73	0.50	0.61
Acid Detergent	CS1	31.S3c	35.63c	37.93c
	CS2	33.70b	37.4Sb	39.7Sb
	CS3	36.S08	40.608	42.908
	S.E	0.72	0.73	0.73
Acid Detergent lignin	CS1	02.90b	03.S3c	04.16c
	CS2	03.36b	04.40b	06. lOb
	CS3	05.338	05.698	06.908
	S.E	0.38	0.28	0.41
Water soluble carbohydrate	CS1	08.52c	06.84c	06.50c
	CS2	10.25b	09.26b	07.50b
	CS3	11.25a	11.06a	10.48a
	S.E	0.40	0.61	0.60
Total digestible nutrient	CS1	62.19a	55.43a	54.45a
	CS2	58.53b	54.66b	54.08a
	CS3	56.92c	53.00c	52.69b
	S.E	0.79	0.36	0.32
Metabolizable energy (Mcal/Kg)	CS1	02.32a	02.01a	01.97a
	CS2	02.15b	01.98b	01.95a
	CS3	02.09c	01.91c	01.90b
	S.E	0.04	0.02	0.01

Mean in the same column bearing different superscripts were significantly ($p < 0.05$) different * CS1, CS2 and CS3 stand for pre heading, heading and milk stages, respectively

In situ nutrients digestibility

In situ DM, OM and NDF digestibilities of all three fodders decreased (P<0.05) with the advancement of age at 24 and 48 h of ruminal incubation (Table 3). The percent reduction in the digestibility of DM, OM and NDF at 48 h ruminal incubation was 11.10, 18.48 and 14.08%; 10.24, 11.25 and 12.18% and 12.59, 18.36 and 23.69% of maize, sorghum and millet fodders, respectively harvested at maturity. The results were in agreement with those of Russel *et al*. (1992) and Havilah *et al*. (1995) who reported that DM, NDF and OM digestibilities of maize fodder decreased with increasing age. Similarly, Goto *et al*. (1991) and Cherney *et al*. (1993) reported that DM, NDF and OM digestibilities of millet, oat, sorghum and other grasses decreased with the advancement of age. Hunt *et al*. (1989) reported that in situ DM digestibility of whole maize plant was 53.7 % at an early maturity after 24 h of ruminal incubation. This value was close to the DM digestibility of maize fodder (53%) incubated for 24 h, when harvested at an early maturity in the present study. Fariani *et al*. (1994) reported that rumen degradation of DM reduced (P<0.05) with advancing age of the grass. The reduced DM and NDF digestibility of matured fodders can be ascribed to the reduced leaf-to-stem ratio (more stem, fewer leaves) because a greater portion of the total DM and NDF was associated with stem tissue.

Table 3. Effect of type of fodder and stage of age on in situ digestibility in sheep

		DM(%)		OM (%)		NDF (%)	
		Incubation Period (h)					
		24	48	24	48	24	48
Maize	CS1	53.008	71.128	65.668	81.338	47.908	65.828
	CS2	46.90b	66.08b	64.50b	74.16b	43.92b	61. 90b
	CS3	43.75c	63.22c	62.00c	73.00c	38.55c	57.53c
	S.E	1.35	1.16	0.54	1.30	1.23	1.20
Sorghum	CS1	51.508	69.578	64.568	80.008	45.758	64.708
	CS2	45.25b	64.35b	63.50b	73.00b	42.00b	60.02b
	CS3	37.90c	56.71c	61.00c	71.00c	33.80c	52.82c
	S.E	1.97	1.87	0.53	1.36	1.77	1.73
Millet	CS1	44.208	63.078	64.008	78.008	43.308	62.258
	CS2	40.40b	59.38b	62.00b	71.50b	37.80b	56.80b
	CS3	35.00c	54.19c	59.00c	68.50c	28.50c	47.50c
	S.E	1.34	1.29	0.73	1.40	2.16	2.15

Means in the same column bearing different superscripts were significantly (P < 0.05) different

* CS1, CS2 and CS3 stand for pre heading, heading and milk stages, respectively.

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EFFECT OF FOLIC ACID ON GROWTH PERFORMANCES AND SURVIVAL RATE OF NEW BORN CALIFORNIAN WHITE AND NEW ZEALAND WHITE RABBITS

AMALI COLONNE[1], R. D. C. S. RANADHEERA[2] AND G. L. L. PRADEEPA SILVA[3]

ABSTRACT

Rabbits are considered as a good meat producer suitable for developing countries as it possesses several good features such as body size, short generation intervals, high reproductive potential, rapid growth rate and high feed conversion efficiency. The only drawback in introducing them in commercial scale farming in developing countries such as Sri Lanka is the high mortality of new born and young rabbits. This experiment was conducted to investigate the influence of feeding folic acid on the improvement of reproductive performance of does and the survival and growth rates newborn rabbits as a remedial measure for the above problem. Ten does from each Californian White and New Zealand White breeds were included in the study. Folic acid was given along with the normal diet to five does of each breed for seven days prior and after mating. Data collected included litter size at birth, total litter weight at birth, litter size at weaning, total litter weight at weaning, individual weights of weaned rabbits up to one month and survival rates in each week. Data were analyzed using Probit and GLM models. The results revealed that there was a significance ($p<0.05$) influence of folic acid on litter size at birth and survival rate up to weaning. Folic acid showed no significant effect on growth rate of newborn rabbits.

Keywords: Rabbit, Reproduction, Folic Acid

INTRODUCTION

The expanding human population and the necessity to raise nutritional standards have indicated the need to increase the production of animal protein in developing countries in recent times. It is an established fact that the supply of animal protein is limited. The malnutrition caused by protein deficiency is common and widespread in most countries.

[1] Graduate from University of Rajarata – Sri Lanka
[2] Lecturer, Department of Agricultural Systems, Faculty of Agriculture, University of Rajarata, Anuradhapura, Sri Lanka
[3] Senior Lecturer, Department of Animal Science, Faculty of Agriculture

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Being a developing nation, Sri Lanka faces a number of nutritional problems including the protein malnutrition. According to the Medical Research Institute of Sri Lanka, an average Sri Lankan should consume 62.4 g of protein and of this amount at least minimum of 20 g protein should be from animal origin, but the per capita protein consumption is only about 49 g and much of this comes from vegetable protein sources (Sivapalan, 1984).

The domestic rabbit, *Oryctotagus cuniculus*, (Order: Lagamorpha and Family: Leporidae) is a descendant of wild rabbits living in their natural environments. Rabbits are gregarious and reproductively successful. They are completely herbivorous. Under natural conditions grasses and other herbaceous plants are foods of choice for them. The barks of woody plants are eaten if herbaceous plants are not available. They most actively forage in the evening or nighttime. Feeding rabbits is easy because nutritionally complete and balanced commercial pelleted diets are readily available (http://www rabbitweb.net/).

High mortality among newborn rabbits is a serious problem encountered in rabbit farming. This is due to various reasons, among which nutritional reasons play an important role. High mortality rates in local conditions usually set a draw back for the development of rabbit production as an industry in Sri Lanka. Therefore, improving the survival rate of newborn rabbits is an important issue to be considered. Increase of vitamins in the diet may be (for example Folic Acid / Vitamin B_9) an option to improve the nutritional status, where the reproduction is concerned. This will help saving energy and resource losses due to reproductive failure and high mortality rates.

There are several advantages of using folic acid to overcome the high mortality of newborn rabbits. Folic acid is safe to use during pregnancy and also it is low cost, freely available and easy to supplement (http://comsewogue.k12 ny.us/~ ssilverman/ bunnies/).

The present study was designed to evaluate the effect of folic acid on the reproductive efficiency of does and survival rates of new born rabbits. The experiment was conducted at Mawalawatta field experimental station of the University of Peradeniya. The rabbitory is maintained in the station for commercial and research purposes. The main problem in the rabbitory is the low survival rate of new born rabbits. The mortality was reported as high as 57 % (Rabbitory records 2005 - 2006 Mawalawatta field experimental station of the University of Peradeniya – Sri Lanka).

MATERIALS AND METHODS

Animals and general management practices

Rabbits were kept in cages. The doe cages were 72 cm x 30 cm x 30.5 cm and installed at 61 cm height above the ground level. Each cage was equipped with two separate feeders. The concentrate feed trough was hung outside whereas the wire rack for roughages was build inside the cages. Water was made available at all time. “Nest Box” has been externally attached to the doe cage. Straw was provided as bedding material. Young rabbits were weaned at 8 weeks of age and reared in groups in colony cages. The size of the buck cages were similar to the doe cages.

Rabbits were fed on grasses and concentrates (Broiler finisher pellets). The concentrate was fed once a day in the morning (Composition is shown in Table 1). Grasses were provided in the mornings and afternoons. Bucks and does were fed approximately with 50 g of concentrate per rabbit per day. The nursing does were given about 100 g of finisher ration per doe. Weaners were given only 40 g of concentrates per day per animal. Grasses were given *ad libitium* and water was made available at all times.

Table 1. Composition of the concentrated feed

Nutrient	Value
Protein	20 %
Fat (min)	7.5 %
Ash (max)	6.5 %
Fiber (max)	4.5 %
Moisture (max)	12 %
Calcium (min)	0.9 %
Phosphorus (min)	0.4 %
M.E. kcal/kg (min)	3050

+ Vitamins, Minerals, Mol D, Inhibitors and Other Permitted additives.

Source: CIC Feeds Pvt. Ltd., Sri Lanka. (2006)

According to the resource availability Californian White and New Zealand White breeds were included in the study. The does were non pregnant. They were randomly distributed into 2 groups (five does in one group of one breed). All the selected animals were caged separately from the rest of the flock. All the cages were located close to each other and positioned in the same direction of the rabbitory. The selected does were transferred to the cages one week prior to the initiation of the experiment. They were kept individually in separate cages.

Treatment of folic acid

The experiment consisted of treatment and control groups as follows.

- Control groups (Californian White without folic acid – CWN, New Zealand White without folic acid – NZWN)
- Folic acid groups (5 mg per day per does of Californian White – CWF, New Zealand White - NZWF)

Accordingly five does from each breed received 5 mg of folic acid per day for seven days period. This was based on the recommended does of 6 mg / day for humans and 5 mg / day for rats. Commercially available folic acid tablets were given with the concentrate feed. The treatment was carried out for seven days before and after mating. In the case of control the same routine was carried out without the folic acid treatment.

Service of does

At the end of one week period of folic acid treatment, the does were set for mating by introducing them to buck cages. If the mating was successful the treatment was continued for another seven days. If the mating was unsuccessful, repeated attempts were made for the subsequent days until the mating was successful. The folic acid treatment was continued until pregnancy was successful.

Management of pregnant does

After the successful service, the does were transferred back to their cages. Each and every doe was given the normal diet. The treatment group was continued with folic acid for the first seven days of the pregnancy, and after that they were on the normal diet.

Statistical analysis

Data on age of the does (sexual maturity of does), time taken to mate, litter size at birth, litter weigh at birth, litter size at weaning, litter weight at weaning and survival rate in Californian White and New Zealand White does were analyzed using Statistical Analysis System (SAS) Computer package.Each animal was considered as a replicate, folic acid administration was considered as the treatment, age of does and breed was considered as non parametric measurements and the weights of new born rabbits were considered as parametric data. General Linear Model Procedure (GLM) with 5 replicates was used to analyze data. Comparison of mean was carried out using LS mean for the confidence interval of 5% (Gomez and Gomez, 1976).

The model used for the data analysis is as follows,

$$Y_{ijk} = \mu + \beta_i + \alpha_j + \gamma_k + \epsilon_{ijk}$$

Where,

Y_{ijk} - Observed values of the parameters concerned

β_i - Effect of i^{th} treatment.

α_j - Effect of j^{th} breed.

γ_k - Effect of k^{th} age group.

μ - Population mean

ϵ_{ijk} - Random Error

RESULTS AND DISCUSSION

Total litter size at birth

Rabbits in all the groups were not successful in mating. There were only four does out of five mated in CWF and NZWN groups. All five were successful in mating in the other two groups. To determine the influence on litter size was considered, the total litter size of all does from each individual groups were fist evaluated.

The total litter size of folic acid treated groups (CWF and NZWF) were higher than that of untreated groups. In the treated groups (Californian White and New Zealand White breeds) these were a total number of 25 pups each on the other hand the untreated groups had a total number of 18 groups each. A significant increment in the litter size could be seen in the treatment groups ($p < 0.05$).

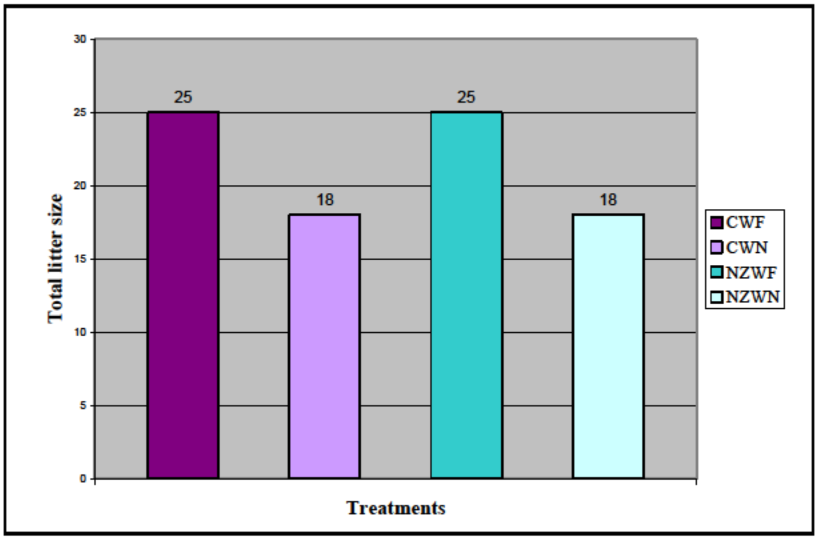

Figure 1. Total litter size at birth in different groups

Average litter size at birth

The average litter size varied from 3.36 – 6.25 in Californian White and 4.5 – 5 in New Zealand White (Figure 2). The CWF group showed the highest average litter size at birth with a value of 6.25 and the value of 5 was shown by the NZWF group. Accordingly, there was a significant ($p > 0.05$) increase of 2.65 kids / litter in CWF group. However, NZWF showed a marginal increment of 0.5 kids / litter. CWN showed the lowest value of 3.6 average litter size.

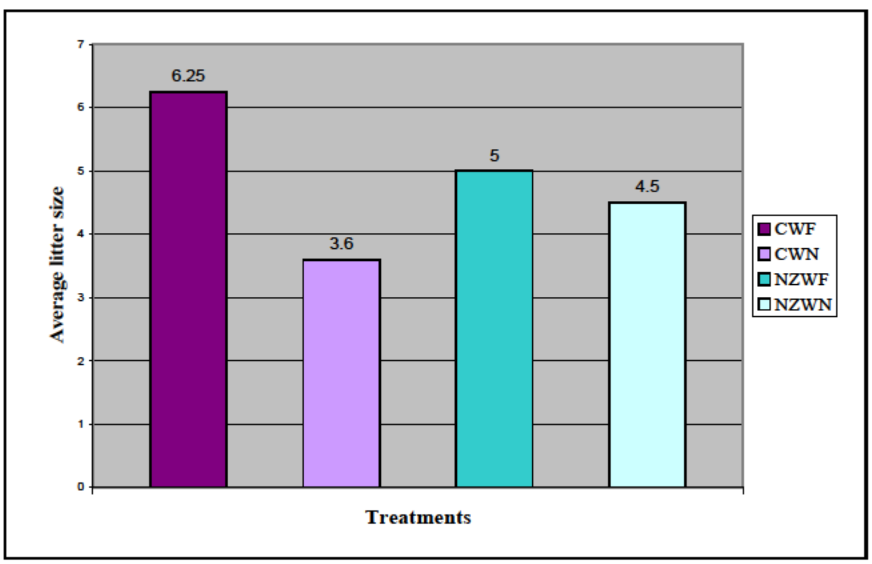

Figure 2. Average litter size of different groups

Litter weights at birth

The total litter weights of new born rabbits were measured at birth. Individual measurements were avoided to minimize the stress. The highest mean birth weight of 78.33 g was observed in CWN group. The CWF group, which showed the highest average litter size at birth showed the lowest average birth weight of 63.0 g. This trend was observed in New Zealand White breeds as well; which showed the average birth weights of 68.4 g and 66.94 g. (Figure 3). These differences in birth weights in different groups were significant ($p < 0.05$).

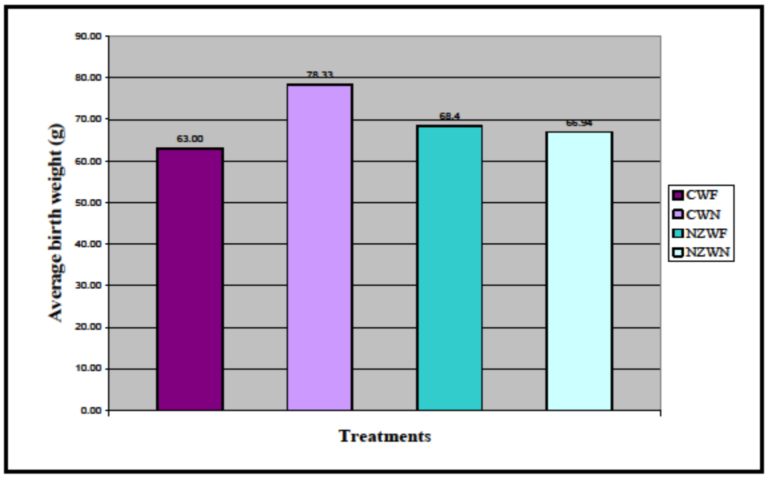

Figure 3. Average litter weights at birth in different groups

Pre weaning growth

In the present study, the average birth weights were the range between 63 – 78 g. The highest average birth weight was observed in CWN, which again carried the lowest average litter size. The average birth weights was increased by 6 – 7 folds at weaning in different groups. The average weights of young rabbits are shown in Table 2. The highest growth rate of 19.77 g / days and the highest average weaning weight (78.33) was observed in CWN group as against the lowest value of 10.08 g / day observed in CWF group. The New Zealand White group showed a growth rate of 10.73 g / day in the treatment and 13.39 g / day in the untreated group. The increments of weights in different groups were non significant ($p > 0.05$).

Table 2. Average weights of litter at birth, weaning and their growth rates

Animal groups	Average Birth Weight	Average Weaning Weight	Growth Rate (g / day)
CWF	63	365.5	10.08
CWN	78.33	593.3	19.77
NZWF	68.4	390.4	10.73
NZWN	66.94	486.67	13.39

Pre weaning mortality

Pre weaning mortality rates in the different treatment groups are shown in Table 3. The mortality rate was lowest in the CWF group; which was 0 %. NZWF group showed a mortality value of 6.67 %. The mortality rate in control groups (CWN and NZWN) were significantly ($p < 0.05$) high and was within the range between 42 % - 57 %.

Table 3. Pre Weaning mortality rate in the different treatment groups

Treatment groups	Mortality Rate (%)
CWF	0
CWN	56.67
NZWF	6.67
NZWN	41.67

Deaths were highest in CWN group during the first week (27.7 %) and it continued through the second week (16.67 %). However, on the third week the rate reduced to 5.55 %. No mortality was observed in CWF group during the first upto fourth week. Among the other groups the second lowest value of mortality was observed in the NZWF group (4 %), and the mortality occurred only during the first week.

Table 4: Mortality of litter from birth to weaning in different groups

		Mortality %		
Breed	**Treatment**	1^{st}	2^{nd}	3^{rd}
CW	Folic acid	0	0	0
	No Folic acid	27.7	16.67	5.55
NZW	Folic acid	4		
	No Folic acid	16.67		5.55

Litter size at weaning

The litters were weaned a month after the birth, and the individual body weight of each kid was taken at the time of weaning. Table shows the total litter size at birth and weaning. The value of 25 litters that was observed at CWF with birth remained at weaning, whereas, the litter size of NZWF declined to 24 at weaning. These values showed a significant difference among groups ($p < 0.05$).

The highest decline of the total litter size was observed in CWN group (10 kids). The latest decline was observed in treated groups (CWF – 0 kids and NZWF – 1 kid).

Relationship between litter size and average litter weight at weaning

The large litter size at weaning showed a lower average weaning weight. The CWN group showed the highest average weaning weight (593.33 g) and it consisted of the lowest litter size at weaning (8). The lowest average weaning weight was produced by CWF group (365.5 g) and the number of litter at weaning was the highest (25). However, folic acid treatment had no significant effect on these values ($p > 0.05$). The relationship between litter size at weaning and average weaning weight per young rabbit was negatively related. This agrees well with the results of Rao *et al*. (1977) and Rollins e*t al*. (1963). This is probably due to the competition among litter in large litters for the limited milk produced of the doe.

Table 5: Litter size at birth and weaning, and the average weaning weight

	Litter size		
Treatment groups	**At birth**	**At weaning**	**Average weight at weaning (g)**
CWF	25	25	365.5
CWN	18	8	593.33
NZW	25	24	390.4
NZWN	18	14	486.67

Accordingly, negative relationship was observed between litter size at weaning and the litter weight at weaning in all the groups. This negative relationship may be due to the milk yield of the doe. According to Lukefahr *et al*. (1981), the litter size at birth was moderately positively related with milk yield, which in turn influenced the litter weight at weaning. The provision of more milk to the young rabbits helped to produce higher litter size and weights at weaning.

Litter size after weaning

The post weaning survival rates are given in Table 4.5. The survival rates were declined compared to the pre-weaning survival rates in all the groups. The highest decline was observed in New Zealand White breeds irrespective of the treatment. Changes among groups were non-significant ($p > 0.05$).

Table 6. Survival rate after weaning in different groups

Treatment	**Survival rates at weaning %**	**Survival rates after one month of weaning %**	**Decline of the rates %**
CWF	100	83.54	16.46
CWN	43.33	35.33	8
NZWF	93.33	55.33	38
NWZN	58.33	21.67	36.66

Growth after weaning

The increase of weights of litter with time showed a positive linear relationship. The highest growth rate was observed in CWN group (20.82 g / day). The lowest growth rate was observed by the CWF group (12.35 g / day) (Table 4.6). However, these differences were non significant ($p > 0.05$).

Table 7. Growth rate after weaning

Treatment groups	Weight at weaning (g)	Weight after 1 month of weaning (g)	Growth rate (g/ days)
CWF	365.5	736	12.35
CWN	593.3	1218	20.82
NZWF	390.4	891	16.68
NZWN	486.67	921.67	14.5

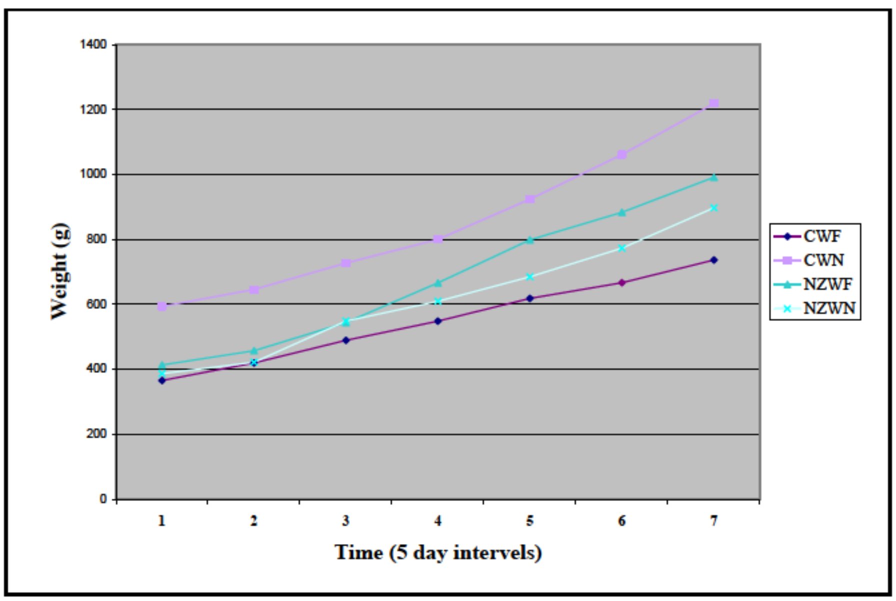

Figure 4: Growth after weaning in different groups

The highest growth rate was observed during pre and post weaning periods in CWN group, howerever the lowest rates were observed in CWF group. It was also noted that the differences of growth rates in pre and post weaning periods were lower in Californian White breed compared to New Zealand White breed. There was no obvious influence of folic acid treatment on the growth rate of young rabbits.

CONCLUSIONS

The results of the present study revealed that administration of folic acid at the rate of 5 mg / doe/ day

Has a positive effect on number of live births, but has no effect on mating.

The mortality rates were reduced in folic acid treated litter.

Survival rate was high in Californian White than in New Zealand White litter.

The effect of folic acid lasted only until the litter were weaned.

The best breed to use in a production farm, out of Californian White and New Zealand white is Californian White.

Feeds could be manufactured by using folic acid as an ingredient to produce a special diet for pregnant does (Increase the production).

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