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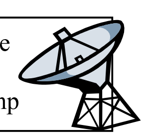

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CONTENTS

RESEARCH NOTES

Agro-morphological Variability Study of Barley *(Hordeum vulgare* L.) Landraces in Jumla, Nepal

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ABSTRACT

Barley is an important winter cereal crop in Jumla (2240-3000 masl), Nepal. It is grown in different cropping patterns in both *Khet* and *Bari* land conditions. A total of 207 accessions of barley landraces collected from various locations of Jumla were studied for agro-morphological characteristics in Khumaltar and Jumla. Data on eight qualitative and five quantitative traits in 2-m row plot were recorded to assess diversity among the landraces. *Bhuwali, Chawali, Lekali* and *Pawai* were four farmer-named traditional barley varieties under cultivation in Jumla. A range of variability was observed among the accessions of barley landraces. All accessions are six-row covered barley possessing rough awns and whitish-brown grains. These landraces exhibit a range of variation in growth class, spike density and rachilla hair length. *Lekali* and *Pawai* are adapted to the high-altitude area of Jumla. Cluster analysis of measured data under on-farm and on-station conditions indicated five distinct clusters. Three principal components explained 84.3% and 60.2% of the total variation from on-station and on-farm, respectively.

Key words: *Hordeum vulgare*, landraces, morphological variation, on-farm, on-station

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the old and an important winter cereal crop for the people living in high mountain areas of Nepal. High level of barley diversity is observed in the Nepalese high lands and the region is considered a center of diversity for barley (Witcombe and Gilani 1979). Barley is cultivated in a wide range of environments in Nepal (Baniya et al 1997). Although, the acreage of barley in Nepal is limited, it is very important crop in remote and food deficit areas. Jumla is a transition zone between lower elevations, where a summer crop follow a winter cereal, and higher elevations where only one crop (crop is grown in summer season only) can be grown. Barley is the second cereal crop to rice in Jumla. It is utilized as food, beverages and livestock feed and also served as an indicator of well-being in the community of remote areas as the crop tolerates cold climate.

Morphological characterization is the foundation of genetic diversity research at any taxonomic level (Chandran and Pandya 2000). It is still an important tool for the management of crop germplasm collections (Ariyo 1993, Polignano et al 1993, Annicchiarico and Pecetti 1994) having been used to identify duplicates, to discriminate among material from different geographic areas, to establish core collections, to investigate relationships between landraces and their wild, and to prioritize material for use in breeding programmes.

Pradhanang and Sthapit (1995), Witcombe and Murphy (1986) and Konishi and Matsuura (1991) reported that high level of variability was observed within and among populations. In Jumla, farmers classify their land according to its utilization and ecological conditions. The major land types are *Khetland*[1] (*Kholapane*[8], *Sim*[7], and *Gadkule*[6]), *Bariland*[2] (*Gharbari*[5] and *Pakhobari*[4]) and *Lekhland*[3]. Barley is cultivated in *Khet*, *Bari* and *Lekh.* The amount of farmyard manure applied is normally between 17 and 27 t ha^{-1} for *Khet* and *Bari*. In *Kehtland*, fertilization is done through *in situ* manuring by the animal herds (Rana et al 2000). A more intensive cropping pattern was observed in *Pakhobari*. *Gharbari* is suitable for residence, kitchen garden and fruit orchards whereas mono cropping is practiced in *Lekhland*. The land types of the study site were 40% *Khetland* and 60% *Bariland* (Paudel et al 1998). The cropping patterns were observed in different land types. Rice–barley is the major cropping pattern in both *Kholapane* and *Gadkul*e *khet* whereas rice–fallow is the major pattern in *Simkhet*. Barley–fallow cropping pattern is usually practiced in *Lekhland.* Similarly, barley–beans in *Gharbari* and barley–buckwheat, barley–beans, barley–proso millet cropping pattern is common in *Pakhobari* and it is considered as the most productive and very important land type with respect to food security.

Chawali, Bhuwali, Lekali and *Pawai* are four farmers' varieties of barley that are under cultivation in these land conditions for their preferred traits and different use values (Paudel et al 1998, Rana et al 2000). Among them, *Chawali* and *Lekali* are two very common landraces grown in large areas and by many farmers. Field study and household survey, indicates that *Chawali* was commonly cultivated in rice fields in winter where as *Lekali* is grown in diverse conditions from lowlands in rice field to *Bari* (upland) on hill tops and terraces under rainfed conditions. These varieties constitute a range of variability in agro-morphological traits and farmers use these traits as descriptors to identify and distinguish the varieties that have been maintained by them on-farm. The study was therefore aimed to measure the range of variation in agro-morphological characteristics among the barley accessions with distinct farmer units of diversity being maintained on-farm.

MATERIALS AND METHODS

A total of 207 accessions of barley landraces were collected from various locations of Jumla ranging from 2260 to 2530 m elevation. Collection was carried out from farmers' fields. Three to five ears from each hill were collected from field at the time of harvest. Each collection was considered as an accession and consisted of bulk of seeds of a particular population from farmers' plots (Table 1). These materials were evaluated on-station for morphological and agronomical variability under Khumaltar conditions (1350 m). Among 207 barley landrace populations only 96 were evaluated on-farm for their agro-morphological traits in farmers' fields by farmers' group in Jumla due to loss of other 111 accessions by insect damage during storage in the farmer's house. One set of these

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[1]*Khetland* – bunded and irrigated land mainly for puddle rice.
[2]*Bariland* – unbunded and unirrigated upland.
[3]L*ekhland* – upland situated at high altitude far from village.
[4]*Pakhobari* – marginal and sloppy land located far from homestead devoted to neglected crops, grass and fodder.
[5]*Gharbari* – unbunded and unirrigated land around homestead with kitchen garden and orchard.
[6]*Gadkule – Khet* land irrigated from snow-melted river.
[7]*Simkhet* – water logged marshy land with poor drainage.
[8]*Kholapane – Khet* land irrigated by stream.

materials with their passport information was supplied to Agriculture Botany Division for *ex situ* conservation.

Samples were planted in 2-m long, 2-row plots, with 25 cm spacing from row to row. The study was carried out under rainfed conditions with 30:30:0 NPK kg/ha fertilization before sowing and 15 kg/ha of N_2 was top-dressed at 2 months after planting. Data on quantitative traits (days to 50% heading, days to maturity, plant height, spikelet groups per spike, spike length, tiller number, effective tiller number and filled grains per head), and qualitative traits (growth class, row number, hoodedness, awn roughness, rachilla hair length, kernel covering and lemma colour) were recorded in five individual plants selected randomly using the IPGRI descriptors for barley (IPGRI 1994). Morphological traits were measured on 10 randomly selected plants of each accession in on-farm study in Jumla.

Descriptive statistics of both quantitative and qualitative traits were calculated by using the MS EXCEL program. In addition, Principal Component Analysis (PCA) and clustering methods using Unweighted Pair Group Method Analysis (UPGMA) were carried for quantitative traits on both sites and diversity indices using Shannon Weaver Index were calculated for qualitative traits. PCA allows reduction of a dimension problem. The techniques consist of reducing the structure and data matrix starting from a linear method and setting new variables called principal components. PCA and cluster analyses allowed identification of groups of objects or variables that are important in determining the amount of variability accounted by each of the axes. Both PCA and cluster analysis were performed using MINITAB-12 software.

Table 1. Number of accessions and collecting sites

Collecting site	Altitude, m	Number of accessions			
		Bhuwali	Chawali	Lekali	Pawai
Bayalkatiya	2500-2530	5	8	-	-
Damaibada	2300-2320	-	4	-	-
Dhaulabada	2320-2380	1	13	1	-
Kartikswami-8	2530	-	1	-	-
Khalla	2530	1	3	1	-
Kotila	2410-2480	2	13	-	-
Rokayabada	2320	2	3	-	-
Seridhuska	2480-2500	7	27	-	1
Silam	2530	1	4	1	-
Talebhir	2480-2520	15	17	-	-
Talium 1, 3-6, 8 and 9	2260-2500	4	53	13	-
Umgad	2500	1	2	-	-
Total		42	148	16	1

RESULTS

Simple statistical analysis of the observed data showed a range of variability among the accessions of barley landraces. These landraces showed variability in spike and grain morphological characters both on-farm and on-station. The differences with high range and diversity indices were observed in plant height (40-74 cm), spike characters such as row numbers (17.59), well filled grains per spike (18-50) and 50% of flowering days (92-117) in quantitative traits. The landraces also showed variability in spike and grain morphological traits both on-farm and on-station (Table 2). The landraces were winter (9.5% *Bhuwali*, 95.3% *Chawali* and 18.8% *Lekali*) and facultative types (78.6% *Bhuwali*, 4.4% *Chawali* and 81.3% *Lekali*) except five samples (11.9%) of *Bhuwali,* which has spring growth habit (Table 3). No variation was observed in row number, hoodedness, awn roughness, kernel covering and lemma colour. However, variation was observed in spike density and rachilla hair length. The *Pawai* landrace of barley had only one accession so its variability could not be measured.

Table 2a. Statistical parameters for quantitative traits of barley from on-station (Khumaltar)

Characters	On-station (Khumaltar)					
	Bhuwali		*Chawali*		*Lekali*	
	Range	X ± SD†	Range	X ± SD†	Range	X ± SD†
Phenological						
50% heading, d	95-117	111.7±7.7	92-117	96.35±4.7	93-117	109.6±9.1
Maturity, d	139-149	147.1±3.1	139-149	144.7±3.8	145-150	148.3±1.4
Morphological						
Plant height, cm	40-72	56.1±6.7	36-74	50.92±6.2	45-70	55.94±7.7
Spike length, cm	-	-	-	-	-	-
Spikelet/spike, n	20-59	44.9±7.8	17-58	38.18±7.5	28-56	45.12±7.1
Tiller, n	-	-	-	-	-	-
Effective tiller, n	-	-	-	-	-	-
Filled grain/head, n	-	-	-	-	-	-
Grain						
1000-grain wt, g	36.4-46	41.1±2.3	24.8-479	38.19±3.1	36.8-46	39.8±2.2

† *X ± SD = Mean ± Standard deviation.*

Table 2b. Statistical parameters for quantitative traits of barley from on-farm trial (Jumla)

Characters	On-farm (Jumla)					
	Bhuwali		*Chawali*		*Lekali*	
	Range	X ± SD†	Range	X ± SD†	Range	X ± SD†
Maturity, d	-	-	-	-	-	-
Morphological						
Plant height, cm	55-61	57.5±2.3	37.5-83	60.8±10	42.9-60	53.4±9.2
Spike length, cm	4-5.4	4.7±0.6	2.6-7.1	4.4±0.7	2.2-4.8	3.6±1.3
Spikelet/spike, n	-	-	-	-	-	-
Tiller, n	2.6-4	3.4±0.5	1.8-8.5	3.8±1.1	2.4-3.9	3.3±0.8
Effective tiller, n	1.6-3.2	2.6±0.6	1.1-6.1	2.9±0.9	1.9-2.7	2.3±0.4
Filled grain/head, n	23-48	37±10	18.2-50	33.1±7.2	26.6-37	30.9±5.7
Grain						
1000-grain wt, g	33-43	39.1±4.2	27-47.2	38.6±3.4	36-43.4	40.7±4.1

† *X ± SD = Mean ± Standard deviation.*

A pairwise association among landraces of barley (on-station and on-farm) was measured from the observed agro-morphological traits using Ward and Euclidean distance and revealed a clear clustering into different morphological groups (Table 4). The resulting dendrograms depicted in Figures 1 and 2 show the relationship between populations of barley landraces and grouped all populations into five distinct clusters for both on-station and on-farm characterizations respectively. In both clusterings, *Chawali* landraces were found to be most diverse and represented in all the clusters (Table 5). However, *Bhuwali* and *Lekali* landrace populations predominantly represented cluster II. The study showed the distribution of landraces in different clusters irrespective of farmers' given name and their descriptions.

Table 3. Frequency distribution and Shannon Weaver indices of qualitative traits of barley (on-station)

Character	*Bhuwali*			*Chawali*			*Lekali*			*Pawai*	
	No. of acc.	Freq. %	H	No. of acc.	Freq. %	H	No. of acc.	Freq. %	H	No. of acc.	Freq. %
Growth class											
Winter	4	9.5		141	95.3		3	18.8		1	100
Facultative	33	78.6	0.67	7	4.7	0.19	13	81.3	0.48	0	0
Spring	5	11.9		0	0		0	0		0	0
Row number											
Six row	42	100	0	148	100	0	16	100	0	1	100
Two row	0	0		0	0		0	0		0	0
Spike density											
Lax	38	90.5		95	64.2		14	87.5		1	100
Intermediate	4	9.5	0.31	53	35.8	0.65	2	12.5	0.38	0	0
Dense	0	0		0	0		0	0		0	0
Hoodedness											
Sessile hoods	0	0		0	0		0	0		0	0
Elevated hoods	0	0	0	0	0	0	0	0	0	0	0
Awnless	0	0		0	0		0	0		0	0
Awned	42	100		148	100		16	100		1	100
Awn roughness											
Smooth	0	0	0	0	0	0	0	0	0	0	0
Rough	42	100		148	100		16	100		1	100
Rachilla hair length											
Short	24	57.1	0.68	125	84.5	0.43	14	87.5	0.69	1	100
Long	18	42.9		23	15.5		2	12.5		0	0
Kernel covering											
Naked grains	0	0	0	0	0	0	0	0	0	0	0
Covered grains	42	100		148	100		16	100		1	100
Lemma colour											
White/brown	42	100		148	100		16	100		1	100
Purple or black	0	0	0	0	0	0	0	0	0	0	0
Pink	0	0		0	0		0	0		0	0

Table 4. Means of relevant quantitative traits for two sites of the clusters formed

Character	Clusters											
	On-station						On-farm					
	I	II	III	IV	V	Mean	I	II	III	IV	V	Mean
50% heading, d	94.8	111.1	95.8	95.2	95.6	100.6	–	–	–	–	–	–
Plant height, cm	50.2	58.2	44.5	55.5	52.4	52.4	56.6	52.6	63.4	61.5	63.4	61.0
Spike length, cm	–	–	–	–	–	–	4.0	4.5	4.3	4.0	4.6	4.3
Spikelet groups/spike, n	46.4	46.5	35.7	37.9	29.3	40.2	–	–	–	–	–	–
Tiller, n	–	–	–	–	–	–	3.2	4.1	3.9	3.6	3.8	3.8
Effective tiller, n	–	–	–	–	–	–	2.5	3.0	2.9	2.7	2.8	2.8
Filled grain/head, n	–	–	–	–	–	–	32.6	30.3	35.0	35.4	33.5	33.8
Unfilled grain/head	–	–	–	–	–	–	2.4	1.9	1.9	1.8	1.8	1.9
Maturity, d	139.0	148.3	144.9	147.1	148.0	145.6	–	–	–	–	–	–
1000-grain weight, g	38.9	41.2	37.4	38.1	38.2	38.9	37.0	37.7	39.1	38.7	39.2	38.7

Table 5. Composition and characteristics of clusters based on observed traits for two locations

Cluster	On-station				On-farm			
	No. of acc.	Landrace name	Total no. types	Cumulative characteristics of landraces in cluster	No. of acc.	Landrace name	Total no. types	Cumulative characteristics of landraces in cluster
I	39	*Bhuwali* (4) and *Chawali* (35)	2	Early heading & maturity, medium plant height & more no. of spikelet groups per spike	8	*Bhuwali* (1), and *Chawali* (7)	2	Medium plant height, short spike, low tillering and low 1000-seed wt.
II	55	*Bhuwali* (34), *Chawali* (8), *Lekali* (12) and *Pawai* (1)	4	Late heading & maturity, taller plant and high number of spikelet groups/spike and 1000-grain weight	14	*Bhuwali* (11), *Chawali* (2) and Unknown (1)	2	Dwarf plant, long spike, high tillering and medium 1000-seed wt.
III	45	*Bhuwali* (3), *Chawali* (40) and *Lekali* (2)	3	Dwarf plant, medium maturity & heading and low seed weight	36	*Bhuwali* (2), *Chawali* (33) and Unknown (1)	2	Tall plant, medium tiller & spike length, moderately high number of grain per head
IV	40	*Chawali* (38) and *Lekali* (2)	2	Medium heading, plant height, maturity & 1000-seed weight	15	*Chawali* (15)	1	Medium plant, short spike, with medium tillering and high number of filled grain/head.
V	28	*Bhuwali* (2), *Chawali* (26)	2	Low seed weight & number of spikelet groups/spike and medium plant height & maturity.	23	*Bhuwali* (1), *Chawali* (21) and Unknown (1)	2	Tall plant, long spike, medium tiller number but higher 1000-seed wt.

Number in parenthesis indicates total number of accessions.

Principal component analysis also showed a marked variation among landraces with great influence of the morphological traits of plant, spikes and grains along the first three axes (Table 6). Figure 3 shows the distribution of barley populations by landrace names under the on-station characterization. Three PCs accounted 84.3% of the total variance of five quantitative characters measured from on-station, and 60.2% of total variance of seven quantitative characters measured from the on-farm trial (Table 6). The first principal component explained 46.4% and 29.5% of the total variance on-station and on-farm, respectively. Eigen values and eigenvectors were different between on-farm and on-station trials. The variation shown between two locations may be due not only to the location difference, but probably also to the differences in number of traits and accessions.

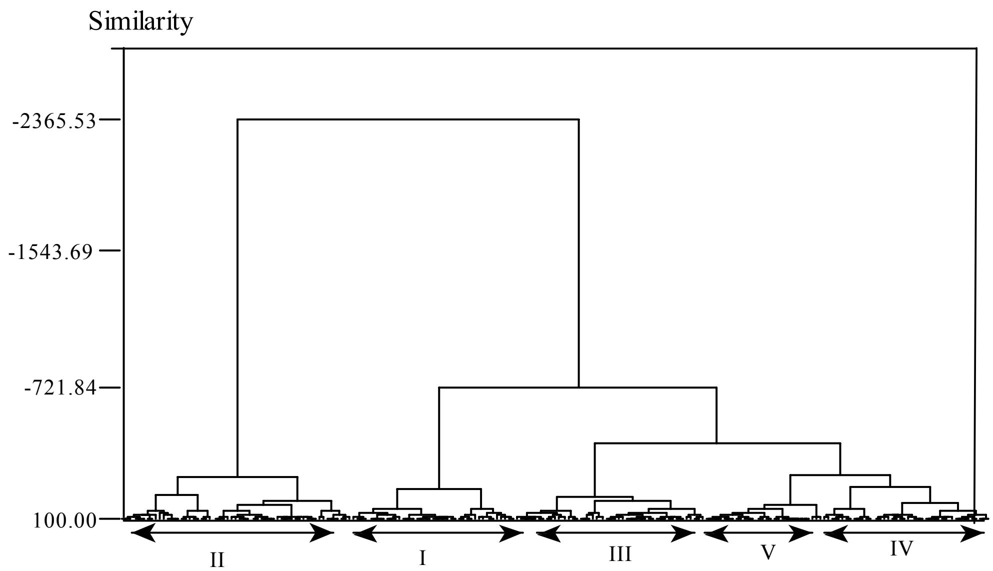

Figure 1. Dendrogram of 207 barley accessions revealed by UPGMA cluster analysis (on-station).

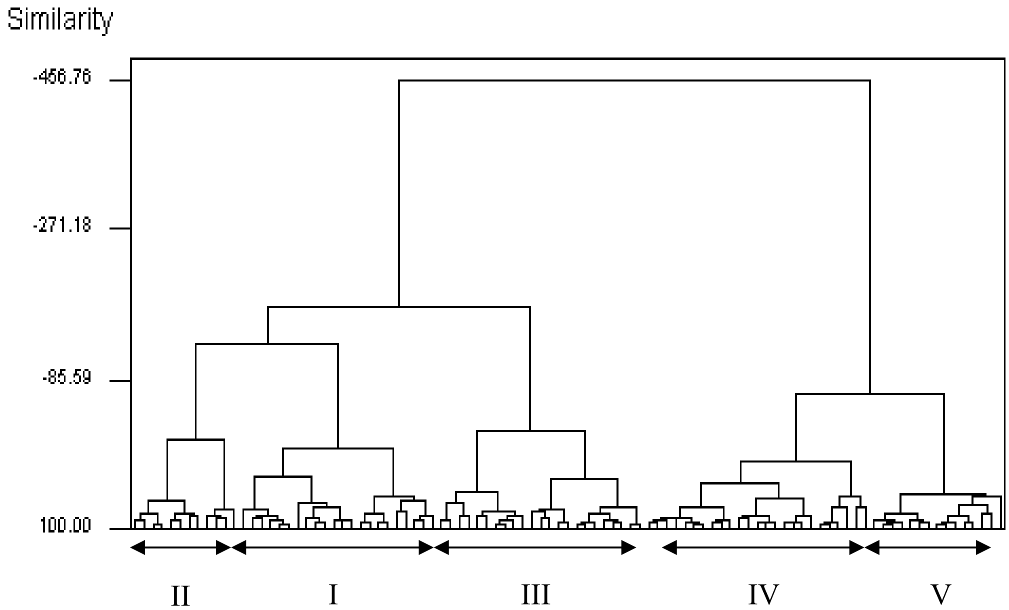

Figure 2. Dendrogram of 96 barley accessions revealed by UPGMA cluster analysis (on-farm).

Table 6. Eigenvectors, eigen values, total variance and cumulative variance for quantitative traits in barley landraces over two sites

Character	On-station (Khumaltar)			On-farm (Jumla)		
	PC1	PC2	PC3	PC1	PC2	PC3
50% heading, d	-0.577	0.013	0.139	-	-	-
Plant height, cm	-0.482	-0.122	0.529	3.94	-0.234	-0.173
Spike length, cm	-	-	-	0.379	0.070	0.372
Spikelet groups/spike, n	-0.327	0.712	0.172	-	-	-
Tiller number	-	-	-	0.505	0.264	-0.281
Effective tiller, n	-	-	-	0.495	0.262	-0.355
Filled grain/head, n	-	-	-	0.230	-0.564	-0.030
Unfilled grain/head	-	-	-	-0.131	-0.371	-0.183
Maturity, d	-0.355	-0.679	-0.070	-	-	-
1000-grain weight, g	-0.449	0.131	-0.816	0.239	-0.379	0.278
Eigen values	2.320	1.221	0.673	2.653	1.662	1.098
% of total variance	46.4	24.4	13.5	29.5	18.5	12.2
% of cumulative variance	46.4	70.8	84.3	29.5	48.0	60.2

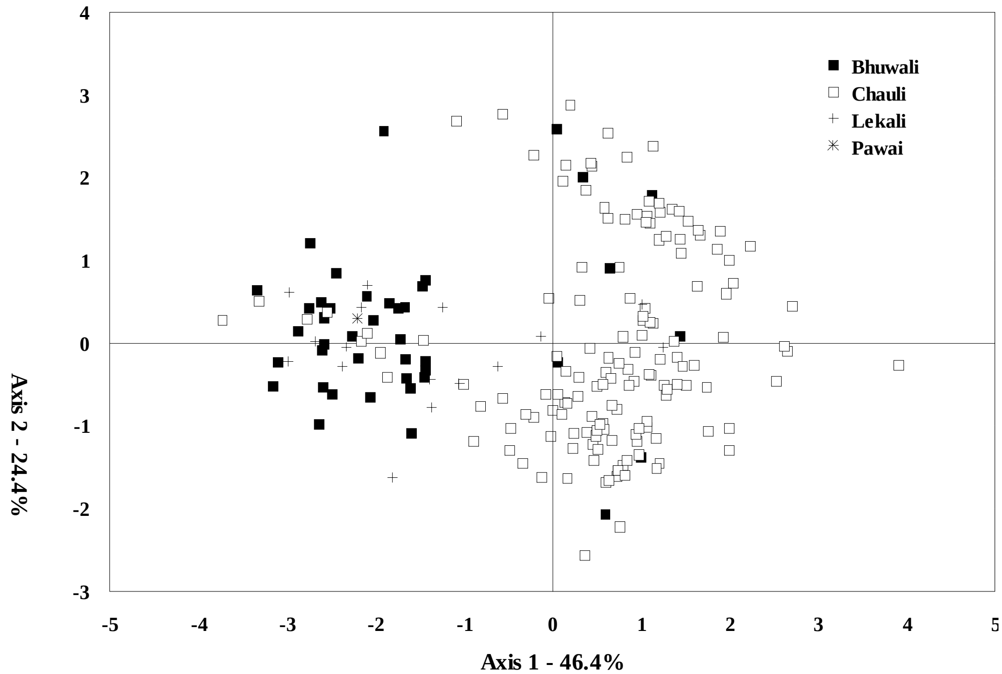

Figure 3. Distribution plot of barley landraces along with the first and second principal components (PCs).

Unlike to the hierarchical clustering, the principal component analysis of quantitative traits revealed a clear grouping of barley populations by landrace names. The accessions of *Bhuwali* and Chawali landraces clustered together and separated by the axis 2 with few outlier accessions (Figure 3). Figure 6 also indicates that these landrace populations were most variable and were encompassed of range of intra-varietal variations for the observed quantitative traits.

DISCUSSION

A large amount of agro-morphological diversity was observed in the barley landraces belonged to four differently named landraces that were under cultivation in Jumla. Morphological diversity of quantitative traits between the three groups of barley landraces under study showed greater variation in both on-farm and on-station (Table 2). *Chawali* and *Bhuwali* landraces is grown in irrigated and well managed conditions and *Lekali* landraces is grown in rainfed and diverse conditions. Similarly, in qualitative traits also variability was observed in growth class, spike density and rachilla hair length (Table 3). The existence of considerable level of diversity in terms of isozyme variability among farmers' barley populations of differently named landraces. *Bhuwali, Chawali*, and *Lekali* consisted greater variation among populations and among farmers named varieties (Bajracharya et al 2001). These landraces can be good source materials for breeding purpose. Hence, it could be a valuable resource to conserve and for utilization with improvement in future.

The analysis of average value of the variables for each group provides information for describing the groups identified. High mean were observed for 50% heading and maturity on on-station and plant height for on-farm indicating that wide variation exists in the population for these traits (Table 4). No variation was observed in grain weight for both on-farm and on-station.

Table 5 gives a general description of each group. The studied populations clustered into five clusters with two sets of observation. In the clustering, *Chawali* landraces were found to be diverse and represented in all the clusters (Table 5). However, *Bhuwali* represented in cluster I and III whereas *Lekali* represented cluster II and IV (Figure 3). It suggests that there is presence of variability in the barley landraces. This study showed the distribution of landraces in different cluster irrespective of farmers' given name and their description. The structure and level of morphological variation revealed in the present study showed a significant level of genetic diversity among the barley accessions of differently named landraces. To an extent, the diverse morphological forms established the genetic identity of the barley landraces.

The studies on landraces have shown the value and importance of agro-morphological characters with direct relevance to local farmers and breeders for conservation, and in estimating diversity of germplasm and in describing the level of discrimination of the varieties (Murphy and Witcombe 1981 have also shown how farmers select preferred maize types from their agro-morphological characters. Similarly, Chu et al (1997) have shown how combining ethno-botanical methods with genetic analysis can give insights into how crop genetic diversity is maintained and managed. These descriptive values of morphological characters are genetically heritable and therefore worthy for the genetic diversity analysis. The first three principal components with eigen value greater than unity explained 84.3% and 60.2% on-station and on-farm of the total variation among the studied landraces for the quantitative traits (Table 6). The first and second principal components accounted for 46.4% and 70.8% on on-station and 29.5% and 48.0% on on-farm respectively of the total variation. 1000-grain weight, grain length and width were the most important traits contributing to the first principal components. Plant height, tiller number, panicle length and grain weight were the important traits contributing to the second and third principal component. Scattered plots of these landraces clearly indicated that there is presence of variability.

Barley landraces were identified according to their group in the dendrogram and graphed in biplots using the first three principal components (Figures 1 and 2). Based on the plots constructed using the first two principal components, groups I, II and III were spatially observed as distinct groups on both the sites while the IV axis was useful for better differentiation of group V.

From the analysis of the groups, the clustering pattern obtained showed an association with the agronomic performance of the accessions. This indicates that the classification can assist in discriminating the groups of material, which can be of future use for plant breeding programme.

This work has been a contribution to increase the knowledge about the barley germplasm conservation in Jumla, Nepal. This better understanding should allow a better conservation and use of the collection in breeding programmes. The research will also assist in the conservation of valuable germplasm, as is the case of local varieties, which hold important local adaptation and are of widespread use by farmers throughout the entire country.

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REFERENCES

Annicchiarico P and L Pecetti. 1994. Morpho-physiological traits as descriptors for discrimination of durum wheat germplasm. *Genet. Resour. Crop Evol.* 41:47-54.

Ariyo OJ. 1993. Genetic diversity in West African okra (*Abelmoschus caillei* (A. Chev.) Stevels): Multivariate analysis of morphological and agronomic characteristics. *Genet. Resour. Crop Evol.* 40:25-32.

Bajracharya J, PR Tiwari, DM Shakya, BK Baniya and BR Sthapit. 2001. Farmer management and isozyme variation in barley landraces (*Hordeum vulgare* L.), Jumla, Nepal. **In:** *On farm management of agricultural biodiversity in Nepal* (BR Sthapit, MP Upadhyay, BK Baniya, A Subedi and BK Joshi, eds), 2003. Proceedings of a National workshop, NARC, LI-BIRD and IPGRI.

Baniya BK, DMS Dongol and KW Riley. 1997. Characterization of Nepalese barley germplasm. *Rachis, Barley and wheat Newsletter*, ICARDA, Aleppo, Syria. Vol.16, No 16. Pp. 16-19.

Chandran K and SM Pandya 2000. Morphological characterization of Arachis species of section Arachis. *Plant Genet. Resour. Newslett.* 121:38-41.

Chu Xu-Jian, Li X, Li R, Xu JC, Li XX and Li RG. 1997. Ethnobotany and genetic diversity of taro. *IPGRI News I. For Asia, the Pacific and Oceania*. IPGRI, Rome, Italy. 23:9-10.

IPGRI. 1994. *Descriptors for barley* (*Hordeum vulgare* L.). International Plant Genetic Resources Institute, Rome, Italy.

Konishi T and S Matsuura. 1991. Geographic differentiation in isozyme genotypes of Himalayan barely (*Hordeum vulgare* L.). *Genome* 34:704-709.

Murphy PJ and JR Witcombe. 1981. Variation in Himalayan barley and the concept of centres of diversity. **In:** *Barley Genetics IV*. Proceedings of the fourth international barley genetics symposium, Edinburgh. Pp. 26-36.

Paudel CL, PR Tiwari, JD Neupane and DP Devkota. 1998. *Strengthening the scientific basis of in situ conservation of agrobiodiversity: Findings of site selection in Jumla, Nepal*. NP working paper No 3/98. NARC/LI-BIRD-Nepal, IPGRI-Rome, Italy.

Polignano GB, P Uggenti and G Scippa. 1993. The patterns of genetic diversity in faba bean collections from Ethiopia and Afghanistan. *Genet. Resour. Crop Evol.* 40:71-75.

Pradhanang PM and BR Sthapit. 1995. Effect of cultivar mixtures on yellow rust incidence and grain yield of barley in the hills of Nepal. *Crop Protection* 14(4):331-334.

Rana RB, CL Paudel, PR Tiwari, D Gauchan, A Subedi, BR Sthapit, MP Upadhyay and DR Jarvis. 2000. *In situ crop conservation: Findings of agroecological, crop diversity and socioeconomic base line survey of Talium ecosite, Jumla*. NP working paper No 3/2000. NARC/LI-BIRD-Nepal, IPGRI-Rome, Italy.

Witcombe JR and MM Gilani. 1979. Variations in cereals from the Himalayas and the optimum strategy for sampling plant germplasm. *Journal of Applied Ecology* 16:633-640.

Witcombe JR and PJ Murphy. 1986. Covered and naked barelys from the Himalaya. 2. Why do they differ from each other so extensively? *Theor. Appl. Genet.* 71:736-741.

PARTICIPATORY CROP IMPROVEMENT OF NEPALESE FINGERMILLET CULTIVARS

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ABSTRACT

A FIELD STUDY WAS UNDERTAKEN ON NEPALESE FINGERMILLET GENOTYPES WITH THE PARTICIPATION OF THE LOCAL COMMUNITY AT PIPALTAR OF NUWAKOT DISTRICT DURING 2003 AND 2004. THE STUDY INCLUDED A) IDENTIFICATION OF SUPERIOR FINGERMILLET CULTIVARS THROUGH DIVERSITY BLOCK MANAGEMENT AND MOTHER SET TRIAL, B) SEED PRODUCTION OF PROMISING LINES, C) FARMERS' FIELD VERIFICATION TRIAL (DIAMOND TRIAL) AND D) CHARACTERIZATION AND DOCUMENTATION OF FINGERMILLET GENOTYPES. RESULTS REVEALED THAT MUDKE, CHAURE AND JALBIRE ARE HIGH YIELDING PROMISING GENOTYPES SUITED TO THAT AREA. FROM HOUSEHOLD SURVEYS CARRIED OUT AMONG 46 SAMPLES (40%), 80 HH HAVE REVEALED THAT MUDKE, CHAURE AND SETO KODO ARE PREFERRED FINGERMILLET CULTIVARS. ABOUT 70% GROW MUDKE, 46% GROW CHAURE WHILE 2% GROW SETO KODO. THE PROGRAMME HAS SUCCESSFULLY EXPLORED THE POTENTIAL OF LOCAL FINGERMILLET CULTIVARS BY THERE EVALUATION AND UTILIZED THEM THROUGH VALUE ADDED PRODUCT DEVELOPMENT AND MARKET PROMOTION.

KEY WORDS: CHARACTERIZATION, CULTIVAR, FINGERMILLET, VARIETAL EVALUATION

INTRODUCTION

Fingermillet (*Eleusine coracana* Gaertn.), a crop of many poor and subsistent people in the hills of Nepal, is the fourth most important cereal crop in the country. It is mostly grown under a maize/millet cropping system. Its area under cultivation is 2,59,130 ha with the production of 2,82,860 mt. (CBS 2061). The national average yield is 1.09 mt ha^{-1}. Even though, the crop is important for the subsistence of rural farming household, its potential has not been fully realized, thus considered neglected and under-utilized in the national perspective. In a food policy review (2001) by International Food Policy Research Institute, it stated that throughout the developing world, poor people subsist on diets consisting of staple foods such as rice or maize and little else. The lack of diversity in the foods they eat often leads to micronutrient deficiencies. This dilemma can be very much true in our country case because people in rural and inaccessible areas have less choice of food items either due to scarcity or poverty. Fingermillet to some extent can mitigate this problem in rural community.

After the initiation of the project, "Enhancing the contribution of Nutritious but Neglected Crops to Food Security and to Increase income of the Rural Poor: Nepal Component of Fingermillet", during 2002 in Hill Crop Research Program, Kabre, diversified studies were carried out in fingermillet crop. The objectives of the project were to conserve and utilize fingermillet genetic resource through development-oriented research and to tackle major causes of it's under use by reviving the cultivation of nutritious but neglected crop.

MATERIALS AND METHODS

Five different activities were carried out under varietal evaluation and production management. The activities were diversity block management, mother set trial, characterization of local fingermillet genotypes and lines, seed production and farmers' field verification trial (Diamond trial).

Eighteen local fingermillet cultivars collected from Nuwakot, Kaski and Dolakha were sown in diversity block management for evaluating performance of the landraces. They were sown in rod-row with the spacing of 10 cm between rows. Plot size was 2 m^2. Chemical Fertilizer was applied at the rate of 30:30:30 NPK kg ha^{-1} and FYM 5 ton ha^{-1}. In the mother set trial, six fingermillet cultivars were grown in the farmers' fields for selecting farmers' preferred cultivars. The trial was conducted in complete randomized block design with four replications. The plot size was $6m^2$ with the spacing of 10 cm between rows. Fertilizers and FYM were applied at the rate of 30:30:30 NPK kg ha^{-1} and 5 ton ha^{-1}, respectively. Likewise, 243 fingermillet cultivars and lines were evaluated at Kabre farm. Seed production of the selected fingermillet cultivars like Kabre kodo-1, GPU-25 and Mudke were carried out and diamond trial (Table 1) was conducted in the farmers' fields.

Table 1. Treatment details of Diamond Trial carried out at Pipaltar during 2003 and 2004

	Improved varieties/improved practice	Improved varieties/Local practice	Local varieties/Improved practice	Local varieties/Local practice
1	Improved fingermillet variety Kabre kodo-1	Improved fingermillet variety Kabre kodo-1	Farmer local Mudke cultivar	Farmer local Mudke cultivar
2	30:30:30 NPK kg ha^{-1}	Urea (small amount)	30:30:30 NPK kg ha^{-1}	Urea (small amount)
3	Spacing between rows 10 cm	No line maintenance	Spacing between rows 10 cm	No line maintenance

RESULTS AND DISCUSSION

Diversity block management and mother set trial

Various qualitative and quantitative traits of different fingermillet genotypes were evaluated in diversity block and mother set trial during 2003 and 2004. The results are presented in Tables 2 and 3.

Table 2. Summery of diversity block management at Pipaltar, Nuwakot during 2003 and 2004

SN	Cultivars	Days to 75% maturity**	Plant height, cm	Plant stand/m^2 **	No. of fingers/head	Grain yield, kg ha^{-1}	Remarks
1	Seto Kodo	128	99.7	72	6	1248	
2	Seto Dalle	123	115.3	74	8	1570	Good for bread
3	Kalo Dalle	126	114.2	96	7	1552	
4	Kalo Jhyape	120	100.3	86	7	1792	
5	Mudke Kodo	126	111.8	88	7	1886	First preference
6	Paheli Mudke	116	108.2	82	8	1860	
7	Chaure Kodo	123	104.1	88	8	1502	
8	Paheli Kodo	129	105.0	64	7	1336	
9	Kukurkane	123	102.0	58	7	1530	
10	Chaure Kodo	123	106.0	88	7	2040	
11	Chitwane Loc.	123	102.8	102	8	1924	
12	Jalbire	129	104.5	82	8	1896	

SN	Cultivars	Days to 75% maturity**	Plant height, cm	Plant stand/m^2 **	No. of fingers/head	Grain yield, kg ha^{-1}	Remarks
13	Seto Jhyape	128	109.3	100	7	1772	
14	Kabre Kodo-1	121	106.9	76	6	1447	
15	Paheli*	-	111.9	-	8	1136	
16	Dalle	124	110.7	62	7	1202	
17	Farmer's Local (Mudke)	125	117.0	96	8	1541	
	Mean	124	107.6	82	7	1602	
	Maximum	129	117.0	102	8	2040	
	Minimum	116	99.7	58	6	1136	
	SD	3.5	5.3	13.5	0.69	275.4	

** and ** included in the year 2004 only.*

Table 3. Summery of mother set at Pipaltar, Nuwakot during 2003 and 2004

SN	Cultivars	Days to 75% maturity	Plant height, cm	Plant stand/m^2	No. of fingers/head	Grain yield, kg ha^{-1}
1	Kabre Kodo-1	135.2	117.4	84.3	6	2588.9
2	GPU-25	133.8	99.0	90.7	6	2786.1
3	GE-5177	137.2	111.7	92.2	7	1911.1
4	GE-0122	132.5	117.1	92.2	6	1844.4
5	Acc#523-1	135.3	113.0	89.8	6	2077.8
6	Mudke Kodo	133.8	110.8	97.3	8	2755.6
	Mean	134.6	111.1	91.1	6	2327.3
	CV, %	3.59	10.58	17.55	13.3	58.8
	F-test	ns	ns	ns	**	ns
	LSD	5.7	-	17.55	0.8	1360

Seed production of promising cultivars

With an aim to supply quality seed and effort to conserve superior fingermillet local genotypes *in-situ*, seed production of elite fingermillet cultivars were carried out (Table 4).

Table 4. Estimated yield of fingermillet from seed production activities at Pipaltar during 2003 and 2004

SN	Cultivars	Year 2003		Year 2004	
		Farmers	Yield, kg ha^{-1}	Farmers	Yield, kg ha^{-1}
1	Kabre Kodo-1	Birman Kumal	2420	Bishwo Kumal	2928
2	GPU- 25	Bishwo Kumal	3300	Bishwo Kumal	3725
3	Mudke	Resham Kumal	2530	-	-

Farmer’s field verification trial (Diamond trial)

This verification trial demonstrated the performance of improved method of cultivation over farmers' practice. Local cultivar, Mudke, with improved practice gave the highest yield followed by improved variety Kabre Kodo-1.

Table 5. Results from the Diamond trial conducted at Pipaltar during 2004

Trt No	Treatment	Grain yield, kg ha^{-1}	Plant height, cm	Maturity days, 75%	No. of plants/m^2	No. of head/m^2	No. of fingers/head
1	Imp. cv./Imp. Practice	2950	111	131	100	103	7
2	Imp. cv../Local practice	2650	106	131	108	110	6
3	Local cv./Imp. practice	3575	97	125	112	114	6
4	Local cv./Local practice	2850	96	125	89	95	7
	Mean	3006.2	102.5	128	102.25	105.5	6.5

Characterization and documentation of fingermillet genotypes

Two hundred forty-three fingermillet genotypes/ lines were evaluated at Kabre, Dolakha during 2004 (Table 6 and Table 7). Variations in both the qualitative and quantitative characteristics were observed among the tested genotypes that could be utilized in the future breeding programmes.

Table 6. Few Qualitative characteristics of 243 fingermillet lines assessed at Kabre during 2004

SN	Characteristics	Ranking				
1	Plant pigmentation at flowering	Non-pigmented 167 (69%)	Pigmented 76 (31%)			
2	Ear shape	Droopy 0 (0%)	Open 25 (10%)	Semi-compact 127 (53%)	Compact 83 (34%)	Fist-like 6 (3%)
3	Ear size	Small 40 (16%)	Medium 121 (50%)	Large 82 (34%)		
4	Finger branching	Absent 242 (99.6%)	Present (0.4%) Entry No. 136			
5	Discontinuity of spikelet	Yes 5 (2%)	No 238 (98%)			
7	Lodging susceptibility	No 238 (97%)	Low 4 (2%)	Intermediate 0 (0%)	High 1 (0.4%)	
8	Spikelet shattering	Absent 236 (97%)	Present 7 (3%)			

Table 7. Quantitative characteristics of 243 fingermillet genotypes/lines assessed at Kabre during 2004

SN	Traits	Minimum	Maximum	Mean	CV, %	SE of mean
1	Plant height, cm	27	107	80	17	0.87
2	Flag L/W ratio	8.7	3.4	-	-	-
3	Culm branching	1	3	1.3	36.3	0.03
4	Culm thickness, mm	5	15	8	16.1	0.07
5	Productive tillers	1	3	1.3	36.3	0.03
6	Finger L/W ratio	6.4	8	-	-	-
7	Disease scoring	1	7	1.3	61	0.05

Fingermillet contributed 22% on the total food sharing in Tallo Pipaltar (Khadka et al 2005). To increase the value of any local crop diversities, experts working in this area must understand the different values that the local crops hold for farmers as well as the ways in which changing social and technological conditions will affect those values. The project has been successful in collecting resource of information on the local fingermillet cultivars in respect to social setting. Large numbers of Nepalese fingermillet cultivars have been assessed in terms of their yield performance as well as agro morphological characteristics, and superior genotypes like Mudke Kodo, GPU-25 and Chaure Kodo have been identified as promising fingermillet cultivars. Moreover so, the project has helped in the utilization, promotion and in the conservation of the countries rich fingermillet resources.

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REFERENCES

CBS. 2061. *Statistical information on Nepalese agriculture 2060*. Central Bureau of Statistics. Agricultural Statistics Division, HMG/Nepal. Singha Durbar, Kathmandu, Nepal.

Khadka R, RP Upreti, S Gautam, YN Ghimere, D Gauchan and S Shrestha. 2005. Baseline study on Fingermillet in Pipaltar, Bidur Municipality, Nuwakot District. **In:** *A Survey report on fingermillet of Nuwakot District (Pipaltar and Khanigaun) under IFAD-NUS Project*. Nepal Agricultural Research Council.

Evaluation of Hybrid and OPV Maize Varieties for Grain Yield and Agronomic Attributes under Farmer's Field Conditions at Dukuchhap

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ABSTRACT

Field experiments were conducted during two consecutive years 2006 and 2007 in full season of maize (May-Sep) at Dukuchhap, Lalitpur to find out impact of growing hybrid and OPV maize in different rows combinations with respect to their pure stands in same environment of growing and to sort out non-lodging maize varieties. The experiments consisted of an open pollinated variety (OPV) 'Deuti' and hybrid 'Gaurab' in different row combinations (50% hybrid + 50% OPV, 75% hybrid + 25% OPV, 75% OPV + 25% hybrid plus their pure stands). The results showed that Gaurab (yellow, flint type) and Deuti (white, semi- flint type, selected from CIMMYT's material ZM 621) did not vary significantly in grain yield and yield components. There was no effect of mixed row culture between the OPV and hybrid for grain yield and yield attributes. A bivariate correlation coefficient between agronomic traits and ear traits indicated that there was a positive relation among these traits. However, a positive and highly significant (r = 0.766**) relationship between ear fill and ear length was observed while a very weak relation (r = 0.096*) between grain weight/ear and ear height was also noticed suggesting taller the ear height lower the grain yield/ear and vice versa. The findings of the study support that plant height and ear height were weakly related with other ear traits; nevertheless, these were highly related to grain weight/per plant. To cope with stalk lodging problem and to attain higher grain yield these varieties are equally potential and recommended to grow under Dukuchhap conditions.

Key words: Hybrid, maize, OPV, yield attributes

INTRODUCTION

Dukuchhap, an outreach research (OR) site of Khumaltar complex of Nepal Agricultural Research Council (NARC), is a village development committee (VDC) which is situated at an elevation of about 1100-1500 m in Lalitpur district. It is about 15 km away from Khumaltar, which represents sloppy land, rainfed upland, rainfed lowland and limited irrigated lowland conditions. The topography of the site varies from gentle to steep slope of hillock, flat land in the river basin, and unbounded terracing in the rainfed uplands.

Maize is one of the important staple crops in Dukuchhap and stalk lodging is a serious limitation in local variety. To cope up this problem, farmers are shifted to hybrid maize cultivation which is high inputs demanding (fertilizer, plant protection, improved husbandry practices) and incurred high cost of hybrid seed. Aside from this, there is no guarantee of getting hybrid seed of adopted hybrid in the region because seed suppliers keep on changing such hybrids on the basis of their availability from neighboring India. The irony is that OPVs which are as good as those of hybrids are not tested and popularized in these domains. Therefore, with a view to compare most promising OPV with hybrid in the area field trials were conducted in Dukuchhap to demonstrate farmers how OPV and hybrid perform in an environment where these varieties are grown under farmers' managed conditions because it has often been perceived that OPVs cannot perform as those of hybrids.

MATERIALS AND METHODS

Field experiments were carried out at Dukuchhap, Lalitpur, 1300 m in normal maize season (May-September) of 2006 and 2007. The experiments were conducted in randomized complete design that consisted row combination between Gaurab hybrid and Deuti, an OPV. Seed of these varieties was obtained from National Maize Research Program (NMRP), Rampur. The row combinations between hybrid and OPV were as follows: 50% hybrid + 50% OPV, 75% hybrid + 25% OPV and 25% hybrid + 75% OPV plus pure stands of hybrid and OPV. They were replicated four times in the field of two farmers.

In 2006, experiment was planted on May 1 in Kadar Thapa's field with two replications and on May 3 in Bharat Bahadur Neupane's field with two replications. In 2007, experiment was planted on May 1 in Kedar Thapa's field with four replications. In both years, at the time of planting, basal dose of N, P_20_5 and K_20 was given at 50:50:60 kg ha^{-1} from diammonium phosphate (DAP) and muriate of potash (MoP). At knee high stage, N at 25 $kgha^{-1}$ was top dressed from urea. A spacing of 75 cm and 25 cm for row and plant was maintained. All other husbandry practices were performed by farmers as practiced in the locality. A gross plot size of six rows of 3 m long ie 13.5 m^2 per plot was maintained. For field weight recording, four innermost rows per plot were harvested. Ear attributes such as ear length, ear fill, ear weight and ear circumference were taken. Grain yield was adjusted to 15% moisture content and 80% of the field weight as shelling recovery. Grain yield was converted into hectare basis for analysis. Statistical analysis of data was done with IRRI Stat software packages version 4.5. Grain yield was calculated as follows:

Grain yield ($kgha^{-1}$) at 15% moisture content (MC) = Field weight (kg)*10000*(100-MC)*0.8/Net harvested area*85

RESULTS AND DISCUSSION

Combined analysis of data for grain yield and yield components over the years between hybrid and OPV revealed insignificant results (Table 1). Hybrid Gaurab and OPV Deuti were found comparable for grain yield and yield attributes. However, overall performance of these attributes remained higher in 2007 than that in 2006 except for ear weight which was found higher in 2006 than in 2007.

Table 1. Interaction effect between row combinations over years for grain yield and yield attributes of (Gaurab) and OPV (Deuti) maize tested during 2006-2007 full season under farmers' field conditions, Dukuchhap, Lalitpur

Treatment	Plant height, cm		Ear height, cm		Ear length, cm		Ear fill, cm		Ear circum-ference, cm		Ear weight, g		Grain yield, kg ha^{-1}	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Pure stand of hybrid	235	254	110	132	21	20	18	18	15	16	213	181	4581	4740
Pure stand of OPV	231	251	114	127	21	21	19	19	16	16	213	188	5059	5399
3 rows hybrid + 3 rows OPV	231	279	115	132	20	21	18	19	16	16	229	209	4974	4905
4 rows hybrid+2 rows OPV	227	254	107	123	20	21	18	18	16	16	225	194	4785	4776
2 rows hybrid+4 rows OPV	230	259	110	135	20	20	19	17	16	16	221	183	5123	4959
Grand mean	231	260	112	133	20	21	19	19	16	16	221	191	4904	4956
F Probability 4 DF	0.376		0.749		0.743		0.763		0.218		0.956		0.917	
LSD (P < 0.05) 12 DF	24.3		18.9		1.8		2.4		0.48		37.3		911	

Numerically average grain yield performance of pure stand of hybrid in both years was inferior (4581-4740 kg/ha) to other treatment combinations including pure stand of OPV. This explains that OPV can compete or even be superior to hybrid at Dukuchhap conditions for obtaining increased grain yield. In other words, it can be inferred that statistically Gaurab hybrid and Deuti OPV are comparable for grain yield and yield related attributes and they are agronomically and physiologically similar in maturity, plant height and yield attributes. It is therefore advised to farmers that composite variety of maize is superior to hybrid because hybrid in general demand increased level of inputs such as fertilizer, yearly replacement of seed which is many times expensive than that of OPV, plant protection and improved husbandry practices.

A two-tailed Pearson Correlation Coefficient between agronomic traits and ear traits of Gaurab and Deuti indicated that there was a positive relation among these traits (Table 2). However, a positive and highly significant (r = 0.766**) relation between ear fill and ear length was observed while a very weak relation (r = 0.096*) between ear height and grain weight/ear was also noticed in the study. This suggests that taller the ear height lower the grain yield/ear. This could be one of the reasons why farmers are reporting stalk lodging in local varieties. There was a positive and highly correlated relationship among ear fill, ear length and ear circumference with grain weight/ear. The results also indicate that plant height and ear height were weakly related to other ear traits which were highly related to grain weight per ear, the important yield attribute.

Table 2. Combined over years bivariate relationship among individual ear traits and agronomic traits between hybrid (Gaurab) and OPV (Deuti) maize as affected by mixed cultures during 2006-2007 at Dukuchhap, Lalitpur (n = 440)

Attribute	Plant height, cm	Ear height, cm	Ear length, cm	Ear fill	Ear circumference
Plant height, cm					
Ear height, cm	0.570 (**)				
Ear length, cm	0.222 (**)	0.163 (**)			
Ear fill	0.181 (**)	0.185 (**)	0.766 (**)		
Ear circumference	0.141 (**)	0.182 (**)	0.308 (**)	0.278 (**)	
Grain weight/ear	0.104 (*)	0.096 (*)	0.592 (**)	0.645 (**)	0.538 (**)

**, **, Correlation significant at the P < 0.05 and P < 0.01 levels, respectively.*

Farmers' perception for Deuti variety in the locality was found positive with respect to its taste as green cobs and lodging resistant. This variety is suited for maize-rapeseed pattern as its maturity is comparable with prevailing local variety.

In this study, there was no significant difference between varied row combinations between hybrid and OPV. However, there are studies which suggest beneficial effects of varieties mixing for many crops. Studies done by Hoekstra et al (1985a) and Midmore and Alcazar (1991) showed that varietal mixture in maize gave higher yield than their pure stands. In mixed cultivar cultures, each cultivar tends to express their competitive ability, which may result in high yields (Hoekstra et al 1985b).

CONCLUSION

On the basis of two years result of the study at Dukuchhap it is recommended that maize hybrid Gaurab and OPV Deuti are comparable for grain yield and yield components. To cope up with stalk lodging problem and to attain higher grain yield these varieties are equally potential. There is no need of growing hybrid for increased grain yield as OPV cv Deuti and similar varieties can compete with hybrid Gaurab. OPV Deuti was equally comparable with local white for maturity that gives a plus point for this variety to fit in the prevailing cropping pattern of maize-rapeseed at Dukuchhap and similar domains in the Katmandu valley.

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REFERENCES

Hoekstra GJ, LW Kannenberg and BR Christie. 1985a. Grain yield comparison of pure stands and equal proportion mixtures for seven hybrids of maize. *Can. J. Plant Sci*. 65:471-479.

Hoekstra GJ, LW Kannenberg and BR Christie. 1985b. Grain yield comparison of pure stands and mixtures of different proportions for two hybrids of maize. *Can. J. Plant Sci*. 65:481-485.

Midmore DJ and J Alcazar. 1991. Mixed planting of potato cultivars: Growth yield and leaf miner damage in the cool tropics. *Exp. Agric*. 1991. 305-318.

Impact of Mulching on Wheat Yield and Weed Floras in the Mid-hills of Nepal

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ABSTRACT

Studies on the effect of mulching and weed management strategies in wheat were initiated at Khumaltar during the winter season of 2000-2002. The treatments were weedy check, handweed alone, post emergence application of sulfosufuron, and NPK application together with or without mulching. Rice straw mulch was applied at the rate of 4 t/ha. *Phalaris minor, Alopecuros* sp., *Chenopodium album, Rumex crispus, Polygonum hydropiper, Stellaria media, Cannabis sativa, and Soliva anthemifolia* were the dominant species. Among them, *C. album, P. minor* and *Alopecuros aqualis* were the dominant species. The effect of mulching was seen six weeks after wheat planting. The weedy check with mulch suppressed the weeds about fifty percent compared to that of without mulching. Wheat yields together with yield attributing characters were also higher in the treatments with straw mulch.

Key words: Management, mulching, suppression, weed floras, wheat

INTRODUCTION

Rice and wheat are the basic staple foods for the Indogangetic region of South Asia. The rice-wheat rotation is the main cropping system in this region. This is also a dominant production system in Nepal. The wheat crop occupies about 0.66 million hectares with an average productivity of 2.07 t/ha. Weeds play an important role in the production system. Many grass and broadleaf weeds are associated with wheat crop. Among them, *Phalaris minor*, a graminicious weed, is spreading and posing a serious problem in the cultivation of wheat in many parts of different agro-ecological regions of Nepal (Ranjit et al 2006). This weed mimics the wheat plants and sets seeds at almost the same time and height as the crop. Now this weed has developed resistance to isoproturon herbicide in neighboring countries. However, isoproturon resistant *P. minor* has not been recorded yet in Nepal. But researchers, extension agents and wheat growers must be careful to keep from spreading this weed in the future. Depending upon location, this weed is known by different names such as Ragate, Gahun ko mama, Ledai, Thulo matte, and Tago naincha (Ranjit et al 2006). Weeds can reduce wheat yield up to 50 percent sometimes even higher depending upon the population density and species.

Research has been carried out in many countries, including South Asia to minimize infestations of *P. minor*. A number of studies showed that mulching as well as herbicides could minimize both grass and broadleaf weeds in wheat. Among straw mulches tested, rice straw at the rate of 10 t/ha gave significantly higher yield of wheat than when no mulch was used (Upadhyaya and Tiwari 1996). Rice and sugarcane straw mulches were tested in wheat. Variable effects were observed over the years. Both types of mulches performed well giving 100 percent weed suppression. Grain yields were the lowest without mulch (Ullah et al 1998). Wheat yield and nutrient uptake were different with straw management. Among the different straw management, e.g. soil incorporation of chopped straw, soil incorporation of well rotten animal manure, and soil incorporation of animal manure together with chopped straw at 5 t/ha, the wheat yield and nutrient uptake were the highest under paddy straw incorporation with animal manure and animal manure incorporation (Verma and Bhagat 1994).

Paddy straw mulch was more effective in suppressing weeds in wheat than was stubble of the preceding crop or white polyethylene (500 gauges) lay between the rows. Nitrogen at 25 kg/ha and 50 kg/ha had no significant effect on weed populations under rainfed conditions. Maximum root growth and water uptake were obtained at 120 kg/ha N and in mulched treatments. The leaf area index was higher in conventional tillage and minimum tillage plus *Lantana camera* mulch (Verma and Acharya 1996). Wheat yields were similar in conventional and no tillage when rice mulch was spread after seeding in the northern Thailand (Jongdee et al 1994). Rice straw mulch plus sulfosulfuron @ 26 gm ai/ha and sulfosulfuron @ 28 gm ai/ha plus hand weeding one were the best in terms of weed suppression and yield attributes of wheat (Ranjit and Suwanketnikom 2003). Rice straw mulch increased wheat yield and suppressed weeds (Roy 1989, Ning and Hu 1990). Paddy straw mulch was more effective than the stubble of the preceding crop under rainfed wheat.

The objective of this study was to evaluate the effect of different weed management strategies with and without rice straw mulch on weeds in wheat in mid hill region of Nepal.

MATERIALS AND METHODS

The mulching experiment was initiated to evaluate its effect on wheat yields, yield parameters and weed floras at Khumaltar in two successive winter seasons during 2000/2001 and 2001/2002. The cropping system of the experimental plot was rice–wheat. The experiment was laid out in randomized complete block design with plot size of 2- × 5-m and the row spacing 25 cm. The variety used was Annapurna–4. The seed rate was 120 kg/ha. Chemical fertilizer was applied at the rate of 80:40:20 $N:P_2O_5:K_2O$ kg/ha. Nitrogen was given in two split doses of basal and topdressing into two equal halves. The treatment combinations were no weeding, one hand weeding, post emergence application of sulfosulfuron @ 28 gm /ha and placement of $N:P_2O_5:K_2O$ (basal dose of NPK applied 10 days after wheat emergence) with and without straw mulch. Sulfosulfuron was mixed with surfactant before application. Chopped rice straw mulch was applied at the rate of 4 t/ha one day after wheat planting. Flood irrigation was given fifty days after wheat sowing.

The number of weeds was recorded from 0.50 m^2 quadrats at 5 and 12 weeks after wheat seeding. Fresh and dry weed biomass was recorded from 0.50 m^2 after cutting the root parts. Post emergence herbicide was applied 8 weeks after wheat seeding when the grass weeds had 4-6 leaves. Herbicide was applied with a 4-nozzle power operated backpack sprayer. Flat fan nozzles were used. Wheat planting was done on 24 Nov 2000 and 23 Nov 2001 in 2000 and 2001 respectively. Harvesting was done in 24 May 2001 and 28 May 2002 in 2000 and 2001 respectively. Data were analyzed by using MSTATC statistical package (Anonymous 1986).

RESULTS AND DISCUSSION

EFFECT ON WEEDS

Weeds like *Chenopodium album, Rumex* sp.*, Polygonum hydropiper, Stellaria media, Cannabis sativa, Senecio vulgaris* were among the broadleaf weeds and *Phalaris minor and Alopecuros* sp. were among the grass weeds in the experimental field. Among them, *C. album, P. minor* and *Alopecuros* were the dominant weeds. In both the years, the number of broadleaf was higher than the grass weeds.

Both grass and broadleaf weeds were suppressed by the straw mulch. Sulfosulfuron herbicide reduced both groups of weeds. Sulfosulforon with mulch reduced grasses by 40 percent compared to no mulch. Placement of NPK reduced weed populations both with mulch and without mulch compared to other treatments 5 weeks after seeding. However, weed populations increased by 12 weeks after seeding, but weed numbers were less with mulch. Broadleaf weeds were comparatively higher than grasses in the NPK placement treatment during 2000/2001 (Table 1 and 2).

Table 1. Effect of different treatments on weeds at five weeks after seeding (WAS) in wheat at Khumaltar, 2000/01 to 2001/02

Treatments	Weed count at 5 WAS/0.50m^2											
	Broadleaf						Grass					
	2000/01		**2001/02**		**Mean**		2000/01		**2001/02**		**Mean**	
	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch
Check	125	78	258	354	192	216	106	46.6	24	7	65	27
Hand weeding†	140	90	265	476	203	283	99	47	20	8	60	28
Sulfosulfuron††	118	88	447	552	283	320	93	50	28	16	61	33
NPK placement	82	59	371	407	277	233	51	28	31	12	41	20
F-test		**		ns				*		ns		
LSD (0.05)		24		-				44		-		

†One handweeding; ††@ 28 g/ha. ns, not significant; *, significant; **, highly significant.

Table 2. Effect of different treatments on weeds at 12 weeks after seeding (WAS) in wheat at Khumaltar, 2000/01 to 2001/02

Treatments	Weed count at 12 WAS/0.50m^2											
	Broadleaf						Grass					
	2000/01		**200102**		**Mean**		2000/01		**2001/02**		**Mean**	
	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch
Check	166	98	1034	478	600	288	86	67	26	26	56	47
Hand weeding	35	37	161	177	98	107	19	21	24	28	22	25
Sulfosulfuron @ 28 g/ha	54	44	274	224	164	134	11	17	11	16	11	17
NPK placement	126	104	258	377	192	241	70	57	54	39	62	48
F-test		**		**				**		ns		
LSD (0.05)		**29**		**223**				**21**		-		

†One handweeding; ††@ 28 g/ha. ns, not significant; *, significant; **, highly significant.

There was no significant difference in weed numbers during the first four weeks after wheat seeding. Grass weeds were less compared to broadleaf weeds both in mulch and no mulch treatments. Weed populations differed in mulch and no mulch treatments 60 days after seeding. There were significant differences between the number of broadleaf and grass weeds. However, there was not much impact of sulfosulfuron and NPK placement on broadleaf weeds in either mulch or no mulch treatments. In the weedy check, mulch suppressed on broadleaf weeds in 2001/02 (Table 1 and 2).

The two year mean data showed that grass weeds were affected by the mulch both 5 and 12 weeks after wheat seeding. There were no differences in weed suppression with handweeding alone and NPK placement did regardless of mulching. The weedy check and sulfosulfuron, with and without mulch suppressed both groups of weeds (Table 1 and 2)).

Both broadleaf and grass weed biomass were less in mulch treatments. NPK placement without mulch and the weedy check without mulch gave comparable weed biomass as compared to handweeding and sulfosulfuron application. Weed biomass was similar in the weedy check, NPK placement. Grass weed weight was also less in mulch compared to without mulch (Table 3).

Table 3. Effect of treatments on weed biomass in wheat at Khumaltar

Treatments	Weed Biomass at 12 WAS/0.50m^2											
	Broadleaf						Grass					
	2000/2001		2001/02		Mean		2000/2001		2001/02		Mean	
	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch
Check	43.3	31.6	18.1	7.1	31	19	13.0	16.5	0.96	0.86	7	7
Handweeding†	5.8	10.0	3.2	2.4	5	6	2.8	4.0	0.61	0.79	2	2
Sulfosulfuron††	13.3	12.0	3.9	1.6	9	7	3.8	5.3	0.30	0.27	2	3
NPK placement	38.3	30.2	14.7	7.6	27	19	5.8	7.0	2.10	1.50	4	4
F-test		**		**				ns		*		
LSD (0.05)		10		3				-		0.55		

†One handweeding; ††@ 28 g/ha. ns, not significant; *, significant; **, highly significant.

EFFECT ON YIELD PARAMETERS

The effect of mulching was noted in wheat plants in 6 weeks after wheat seeding. Wheat plants were dark green in all the treatments with mulch compared to without mulch. There was a significant difference in the number of tillers/m^2 and grain yield in 2000/2001. Tillers/m^2 ranged from 202 in the weedy check without mulch to 399 in sulfosulfuron plus mulch. Tillers/m^2 was more in mulch compared to no mulch in all treatments except the NPK placement. Grain yield was significantly different, yielding higher in treatments with straw mulch. The highest grain yields were 4104 and 3878 kg/ha recorded in sulfosulfuron with and without mulch, respectively, followed by hand weeding (3770 and 3478 kg/ha) with and without mulch. The lowest grain yield 2819 and 1684 kg/ha, was recorded in the weedy check with and without mulch respectively. In all treatments, grain yields were higher with mulch compared to without mulch (Table 4).

Table 4. Treatment effect on the yield attributes of wheat at Khumaltar, 2000/2001 to 2001/02

Treatments	Plant height, cm						Tillers/m^2					
	2000/01		2001/02		Mean		2000/01		2001/02		Mean	
	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch
Check	111	111	95	108	111	110	202	242	125	273	164	258
Hand weeding one	113	113	105	108	113	111	285	300	184	262	235	281
Sulfosulfuron @ 28 g/ha	114	114	101	105	114	110	372	399	207	222	290	311
NPK placement	113	115	92	101	113	108	277	270	119	199	198	235
F-test		ns		*				**		**		
LSD (0.05)		-		5.2				39		23.3		

Table 4. Contd…

Treatments	Seeds/panicle						1000 seed wt, g					
	2000/01		2000/01		2000/01		2000/01		2000/01		2000/01	
	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch	Mulch	No Mulch	Mulch	No mulch	Mulch
Check	43	52	43	52	43	52	33	32	37	36	35	34
Hand weeding one	54	49	50	48	52	49	32	31	35	35	34	33
Sulfosulfuron @ 28 g/ha	53	47	43	45	48	46	32	32	37	37	35	35
NPK placement	58	47	45	46	52	47	33	31	35	35	34	33
F-test		ns		ns		ns		ns		ns		ns
LSD (0.05)		-		-		-		-		-		-

Table 4. Contd…

Treatments	Yield, kg/ha					
	2000/01		2001/02		Mean	
	No mulch	Mulch	No Mulch	Mulch	No mulch	Mulch
Check	1684	2819	1569	2715	1627	2767
Hand weeding one	3478	3770	2439	3028	2959	3399
Sulfosulfuron @ 28 g/ha	3878	4104	2693	3084	3286	3594
NPK placement	1886	3018	1645	2003	1766	2511
F-test		**		*		
LSD (0.05)		344		456		

ns, not significant; *, significant; **, highly significant.

Plant height, tillers/m^2 and grain yield were significantly different in 2001/02. Plant height ranged from 92 cm in NPK placement plus no mulch to 107 cm in sulfosulfuron, handweeding plus mulch. Number of tillers/m^2 ranged from tillers/m^2 119/m^2 in NPK placement plus no mulch to (273/m^2) in mulch plus weedy check. Grain yield was lower in 2001/02 than in 2000/01. However, grain yields were higher in all treatments with mulch (Table 4). The two year mean showed that there is not much differences in plant height, seeds per panicle and thousand seed weight. But tillers per square meter and grain yield were higher in all treatments with mulch than without mulch (Table 4).

CONCLUSION

Phalaris minor and *Alopecuros* sp. were major grass weeds in the wheat field. *Chenopodium album, Rumex* sp., *Stellaria media, Polygonum hydropiper* and *Senecio vulgaris* were among the broadleaf weeds. Straw mulch reduced broadleaf as well as grass weeds in both the years. About 50 percent weeds were reduced in no weeding with mulch. The suppression of grass weeds by sulfosulfuron plus mulch was higher. Mulch increased grain yield of wheat. Higher yield was recorded with herbicide plus mulch in both the years. From this study, it can be concluded that rice straw mulch alone may achieve significantly higher yields than control. However, it is possible to increase grain yield by adding herbicide or hand weeding to mulch in the mid hill regions.

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REFERENCES

Anonymous. 1986. MSTATC User's guide. East Lansing, Michigan State University, USA.

Jongdee B, DA Saunders and GP Hettel. 1994. Tillage methods for wheat after rice in paddy soils in Thailand. Wheat in heat stressed environments: irrigated, dry areas and rice-wheat farming systems. **In:** *Proceedings of the international conferences* held at Wad Medani, Sudan 1-4 February 1993 and Dinapur, Bangladesh 13-15 Feb., 1993. Pp. 272-275.

Ning CG and TG Hu. 1990. The role of straw covering in crop production and soil management. *Better Crops International* 6(2):6-7.

Ranjit JD and R Suwanketnikom. 2003. Response of weeds and wheat yield to tillage and weed management. *Kasetsart J. Nat. Sci.* 37:389-400.

Ranjit JD, RR Bellinder, P Hobbs, NK Rajbhandari and P Kataki. 2006. Mapping *Phalaris minor* under the rice-wheat cropping system in different agro-ecological regions of Nepal. *Nepal Ag. Research Journal* 7:54-62.

Roy K. 1989. Effects of mulching and nitrogen application on weed population in rainfed wheat. *Agricultural Science Digest* 9(2):102-104.

Upadhyaya VB and JP Tiwari. 1996. Influence of nitrogen, seed rate and mulch on wheat (*Triticum aestivum*) varieties under late sowed conditions. *Indian Journal of Agronomy* 41:4,562-565.

Ullah R, A Rashid, A Khan and S Gulam. 1998. Effect of different mulching materials on the growth and production of wheat crop. *Sarhad Journal of Agriculture* 14:1,21-25.

Verma TS and RM Bhagat. 1994. Nutrient dynamics and wheat yield as influenced by paddy straw management practices. *Crop Research*, Hissar 7(3):382-390.

Verma MC and CL Acharya. 1996. Root development, leaf area index, water use and yield of rainfed wheat under different soil conservation practices and levels of nitrogen. *Journal of the Indian Society of Soil Science* 44(4):625-632.

Soil Fertility under Improved and Conventional Management Practices in Sanga, Kavrepalanchowk District, Nepal

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ABSTRACT

A study was carried out to compare the fertility of soils under improved soil management practice with that of prevailing conventional practice and to assess the farmers' perception on the improved practice in the upland farming system. The study was carried out in Nasikasthan Sanga of Kavrepalanchok district of Nepal. Soil samples were collected from fields under improved conventional practice. Samples were taken at 0-15 and 15-30 cm depths and were analyzed for various physico-chemical properties to compare the fertility status of the soils under both the practices. Altogether 68 farmers were interviewed to have information on farming practices and information pertinent to improved soil management practice being adopted by them. Results from soil physico-chemical analysis showed higher fertility of soils under improved practice in terms of more favorable pH level, contents of exchangeable bases, available phosphorus and soil organic matter compared to prevailing conventional soil management practice. Moreover, majority of the farmers believed that soil fertility and physical condition of their upland soils had improved and that the productivity of major upland crops had also increased after the adoption of improved soil management practice. Improved practice could play an important role in the sustainable management of upland soils in the mid hills of Nepal. It is however, desirable to conduct long-term research to further ascertain the effect of the practice on soil fertility of different soil types and land uses.

Key words: Improved soil management practice, organic matter, soil fertility, upland

INTRODUCTION

The overall status of inherent soil fertility is poor in most of the cultivated soils in the mid hills of Nepal. According to Shreier et al (1995) and Brown (1997) nitrogen and phosphorus levels in the soils are highly deficient with low organic matter content and supply. However, due to wide distribution of mica dominated bed rocks, potassium is abundantly available (Shreier 1999). Fertility decline of the mid hills soils have been reported by many authors (Carson 1992, Turton et al 1995, Schreier et al 1999, Neupane and Thapa 2001 and Pilbeam et al 2005). Major reasons leading to the decline in soil fertility are regarded as accelerated erosion, problems associated with red soils, reduced FYM/compost supply, and increased use of acid forming chemical fertilizers.

Two principal practices for maintaining soil fertility in the mid hills of Nepal are application of FYM and/or application of chemical fertilizers (Pilbeam et al 2005). FYM and compost are the main sources of plant nutrients and organic matter to the soil in the subsistence upland farming system of mid hills. However, there exist two issues related to the application of FYM and compost- problems of supplying an adequate amount of FYM and compost, and problems associated with the quality of FYM and compost. The supply of FYM and compost have been constantly declining owing to the reduced livestock herd size maintained by the farmers due to the shortage of labor, and gradually shrinking grazing lands and landholdings (Poudel and Thapa 2001). Preparation and use of compost, on the other hand, has also been marred by the above mentioned reasons together with reduced supply of plant residues and forest litter as its main ingredients. On the other hand, in the usual farmers' practice, farmers do not pay much attention to the proper decomposition of FYM leading to high C/N ratio and poor quality of FYM. Exposure to direct sunlight of FYM and wastage of cattle urine also result in substantial nutrient loss. Only few farmers practice composting, but without following proper methods, yielding compost of poor quality.

With increasing cropping intensity and introduction of high nutrient demanding cash crops, increasing trend of chemical fertilizers application has been observed over the last couple of decades. However, due to the farmers' increased tendency of applying acid forming nitrogenous fertilizers only such as urea, improper combination of fertilizers and mistiming of application have resulted in adverse effects in soil environment leaving the fertility status of uplands of mid hills at stake.

Realizing the seriousness of the problem, the Government of Nepal has introduced a package of improved practices, through its agriculture extension system, aiming at correcting the above mentioned problems associated with application of FYM and compost, and chemical fertilizers for sustainable management of upland soils through the effective organic matter management. The improved practice imparts knowledge and skills on farmers about the preparation and utilization of FYM and compost to enhance the quality of FYM and compost and to ensure the preservation of otherwise being lost nutrients in the course of preparation and application of FYM and compost, and through uncollected livestock urine. On the other hand, under the improved practice, farmers are also provided with necessary knowledge and skills about the judicious use of chemical fertilizers. The improved practice is being disseminated among the farmers through the farmers' field-based training and demonstration activities.

It is indispensable to have the comprehensive assessment of agricultural technology being adopted by the farmers for its successful wider scale dissemination among the farming communities. Particularly, only a few studies have been conducted so far in determining the effectiveness of improved practice in improving soil fertility status of the upland soils in the mid hills. This paper attempts to assess the effectiveness of the improved soil management practice mainly through comparing the fertility status of soils under improved practice with that of other prevailing practices in one of the intensively cultivated upland fields of the mid hills of Nepal.

MATERIALS AND METHODS

Study area

The study was conducted in May-June, 2006 in the three settlements (ward number 2, 5 and 6) of

Sanga Nasikasthan Village Development Committee (VDC) in Kavrepalanchok district of central Nepal. Situated at 1,480 to 1850 m from average sea level, Sanga lies about 25 km east of Kathmandu, the capital city. It occupies a total area of 918 km^2. The VDC enjoys mainly subtropical climate but the southern part also experiences temperate climate. The temperature reaches as high as 34^0C during summer (Jun-Aug) and as low as 2^oC during winter (Dec-Feb) with annual precipitation of 1581 mm. June to September is the main season for rainfall and receives 80% of the total annual precipitation. The VDC has mostly sloppy topography (70% of the total area). Total agricultural land is 850 ha with 550 ha upland area.

The soils of the VDC are broadly divided into red and non-red soils. The red soils correspond to Rhodustults and Haplustults formed, on quartzitic phyllite, while non-red soils correspond to Ustochrepts and Dystrochrepts, formed on phyllite, schist, quartzite, sandstone and siltstone, following the Soil Taxonomy of the USDA system (Brown et al 1999).

Major upland crops are maize (*Zea mays* L.), buckwheat (*Fagopyrum esculentum* L.), wheat (*Triticum aestivum* L.), rapeseed mustard (*Brassica campestris*, var. *toria*), potato (*Solanum tuberosum* L.), finger millet (*Eleucine corocana* L.) and vegetables. Likewise, rice (*Oryza sativa* L.), wheat and potato and vegetables are the major crops grown in the irrigated land.

The VDC has 1008 households with the population of 5,968 (Male-51.34%, Female-48.66%). Agriculture and livestock raising are the main occupation of the villagers.

Soil sampling and analysis

Soil samples were collected as per the sampling framework given in Table 1. Fields, at least for five years, under these practices were used for sampling. Samples were taken at the depths of 0-15 and 15-30 cm. Composite samples were prepared from the three sub-samples taken at each sampling depth.

Table 1. Soil sampling framework used for the collection of soil samples

Category	Soil management practice	Representative cropping pattern
Improved	Improved FYM/compost + NPK fertilizers (n = 5)	Maize-Potato/Vegetable
Conventional	N fertilizers only + Conventional FYM (n = 5)	Maize-Mustard/Potato
High external inputs- based	Poultry litter + Conventional FYM + Chemical fertilizer (n = 5)	Vegetables/Potato-Maize
Legume-based	NPK Fertilizers + Legumes (n = 5)	Maize-Legumes-Potato/Mustard
Reference soils	Virgin forest soils (n = 5)	

The samples were air-dried and passed through a 2-mm mesh sieve to determine various physico-chemical properties. Soil pH was determined in H_2O or 1 M KCl with soil to solution ratio of 1:5 by the glass electrode method (denoted as pH_w and pH_k). Total carbon (T-C) and total nitrogen (T-N) contents were determined with an NC analyzer (Sumika Chemical Analysis Service, Co., Tokyo, Sumigraph model NC-80). Available P content was determined by the Bray II method (Bray and Kurtz 1945). Exchangeable Al, H and NH_4 were extracted with 1 M KCl. The contents of exchangeable acidity (Al + H) was determined by the titration method with 0.01 M NaOH and content of the exchangeable Al with 0.01 M HCl. The content of exchangeable H was calculated as the difference between the values of the exchangeable acidity and exchangeable Al. The amount of exchangeable NH_4 was determined by the Indophenol blue method (Mulvaney 1996). Cation exchange capacity (CEC) and the contents of exchangeable bases (Ca, Mg, K and Na) were determined after successive extraction using 1 M NH_4-OAc (pH 7.0) and 10% NaCl. The amount of NH_4^+ replaced by Na was determined by the steam distillation and titration method. Exchangeable base concentrations were determined by atomic absorption spectrometry (Ca, Mg, and K) and by flame photometry (Na) (Shimadzu, Co., Kyot, AA-610S). Particle size distribution was determined by the pipette method. Bulk density was determined after oven drying at 105^{o}C of core samples of undisturbed soils.

Operational definition of soil management practices

Improved soil management practice: This is an organic matter-based soil management practice. In this practice, FYM and compost are prepared and applied in the fields following the prescribed procedure. The prescribed procedure, which aims at nutrient preservation and quality enhancement of FYM and compost, and utilization of cattle urine as the important source of nitrogen for the crop, involves the following steps:

i) Protect from direct sunlight
ii) Protect from rain and run-on water
iii) Add cattle urine into the FYM or compost pit or use directly in the field as a source of nitrogen.
iv) Prepare compost using effective micro-organisms (EM) following prescribed procedure.
v) Incorporate the FYM or compost in the field during land preparation or keep in big heaps, covered with plastic or other covering materials, for later use.

Moreover, while fertilizing with chemical fertilizers, a combination of urea, diammonium phosphate (DAP) and muriate of potash (MOP) is used based on recommendation of soil test results.

Conventional soil management practice: In this practice, farmers used FYM prepared by their own conventional method. In usual farmers' conventional method of preparation, due to the farmers' ignorance about the proper method of preparation, FYM is not properly decomposed. Moreover, FYM is exposed to direct sunlight resulting in substantial nutrient loss. There is also no system of collection and utilization of cattle urine. Only inorganic fertilizer used is urea. This practice is the most common practice in subsistence farming of the study area.

High external inputs-based: In this case, the main source of plant nutrients was inorganic fertilizers which were supplemented by poultry litter and a little amount of conventional FYM. This was the popular soil management practice among commercial and semi commercial vegetable growers. This type of practice can be regarded as 'high external inputs' based soil management practice

Legumes-based: In this practice besides using inorganic fertilizers and conventional FYM, farmers incorporated one legume crop, mostly peas, in the yearly cropping cycle. In this soil management practice, legume crop serves two purposes, namely, as a source of nitrogen in the soil and as a cash crop as there was a good market for green peas in the local market.

Farmers' interview

Information about farmers' perception on the improved soil management practices was obtained through the interview with the farmers adopting the improved practice. Out of the 115 farmers adopting the improved practice, 68 farmers (60%) were randomly selected for the interview.

A set of structured questionnaire was used for the interview. Questionnaire was pre tested by interviewing one SSM practicing farmer from each ward. The final set of structured questionnaire mainly consisted of questions pertinent to household demographic information of the respondent, general information on farming practices, farmer's resource endowment, and farmers' perception about the role of improved practice in improving soil fertility status of upland fields and productivity of upland crops.

Data analysis

Statistical significance of difference in the soil physico-chemical parameters between the two soil management practices was determined through t-test using SPSS (SPSS Inc. 2002). The t-test was also used to compare productivity of upland crops before and after the adoption of improved practice. Other results of interview for both the practices were compared using simple arithmetic.

RESULTS AND DISCUSSION

General aspects of soil fertility

Results of physico-chemical analysis of the soils are given in Table 1 and 2. Relatively low T-C contents for both the soils might be due to the apparent fact that soil carbon pool increasingly diminishes when forest lands are converted into agricultural land for cultivation. The contents of T-C and T-N of the soils under improved practice were higher than those under conventional practice. Comparatively higher T-C, T-N levels of soils under improved practice might be due to the return of organic manures and residues to the upland fields through the means of improved FYM and compost. Relatively low level of the T-N for both the practices reflects the fact that Nepalese soils, especially upland soils of the mid hills, mostly being deficient in nitrogen (Pandey 1996).

Table 1. Selected physico-chemical properties of soils studied (0-15 cm)

Parameters	Conventional practice (n = 5)		Improved practice (n = 5)	
	Ave	(sd)	Ave	(sd)
pHw**	5.11	(0.35)	5.88	(0.24)
pHk**	3.82	(0.18)	4.85	(0.34)
EC	6.33	1.68	8.83	3.19
Exchangeable H	0.30	0.34	0.07	0.01
Bulk Density, g cm-3	1.15	(0.05)	1.20	(0.01)
Total C*, g kg-1	9.40	(1.07)	12.34	(1.65)
Total N*, g kg-1	0.99	(0.11)	1.34	(0.21)
C/N	9.54	(0.60)	9.24	(0.30)
Mineral N, g kg-1	69.46	(14.35)	129.41	(69.46)
NH4-N, cmolc kg-1	0.05	(0.01)	0.05	(0.01)
Available P**, mg kg-1	14.13	(3.58)	272.91	(61.06)
Exchangeable Ca**, cmolc kg-1	1.87	(1.28)	4.43	(1.06)

Parameters	Conventional practice (n = 5)		Improved practice (n = 5)	
	Ave	(sd)	Ave	(sd)
Exchangeable Mg **, cmolc kg-1	0.42	(0.17)	1.30	(0.28)
Exchangeable K, cmolc kg-1	0.21	(0.09)	0.45	(0.26)
Exchangeable Na, cmolc kg-1	0.05	(0.02)	0.05	(0.02)
Sum bases*	1.99	(1.80)	5.00	(1.66)
Base saturation, %	27.26	(25.89)	54.07	(17.91)
CEC*, cmolc kg-1	7.39	(1.14)	9.30	(0.91)
ECEC*, cmolc kg-1	2.66	1.49	5.02	1.64
Exchangeable Al*, cmolc kg-1	0.68	(0.46)	0.02	(0.04)
Al Saturation*	32.90	(23.42)	0.67	(1.18)
Clay*, %	9.14	(2.93)	18.97	(7.68)
Silt , %	18.39	(3.12)	18.24	(2.24)
Sand, %	72.47	(3.13)	62.79	(9.43)

*Sum bases, exchangeable Ca + Mg + K + Na; base saturation, sum bases/CEC X 100; ECEC (effective CEC), exchangeable Ca + Mg + K + Na + Al; Al saturation; exchangeable Al/ECEC X 100. *, **, Indicate significant differences between the two soil management practices at 5% and 1% level of significance respectively using t-test.*

Relatively low CEC levels were found which are probably associated with the dominance of kaolinitic clays in the highly weathered soil minerals. Shah and Schreier (1995) described the reasons for low cation exchange capacity in Jhikhu Khola watershed, one of the typical watersheds in the mid hills of Nepal, as the result of inherited bedrock conditions (sandstone, siltstone, quartzite), and extensive weathering leaving kaolinite as the dominant clay minerals in these soils. For them, the low level of soil organic matter resulted from the historic losses of organic matter due to soil erosion, crop removal and litter collection was the another cause for the low exchange capacity of the soils. Comparatively higher CEC values for soils under improved management are

Table 2. Selected physico-chemical properties of poils studied (15 - 30 cm)

Parameters	Conventional practice (n = 5)		Improved practice (n = 5)	
	Ave	(sd)	Ave	(sd)
pHw**	4.76	(0.37)	5.86	(0.39)
pHk*	3.78	(0.17)	4.59	(0.47)
EC*	3.78	(1.00)	6.12	(1.75)
Exchangeable H	0.16	(0.04)	0.09	(0.03)
Bulk density, g cm-3	1.21	(0.07)	1.30	(0.06)
Total C*, g kg-1	5.41	(1.43)	7.50	(0.88)
Total N**, g kg-1	0.61	(0.09)	0.88	(0.12)
C/N	8.93	(1.24)	8.50	(0.37)
Mineral N, g kg-1	39.25	(8.66)	53.07	(16.58)
NH4-N *, cmolc kg-1	0.05	(0.01)	0.03	(0.01)

Available P, mg kg-1	4.73	(1.70)	72.88	(26.45)
Exchangeable Ca**, cmolc kg-1	1.30	(1.72)	3.21	(1.17)
Exchangeable Mg **, cmolc kg-1	0.27	(0.11)	1.00	(0.36)
Exchangeable K, cmolc kg-1	0.11	(0.04)	0.22	(0.12)
Exchangeable Na, cmolc kg-1	0.04	(0.02)	0.05	(0.01)
Sum bases*	1.72	(1.79)	4.48	(1.63)
Base saturation, %	22.97	(24.91)	56.70	(22.97)
CEC, cmolc kg-1	7.74	(1.53)	8.02	(1.23)
ECEC, cmolc kg-1	3.32	(1.20)	4.51	(1.59)
Exchangeable Al *, cmolc kg-1	1.63	(0.25)	0.04	(0.04)
Al Saturation*	54.26	(29.73)	1.21	(1.48)
Clay *, %	10.69	(2.11)	19.92	(7.24)
Silt, %	19.18	(2.72)	19.04	(2.68)
Sand, %	70.13	(3.05)	61.04	(9.37)

*Sum bases, exchangeable Ca + Mg + K + Na; base saturation, sum bases/CEC X 100; ECEC (effective CEC), exchangeable Ca + Mg + K + Na + Al; Al saturation; exchangeable Al/ECEC X 100. *, **, Indicate significant differences between the two soil management practices at 5% and 1% level of significance respectively using t - test.*

attributable to high clay content of these soils. And, in case of surface soils, higher levels of soil organic matter derived from enhanced quality and quantity of FYM/compost may also have contributed to the higher CEC values. CEC is potential capacity of cation retention measured at pH 7. So, this does not reflect field pH condition. Effective CEC (ECEC) values for the both of soils were much lower than the respective CEC values. It suggests the contribution of negative charges derived from clay minerals to the level of the CEC and that predominance of permanent negative charges of clay minerals under acidic conditions. Moreover, permanent negative charge of soils under improved management might have been derived more from the increased input of improved FYM or compost leading to comparatively higher CEC values.

The results showed soils under both management systems to be acidic. This finding is consistent with the previous findings in the context of the mid hills of Nepal (Shreier et al 1999, Brown et al 1999). The general soil acidity in the mid hills comes from mainly two sources, namely, dominance of quartzite parent materials and increasing use of acidifying fertilizers like ammonia and urea. Negative consequences of continuous application of acidifying fertilizers have been also reported elsewhere. In Northwest Nigeria high rates of application of acidifying mineral fertilizers over extended periods resulted pH dropping to below 5 (Kyiogwom et al 1998). However, soils improved management practice showed less acidic condition. Comparatively more favorable pH in this soils compared to soils under conventional practice may be attributed to the use of good quality FYM or compost and use of combination of NPK fertilizers.

Relatively, low exchangeable Mg level in both the soils was probably the impact of inherent parent materials such as sandstone, siltstone and quartz. Relatively favorable exchangeable K values are expected to be the result of wide distribution of mica within the parent material (Shreier et al 1999). Higher contents of exchangeable Ca and Mg were observed in improved practice than the conventional one, which are attributable to the judicious use of chemical fertilizers and use of enhanced quantity and quality of FYM and compost in the former one. Moreover, the variation in the level of exchangeable bases in these two soils was probably also due to the influence of respective pH and CEC values of these soils that in turn, can be expected to be affected by soil management practices and soil texture.

Improved practice soils were free from potential Al toxicity with only traces of Ex Al. Conventional practice soils, on the other hand, were found to be more vulnerable for potential Al toxicity with exchangeable Al value of 0.68 and 1.63 $cmol_c$ kg^{-1} for the surface and sub-surface soils, respectively. Importantly, considering critical Al saturation of >20 percent for optimum maize yield (Juo and Franzluebbers 2003) and the maize being the main upland crop in the study area, conventional practice soils with Al saturation of 54.2 may be regarded as unsuitable for maize cultivation.

The two soils were found greatly varied with available P level. Low available P contents for conventional soils could be ascribed to the lack of P source as fertilizer and their highly acidic condition. Moreover, use of acidifying fertilizer like urea alone also might have affected decreasing pH and the resulting comparatively lower P level. This is because of increasing P unavailability in the soils with strongly acidic reaction. Other studies also reported the similar findings in the soils of the mid hills of Nepal (Shreier et al 1999 and Westarp et al 2004). One experiment conducted in cotton soil revealed that phosphorus use efficiency was double (11.2 kg ha^{-1}) at soil pH between pH 6.0 and 7.0 as compared to the amount at soil pH 5.09. On the other hand, a high level of available P in improved practice soils was probably due to the fertilization effects of DAP-a P containing fertilizer and an increased rate of good quality FYM and compost. These results, however, somewhat contradicted with the fact that problem of P absorption in rain-fed soils (Shreier et al 1999) and mid hills soils to be generally deficient in available P (Pandey 1996, Shreier et al 1999, Westarp et al 2004). Pierzynski et al (1994) also reported that in general, the acidic nature of soils and inherited low P-levels influence the availability of phosphorus in the Hindu Kush Himalaya region.

Higher clay content of improved practice soils was found which seemed to have resulted due to the difference in inherent soil types and might be partially responsible for the differences in other physico-chemical properties between these two soils.

Comprehensive evaluation of improved and conventional practice in relation to soil fertility

Different variables pertinent to soil physico-chemical properties discussed in preceding section may also be correlated with each other and so may not be independent of each other. Principal component analysis (PCA) provides a way of transforming large numbers of possibly correlated variables into smaller numbers of uncorrelated variables called principal components. With PCA, number of variables of the data set is reduced but most of the original variability in the data is retained.

Variables analysed in PCA were pH_w, pH_k, T-C, T-N, C/N, NH_4-N, available P, exchangeable Ca, Mg and K, CEC, exchangeable Al, ECEC, Al saturation, bulk density clay, silt and sand content and. The PCA could extract four principle components, PC 1, PC 2 and PC 3 and PC 4 (Table 3). All the PCs collectively explained 90% variation in the data. PC 1 showed high factor loading for most of the variables studied. It has contributed 63% to the variation in the data having variables, pH, Exch. bases, SOM, clay content, available P, etc. with high positive factor loading and exchangeable Al, Al saturation and sand content as variables with high negative factor loading (Table 3). Likewise, PC 2 could explain only 11.4% variation having variables, NH_4-N and silt with high positive and negative factor loading respectively. PC 3 and PC 4 did not show any variable with high factor loading (> 70%).

Figure 1 shows the PC ordination of the first two principal components, with the data points grouped according to the soil management practice. The distribution of the data points in the ordination diagram shows high propensity of improved practice soils for PC 1 indicating clay soils with higher fertility status compared to conventional practice soils. Conventional practice soils, on the other hand, showed relatively high inclination towards PC 2 but at the same time very low inclination for all other fertility parameters described by PC 1 indicating light and less fertile soils. Distribution of data points also indicates more variation in data of improved practice than conventional practice. Thus, improved practices showed preferable properties of soil fertility for the crop production compared to conventional practice soils.

Table 3. Principle component analysis (PCA) of the variables studied for the surface soils (0-15 cm) in different soil management practices

Parameters	Factor loadings			
	PC 1	PC 2	PC 3	PC 4
pHw	0.78	-0.51	-0.14	0.26
pHk	0.97	-0.14	0.03	0.10
Bulk density	0.72	-0.01	0.35	-0.19
T-C	0.90	0.16	0.30	0.12
T-N	0.95	0.15	0.16	-0.02
C/N	-0.64	-0.05	0.50	0.53
CEC	0.71	0.11	0.29	0.33
Exchangeable Ca	0.85	0.05	-0.31	-0.32
Exchangeable Mg	0.95	-0.10	0.00	0.21
Exchangeable K	0.80	0.44	0.07	0.15
Exchangeable Al	-0.80	0.19	0.52	-0.14
ECEC	0.91	0.12	-0.15	-0.25
Al saturation	-0.83	0.12	0.46	-0.11
NH4-N	-0.14	0.76	-0.35	0.36
Available P	0.80	-0.39	0.03	0.39
Clay	0.82	-0.07	0.39	-0.31
Silt	0.37	0.82	-0.07	0.09
Sand	-0.85	-0.19	-0.33	0.25
Contribution, %	63.01	11.44	8.76	6.84

Assessment of appropriateness of 'improved FYM/compost' technology from farmers' perspectives

Improvement in soil fertility and surface hardness: Sixty percent of farmers interviewed believed that fertility of their upland soils had been improving since the adoption of improved practice. Such farmers cited combined use of NPK fertilizers and improvement in quality of FYM and compost as the major reasons. However, rest expressed that they did not experience any change in the overall fertility.

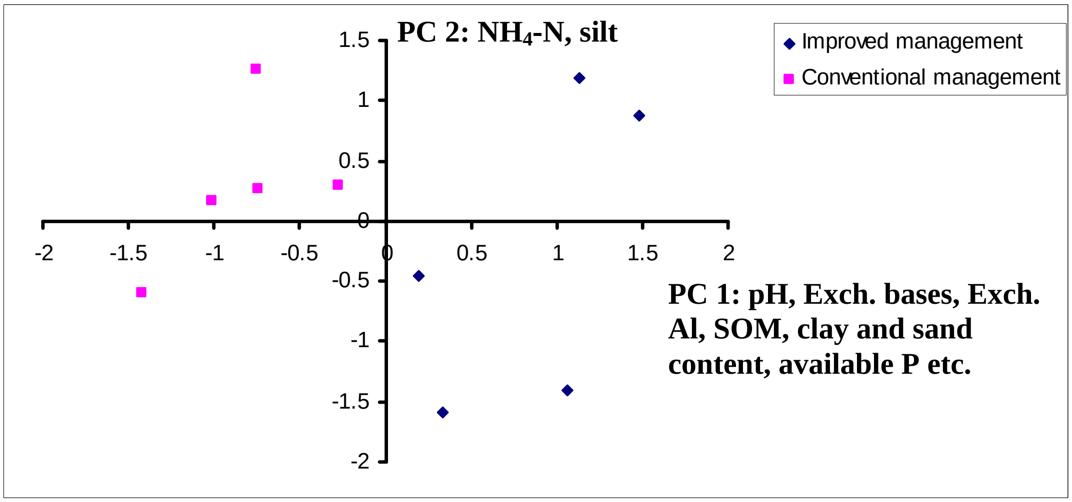

Figure 1. PCA ordination for the first two principle components (PC 1 and PC 2) for the soil analysis data.

On the other hand, most of the farmers (75%) perceived that the use of improved FYM/compost and fertilization with combination of N, P and K fertilizers resulted in decrease in soil hardness of their upland fields making the cultivation practices easier than before. However, others believed that there was no change in the soil hardness. The farmers with negative opinion on soil fertility and soil hardness improvement thought that their soils were too deteriorated and would need more time for the recovery of the fertility and good physical condition.

Change in productivity of upland crops: Productivity of major upland crops in the study area before and after adoption of 'improved FYM/compost' technology is compared in Table 4. A significant increase in productivity of three main upland crops, namely, maize (*Zea mays* L.) ($P < 0.001$), mustard (*Brassica juncea* L.) ($P < 0.01$) and potato (*Solanum tuberosum* L.) ($P < 0.001$) was observed after adoption. Better nutrient and crop management following the adoption of the new practice might be expected to have played a major role in increasing the productivity.

Table 4. Change in productivity of major upland crops (mt ha^{-1})

Crop	Before adoption of improved practice	After adoption of improved practice	% change
Maize (n = 68)	1.5	2.0	27.4
Mustard (n = 68)	0.4	0.5	21.9
Potato (n = 68)	4.6	7.1	53.0

Average productivity of maize, mustard and potato in Kavrepalanchok district was 2.45, 0.98 and 18.5 mt ha^{-1} respectively in 2004 (DADO 2005). The productivity after the adoption of improved practice as shown in Table 4 corresponds to the productivity in 2004. From the table it can be seen that the productivity of all the three crops after the adoption of new improved practice in the VDC was lower than the district average for the same season.

The increase in productivity can not be solely attributed to the effect of positive change in soil fertility since in many cases farmers commented that they were able to enjoy better harvest for the particular crop due to improvement in other aspects of crop management including increased use of improved and high yielding hybrid variety of maize, mustard and potato effective plant protection measures among others.

CONCLUSION

Soil fertility decline has been one of the main reasons for poor agricultural growth in Nepal in recent decades. Mid hills region has been worst hit by this problem because of its fragile geomorphology, steep topography and intense human pressure on land and forest resources. This situation is posing a threat to the sustainability of the agriculture system in the region. A number of factors are responsible for the decline in soil fertility. The three major factors often cited are accelerated soil erosion, increased use of acidifying fertilizers and reduced organic matter input into the soils. Many efforts are being made to avert the further worsening of the situation and restore the fertility. Organic matter based improved soil management practice is one of participatory approaches aiming at improving the soil fertility of upland soils in the mid hills of Nepal.

FYM and compost play a vital role in supplying a major fraction of plant nutrients and organic matter input into the soil in upland farming system of the mid hills. However, improper handling of preparation and field application procedures by the farmers cost substantial nutrient loss and result in poor quality of the FYM and compost. Moreover, there is a general tendency of farmers applying nitrogenous fertilizers only. This practice is believed to be responsible for the increased soil acidity and surface hardness. An improved soil management practice has been introduced to help solve above mentioned problems. This study compared the soil fertility of soils under improved soil management practice with that of prevailing conventional soil management practices and assessed the improved practice from farmers' perspectives.

Results of soil analysis showed higher fertility of soils under improved soil management practice than the soils under conventional management practices in terms of more favorable soil pH, T-C, T-N, CEC, exchangeable bases, mainly exchangeable Ca and Mg, and exchangeable Al. Moreover, soils under improved practice have higher clay content than that of conventional practice which might have influence on the fertility of the both the soils.

A number of positive effects of the adoption of the improved practice were observed. Farmers believed that fertility of their upland soils had increased and that soil hardness had also reduced facilitating ease of cultivation. A significant increase in the productivity of major upland crops including maize (*Zea mays* L.), mustard (*Brassica campestris*, var. toria), and potato (*Solanum tuberosome* L.) was found in farmers' interview. It should be, however, noted that other aspects of crop management such as use of hybrid seeds, plant protection measures and so on also played a role in increasing production.

Moreover, it is desirable to conduct a long term research on the effect of applying improved soil management practice on different soil types and land uses of the mid hills of Nepal to further ascertain the results obtained.

REFERENCES

Bray RH and LT Kurtz. 1945. Determination of total, organic, and available forms of phosphorus in soil. *Soil Sci.* 59:39-45.

Brown S. 1997. Soil fertility, nutrient dynamics and socio-economic interactions in the middle mountains of Nepal. 2004. *PhD Thesis*, interdisciplinary studies in resource management science, University of British Columbia, Vancouver, BC. **In:** Agricultural intensification and the impacts on soil fertility in the middle mountains of Nepal (S Westarp, H Shreier, S Brown and PB Shah, eds). *Can. J. Soil Sci.* 84: 323-332.

Brown S, H Shreier, PB Shah, and L. Lavkulich. 1999. Modeling of soil nutrient budgets: an assessment of agricultural sustainability in Nepal. *Soil Use Manage* 15:101-108.

Carson B. 1992. The land, the farmer and the future: A soil fertility management strategy for Nepal. *ICIMOD Occasional Paper, No. 21*. ICIMOD, Kathmandu, Nepal.

CBS. 2002. *Statistical pocket book, Nepal*. 2002. National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal.

HMG/N. 2004. *Statistical information on Nepalese agriculture 2003/2004*. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, His Majesty's Government, Singha Darbar. Kathmandu.

Juo ASR and Franzluebbers. 2003. Tropical Soils: Properties and Management of Sustainable Agriculture. Ist Edn. Oxford University Press, Inc, New York.

Kyiogwom UB, BF Umaru and HM Bello. 1998. The use of indigenous knowledge in land classification and management among farmers in the Zamfara Reserve (Electronic version). **In:** *Prospects of pastoralism in West Africa* (I Hoffmann, ed). Giessener Beiträge zur Entwicklungsforschung, Reihe I (25):220–227.

Mulvaney RL. 1996. Nitrogen – Inorganic forms. In: Methods of soil analysis (DL Sparks et al., eds.) Part 3. SSSA Book Ser. 5. SSSA, Madison. WI. Pp. 1123-1184.

Neupane RP and GB Thapa. 2001. Impact of agro-forestry intervention on soil fertility and farm income under the subsistence farming system of the middle hills, Nepal. *Agriculture, Ecosystems and Environment* 84:157-167.

Pandey SP. 1996. Soil fertility and nutrient management. **In:** *Sustainable management of soils in rainfed cropping systems in the mid-hills of Nepal*, Compilation of Main Findings. Swiss Development Cooperation (SDC)/Nepal, Agricultural Project Services Centre (APROSC), Kathmandu, Nepal.

Paudel GS and GB Thapa. 2001. Changing farmers' land management practices in the hills of Nepal (Electronic version). *Environmental Management* 28(6):789-803.

Pierzynski GM, JT Sims and GF Vance. 1994. *Soil environmental chemistry*. Lewis Publishers, CRC Press Inc., USA.

Pilbeam CJ, SB Mathema, PJ Gregory, and PB Shakya. 2005. Soil fertility management in the mid-hills of Nepal: Practices and perceptions. *Agriculture and Human Values* 22:243-258.

Schreier H, S Brown, LM Lavkulich and PB Shah. 1999. Phosphorus dynamics and soil P-fertility constraints in Nepal. *Soil Science* 164(5):341-350.

Schreier H, PB Shah, and S Brown. 1995. Challenges in mountain resource management in Nepal: Process, trends and dynamics in a middle mountain watershed. *Workshop Proceedings*. International Development Research Center and International Center for Integrated Mountain Development, Kathmandu, Nepal.

Turton CN, A Vaidya, JK Tuladhar and KD Joshi. 1995. *Towards sustainable soil fertility management in the hills of Nepal*. Chatham Maritime (Kent): Natural Resources Institute and Lumle Agriculture Center Pokhara.

Westarp S, H Shreier, S Brown and PB Shah. 2004. Agricultural intensification and the impacts on soil fertility in the middle mountains of Nepal. *Can. J. Soil Sci.* 84: 323-332.

Wheat Production under Long-term Application of Inorganic and Organic Fertilizers in Rice-Wheat System under Rainfed Conditions

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ABSTRACT

Under rainfed rice-wheat cropping system, experiments were conducted on wheat variety Annapurna-2 from 1998 to 2002 to study the effect of continuous application of inorganic and organic fertilizers in longer run on wheat production and soil properties in alluvial soil of Khumaltar, Lalitpur at 1365 msal. Eleven different fertilizers combinations comprised of inorganic and organic fertilizers were used. The results of the five-year experiment indicate that the applications of optimal level of inorganic fertilizers could supply the plant nutrients to wheat crop to produce sustainable yield. On the other hand, organic fertilizers could help to increase the crop yield and maintain soil fertility at the same time. Residual effect of available phosphorus applied in previous rice crop had significant response on wheat yield. For maintaining soil fertility, application of FYM and incorporation of crop residue into soil are worth practicable.

Key words: Inorganic and organic fertilizers, rice-wheat cropping system, wheat crop

Wheat is one of the important winter crops in Nepal, which contributes 18% of its share in total cereal production and 39% (MoAC 2005) in total GDP from agriculture. As with the saying that wheat is grown by fertilizers, farmers in Nepal prefer growing wheat with more inorganic (Bhattarai and Mishra 1998) and with some organic fertilizers than the rice crop.

With the increasing population every year, the pressure for increasing food production has also increased to feed the increasing population. This has compelled people to introduce high yielding crop varieties. With the introduction of such high yielding crop varieties, the use of chemical fertilizers have also been increased. The application of inorganic fertilizers however, are not judicious or as per recommendation (Maskey et al 2000). Continuous application of acidifying fertilizers for long period; especially ammonium sulphate and urea have turned the soil into acidic conditions which in turn have affected on the unavailability of nutrients to crops other than degrading soil health and environment, too.

In the hill agriculture, application of FYM is a common practice. Quality FYM helps improve physico-chemical properties of soil and makes soil nutrients available to plants gradually for longer period. Inorganic fertilizers while in combination with organic fertilizers help improve soil health and sustain crop yield. For better crop production, combinations of both play important role. Fertilizer use, though has been a prime contributing factor for the increased agricultural productivity in these areas, there are situations when they are not available in right time and adequate quantity despite high priced. Additionally, there is a risk of environmental hazards due to their imbalanced application resulting into declined soil fertility, crop productivity, and environmental instability. On the other hand, inadequate plant nutrients supply has been considered as one of the factors of lower crop productivity.

The long-term effects of using inorganic fertilizers are of great significance in relation to sustain the crop yield, maintain soil fertility and protect the environment as well. For a resource poor country like Nepal, the use of fertilizer alone may not be a viable solution to sustain the crop yield and maintain soil health under rice-wheat system; the predominant cropping system. In order to study these effects, experiments on the use of inorganic fertilizers and organic manure on wheat production under rice-wheat system were initiated in 1980/81 in various locations of the country. This study is also a part of the experiment. This experiment in particular has been started in 1993 at Khumaltar with the objective of studying the effect of long-term application of chemical and organic fertilizers on the wheat yield and soil properties.

MATERIALS AND METHODS

The experiment was laid out in a randomized complete block design (RCBD) as described by Gomez and Gomez (1984) with eleven treatments replicated four times. The details of the treatments are given in Table 1. Since the experiment was in rice-wheat cropping system, the fertilizer details of the rice season are also shown in the table. The size of each plot was 4- × 3-m. Nitrogen, phosphorus and potash was supplied through di-ammonium phosphate, urea and muriate of potash, respectively. Full dose of phosphorus and potash and half dose of nitrogen were applied at the time of sowing. Full dose of organic manure was applied at the time of final land preparation. The seeds of wheat variety Annapurna-2 were sown in rows with spacing of 20 cm. The remaining half dose of nitrogen was top dressed at crown-root-initiation stage. Yield and yield attributing parameters; tiller number, panicle number, length, plant height, 1000-grain weight were recorded. Composite soil samples were taken after each crop harvest for chemical analysis. Statistical analysis was done in IRRISTAT (2005).

Table 1. Treatment details of the experiment

Treatment no.	Treatment details	
	Wheat ($N:P_2O_5:K_2O$, kg ha^{-1})	Rice ($N:P_2O_5:K_2O$, kg ha^{-1})
1	0:0:0 (Control)	0:0:0 (Control)
2	100:0:0	100:0:0
3	100:40:0	100:40:00
4	100:0:30	100:0:30
5	100:40:30	100:40:30
6	100:40:30	100:40:30
7	100:40:30	100:40:30
8	50:0:0 + 15 cm rice straw	50:0:0 + 15 cm wheat straw
9	50:20:0	50:20:0
10	FYM 10 tons ha^{-1}	FYM 10 tons ha^{-1}
11	100:40:30	Green manure (soybean)

RESULTS AND DISCUSSION

Yield and yield components

Tiller number: Treatment effects were not significant for tiller number per square meter almost in all of the year except 1999 (p = 0.003) (Table 2). Combined analysis over the years showed a significant effects (P < 0.000) while treatment effect was insignificant. The highest tiller per meter square of 352 was recorded from treatment 6 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) and 7 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) followed by treatment 11 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) with the mean of 350. Variation over the years is quite distinct which was mainly due to variation in climatic conditions.

Table 2. Effect on tiller numbers of wheat crop with application of inorganic fertilizers and organic manure

	Treatment	Tiller number/m^2					Combined
		1998	1999	2000	2001	2002	
1	0:0:0 N:P_2O_5:K_2O, kg ha^{-1} (Control)	218	191	323	223	557	302
2	100:0:0 N:P_2O_5:K_2O, kg ha^{-1}	222	228	360	277	598	337
3	100:40:0 N:P_2O_5:K_2O, kg ha^{-1}	265	330	347	208	389	308
4	100:0:30 N:P_2O_5:K_2O, kg ha^{-1}	240	331	358	204	415	310
5	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	260	328	388	220	438	327
6	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	305	279	420	291	467	352
7	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	262	227	419	295	558	352
8	50:0:0 N:P_2O_5:K_2O, kg ha^{-1} + 15 cm stubbles	258	220	304	237	492	302
9	50:20:0 N:P_2O_5:K_2O, kg ha^{-1}	220	316	346	237	442	312
10	FYM 10 tons ha^{-1}	265	259	421	254	541	348
11	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	248	256	354	293	598	350
	Mean	251	270	367	249	500	327
	CV, %	21.4	19.7	23.1	27.2	25.0	25.9
	Prob						
	Treatment	ns	0.003	ns	ns	ns	ns
	Year						0
	Treatment * Year						ns
	LSD (0.05)						53

Plant height: Plant heights in different years were not affected significantly by treatments (Table 3). On combined analysis, the treatment effects were significant (p = 0.000). The response due to year was also significant (p = 0.000). The highest plant height of 89 cm was recorded from the treatment 6 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}). Most of the treatment effects were at par except the treatment 1 (Control), which produced the least mean plant height of 78.8 cm. Over the years, the highest plant height of 111.6 cm was recorded from the treatment 10 (FYM 10 tons ha^{-1}). Interaction between treatment and year was significant (p = 0.04).

Panicle length: Except 1998 and 2001, the panicle length analysis showed a significant response (p < 0.00) over the years (Table 4). However, in the year 2002, the highest panicle length of 8.3 cm was recorded from the treatment 11 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) which had soybean green manure incorporated into the soil previous season. The combined analysis over the years showed significant result (p = 0.000). Treatment 6 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) produced the highest mean panicle length of 10 cm which was at par with treatment 5 (100:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}). Panicle length was significantly affected by the recommended dose of the inorganic fertilizers.

Grain yield: The treatment response on grain yield was insignificant in most of the years except in 2000 (P = 0.002) (Table 5). On combined analysis, the response was significant (P = 0.004). The highest mean grain yield of 2929 kg ha^{-1} was recorded from the recommended dose of NPK ie treatment 5 (100:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}) indicating the better response of wheat to applied nutrients through inorganic source. The balanced application of nutrients has its incremental effects on wheat grain yield. Similar findings have also been reported from the long-term fertility

Table 3. Effect on plant height (cm) of wheat crop with application of inorganic fertilizers and organic manure

	Treatment	Plant height, cm					Combined
		1998	1999	2000	2001	2002	
1	0:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} (Control)	104.3	67.5	80.6	64.4	77.0	78.8
2	100:0:0 $N:P_2O_5:K_2O$, kg ha^{-1}	106.5	79.1	86.3	71.2	90.3	86.7
3	100:40:0 $N:P_2O_5:K_2O$, kg ha^{-1}	107.0	81.9	87.1	70.5	81.8	85.7
4	100:0:30 $N:P_2O_5:K_2O$, kg ha^{-1}	109.1	84.1	90.6	67.9	84.5	87.2
5	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	111.2	85.8	90.2	69.4	81.8	87.7
6	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	107.1	87.4	97.3	70.4	83.0	89.0
7	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	110.9	87.3	93.7	68.8	81.3	88.4
8	50:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} + 15 cm stubbles	106.5	76.4	86.3	77.1	70.5	83.4
9	50:20:0 $N:P_2O_5:K_2O$, kg ha^{-1}	106.8	75.9	87.2	75.3	77.5	84.5
10	FYM 10 tons ha^{-1}	111.6	75.2	88.9	75.3	76.0	85.4
11	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	104.4	85.5	90.2	65.2	85.0	86.0
	Mean	107.7	80.6	88.9	70.5	80.8	85.7
	CV, %	3.05	3.83	7.29	10.10	11.85	7.98
	Prob						
	Treatment	0.028	0.000	ns	ns	ns	0.000
	Year						0.000
	Treatment * Year						0.044
	LSD (0.05)						4.27

Table 4. Effect on panicle length of wheat crop with application of inorganic fertilizers and organic manure

	Treatment	Panicle length, cm					Combined
		1998	1999	2000	2001	2002	
1	0:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} (Control)	14.9	7.1	3.4	11.3	6.0	8.5
2	100:0:0 $N:P_2O_5:K_2O$, kg ha^{-1}	15.4	8.7	3.7	12.0	7.3	9.4
3	100:40:0 $N:P_2O_5:K_2O$, kg ha^{-1}	15.9	8.8	4.4	12.6	7.5	9.8
4	100:0:30 $N:P_2O_5:K_2O$, kg ha^{-1}	15.4	8.9	5.0	11.7	7.8	9.7
5	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	15.8	8.6	5.1	12.7	7.8	9.9
6	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	16.8	8.4	5.5	12.1	7.3	10.0
7	100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	16.2	9.0	4.2	11.6	7.8	9.8
8	50:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} + 15 cm stubbles	15.4	6.9	3.0	12.4	6.8	8.9

	Treatment	Panicle length, cm					Combined
		1998	1999	2000	2001	2002	
9	50:20:0 N:P_2O_5:K_2O, kg ha^{-1}	15.2	7.8	4.4	12.7	7.5	9.5
10	FYM 10 tons ha^{-1}	15.8	7.3	4.3	11.8	6.3	9.1
11	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	15.5	7.6	3.8	11.5	8.3	9.3
	Mean	15.7	8.1	4.3	12.0	7.3	9.5
	CV, %	4.63	7.39	17.89	6.41	9.21	8.55
	Prob						
	Treatment	ns	0.000	0.002	ns	0.001	0.000
	Year						0.000
	Treatment * Year						0.025
	LSD (0.05)						0.505

experiments in Parwanipur and Tarahara (Yadav et al 1998). Increment in the wheat grain yield could be due to application of phosphorus that might have been available from the phosphorus applied in previous rice crop. The effects of phosphorus in wheat grain yield have also been reported by Yadav et al (1998), Bhattarai and Mishra (1998) and Regmi (1998). Finding of Brar et al 1998 also confirms the significant response of P on wheat production.

Table 5. Effect on grain yield of Annapurna 2 wheat crop with application of inorganic fertilizers and organic manure

	Treatment	Grain yield, ton ha^{-1}					Combined
		1998	1999	2000	2001	2002	
1	0:0:0 N:P_2O_5:K_2O, kg ha^{-1} (Control)	2498	1524	3383	1289	1503	2030
2	100:0:0 N:P_2O_5:K_2O, kg ha^{-1}	2299	2559	3700	2266	1925	2550
3	100:40:0 N:P_2O_5:K_2O, kg ha^{-1}	2228	2696	4444	1211	1688	2453
4	100:0:30 N:P_2O_5:K_2O, kg ha^{-1}	2884	2617	5041	958	1933	2687
5	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	2835	2627	5063	2031	2089	2929
6	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	2963	2768	5510	1231	1244	2743
7	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	2370	2432	4240	1758	2180	2596
8	50:0:0 N:P_2O_5:K_2O, kg ha^{-1} + 15 cm stubbles	2404	2090	2998	1445	1480	2083
9	50:20:0 N:P_2O_5:K_2O, kg ha^{-1}	2305	2071	4427	1637	1684	2424
10	FYM 10 tons ha^{-1}	2581	2383	4330	1250	1700	2449
11	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	2452	2793	3766	1953	1981	2589
	Mean	2529	2415	4264	1548	1764	2503
	CV, %	17.65	21.81	17.89	59.34	28.79	28.46
	Prob						
	Treatment	ns	ns	0.002	ns	ns	0.004
	Year						0.000
	Treatment * Year						ns
	LSD (0.05)						445

The effect of the application of FYM @ of 10 tons ha-1 (treatment 10) was also encouraging (2449 kg ha^{-1}). The lower yield from treatment 10 was possibly due to low mineralization rate as affected by lower temperature and moisture condition during crop growth period (Bhattarai and Mishra 1998, Tripathi and Suwal 1999 and Pandey et al 1998). Residual effect of soybean was observed on wheat yield on combined analysis.

Straw yield: The response of the treatment was significant ($P < 0.05$) except in the years 1998 and 2001 (Table 6). Treatment responses were varied over the years. However, in the combined analysis over the years, the highest straw yield was obtained from the treatment 5 (100:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}) followed by treatment 7. Similar findings have been reported by Bhattarai and Mishra (1998). It could have been due to higher nitrogen application in the treatment. Straw yields are higher in the treatments with recommended dose of fertilizers. Like in grain yield, wheat straw yield was significantly higher in the treatments where green manure was applied in rice season and recommended dose of fertilizer was applied in wheat indicating the sufficient supply of the nutrients to crop.

Effects on soil properties

Nitrogen: Variations in soil nitrogen due to various treatments were insignificant in combined analysis of the data over the years. However, there were increments in soil nitrogen in every treatment at the end of the five years. Similar findings have been reported by Bhattarai and Mishra (1998). Higher nitrogen percent in treatment 10 (Table 7) could possibly due to increasing soil humus content through continuous application of organic fertilizer (Larson and Clapp 1984).

Available phosphorus: On combined analysis, the treatment effects were insignificant. Variation due to years on available soil phosphorus was significant (Table 7). Treatment 11 (100:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}) had the highest available phosphorus (127.77 kg ha^{-1}) which could have been resulted due to the residual effect of the soybean incorporated in the rice season. Gami and Sah (1998) also reported similar finding in the long-term experiment. Considerable amount of available P was build up with all rates of P application confirming with the result of Brar and Pasricha 1998.

Table 6. Effect on straw yield of wheat crop with application of inorganic fertilizers and organic manure

Treatment	Straw yield, ton ha^{-1}					Combined
	1998	1999	2000	2001	2002	
1 0:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} (Control)	2051	2168	4024	2188	2236	2533
2 100:0:0 $N:P_2O_5:K_2O$, kg ha^{-1}	1739	2676	5664	4395	3596	3614
3 100:40:0 $N:P_2O_5:K_2O$, kg ha^{-1}	1725	2950	7207	2461	2088	3286
4 100:0:30 $N:P_2O_5:K_2O$, kg ha^{-1}	2250	3301	7331	2324	2813	3604
5 100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	2182	3438	6992	4961	2479	4010
6 100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	2446	2988	7852	2988	2446	3744
7 100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	1810	2735	7286	4687	3280	3959
8 50:0:0 $N:P_2O_5:K_2O$, kg ha^{-1} + 15 cm stubbles	1651	1612	3926	3086	2722	2599
9 50:20:0 $N:P_2O_5:K_2O$, kg ha^{-1}	1795	2305	6387	2598	3081	3233
10 FYM 10 tons ha^{-1}	2188	2559	5156	3203	3480	3317
11 100:40:30 $N:P_2O_5:K_2O$, kg ha^{-1}	1960	2305	7442	3360	3539	3721
Mean	1982	2640	6297	3296	2887	3420
CV, %	21.7	24.75	28.48	61.26	24.13	39.14
Prob						
Treatment	ns	0.019	0.029	ns	0.031	0.004
Year						0.000
Treatment * Year						ns
LSD (0.05)						836

However, addition of straw to 50 kg N ha^{-1} could not increase the available phosphorus in soil (Treatment 8). The second highest available phosphorus in soil was recorded in treatment 5 followed by treatment 6 in which recommended dose of phosphorus was applied continuously. The lowest available soil phosphorus (52.55 kg ha-1) was recorded in treatment with no nutrient at all. Treatments with application of lower amounts of phosphorus had also lower available phosphorus in soil.

Table 7. Combined mean of five years data on soil properties (1998-2002)

	Treatment	N, %	Av P_2O_5, kg ha^{-1}	Av K_2O, kg ha^{-1}	OM, %
1	0:0:0 N:P_2O_5:K_2O, kg ha^{-1} (Control)	0.106	2.55	152.75	1.68
2	100:0:0 N:P_2O_5:K_2O, kg ha^{-1}	0.162	83.03	175.50	1.96
3	100:40:0 N:P_2O_5:K_2O, kg ha^{-1}	0.165	109.38	187.00	2.28
4	100:0:30 N:P_2O_5:K_2O, kg ha^{-1}	0.169	108.12	193.70	2.97
5	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	0.183	117.45	193.50	3.52
6	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	0.166	116.45	205.95	3.44
7	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	0.173	112.49	191.20	3.32
8	50:0:0 N:P_2O_5:K_2O, kg ha^{-1} + 15 cm stubbles	0.165	81.66	190.50	3.66
9	50:20:0 N:P_2O_5:K_2O, kg ha^{-1}	0.154	79.75	182.95	3.45
10	FYM 10 tons ha^{-1}	0.172	67.73	162.75	3.97
11	100:40:30 N:P_2O_5:K_2O, kg ha^{-1}	0.162	126.77	185.85	2.46
	Mean	0.162	95.90	183.79	2.97
	F-test				
	Treatment	ns	ns	ns	0
	Year	0	0	0	0
	T*Y	ns	ns	ns	ns

Available potassium: Treatments were insignificant on combined analysis of all five years' data. The effect of the year on available potassium was significant which might be due to climatic variations over the years. Treatment 6 (100:40:30 N:P_2O_5:K_2O kg ha^{-1}) produced the highest amount of available potassium in the soil (205.95 kg ha^{-1}) followed by treatment 4 (193.7 kg ha^{-1}) having 100:0:30 N:P_2O_5:K_2O kg ha^{-1} application. The least available potassium 152.75 kg ha^{-1} was recorded in treatment 1 (control).

Organic matter: The highest soil organic matter was recorded in treatment 10 which had continuous supply of FYM @ 10 ton ha^{-1} (Table 7) followed by treatment 8 in which 15 cm of rice straw (stubbles) was incorporated into the soil along with 50:0:0 N:P_2O_5:K_2O kg ha^{-1}. Gami and Sah (1998) have also reported the increment of organic matter in soil when FYM and chopped straw was applied in the soil. Soil organic matter content, in general was high in almost all treatments having high phosphorus or FYM application. It could be due to high amount of root and stubbles incorporated into the soil (Regmi 1998). Treatment effects of soil organic matter content were highly significant and the effect over the years was significant.

CONCLUSION

The result of this long-term experiment under rice-wheat cropping system demonstrated that the sustainable wheat production could be possible through inorganic fertilizers application with optimal level of NPK and high yielding variety under rice-wheat system in rainfed conditions. Single application of nitrogenous fertilizers or organic manures could not supplement the nutrients in sufficient amount required by the wheat crop for sustainable production under rainfed conditions. Further study should be continued focusing more on the use of the combination of inorganic and organic manure in various ratio in order to identify the best combination that would result into sustainable production along with better soil fertility and environment-friendly conditions.

REFERENCES

Bhattarai EM and R Mishra. 1998. Effect of long term application of chemical fertilizer and manure on crop production and soil fertility under rice-wheat cropping pattern at Khajura, Nepalgunj. **In:** *Proceedings of first national workshop on long-term soil fertility experiments* (SL Maskey, BP Tripathi, AP Regmi, JK Tuladhar and B Adhikary, eds). Soil Science Division, Nepal Agricultural Research Council, CIMMYT/HARP, Khumaltar, Nepal. Pp. 59-84.

Brar BS, Y Singh, NS Dhillon and B Singh. 1998. Long term effects of inorganic fertilizers, organic manures and crop residues on the productivity and sustainability of a rice-wheat cropping system in North-West India. **In:** *Long-term soil fertility management through integrated plant nutrient supply* (A Swarup, DD Raddy and RN Prasad, eds). Indian Institute of Soil Science, Bhopal, India. Pp. 169-182.

Brar BS and NS Pasricha. 1998. Long-term studies on integraed use of organic and inorganic fertilizers in maize-wheat-cowpea cropping system on alluvial soil of Punjab. **In:** *Long-term soil fertility management through integrated plant nutrient supply* (A Swarup, DD Raddy and RN Prasad, eds). Indian Institute of Soil Science, Bhopal, India. Pp. 154-168.

Gomez KA and AA Gomez. 1984. *Statistical procedures for agricultural research.* 2nd Edition. John Willy and Sons, New York. 680 pp.

IRRISTAT. 2005. IRRISTAT for Windows. Ver. 5.0. International Rice Research Institute, Manila, Philippines.

Maskey SL, RK Shrestha, B Shrestha, BP Tripathi, RC Munankarmy, YG Khadka, EM Bhattarai and SP Shrestha. 2000. *Strategies for soil fertility research in the hills of Nepal*. Soil Science Division, NARC, Khumaltar, Lalitpur, Nepal, 162 pp.

Regmi AP. 1998. Long-term soil fertility experiment on the rice-rice-wheat system at Bhairahawa. **In:** *Proceedings of first national workshop on long-term soil fertility experiments* (SL Maskey, BP Tripathi, AP Regmi, JK Tuladhar and B Adhikary, eds). Soil Science Division, Nepal Agricultural Research Council, CIMMYT/HARP, Khumaltar, Nepal. Pp. 95-115.

MoAC. 2005. *Statistical information on Nepalese Agriculture*. Agri-Business Promotio and Statistics Division, Agri Statistics Section, Ministry of Agriculture and Cooperatives (MoAC), His Majesty's Government, Singha Durbar, Kathmandu, Nepal.

Larson WE and CE Clapp. 1984. Effects of organic matter on soil physical properties. Organic matter and rice. IRRI, Los Banos, Philippines.

Pandey PR, SP Pandey and YG Khadka. 1998. Long-term effect of organic and inorganic fertilizer on rice-wheat system in rainfed lowland condition of Khumaltar. **In:** *Proceedings of first national workshop on long-term soil fertility experiments* (SL Maskey, BP Tripathi, AP Regmi, JK Tuladhar and B Adhikary, eds). Soil Science Division, Nepal Agricultural Research Council, CIMMYT/HARP, Khumaltar, Nepal. Pp. 116-134.

Tripathi BP and BN Suwal. 1999. Effect of organic and inorganic fertilizers on rice and wheat yields and soil properties in rice-wheat system in rainfed lowland ecosystem. *Nepal Ag. Res. Journal* 3:89-93.

Yadav CR, RB Bhujel, HK Prasain and AL Chaudhary. 1998. Long-term fertility trail on rice-wheat-fallow cropping system at Tarahara. **In:** *Proceedings of first national workshop on long-term soil fertility experiments* (SL Maskey, BP Tripathi, AP Regmi, JK Tuladhar and B Adhikary, eds). Soil Science Division, Nepal Agricultural Research Council, CIMMYT/HARP, Khumaltar, Nepal. Pp. 35-58.

Study on the Effects of Vermicompost on the Nodulation and the Yield of Chickpea

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ABSTRACT

Pot experiment was conducted in a randomized complete block design with three replication and six treatments in the screenhouse of Soil Science Division, Khumaltar during the year 2003 and 2004. The objective of the experiment was to find out the effect of vermicompost in combination with or without soil and mineral fertilizers on the yield and other attributes of chickpea. The results showed an encouraging effect of vermicompost application on the plant height, root length and biomass dry weight of chickpea when vermicompost was applied in equal ratio with soil (5 kg each/pot) and 10:20:15 kg N: P_2O_5:K_2O kg ha^{-1}. Vermicompost with equal ratio of soil (5 kg each/pot) also produced the highest mean grain yield of 10.6 gm per pot. However, no significant treatments effects were observed for root length and straw weights of the chickpea.

Kew words: Chickpea, mineral fertilizer, nodulation, vermicompost, yield

INTRODUCTION

Legumes are mostly grown in Nepal as a source of human and animal protein. It enriches the soil with nitrogen maintaining soil fertility by fixing atmospheric nitrogen with the help of rhizobium associated in the root nodules. In Nepal, the common legumes grown in terai during winter are lentil, mungbean, chickpea, cowpea, pigeon pea and horse gram, while in hill and valley, soybean, phaseolus bean and black gram are grown during summer (MoAC 1999). In the recent years, the area under legumes cultivation is decreasing due to many biotic and abiotic factors (Neupane et al 2005). Among the biotic factors; fewer number of nodules in the root system, pest infection are few examples while drought, soil acidity and unfavorable soil conditions comprise the abiotic factors. In addition, soil health and the proper nutrient management are also important factors that may limit the legume production.

Except on vermicompost, several research works on bacterial, mineral and organic fertilizers from various sources have already been done in Nepal (Maskey and Bhattarai 1994). Compost produced by traditional processes is generally low in plant nutrient content and the process itself is also slow and time consuming. On the other hand, certain special type of earthworm (*Eisenia foitida*) has the capacity to convert the biodegradable organic waste into higher quality compost at comparatively faster rate (Bhattarai 2003) than that of the traditional method. Such a compost usually known as "vermicompost" is rich in plant nutrients and contains higher number of microorganisms, which are responsible for decomposition process (Yami et al 2003). Hence, in order to find out the effect of vermicompost either alone and/or in combination with soil and mineral fertilizers on the yield and other parameters of chickpea, this experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted in a randomized complete block design with six treatments and three replications, each treatment conducted on an earthen pot of 12 kg capacity filled with vermicompost alone and/or mixed with soil and/or mineral fertilizers up to 10 kg capacity depending upon the type of treatment. The experiment was laid out in the screen house of Soil Science Division, Khumaltar, Lalitpur during year 2003 and 2004. The vermicompost with 1.4% N, 0.8% P and 4.38% K content was used in the experiment, which was prepared from the farm waste. The nutrient content of the soil used in the pot were N% 0.156, P_2O_5 155 kg ha^{-1}, K_2O 874 kg ha^{-1} and OM% 2.01 with soil pH of 5.6. In each of the pot, seven seeds of local chickpea cultivar were sown. One week after germination, plants were thinned to five plants in each pot. Urea, single super phosphate (SSP) and muriate of potash (MOP) were applied in liquid form in single application at one week after germination. The cultural practices were followed as normal as and when required. At the 50% maturity stage, single plant was taken out from every pot for recording nodulation, plant height, root length and dry biomass. After 90 days of seeding, crop was harvested and grain and straw yield were recorded. Statistical analysis of the data was done in MSTAT-C version 2.1 software. The treatment details are given below:

Treatments	Details
Treatment 1	Control (Soil 10 kg/pot)
Treatment 2	Soil + Vermicompost (5 kg each/pot)
Treatment 3	Vermicompost (10 kg/pot)
Treatment 4	Soil (10 kg/pot) + Full dose of mineral fertilizer (20:40:30 $N:P_2O_5:K_2O$ kg/ha)
Treatment 5	Soil (5 kg/pot) + Vermicompost (5 kg/pot) + Half dose of mineral fertilizer (10:20:15 $N:P_2O_5:K_2O$ kg/ha)
Treatment 6	Soil (10 kg/pot) + high dose of mineral fertilizer (60:60:60 $N:P_2O_5:K_2O$ kg/ha)

RESULTS AND DISCUSSION

Plant height

Effect of the treatments on plant height was highly significant in the first year but was insignificant in the second year of the experiment (Table 1). The highest plant height (46.2 cm) was obtained from treatment 5 having equal amount of soil and vermicompost (5 kg each/pot) plus half dose of recommended mineral fertilizer (10:20:15 $N:P_2O_5:K_2O$ kg/ha) followed by treatment 3 (40.7 cm) having only vermicompost @ 10 kg/pot. In the second year, treatment effects were insignificant however, treatment 6 (Soil 10 kg/pot + high dose of mineral fertilizer @ 60:60:60 $N:P_2O_5:K_2O$ kg/ha) produced the highest plant height of 46.2 cm followed by treatment 2 (45.0 cm). In the combined analysis of the two years data, treatment 2 having equal amount of soil and vermicompost produced the significantly highest plant height of 42.6 cm followed by treatment 5 (42.0 cm) and treatment 3 (41.5 cm) respectively. Interaction between treatment and year was highly significant ($p = 0.0017$). Treatment effects was also significant ($p = 0.0342$). Increased in plant height is possibly due to the growth promoting substances, which are present in vermicompost. Nutrients from soil and fertilizers have also their effects on the plant heights. Similar results have also been reported by Asewar et al (2004) and Arya et al (2007).

Root length

In the both the years of the experiment, treatment effects were not observed significant for root length (Table 1). However, the effect of vermicompost alone and with other combination was quite impressive. In the first year, treatment 5 produced the highest root length (14.6 cm) while treatment 2 produced the highest root length of 15.5 cm in the second year. An insignificant response was observed when combined analysis was done.

Nodulation

The effects of the treatments on the count of the nodulation were quite noticeable in both of the years (Table 2). Unexceptionally, the number of nodulation in the second year was higher than the first year due to more rhizobial activity in the second year. Both treatment effects and their interaction over years were highly significant (Table 2). In the first year, treatment 3 (vermicompost only) produced the highest number of nodules per plant (16) followed by treatment 2 (14) which was comprised of equal amount of soil and vermicompost. This could be possibly due to the different type of enzymes produced by organic fertilizers (vermicompost) that helped to produce increased number of nodules in the plants.

Table 1. Treatment effects on plant height and root length of chickpea (2003-2004)

	Treatment details	Plant height/plant, cm			Root length/plant, cm		
		2003	2004	Mean	2003	2004	Mean
1	Control (Soil 10 kg/pot)	23.7[c]	43.5	33.6[b]	11.2	15.7	13.5
2	Soil + Vermicompost (5 kg each/pot)	40.2[ab]	45.0	42.6[a]	13.7	15.5	14.6
3	Vermicompost (10 kg/pot)	40.7[ab]	42.2	41.5[a]	12.5	12.7	12.6
4	Soil (10 kg/pot) + Full dose of mineral fertilizer (20:40:30 $N:P_2O_5:K_2O$ kg/ha)	30.1[bc]	43.5	36.8[ab]	12.0	15.2	13.6
5	Soil (5 kg/pot)+Vermicompost (5kg/pot) + Half dose of mineral fertilizer (10:20:15 $N:P_2O_5:K_2O$ kg/ha)	46.2[a]	37.7	42.0[a]	14.6	14.0	14.3
6	Soil (10 kg/pot) + high dose of mineral fertilizer (60:60:60 $N:P_2O_5:K_2O$ kg/ha)	37.1[ab]	46.2	41.6[a]	14.3	10.7	12.5
	Mean	36.37	43.04	39.70	13.083	14.00	13.57
	CV, %	19.34	11.88	15.49	28.220	23.88	26.01
	F-test						
	Treatment	**	ns	*	ns	ns	ns
	Year × Treatment	-	-	**	-	-	ns
	LSD	10.37		6.281			

*ns, not significant. *, significant (0.05). **, highly significant (0.01).*

Biomass dry weight

Biomass production was not significantly different in the second year as compared to the first year (Table 2). In the first year of the experiment, the treatment 5 (equal amount of soil and vermicompost plus half of the recommended mineral fertilizers) out yielded other by producing 2.84 gm per plant biomass. Vermicompost alone (treatment 5) produced the second highest biomass production of 2.23 gm per plant. In the second year, the effects of the treatments were insignificant. This could be due to the increased microbial activities produced by the organic fertilizers, which might have been developed at the end of the second year. Similar result was also reported by Rajkhowa et al (2000). Variation due to years and treatments on combined analysis showed a significant response on biomass dry weight production.

Table 2. Treatment effect on nodulation and biomass dry weight of chickpea (2003-2004)

	Treatment details	No. of nodules/plant			Biomass dry weight/plant, g		
		2003	2004	Mean	2003	2004	Mean
1	Control (Soil 10 kg/pot)	8.0[bc]	71.2[ab]	39.6[a]	0.30[d]	2.7	1.5
2	Soil + Vermicompost (5 kg each/pot)	14.0[ab]	64.5[ab]	39.2[a]	2.23[ab]	2.9	2.5
3	Vermicompost (10 kg/pot)	16.0[a]	6.0[d]	11.0[b]	1.77[abc]	2.4	2.1
4	Soil (10 kg/pot) + Full dose of mineral fertilizer (20:40:30 N: P_2O_5:K_2O kg/ha)	5.0[cd]	46.7[bc]	25.8[ab]	0.54[cd]	2.9	1.7
5	Soil (5kg/pot)+Vermicompost (5kg/pot) + Half dose of mineral fertilizer (10:20:15 N: P_2O_5:K_2O kg/ha)	3.0[cd]	11.0[cd]	7.0[b]	2.84[a]	2.5	2.7
6	Soil (10kg/pot) +high dose of mineral fertilizer (60:60:60 N: P_2O_5:K_2O)	1.0[d]	90.2[a]	45.6[a]	0.88[bcd]	3.1	1.9
	Mean	7.833	48.29	28.06	1.429	2.79	2.107
	CV, %	74.15	51.52	64.3	65.11	36.14	46.0
	F-test						
	Treatment	*	**	**	**	ns	ns
	Year × Treatment	-	-	**	-	-	*
	LSD	6.19	36.66	24.84	1.370		2.329

*ns, not significant. *, significant (0.05). **, highly significant (0.01).*

Grain and straw yields

The effects of the treatments were significant on grain yield of chickpea in both the years (Table 3). In the first year, treatment 2 (equal amount of soil and vermicompost) produced the highest mean grain yield of 14.2 gm per plot followed by treatment 5 (equal amount of soil and vermicompost plus half of the recommended mineral fertilizers) with the mean grain yield of 14.03 gm per plant. In the second year, treatment 6 out yielded others by producing the highest mean grain yield of 7.3 gm per plot followed by treatment 2 with the mean grain yield of 6.9 gm per plot. Similar effects on the grain yield have been reported by Rajkhowa et al (2000), when vermicompost was applied with mineral fertilizers. Bhattarai (2003) has also reported the increase in the grain yield of wheat and maize when soil and vermicompost was applied at equal ratio (1:1).

Table 3. Treatment effect on grain and straw yield of chickpea (2003-2004)

	Treatment details	Grain yield, g			Straw yield/pot, g		
		2003	2004	Mean	2003	2004	Mean
1	Control (soil 10 kg/pot)	5.4^{c}	6.3^{a}	5.8	8.4	41.07	24.7^{a}
2	Soil + Vermicompost (5 kg each/pot)	14.2^{a}	6.9^{a}	10.6	19.2	59.3	39.3^{ab}
3	Vermicompost (10 kg/pot)	11.6^{ab}	2.9^{b}	7.3	17.6	77.9	47.8^{a}
4	Soil (10 kg/pot) + Full dose of mineral fertilizer (20:40:30 N:P_2O_5:K_2O kg/ha)	7.6^{bc}	6.3^{a}	7.0	10.6	67.4	39.06^{ab}
5	Soil (5kg/pot)+Vermicompost (5kg/pot) + Half dose of mineral fertilizer (10:20:15 N:P_2O_5:K_2O kg/ha)	14.03^{a}	3.5^{b}	8.7	13.7	56.1	34.9^{ab}
6	Soil (10kg/pot) + High dose of mineral fertilizer (60:60:60 N:P_2O_5:K_2O kg/ha)	10.02^{ab}	7.3^{a}	8.6	14.1	62.0	38.0^{ab}
	Mean	10.50	5.573	8.038	13.98	60.68	37.32
	CV, %	36.23	38.88	38.52	72.32	26.05	35.55
	F-test						
	Treatment	*	*	ns	ns	ns	*
	Year × Treatment	-	-	**	-	-	ns
	LSD	4.055	2.309				13.55

*ns, not significant. *, significant (0.05). **, highly significant (0.01).*

Treatment response to straw yields over the two years were not significant (Table 3). However, it was found significant when combined analysis over two years was performed. In the first year, treatment 2 produced the highest mean straw (19.2 g/pot) and treatment 3 was the highest with 77.9 gm per pot in the second year. Treatment 3 also produced the significant highest mean yield of 47.8 gm per pot followed by treatment 2 (39.3 gm per pot) when combined analysis was performed on straw yield. Straw yield was more or less similar in treatment 2, 4 and 6 indicating that application of vermicompost alone or in combination with equal amount of soil and half dose of mineral fertilizer is better for straw yield. Similar result has also been reported by Bajracharya et al (2007). Jat and Ahlawat (2004) also observed significantly increased in straw yield with the application of vermicompost only.

Correlation of the plant parameters

Correlation analysis of biomass dry weight, nodule numbers, plant height, root length, grain yield and straw yield has been presented in the table 4. A high degree of significant association of biomass dry weight was observed with nodule numbers, plant height and straw yield. A very high degree of positive association was observed between plant height and biomass dry weight (0.754). Similarly, straw yield and nodule number have also positive correlation with biomass dry weight. A negative insignificant relation was obtained between grain yield and nodulation number (-0.1294).

Table 4. Correlation analysis of the plant parameters (Correlation/P-Value)

	Biomass dry weight	Nodules number	Plant height	Root length	Grain yield
Nodules number	0.4660 0.0008				
Plant height	0.7544 0.0000	0.3138 0.0298			
Root length	0.3187 0.0272	0.1082 0.4643	0.2077 0.1565		
Grain yield	-0.0651 0.6602	-0.1294 0.381	0.1242 0.4002	-0.0378 0.7986	
Straw yield	0.4682 0.0008	0.3775 0.0082	0.374 0.0089	0.0930 0.5293	-0.3722 0.0092

CONCLUSION

The effect of vermicompost in combination with other mineral fertilizer and/or soil is quite encouraging for better crop growth and yield of chickpea. Even at the lower dose than that of the recommended dose of the mineral fertilizers, vermicompost has shown better results for nodulation and crop yield, which is not only economical but also beneficial with soil improvement point of view.

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REFERENCES

Arya RL, JG Varshney, L Kumar. 2007. Effect of integrated nutrient application in chickpea mustard intercropping system in the semi-arid tropics of North India. *Communications in Soil Science and Plant Analysis* 38(1&2):229-240.

Asewar BV, SS Bainade, OD Kohire and PS Bainade. 2004. Integrated use of vermicompost and inorganic fertilizer in chickpea. *Indian Journal of Agriculture* 7:359-361.

Bajracharya SK, DP Sherchan and S Bhattarai. 2007. Effect of vermicompost in combination with bacterial and mineral fertilizers on the yield of vegetable soybean. *Korean J. Crop Science* 52(1):100-103.

Bhattarai S. 2003. Quality compost production with vermicompost from the farm and household waste. **In:** *Proceedings international conference on woman, science and technology for poverty alleviation*, 31 March to 2 April 2003, Katmandu, Nepal.

Jat RS and IPS Ahlat. 2004. Effect of vermicompost, biofertilizer and phosphorus on growth and nutrient uptake by gram (*Cicer arietinum*) and their residual effect on fodder maize (*Zea mays*). *Indian Journal of Agricultural Science* 74(7):359-361.

Maskey SL and S Bhattarai. 1994. Effect of long term application on different sources of organic manure on maize/wheat rotation. **In:** *Proceeding of IInd National conference on science and technology*, 8-11 June 1994, RONAST, Kathmandu. Pp. 215-217.

MoAC. 1999. *Statistical information of Nepalese agriculture 1993/94*. Agricultural Statistics Division, Ministry of Agriculture and Cooperative (MoAC), Kathmandu, Nepal.

Neupane RK, M Joshi, S Pande and NK Yadav. 2005. *On-farm IPM of chickpea in Nepal: Dissemination, adoption and promotion*, summary of NARC-ICRISAT-NRI workshop, November 2004, Katmandu, Nepal. Pp. 17-18.

Rajkhowa DJ, AK Gogoi, R Kandali and KM Rajkhowa. 2000.Effect of vermicompost on green gram nutrition. *Journal of the Indian Society of Soil Science* 48(1):207-208.

Yami KD, S Bhattarai and S Adhikari. 2003. Vermicomposting and microflora analysis of vermicompost and gut of red earthworm. *Nepal Journal of Science and Technology* 5:127-132.

Response of Cauliflower (*Brassica oleracea* var. *Botrytis*) to the Application of Boron and Phosphorus in the Soils of Rupandehi District

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ABSTRACT

A field experiment was conducted at Paklihawa Campus of the Institute of Agriculture and Animal Science, Rupandehi, Nepal, during Oct 2004 to Feb 2005 to study the effects of boron and phosphorus on the soil nutrient status, nutrient uptake by plant and yield of cauliflower (*Brassica oleracea* var. *botrytis* L.) variety *Snowball-16*. Sixteen treatment combinations, including four levels of boron (0, 0.65, 1.3, 1.95 kg boron ha^{-1}) and four levels of phosphorus (0, 30, 60, 90kg P_2O_5 ha^{-1}) were included. The soil was loamy with very low in boron. Curd yield, harvest index, boron and phosphorus uptake by plant and available boron in soil were significantly increased by the application of boron and phosphorus in soils. Available phosphorus in soils after the crop harvest was significantly increased by phosphorus application. The highest curd yield, boron and phosphorus uptake by plant as well as available boron and phosphorus in soils after the crop harvest were obtained from the application of 1.3 kg boron with 60 kg P_2O_5 ha^{-1}. The boron uptake by plant was decreased by the application of more than 1.3kg boron ha^{-1} while the phosphorus uptake was increased with increased application of phosphorus upto 90 kg P_2O_5 ha^{-1}. There were quadratic responses of curd yield, harvest index and plant boron uptake to the applied boron; quadratic response of plant phosphorus uptake to the applied phosphorus, while responses of curd yield, and harvest index to the applied phosphorus were linear. Highly significant positive correlations between curd yield and leaf boron content (r = 0.68**) as well as curd yield and plant phosphorus content (r = 0.79**) were observed. In conclusion, the combined application of 1.3 kg boron and 60 kg P_2O_5 ha^{-1} was found to be the best for cauliflower production under Paklihawa soil conditions of Rupandehi district and can be recommended to the growers of this region.

Key words: Borax, *Brassica oleracea* var. *botrytis*, curd yield, phosphorus

INTRODUCTION

Cauliflower is an economically important winter vegetable of Nepal. It is nutritionally rich and has medicinal value. The agro-climatic conditions across the country favor the production of cauliflower even in summer season with export potentiality. From production aspect, it requires balanced dose of plant nutrients, particularly nitrogen, phosphorus, potassium, boron and molybdenum (Mengel and Kirkby 1987). The productivity of cauliflower is not satisfactory due to poor soil fertility and imbalanced fertilization. Micronutrients deficiency is more prevalent in Nepalese soils (Fujimoto

1998, Jaishy et al 2000). The deficiency of boron causes browning and bitterness of curd with hollow stem. Similarly, poor root growth, delayed crop maturity and curd quality deterioration are caused by phosphorus deficiency (Mitra 1990). Boron deficiency is commonly found in sandy loam soils due to more leaching of this element; therefore, its problem is more prevalent in Rupandehi district. Due to soil alkalinity, phosphorus fixation by soil constituents is another problem of the area.

Although several studies have been conducted on boron and phosphorus requirements of cauliflower in the various parts of the world, there is limited information under Nepalese soil conditions on this aspect. Moreover, no research work has been reported on the effects of boron and phosphorus in cauliflower production in the Rupandehi district. The present research, therefore was conducted to determine the effects of different doses of boron and phosphorus on the nutrient status, uptake and yield of cauliflower.

MATERIALS AND METHODS

TREATMENT DETAILS

The experiment was conducted at Horticulture farm of Institute of Agriculture and Animal Science, Paklihawa Campus, Rupandehi, Nepal. Field experiment was conducted during Oct 2004 to Feb 2005 in a randomized complete block design consisting of 16 treatment combinations with three replications. Individual plot size was 6.75 m^2 (3 × 2.25 m^2) having 25 plants. The test crop was cauliflower of variety *Snowball-16*. The treatment combinations were 0, 0.65, 1.3, 1.95 kg B ha^{-1} and 0, 30, 60, 90 kg P_2O_5 ha^{-1}. Boron was applied through Borax (11% B) and phosphorus through single super phosphate (16% P_2O_5). The recommended dose of nitrogen was applied through urea and potassium through muriate of potash. Half dose of nitrogen, full dose of phosphorus and potassium and 70% of boron were incorporated into the soil at the time of seedling transplanting. Remaining 30% boron was applied as a foliar spray of 0.4% boron solution at two months after seedling transplanting. Remaining amount of nitrogen was split into two equal parts and each part was top dressed at one and two months after transplanting.

Table 1. Treatment combinations used for the field experiment

Treatment no.	Treatment combinations		Symbol
	Boron (B), kg ha^{-1}	Phosphorus (P_2O_5), kg ha^{-1}	
T_1	0	0	B_0P_0
T_2	0	30	B_0P_{30}
T_3	0	60	B_0P_{60}
T_4	0	90	B_0P_{90}
T_5	0.65	0	$B_{0.65}P_0$
T_6	0.65	30	$B_{0.65}P_{30}$
T_7	0.65	60	$B_{0.65}P_{60}$
T_8	0.65	90	$B_{0.65}P_{90}$
T_9	1.30	0	$B_{1.3}P_0$
T_{10}	1.30	30	$B_{1.3}P_{30}$
T_{11}	1.30	60	$B_{1.3}P_{60}$
T_{12}	1.30	90	$B_{1.3}P_{90}$
T_{13}	1.95	0	$B_{1.95}P_0$
T_{14}	1.95	30	$B_{1.95}P_{30}$
T_{15}	1.95	60	$B_{1.95}P_{60}$
T_{16}	1.95	90	$B_{1.95}P_{90}$

SOIL SAMPLING AND LABORATORY ANALYSIS

Composite soil samples from each block were taken before transplanting of cauliflower seedlings. The samples were air-dried and sieved through 2 mm for analysis. Nitrogen, phosphorus, potassium and boron were analyzed by Kjeldahl distillation unit (Bremmer and Mulvaney 1982), Olsen's bicarbonate (Olsen et al 1954), Ammonium acetate (Pratt 1965) and Azomethine-H (Gaines and Mitchell 1979) methods, respectively. Organic matter content (Walkley and Black 1934), soil texture by hydrometer (Gee and Bauder 1986) and soil pH by digital pH meter were analyzed.

Table 2. Physico-chemical properties of the soil before the field experiment

Rep	OM, %	Total N, %	P_2O_5, kg ha^{-1}	K_2O, kg ha^{-1}	B (µg gm^{-1})	pH	Sand, %	Silt, %	Clay, %	Soil textural class
1	1.27	0.126	196.7	156.9	< 0.1	7.7	45	38	17	Loam
2	1.19	0.118	200.3	144.6	< 0.1	7.6	43	40	17	Loam
3	1.24	0.141	185.0	148.7	< 0.1	7.6	44	39	17	Loam

After the crop harvesting, the composite soil samples from each plot were sampled and were analyzed for boron and available phosphorus by using Azomethine-H (Gaines and Mitchell 1979) and Olsen's Bicarbonate (Olsen et al 1954), respectively. Plant samples from each plot were analyzed for total boron and phosphorus using Azomethine-H (Gaines and Mitchell 1979) and vanadomolybdophosphoric yellow (Moore 1991), respectively.

DATA OBSERVATION AND STATISTICAL ANALYSIS

Fresh weight of total biomass and curd weight were taken from central nine plants from each plot. The analysis of variance followed by DMRT (Duncan's Multiple Range Test) was used to analyze the data and to separate the means. Correlation analysis was used to show the relationship between yield and yield parameters. The data analysis procedures were followed as described by Gomez and Gomez (1984) using MSTATC, Minitab and MS-Excel.

RESULTS AND DISCUSSION

Curd yield

The boron and phosphorus and their interaction effects in relation to curd yield were highly significant (Table 3). The individual effect of boron on curd yield was the highest (19.44 mg ha^{-1}) at $B_{1.3}$ level, which was significantly greater than $B_{1.9}$ and B_0 levels but similar to $B_{0.65}$. Like this P_{90} level had the highest (17.07 mg ha^{-1}) curd yield which was significantly higher than P_{30} and P_0 levels but at par with P_{60}. The curd yield was highly correlated with plant phosphorus uptake (r = 0.79**) and leaf boron (r = 0.68**) uptake. The curd yield was increased upto $B_{1.3}$ levels of boron application into soil while it was decreased at $B_{1.95}$ level. Similarly, the curd yield was increased from P_0 to P_{90} levels of phosphorus application. The maximum curd yield (26.47 mg ha^{-1}) was found from $B_{1.3}P_{60}$, which was similar to $B_{1.3}P_{90}$, $B_{1.95}P_{30}$ and $B_{1.95}P_{90}$ levels of boron and phosphorus application.

Table 3. Curd yield response of cauliflower to applied boron and phosphorus

Treatments	Curd yield, mg ha^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	9.65f	9.44f	14.99e	17.07de	12.79c
$B_{0.65}$	16.69de	15.73e	20.58c	22.46bc	18.86b
$B_{1.3}$	19.44cd	22.58bc	26.47a	26.24a	22.29a
$B_{1.95}$	14.53e	25.65ab	20.88c	24.73ab	22.85a
Mean	15.08D	18.35C	20.73B	22.63A	19.19
SEM (0.05)	B*P 1.094	B 0.54	P 0.54		
LSD (0.05)	3.159	1.58	1.58		
CV, %	9.87				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Curd yield responded linearly to boron and phosphorus applications (Figure 1a, 1b). Similar findings were also reported by Baral et al (1986) that application of 60 kg P_2O_5 along with 1.5 kg boron ha^{-1} increased the total curd weight, curd size and marketable curd yield. Soil application of borax at the rate of 20 kg ha^{-1} increased curd yield (Mishra 1972, Thakur et al 1991). The results were in agreement with the finding of Pandey et al (1974) and Randhawa and Bhail (1976). The increase in yield might be due to synergistic interaction effects between applied boron and phosphorus in the soil.

Harvest index

The phosphorus application to soil had no significant effect on harvest index of cauliflower but applied boron and their interaction effects were found to be significant (Table 4). The maximum harvest index (49.14%) was obtained from $B_{1.95}P_{30}$ which was similar to all treatments except control, B_0P_{30}, and B_0P_{60}. The harvest index with applied boron had quadratic relationship (Figure 1c) while with applied phosphorus had linear (Figure 1d). The mean harvest index was increased from B_0 to $B_{1.95}$ and $B_{1.95}$ (39.9%) was significantly higher than B_0 while it was similar to $B_{0.65}$ and $B_{1.3}$ levels.

Table 4. Harvest index of cauliflower as affected by boron and phosphorus application

Treatments	Harvest index, %				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	28.14cd	22.85d	31.93bcd	46.08ab	32.25b
$B_{0.65}$	39.56abc	37.81abcd	42.30abc	34.54abcd	38.55ab
$B_{1.3}$	41.55abc	39.39abc	36.26abcd	40.16abc	39.34ab
$B_{1.95}$	33.76abcd	49.14a	40.05abc	36.67abcd	39.90a
Mean	35.75ns	37.30ns	37.64ns	39.36ns	37.51
SEM (0.05)	B*P 4.719	B 2.36	P 2.36		
LSD (0.05)	3.63	6.81	6.81		
CV, %	21.79				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Boron uptake

The applied boron and phosphorus as well as their interaction effects were highly significant on boron uptake by plant (Table 5 and 6). The individual effect of applied boron on boron uptake by leaf and curd were the highest (19.5 µg gm^{-1} and 17.75 µg gm^{-1}) at $B_{1.3}$ level and it was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. Like this, the individual effect of applied phosphorus on boron uptake by leaf was the highest (4.33 µg gm^{-1}) at P_{30} level and it was significantly higher than P_{90}, P_{60} and P_0 levels. The $B_{1.3}$ had the highest mean boron uptake by leaf (20.22 µg gm^{-1}) and curd (17.6 µg gm^{-1}) which were significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. Similarly, among the different levels of phosphorus, P_{60} had the highest mean boron uptake by leaf (14.29 µg gm^{-1}) and curd (17.12 µg gm^{-1}) which were significantly higher than other levels of phosphorus including control. The highest boron uptake by plant leaf and curd were recorded at $B_{1.3}P_{60}$. The boron uptake by plant leaf and curd was increased with increasing levels of boron upto $B_{1.3}$ and phosphorus upto P_{60} levels, and then it was decreased. The curd boron content was correlated (r = 0.5*) and leaf B content was highly correlated (r = 0.66**) with phosphorus content of plant. The curd boron was also highly correlated (r = 0.63**) with leaf boron. The boron uptake by cauliflower leaf and curd with applied boron had quadratic relationship (Figure 1e, 1f).

Table 5. Boron uptake by cauliflower leaf as affected by boron and phosphorus fertilization

Treatments	Boron uptake by leaf, µg gm^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	1.98m	4.33l	0.65p	1.66n	2.157d
$B_{0.65}$	11.15h	8.66i	8.00j	1.02o	7.208c
$B_{1.3}$	19.50d	17.67e	26.82a	22.00b	20.22a
$B_{1.95}$	5.00k	11.74g	21.70c	15.19f	14.69b
Mean	9.40D	10.60B	14.29A	9.96C	11.06
SEM (0.05)	B*P 0.044	B 0.022	P 0.022		
LSD (0.05)	0.129	0.064	0.064		
CV, %	6.7				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Table 6. Effects of boron and phosphorus on boron uptake by cauliflower curd

Treatments	Boron uptake by curd, µg gm^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	5.33l	6.71k	11.07i	4.03m	6.78d
$B_{0.65}$	11.41h	10.93i	14.41f	9.37j	11.53c
$B_{1.3}$	17.75d	13.72g	23.51a	17.26e	17.60a
$B_{1.95}$	11.03i	13.74g	19.47c	21.68b	16.94b
Mean	11.3C	11.28C	17.12A	13.55B	13.21
SEM (0.05)	B*P 0.079	B 0.039	P 0.039		
LSD (0.05)	0.229	0.114	0.114		
CV, %	10.3				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

The result confirmed the earlier work of Gupta (1993) that optimum level of soil phosphorus increased the boron uptake by cauliflower. Similar findings were also reported by Stoyanov (1971) that optimum level of phosphorus supply increased the boron uptake by plant. Kotur and Kumar (1989) also showed a positive response of added phosphorus on boron uptake by cauliflower.

Phosphorus uptake

The individual as well as interaction effects of applied boron and phosphorus on phosphorus uptake by cauliflower was significant (Table 7). The individual effect of applied boron on phosphorus uptake by plant was the highest (30.05 kg ha^{-1}) at $B_{1.3}$ level and it was greater than $B_{1.95}$, $B_{0.65}$ and B_0 levels. The effect of applied phosphorus on phosphorus uptake by plant was the highest (29.73 kg ha^{-1}) at P_{90} level and it was significantly higher than P_{30} but similar to P_{60} level. The mean phosphorus uptake by cauliflower was increased with increasing levels of boron from B_0 to $B_{1.95}$ and it also increased with increasing level of phosphorus upto P_{60} level. The maximum phosphorus uptake was recorded at $B_{1.95}P_{90}$. The phosphorus uptake from $B_{1.3}P_{30}$, $B_{1.3}P_{60}$, $B_{1.3}P_{90}$, $B_{1.95}P_{30}$ and $B_{1.95}P_{60}$ were similar to $B_{1.95}P_{90}$. Highly significant correlation (r = 0.66**) was found between plant phosphorus uptake and leaf boron content. The phosphorus uptake by plant with applied phosphorus had quadratic relationship (Figure 1g).

The present results support the findings of several workers (Robertson and Loughman 1974, Loughman 1977) who reported that boron played an important role in phosphate transport across cell membranes. Malewar and Indulkar (1993) revealed that boron containing phosphorus fertilizer showed significant increase in phosphorus uptake as compared to non-boron phosphorus sources. Similar finding was also reported by Randhawa et al (1979) that boron deficiency caused thickening of roots and retarded root elongation, resulting smaller absorbing root surface and reduced phosphorus uptake.

Table 7. Phosphorus uptake by cauliflower as influenced by boron and phosphorus application

Treatments	Phosphorus uptake by cauliflower, kg ha^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	25.85bcd	20.83de	25.66bcd	29.73bc	25.52b
$B_{0.65}$	25.26bcd	19.51de	32.68b	26.12bcd	25.89b
$B_{1.3}$	30.05bc	41.55a	41.64a	40.01a	38.31a
$B_{1.95}$	24.51cd	44.02a	43.34a	45.75a	39.41a
Mean	26.41B	31.48B	35.83A	35.40A	32.27
SEM (0.05)	B*P 2.33	B 1.16	P 1.16		
LSD (0.05)	6.73	3.36	3.36		
CV, %	12.75				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Soil boron

The applied boron, phosphorus and their interactions had significant effects on boron status of soil (Table 8). The individual effect of applied boron on soil boron content was the highest (1.32 µg gm^{-1}) at $B_{1.3}$ and it was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0. The highest boron content of soil was obtained from $B_{1.3}P_{60}$ which was significantly higher than other treatments. The mean soil boron status was increased with increasing levels of applied boron up to 1.3 kg boron ha^{-1} and it was also increased with increasing levels of phosphorus up to P_{90}. The $B_{1.3}$ level had the highest mean soil boron content (1.31 µg gm^{-1}) which was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. The soil application with 90 kg P_2O_5 ha^{-1} had the highest mean soil boron content (1.1 µg gm^{-1}) which was significantly greater than other levels of boron, including control.

Table 8. Estimates of soil boron after the crop harvest from boron and phosphorus applied plots

Treatments	Soil boron content, µg gm^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	0.10i	0.10i	0.10i	0.10i	0.1d
$B_{0.65}$	0.60g	0.54g	0.93e	1.40b	0.86b
$B_{1.3}$	1.32c	0.72f	1.76a	1.45b	1.31a
$B_{1.95}$	1.20d	0.33h	0.10i	1.46b	0.75c
Mean	0.80B	0.422D	0.722C	1.103A	0.76
SEM (0.05)	B*P 0.025	B 0.012	P 0.012		
LSD (0.05)	0.074	0.037	0.037		
CV, %	5.32				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Soil phosphorus

The applied phosphorus had significant effect on phosphorus content of soil but the applied boron and their interaction effects were found to be insignificant. The mean available soil phosphorus was the highest (292.7 kg ha^{-1}) at P_{90} level which was similar to P_{60} but significantly higher than P_{30} and P_0 levels. The phosphorus content of soil was the highest at $B_{0.65}P_{90}$ and it was similar to treatments consisting of P_{90} and P_{60} levels. But they were significantly different from P_0 and P_{30} levels. The mean available soil phosphorus was increased from P_0 to P_{90} (Table 9) and the P_{60} was similar to P_{90}. It seems that the application of 60kg P_2O_5 ha^{-1} is judicious for the higher level of soil phosphorus in the soils of Paklihawa. The higher doses of applied phosphorus above P_{60} level might have reacted with other soil mineral elements and made them unavailable form in soils.

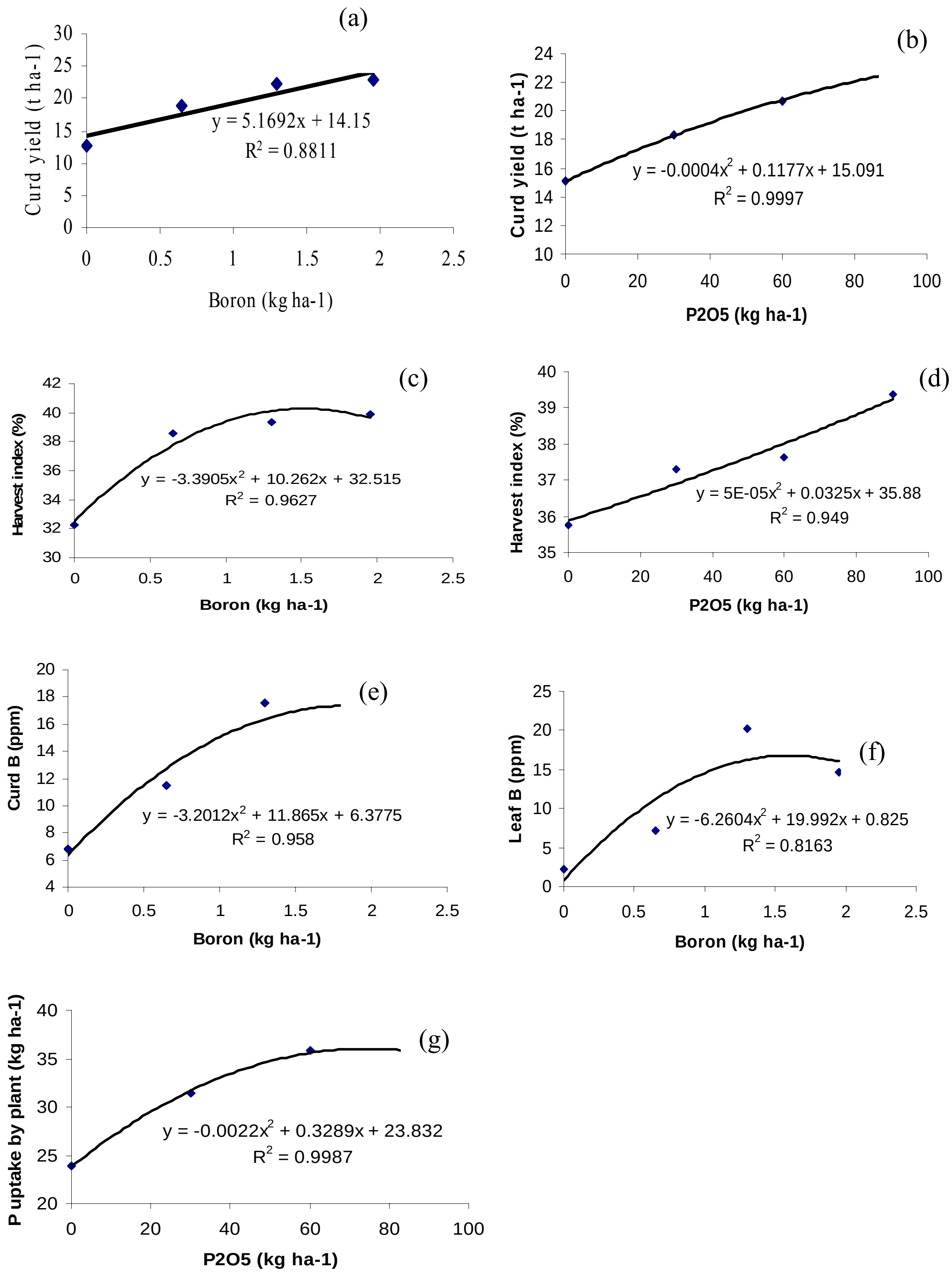

Figure 1. Response of cauliflower characteristics to different levels of boron and phosphorus applied.

Table 9. Estimates of phosphorus content of soil after the crop harvest from boron and phosphorus applied plots

Treatments	Available soil phosphorus (kg ha^{-1})				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	224.9bc	252.0abc	253.4abc	291.9abc	255.5ns
$B_{0.65}$	247.2bc	243.8bc	301.3ab	344.2a	284.1ns
$B_{1.3}$	200.7c	245.2bc	276.8abc	278.2abc	250.2ns
$B_{1.95}$	240.9bc	244.7bc	277.2abc	256.7abc	254.9ns
Mean	228.4C	246.4BC	277.2AB	292.7A	261.19
SEM (0.05)	B*P 28.31	B 14.16	P 14.16		
LSD (0.05)	81.77	40.88	40.88		
CV, %	18.77				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

CONCLUSION

The study showed that yield of cauliflower was the highest at 1.3 kg boron with 60kg P_2O_5 ha^{-1}. The research showed a significant correlation between boron and phosphorus uptake by plants. Similarly, significant correlation between plant boron uptake and soil phosphorus content and vice versa were also observed. Synergistic interaction could be obtained by applying boron and phosphorus within soil and plant system. It can be recommended that 1.3 kg boron with 60 kg P_2O_5 ha^{-1} is optimum for cauliflower production at Paklihawa location in Rupandehi district, Nepal but further research is needed to quantify these effects at different locations of the district.

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REFERENCES

Baral DR, TB Khatri-Chhetri and R Adhikari. 1986. Assessment of the needs of secondary and micronutrients for cauliflower in Rampur, Chitwan, Nepal. *J. Inst.Agric. and Anim. Sci.* 7:21-30.

Bremmer JM and CS Mulvaney. 1982. Nitrogen total. **In:** *Methods of soil analysis*, Part II (AL Page, RH Miller and DR Keeney, eds). Amer. Soc. Agron. Pp. 59-69.

Fujimoto T. 1998. Current status of soil fertility in Nepal (Part 2). **In:** *Soil science programs at a glance*. Soil Testing and Service Section, Crop Development Division, Department of Agriculture, Ministry of Agriculture, Lalitpur, Nepal. Pp. 26-28.

Gaines TP and GA Mitchell. 1979. Boron determination in plant tissue by Azomethine-H method. *Comm.Soil Sci. Plant Anal.* 10:1099-1108.

Gee GW and JW Bauder. 1986. Particle size analysis. **In:** *Methods of soil analysis*, Part I (A Klute, ed). Amer. Soc. Agron. Pp. 11-59.

Gomez KA and AA Gomez. 1984. *Statistical procedures for agricultural research*. A Wiley Interscience Publication, John Wiley and Sons, New York.

Gupta UC. 1993. Factors affecting boron uptake by plants in boron and its role in crop production. *Crop Science*. Pp. 88-104.

Jaishy SN, T Fujimoto and R Manandhar. 2000. Current status of soil fertility in Nepal. **In:** *Proceeding of 3rd National Conference on Science and Technology*. RONAST, Nepal. Pp. 1097-1104.

Kotur SC and S Kumar. 1989. Response of cauliflower to boron in Chhotanagpur region. *Ind. J. Agric. Sci.* 59:640-644.

Loughman BC. 1977. Metabolic factors and utilization of phosphate by plants. *Ciba Foundation Symposium*. 57:155-174.

Malewar GU and BS Indulkar. 1993. Effect of phosphorus and boron on cauliflower. *Ind. Soc. Veg. Sci.* 20(1):26-30.

Mengel K and EA Kirkby. 1987. *Principles of plant nutrition*. Second Edition. International Potash Institute, Berne, Switzerland.

Mishra DP. 1972. Sambalpur cauliflower needs boron. *Intensive Agriculture* 10:11-12.

Mitra SK. 1990. Cauliflower. **In:** *Nutrition of vegetable crops* (SK Mitra, MK Sadhu and TK Bose, eds). Naya Prokash, Calcutta, India. Pp. 133-148.

Moore KP. 1991. Determination of phosphorus in plant tissue by colorimetry. **In:** *Plant analysis reference procedures for the Southern region of the United States* (CO Plank, ed). Southern Cooperative Bull, 368, University of Georgia, Athens, GA. Pp. 29-32.

Nepal Agri-Business Promotion and Statistics Division. 2004. *Statistical information on Nepalese Agriculture*. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Co-operatives, Singha Durbar, Kathmandu, Nepal.

Olsen SR, CV Cole, FS Watanabe and HC Dean. 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. USDA. 939p.

Pandey UC, UC Shukla and K Singh. 1974. Effect of zinc and boron on yield and quality of cauliflower (*Brassica oleracea* var. botrytis). *Haryana J. Hort. Sci.* 3:201-206.

Pratt PF. 1965. Potassium. **In:** *Methods of soil analysis*. Part II: chemical and microbial properties (CA Black, ed). Amer. Soc. Agron., Madison, USA. Pp. 1005-1049.

Randhawa KS and AS Bhail. 1976. Effect of nitrogen, phosphorus and potassium on cauliflower. *Ind. J. Hort.* 33:83-91.

Randhawa NS, DL Dev, PN Takkar and NS Pasricha. 1979. Phosphorus micronutrient interaction in soils and plants. **In:** *Phosphorus in soils, crops and fertilizers*. Ind. Soc. Soil Sci. New Delhi, India. Pp. 58-72.

Robertson GA and BC Loughman. 1974. Modification of phosphate transport in V*icia faba* by boron deficiency, growth inhibitors and metabolic inhibitors. **In:** *Membrane transport in plants* (U Zimmerman and J Dainty, eds). Springer Verlag, New York. Pp. 444-449.

Stoyanov DV. 1971. Conditions for the boron nutrition of tobacco in Bulgeria. *J. Agrochemical* 6:99.

Thakur OP, PP Sharma and KK Singh. 1991. Effect of nitrogen and phosphorus with and without boron on curd yield and stalk rot incidence in cauliflower. *Ind. Soc. Veg. Sci.* 18(2):115-121.

Walkley A and IA Black. 1934. An examination of direct method for determining organic matter and a proposed modification of the chromic acid titration method. *J. Soil Sci. Soc. Amer.* 37:29-38.

Effect of NPK on Vegetative Growth and Yield of Desiree and Kufri Sindhuri Potato

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ABSTRACT

A field experiment was carried out to assess the effect of NPK on vegetative growth and yield of potato cultivars; Kufri Sindhuri and Desiree at different nutrient levels (0:0:0, 50:50:50, 100:50:50, 100:75:50, 100:75:100, 100:100:100 and 150:100:100 N, P_20_5 and k_20 kg ha^{-1}) in sandy loam soils at Rampur, Chitwan, Nepal during 1999/2000. The experiment was laid out in a split plot design with 4 replications. Plant height, number of stems, fresh weight of stem and leaves were recorded at 15 days interval during crop growth period and tuber yield at maturity stage. Kufri Sindhuri was taller than Desiree at all the stages of plant growth. Increasing levels of NPK increased the plant height by 15-42 percent. The levels of NPK imparted to a significant effect on fresh weight of leaves and stems at each successive stages of crop growth. Kufri Sindhuri responded nitrogen up to 150 kg ha^{-1} while Desiree yielded higher at 100:100:100 kg NPK ha^{-1}. The yield increase of potato tuber was associated with increase in the plant height, fresh weight of leaves and stems as a result of applied NPK.

Key words: Desiree, fresh weight, Kufri Sindhuri, nutrients, tuber yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most productive food crops when considered in terms of yield per unit area and per unit time. In Nepal, potato is ranked as the fourth most important crop (APP 1995). It is a staple food in high hills where as it is used as major vegetable in other areas. It is, therefore not only a major food crop, but also an income generating one.

The potato plant consumes high level of nutrients during a short growth period (90 days). Variations in soil fertility affect on several characters that influence the growth and yield (Pushkarnath 1976). Good vegetative growth and tuberisation, which lead to good yield, are possible only when adequate quantities of mineral nutrients are supplied (Benepal 1967). One ton of potato tubers remove 5 kg N, 1.8 kg, P_20_5 and 9 kg K_20 (Shnek 1994). Significant response to NPK application on potato crops has also been reported by Singh and Singh (1995) and Singh et al (1993).

It is well known that even in the same growing condition, cultivars differ in their yield performance. Similarly vegetative growth and yield performance of cultivar varies depending on the soil and climatic condition (Pushkarnath 1976). Significant potato responses to NPK application have been reported by various workers in different agro-climatic condition and optimum dose of NPK varied with the soil and potato varieties (Singh and Singh 1995, Maity and Arora 1980). Response of potato to NPK in soil of Chitwan had already been reported (Adhikari et al 1998-1999, Basnet et al 2000-2001) but there was little information on the effect of nutrient in relation to different growth stages of potato. Kufri Sindhuri and Desiree are popular potato cultivars in Tarai and inner Tarai. The present investigation is therefore an attempt to study the effect of various levels of NPK for these recommended potato cultivars on their vegetative growth and yield in Chitwan conditions.

MATERIALS AND METHODS

The experiment was carried out during 1999/2000 in the sandy loam soil at Rampur, Chitwan. Before planting the soil pH was 4.8 to 5.2 and organic matter varied from 2.55 to 3.22 percent. The N, P_20_5 and K_20 contents in 20-cm layer of soil were 2400 to 2800, 96.54 to 108.58 and 211.87 to 277.76 kg respectively.

The experiment was laid out in a split plot design with 4 replications. Potato cultivars, Desiree and Kufri Sindhuri were selected as main plot. Seven different combination of NPK ie 0:0:0 50:50:50, 100:50:50, 100:75:50, 100:75:100, 100:100:100 and 150:100:100 kg ha^{-1}, respectively were taken as sub-plots. Individual sub-plot was consisted of 4.2- × 2.5-m with seven rows, each of which maintained 10 plants. Half dose of N and full dose of P and K were applied in furrows and mixed with soil thoroughly at planting time. The remaining half dose of N was topdressed at the time of earthing-up after 5 weeks of planting. The sources of fertilizers were di-ammonium phosphate (18:46:0), urea (46:0:0) and Muriate of potash (0:0:60). Well-sprouted disease free tubers of Kufri Sindhuri and Desiree weighing approximately 40-50 g were planted at 60 cm row distance and 25 cm plant-to-plant spacing within rows. Two rows in each side of the subplot left for boarder rows. The tubers of both cultivars were planted on 2 November 1999.

The crop was irrigated after 45 days of planting through furrow method. Two sprays of Moncozeb (Dithane M-45) and one spray of Metalaxyl (Krilaxyl) were alternatively used to control the late blight disease during first fortnight of January when the environment was conducive for late blight pathogens. Weeding, earthing up and other cultural practices were carried out as per the recommended practices.

One month after planting, three plants were uprooted from each sub plot on 30, 45, 60 and 75 days after planting (DAP). These plants were separated into leaves, stems, and tubers and weighed immediately for recording the fresh weights. Observations on plant height (cm), number of stems $plant^{-1}$ was recorded on randomly selected plants in each sub-plot. The cultivars, Desiree and Kufri Sindhuri were harvested on 3 and 28 Feb 2000, respectively. The data were analyzed following the procedure as described by Gomez and Gomez (1984). LSD test was used to compare the means among the treatments.

RESULTS AND DISCUSSION

Effect on germination

In general fertilizer levels had negligible influence on germination. Treatments having 100:100:100 NPK kg ha^{-1} had non-uniform germination in the initial stages as compared to other treatments, but by the time when the crop reached 30 days of planting, about 95 percent germination was observed in most of the plots (data not shown). Early and uniform germination was observed in control plots. It was also observed that increasing levels of fertilizer delayed the emergence of tubers.

Effect on plant height

There was significant effect of NPK levels on height of plant over their zero level except at 30 DAP (Table 1). Significant increase in plant height was recorded up to the application of 100:50:50 NPK kg ha^{-1}. Kufri Sindhuri was significantly taller than Desiree at all the stages of plant growth. Increasing levels of nutrients increased plant height by 15-42 percent as compared to zero level. This is because relatively high dose of nitrogen application results in vigorous growth of the plant. Madhikarmy (1979) and Sharma and Upadhaya (1993) have also reported similar result. Increasing P and K rates had no effect on plant height at all the stages of plant growth. Jagirdar et al (1984) and Singh et al (1993) reported that increase in the level of P and K had no effect on plant height. High soil fertility and nitrogen application results in vigorous growth of the plant (Sharma and Upadhaya 1993).

Effect on number of stem

The number of stems per hill mostly depends upon varietal character. However in the present study, fertilizer levels did not show significant effect on the number of stems. Long duration (120 days) variety, Kufri Sindhuri had significantly more number of stems than the short duration (90 days) Desiree at later stage of plant growth (60 and 75 DAP) (Table 2). Sharma and Singh (1988) and Nandekar et al (1991) also showed that none of the nutrients applied could affect the number of stems significantly.

Table 1. Effect of NPK on plant height (cm) at different dates of observation at Rampur, Chitwan, 1999/2000

Treatment	Days after planting			
	30	45	60	75
Variety (V)				
Kufri Sinduri	22.18	60.70	71.20	74.20
Desiree	18.65	48.70	56.30	58.20
F-test	*	**	**	**
LSD (0.05)	1.80	4.14	5.04	5.02
Nutrient (N) ($N:P_20_5:K_20$), kg ha^{-1}				
0:00:00	21.80	37.20	45.40	46.80
50:50:50	20.96	48.10	57.50	51.50
100:50:50	20.53	60.20	68.70	71.30
100:75:50	20.74	58.60	67.80	70.80
100:75:100	20.01	58.30	67.50	70.60
100:100:100	18.13	58.70	67.10	69.90
150:100:100	20.74	61.80	72.20	74.20
F-test	ns	**	**	**
LSD (0.05)		3.81	4.43	4.27
Interaction (V × N)	ns	ns	ns	ns

*ns, not significant. *, significant at 5% level. **, significant at 1% level.*

Table 2. Effect of NPK levels on number of stem per hill in potato at Rampur, Chitwan, 1999/2000

Treatment	Days after planting			
	30	45	60	75
Variety (V)				
Kufri Sinduri	4.21	4.35	4.35	4.49
Desiree	3.01	3.23	3.08	2.89
F-test	ns	ns	*	*
LSD (0.05)			0.61	0.53
Nutrient (N) ($N:P_20_5:K_20$), kg ha^{-1}	ns	ns	ns	ns
Interaction (V × N)	ns	ns	ns	ns

*ns, not significant. *, significant at 5% level.*

Effect on fresh weight of leaves

Leaf weight indicates the size of photosynthetic system and intercepted radiation and there is a relationship between leaf area and total tuber yield. Kufri Sindhuri had significantly higher leaf weight than Desiree at 60 and 75 DAP (Table 3). It is evident from table 3 that the levels of NPK significantly increased the fresh weight of leaves at all the growth stages except 30 DAP. Significant increase in leaf weight was recorded with the application of fertilizers 100:50:50 NPK kg ha^{-1} as compared to zero level (control). Leaf weight was increased significantly from 45 to 75 days. Sharma and Arora (1987) have reported similar results. Increase in P and K had no prominent effect on fresh weight of leaves. Puskarnath (1976) and Taya et al (1994) also reported that the rates of increase in top growth and leaf weight are directly related to the level of N applied. Increase in P and K had no prominent effect on fresh weight of leaves. Puskarnath (1976) and Taya et al (1994) also reported that the rates of increase in top growth and leaf weight are directly related to the level of N applied.

Interaction of nutrients in soils and plants is an important factor in determining the yield of crops. Since nitrogen is required for the formation of chlorophyll and phosphorus for cell division and elongation (Basnet et al 2000-2001). Interaction effect of fertilizer levels and cultivars on leaf weight was also significant at all the observations except 30 DAP (Table 3). Potato varieties differ greatly in their to NPK application indicating a strong interaction of varieties with NPK application with regards to their leaf weight at different growth stages. Kumar et al (1991) and Grewal and Trehan (1993) reported that short duration varieties response less to NPK during different growth stages than long duration varieties. In Kufri Sinduri increasing level of nitrogen up to 100 kg ha^{-1} at 45, 60 and 75 days of planting significantly increased in the leaf weight. But increasing level of P up to 75 kg ha^{-1} had no effect on leaf weight of Kufri Sinduri except 75 DAP. Increasing level of K had little effect on weight of leaf at all the growth stage. Grewal and Trehan (1993) also reported similar results. Desiree is a short duration variety and less responsive to NPK at different growth stages as compared to Kufri Sinduri. The increment of nitrogen dose from 100-150 kg ha^{-1} had no effect on leaf weight at all the growth stages. Increasing P rate had no prominent effect on leaf weight of Desiree at all the growth stages whereas K level up to 100 kg ha^{-1} had a little effect during 45 and 75 DAP.

Effect on fresh weight of stems

Significant cultivar difference was also found on stem weight during later stage of crop growth (60 and 75 DAP). The levels of NPK imparted a significant effect on fresh weight of stem at each successive stages of crop growth except 30 DAP (Table 4). In the beginning, the increase in fresh weight was more but it declined after 60 DAP. The increase in the fresh weight of stem by NPK application is due to its association with the metabolic activities of the plant that brings about better growth (Singh and Singh 1995). Nitrogen and phosphorus had increasing effect on fresh weight of stems. Soltanpour and Cole (1978) reported that application of N and P fertilizers to the soil increased the fresh weights of stems. Taya et al (1994) reported that K has not significant effect on fresh weight of stems. Analysis of variance showed a non-significant interaction between cultivars and fertilizer levels at early stages of plant growth (30 and 45 DAP). The long duration variety Kufri Sinduri had significantly response to N and P on stem weight during 60 and 75 DAP where as application of K had no apparent effect on Deiree at all the growth stages. The results indicated that potato varieties differ greatly in their response to NPK application with regards to their stem weight during 60 and 75 DAP.

Effect on tuber yield

Tuber yield calculated on per plot basis ranged from 25.7 to 35.7 and 14.9 to 21.1 t ha^{-1} in Kufri Sindhuri and Desiree, respectively (Figure 1). The highest tuber yield of Kufri Sindhuri and Desiree ie 35.3 and 21.1 t ha^{-1} was obtained at 150:100:100 and 100:100:100 NPK kg ha^{-1} respectively. Significant increment in tuber yield was found up to the application of 100:50:50 NPK kg ha^{-1}. Long duration variety, Kufri Sinduri is high yielder than Desiree. Kufri Sinduri was found more responsive to nitrogen than Desiree at Rampur, Chitwan.

Table 3. Effect of NPK on fresh weight of leaves (g $hill^{-1}$) at Rampur, Chitwan, 1999/2000

Treatment	Days after planting			
	30	45	60	75
Variety (V)				
Kufri Sinduri	36.55	140.26	288.41	273.67
Desiree	34.67	97.69	139.32	131.79
F-test	ns	ns	**	**
LSD (0.05)			58.45	55.79
Nutrient (N) ($N:P_20_5:K_20$), kg ha^{-1}				
0:00:00	34.71	74.51	141.76	128.99
50:50:50	34.95	111.85	175.77	176.56
100:50:50	37.12	127.99	225.44	195.51
100:75:50	35.30	123.36	228.75	222.68
100:75:100	34.35	127.21	236.68	221.87
100:100:100	36.30	134.91	227.50	221.38
150:100:100	36.54	132.99	261.17	252.13
F-test	ns	**	**	**
LSD (0.05)		17.08	33.32	33.79
Interaction (V × N)				

KS × 0:0:0	36.30	78.09	200.59	175.56
KS × 50:50:50	36.04	125.50	230.16	238.25
KS × 100:50:50	38.29	155.79	290.67	257.67
KS × 100:75:50	35.78	155.00	306.57	317.16
KS × 100:75:100	36.07	152.00	320.90	301.54
KS × 100:100:100	36.36	159.37	300.00	273.13
KS × 150:100:100	37.02	156.08	370.12	352.41
De × 0:0:0	33.13	70.93	82.93	82.42
De × 50:50:50	33.86	98.20	121.38	114.88
De × 100:50:50	35.96	100.19	160.21	133.36
De × 100:75:50	34.81	91.73	150.93	128.21
De × 100:75:100	32.63	102.41	152.47	142.21
De × 100:100:100	36.24	110.46	155.00	169.63
De × 150:100:100	36.02	109.90	152.32	151.84
F-test	ns	**	**	**
LSD (0.05)		24.15	47.12	47.79

*KS, Kufri Sindhuri. De, Desiree. ns, not significant. **, significant at 1% level.*

The initial soil analysis showed high amount of organic matter, nitrogen, and phosphorus and medium amount of potassium in the soil samples of the experimental plots. The value above 1.29 % organic matter, the available total NPK more than 543, 22 and 333 kg ha^{-1} respectively considered as rich amounts in soils (Arora et al 1979). In the experimental plot nitrogen and phosphorus were higher than these values. High nutrient status of the experimental plot played a significant role in increasing the fertility status of the soils. Kufri Sindhuri responded nitrogen was up to 150 kg ha^{-1}, while Desiree yield started to decline slightly beyond N 100 kg ha^{-1}. Nitrogen assist to increase leaf area, leaf weight, stem weight, plant height. The increase in the yield of potato tubers was found to be associated with increase in the plant height, fresh weight of leaves and stems as a result of applied of NPK. Sharma and Singh (1988) and Rykbost et al (1993) reported the increase in the yield of potato tubers due to NPK application. Significant increasing yield of Kufri Sindhuri and Desiree was recorded with 100:50:50 NPK kg ha^{-1} with the ration of 1:0.5:0.5 (Figure 1).

The finding of this study suggests that in sandy loam soils of Rampur, Chitwan potato cultivar Kufri Sindhuri yields high at higher level of N (150 kg/ha) while Desiree yields higher at 100:100:100 NPK kg ha^{-1} of mineral nutrients.

Table 4. Effect of NPK on fresh weight of stems (g $hill^{-1}$) at Rampur, Chitwan, 1999/2000

Treatment	Days after planting			
	30	45	60	75
Variety (V)				
Kufri Sinduri	18.75	78.25	145.21	140.38
Desiree	12.91	52.60	69.02	65.11
F-test	ns	ns	**	**
LSD (0.05)			41.25	49.30
Nutrient (N) ($N:P_2O_5:K_2O$), kg ha^{-1}				

0:00:00	15.00	39.76	55.63	51.52
50:50:50	16.69	56.42	88.09	86.40
100:50:50	16.77	72.33	109.25	98.10
100:75:50	16.38	72.30	120.23	118.48
100:75:100	15.42	71.46	116.53	111.56
100:100:100	15.56	70.38	125.19	118.44
150:100:100	15.00	75.30	134.86	134.71
F-test	ns	*	**	**
LSD (0.05)		9.19	17.30	16.25
Interaction (V × N)				
KS × 0:0:0	17.52	49.29	74.93	72.54
KS × 50:50:50	20.50	69.00	122.37	117.52
KS × 100:50:50	20.54	86.40	141.64	126.09
KS × 100:75:50	19.04	84.50	163.25	168.17
KS × 100:75:100	18.38	87.00	155.83	150.38
KS × 100:100:100	17.60	82.69	170.71	160.46
KS × 150:100:100	17.67	88.83	187.71	187.54
De × 0:0:0	12.48	30.23	36.33	30.49
De × 50:50:50	12.87	43.83	53.82	55.29
De × 100:50:50	13.00	58.26	76.85	70.12
De × 100:75:50	13.71	60.10	77.21	68.79
De × 100:75:100	12.56	55.92	77.23	72.75
De × 100:100:100	13.52	58.07	79.67	76.42
De × 150:100:100	12.33	61.77	82.02	81.87
F-test	ns	ns	**	**
LSD (0.05)			24.47	22.99

*KS, Kufri Sindhuri. De, Desiree. ns, not significant. *, significant at 5% level. **, significant at 1% level.*

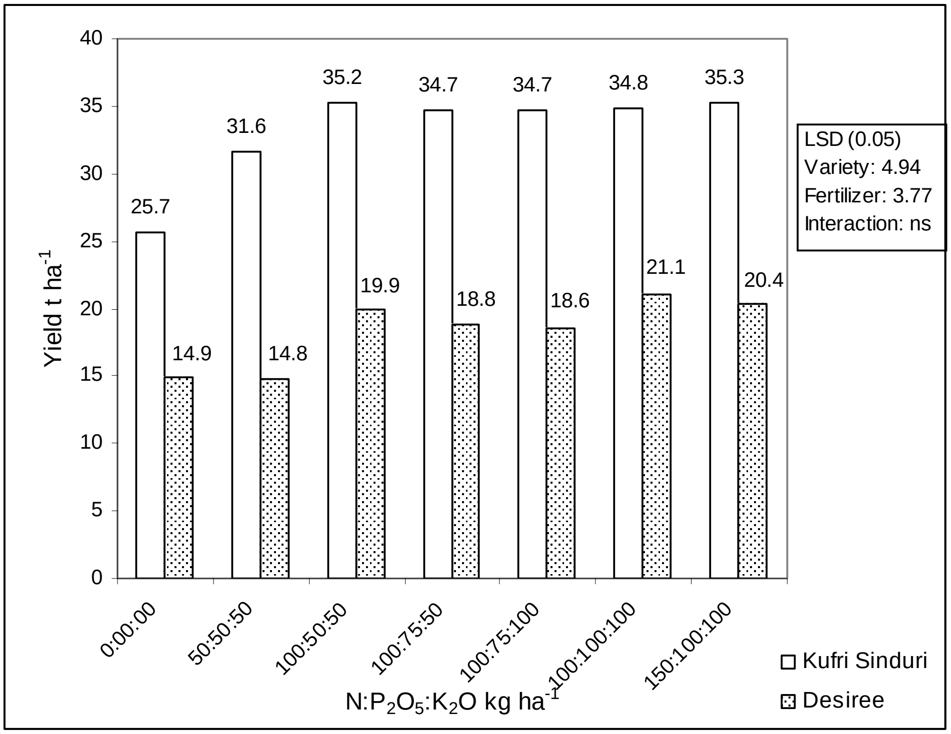

Figure 1. Effect of N, P and K on tuber yield of potato at Rampur, Chitwan, 1999/2000.

REFERENCES

Adhikari RC, MD Sharma, SM Shakya, G Upreti and GP Rai. 1998-1999. Effect of fertilizers on tuber size and yield of potatoes in Rampur, Chitwan. *J. Inst.Agric. Anim. Sci.* 21-22:85-93.

APP. 1995. Agriculture Perspective Plan. National Planning Commission, Kathmandu, Nepal. 633 p.

Arora BR, IM Chhibba and GS Sekhon.1979. *Practical manual soils and waters testing for BSc (Agri) honors in soils*. Department of soils, Punjab Agricultural University, Ludhiana, India. 136 p.

Basnet KB, MD Sharma and RC Adhikari. 2000-2001.Effect of different level of potash on the performance of potato under humid subtropical condition of Chitwan. *J. Inst.Agric. Anim.Sci.* 21-22:1-7.

Benepal PS. 1967. Inter relations among plant nutrients, application levels on yields of potatoes. *Amer. Potato J.* 44(6)187-194.

Gomez KA and A Gomez. 1984. *Statistical procedure for agricultural research*. Second Edition. John Willy and Sons, New York. 680 p.

Grewal JS and SP Trehan. 1993. Phosphorus and potassium nutrition of potato. **In:** *Advances in horticulture 7* (KL Chadha and JS Grewal, eds). Malhotra Publishing House, New Delhi. Pp. 260-296.

Jagirdar SAP, MH Laghari and MS Panhwar. 1984. Effect of fertilizer on growth and yield of potato. *Pakistan J. Agri. Research* 5(3):162-164.

Kumar R, SC Khurana and ML Pandita. 1991. Correlation studies in potato. *J. Indian Potato Assoc.* 18(3-4):169-171.

Madhikarmy SG. 1979. Effect of NPK fertilization on the performance of Kufri Jyoti potato (*Solanum tuberosum). Nepalese J. Agric*. Nepal Agricultural Association. 14:125-131.

Maity K and P. N. Arora. 1980. Effect of varieties, levels and sources of potash on potassium composition and uptake in potato. *Indian J. Agron.* 25(1):1-8.

Nandekar DN, TR Sharma, RC Sharma and SD Sawarkar. 1991. Fertilizer requirements of potato cv Kufri Badshah in Madya Pradesh. *J. Indian Potato Assoc.* 16(2/3):123-126.

Pushkarnath. 1976. *Potato in sub-tropics*. Orient Longman. 289 p.

Rykbost KA, NW Christensen and J Maxwell. 1993. Fertilization of russet Burbank in short-season environment. *Ameri. Potato J.* 70:699-708.

Sharma RC and NC Upadhaya. 1993. Nitrogen nutrition of potato. **In:** *Advances in horticulture 7* (KL Chadha and JS Grewal, eds). Malhotra Publishing House, New Delhi. Pp. 231-259.

Sharma UC and K Singh. 1988. Response of potato N, P and K in acidic hill soil of Meghalaya. *J. Indian Potato Assoc.* 15(1-2):40-44.

Sharma UC and BR Arora. 1987. Effect of nitrogen, phosphorus and potassium application on yield of tubers. *J. Agric. Sci. Camb.*108:321-328.

Shnek M. 1994. *Multi-K 13-0-46 for potatoes*. Haifa Chemicals Ltd, Haifa Bay, Israel. 8 p.

Singh J, M Singh, MS Saimbni and KS Kooner. 1993. Growth and yield of potato cultivars as affected by plant density and potassium levels. *J. Indian Potato Assoc.* 20(3-4):279-282.

Singh VN and SP Singh. 1995. Effect of levels and methods of potassium application on vegetative growth and yield of potato cv Kufri Badshah. *J. Indian Potato Assoc.* 22(3-4):118-121.

Soltanpour PN and CV Cole. 1978. Ionic Balance and growth of potatoes as affected by N plus P fertilization. *Amer. Potato J.* 55:549-559.

Taya JS, YS Mallik ML Pandita and SC Khurana. 1994. Fertilizer management in potato based cropping system. 1: Growth and yield of Potato. *J. Indian Potato Assoc.* 21(3-4):184-488.

Influence of Long-term Use of Organic and Inorganic Nutrients on HLB Disease of Wheat under Rice-Wheat Cropping Pattern

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ABSTRACT

Helminthosporium leaf blight (HLB) is one of the most destructive diseases of wheat in terai (plain) region of Nepal. This study was conducted to determine the effect of long-term application of various levels of nitrogen (N), phosphorus (P), potassium (K) and organic nutrients on HLB disease of wheat. The experiment was superimposed on long-term fertility experiment conducted in RCB design with three replications under rice-wheat cropping pattern at National wheat research program (NWRP), Bhairahawa, Nepal. The treatments include various combinations of nitrogen 100 kg ha^{-1}, phosphorus 0 and 60 kg ha^{-1}, and potash 0, 50 and 100 kg ha^{-1} with or without Sesbania (*Sesbania cannabina)* and farm yard manure (FYM). Area under disease progress curve (AUDPC) was calculated using the disease scores and yield parameters were recorded. Among the inorganic nutrients, long-term deficiency of potash in the field markedly enhances the HLB disease. Application of phosphorus in various doses increased the HLB severity in absence of potash. Regular application of at least potash 50 kg ha^{-1} in wheat noticeably reduced the HLB disease. Regular use of FYM 10 ton ha^{-1} for long-term considerably reduced the HLB disease but long-term use of Sesbania as green manure did not show any impact on HLB severity. Inclusion of potash in nutrients considerably increased the yield and thousand grain weight (TGW) of wheat. In long term, balanced use of inorganic and organic nutrients with special attention on regular inclusion of potash and FYM in the nutrient combinations is vital in suppression of HLB disease under rice-wheat cropping pattern.

Key words: AUDPC, FYM, Helminthosporium leaf blight, potassium

INTRODUCTION

Rice-wheat is the most important cropping pattern in terai (plain) areas of Nepal. Helminthosporium leaf blight (HLB) is one of the most destructive diseases of wheat in terai regions of Nepal. HLB generally occurs with complex infection of spot blotch (caused by *Cochliobolus sativus* (Ito & Kurib.) Drechsler ex. Dastur (anamorph: *Bipolaris sorokiniana*) and tan spot (caused by *Pyrenophora tritici repentis* (Died.) Drechsler (anamorph: *Drechslera tritici repentis*) in plain areas of Nepal (Sharma et al 2003). HLB prevails every year in the major wheat growing areas of the country due to the lack of durable and highly resistant cultivars, use of unbalanced fertilizers and poor management conditions. The losses due to the disease are remarkable in many regions of indo-gangetic plains including Nepal (Duveiller and Gilchrist 1993, Duveiller 2002). The yield losses due to HLB in farmers' fields of Nepal ranged from 20 to 25 percent (Saari 1997, Duveiller 2002**)**. The pathogens are weak hemi biotrophs, so cultural practices prominently influence the severity of disease (Ruckstuhl 1997, Naitao and Yousan 1997, Bocus and Shroyer 1998, Mathieoson et al 1990). Disease severity is increased under stressed plant growth conditions caused by low or unbalanced soil nutrients level, potash deficiency, poor management practices and high temperature and hot wind during the later stage of the crop (Ruckstuhl 1997, Naitao and Yousan 1997, Bhatta et al 1997, Sharma et al 2005). Resistant genotypes, seed treatment and foliar sprays with triazole fungicides are effective against the disease (Bhatta et al 1997, Naitao and Yousan 1997), however, except resistant genotypes; the other methods are not economically practicable for poor farmers of Nepal. Among several factors of cultural management, the role of plant nutrients is supreme in the suppression of HLB disease. Application of potash fertilizer reduces the HLB incidence significantly in both short- and long-term fertility conditions (Regmi et al 2002, Sharma et al 2005). Nepalese farmers use unbalanced and less amount of fertilizers in wheat, which results in lower yield due to the combined effect of nutrient deficiency and higher HLB disease.

Determination of role of various combinations of major inorganic and organic nutrients on HLB severity in long run could help to develop a durable and cost effective technology for HLB management. Therefore, this study was conducted to find out the effect of long-term use of various levels of nitrogen, phosphorus, potash, green manure and FYM on HLB disease of wheat.

MATERIALS AND METHODS

The experiment was superimposed on long-term fertility experiment under rice-wheat cropping system conducted at National Wheat Research Program, Bhairahawa in the year 2003-04. The long-term fertility experiment has been continuously conducted since 1988 with slight modification of treatments in 1995. The design was RCB with three replications. Genotype Nepal 297 was used in both the years. The final treatments after modification in 1995 include application of various combinations of nitrogen 100 kg ha^{-1}, phosphorus 0 and 60 kg ha^{-1}, and potash 0, 50 and 100 kg ha^{-1}, with or without Sesbania and farm yard manure (FYM). Sesbania was grown for 60 days and mixed on field before rice planting whereas, FYM 10 ton ha^{-1}, was applied to wheat only. Half of the nitrogen and full dose of phosphorus and potash was applied as basal and remaining half dose of nitrogen was applied 25 days after seeding as top dress. Ten main tillers in each plot were randomly selected and tagged prior to scoring disease intensity. Severity of disease was recorded by visually assessing the percent diseased leaf area on the flag leaf and penultimate leaf of tagged tillers. Three scores were recorded at 7 days intervals after the heading stage of the crop. Area under disease progress curve (AUDPC) was calculated following the formula given by Das et al (1992). Yield and thousand grain weight were recorded for analysis of yield features.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance revealed that the treatments differed significantly ($P < 0.01$) for HLB AUDPC, yield and thousand-grain weight (TGW) in both years (Table 1). FYM had significant ($P < 0.01$) effect on suppression of HLB severity in both the years. Application of potash significantly ($P < 0.01$) reduced the HLB severity. Application of phosphorus in absence of potash significantly (P <

0.01) increased the disease severity. The effect of Sesbania before rice was insignificant for HLB AUDPC.

Effects of potash on HLB

Application of potash significantly reduced HLB severity on wheat under long-term rice-wheat cropping pattern (Table 1). Significantly lower disease in the treatments of NPK 100:60:100 and 100:60:50 kg ha^{-1} than in NPK 100:60:0 kg ha^{-1} signifies the impact of potash fertilizer on suppression of HLB disease under long-term fertility conditions (Figure 1). This result supports the outcomes of various similar previous studies (Sharma et al 2005, Regmi et al 2002**)**. Thin cell walls, weakened stalks and stems, smaller and shorter roots and accumulation of unused nitrogen caused

Table 1. Combined mean HLB AUDPC on different treatments of long-term soil fertility experiment conducted at Bhairahawa during 2003 and 2004

SN	Treatments	Combined mean AUDPC of 2003 and 2004†
1	Sesbania before rice and NPK 100:60:100 kg ha^{-1}	483c
2	Sesbania before rice and NPK 100:60:0 kg ha^{-1}	1027a
3	Sesbania before rice and NPK 100:60:50 kg ha^{-1}	571c
4	NPK 100:60:0 kg ha^{-1}	1052a
5	NPK 100:60:50 kg ha^{-1}	516c
6	NPK 100:60:100 kg ha^{-1}	536c
7	FYM 10 t ha^{-1} in wheat and NPK 100:60:0 kg ha^{-1}	601c
8	FYM 10 t ha^{-1} in wheat and NPK 100:60:50 kg ha^{-1}	437c
9	FYM 10 t ha^{-1} in wheat and NPK 100:60:100 kg ha^{-1}	453c
10	FYM 10 t ha^{-1} in wheat and NPK 100:0:0 kg ha^{-1}	463c
11	Sesbania before rice and NPK 100:0:0 kg ha^{-1}	759b
12	NPK 100:50:0 kg ha^{-1}	1035a
13	NPK 100:100:0 kg ha^{-1}	1120a
14	NPK 100:0:0 kg ha^{-1}	840b

† Means in a column followed by the same letter do not differ significantly at P = 0.05 according to Duncan's multiple range tests.

by potassium deficiency enhance the disease infection (Anonymous 1998). Similarly, treatment 100:60:100 NPK kg ha^{-1} and 100:60:50 NPK kg ha^{-1} were statistically at par which suggest that the use of potash 50 kg ha^{-1} is sufficient to suppress the incidence of HLB under long-term fertility conditions (Figure 1).

Likewise, the insignificant differences for AUDPC among treatments Sesbania + 100:60:50, FYM + 100:60:50 and 100:60:50 indicate that application of balance dose of inorganic fertilizers is sufficient to reduce the HLB severity.

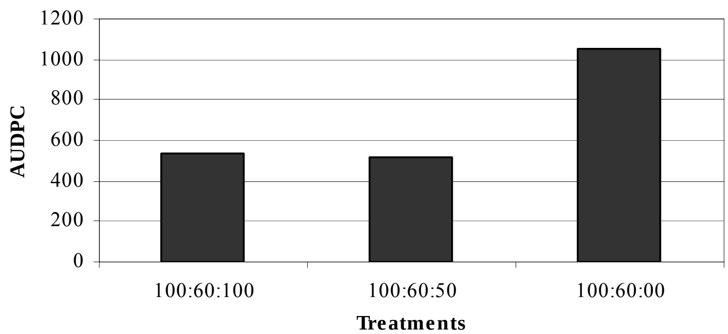

Figure 1. Effect of potash on HLB of wheat under long-term fertility (rice-wheat) conditions during 2003 and 2004.

Effects of phosphorus on HLB

The effect of phosphorus was adverse on HLB disease in absence of potash (Table 1). The incidence of HLB was high in treatments 100:100:0, 100:60:0 and 100:50:0 in both the years. Significantly higher AUDPC in treatments having only nitrogen and phosphorus than the treatments having NPK and only nitrogen indicate the adverse effect of phosphorus on HLB disease (Figure 2); however, the reasons behind this is not clear and need further investigation. The present results agree with the results of Gharti et al (2002). Similarly, significantly less HLB in the treatments Sesbania + NPK 100:0:0 and only NPK 100:0:0 kg ha^{-1} than the treatments NPK 100:50:0, 100:60:0 and 100:100:0 kg ha^{-1} suggests that for the suppression of HLB disease, application of nitrogen only should be prioritized over application of nitrogen and phosphorus. Likewise, statistically at par HLB incidences in treatments 100:50:0, 100:100:0 and 100:60:0 point out that the levels of phosphorus in the absence of potash haven't any effect on HLB severity. The present results support the previous findings that disease caused by *Cochliobolus sativus* is not affected by the addition of phosphorus (Bailey et al 1980).

Effects of FYM on HLB

The significant and lowest AUDPC in the treatments having FYM and FYM + potash proves the paramount role of these two nutrients on HLB suppression (Table 1). The least HLB disease in treatment having FYM 10 ton ha^{-1} + potash may be partially due to the reduction of primary inoculums present in the soil, because application of cow dung, urine and high levels of organic matter inhibit the conidial germination of *B. sorokiniana* (Akhtar et al 2006).

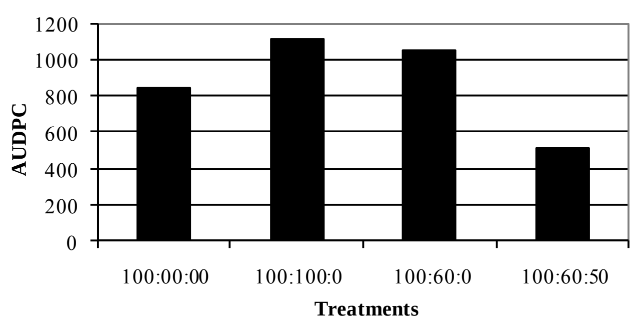

Figure 2. Effect of phosphorus on HLB of wheat under long-term fertility (rice-wheat) conditions during 2003 and 2004.

Likewise, the insignificant differences for HLB severity among 100:60:100 NPK kg ha^{-1}, 100:60:50 NPK kg ha^{-1} and FYM 10 ton ha^{-1} + 100:60:0 NPK kg ha^{-1} point out that application of FYM 10 ton ha^{-1} could suppress the HLB severity equal to the application of 50-100 kg potash ha^{-1}. These results agree with previous reports, which advocated that organic materials reduce disease incidence caused by many plant pathogenic bacteria, fungi and nematodes (Abawi and Widmer 2000, Conn and Lazarovits 2000, Lazarovits et al 2001).

Significantly less disease in FYM 10 t ha^{-1} + 100:0:0 NPK kg ha^{-1} than the treatments Sesbania + 100:0:0 NPK kg ha^{-1} and only 100:0:0 NPK ha^{-1} confirms the sole effect of FYM on HLB suppression (Figure 3). Similarly, significantly lower disease in FYM 10 ton ha^{-1} + 100:60:0 NPK ha^{-1} as compare to treatments Sesbania before rice + 100:60:0 NPK kg ha^{-1} and only 100:60:0 NPK kg ha^{-1} suggest the importance of FYM in HLB management under different nutrient combinations.

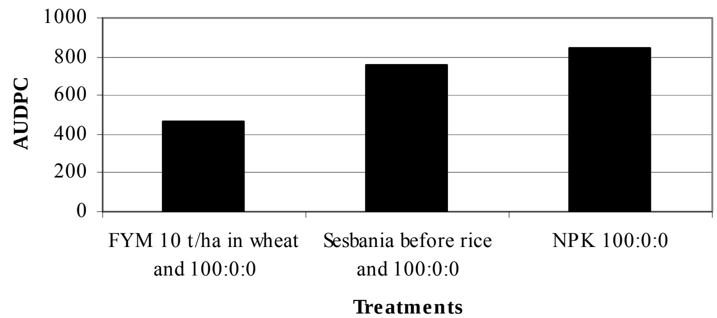

Figure 3. Effect of FYM on HLB of wheat under long-term fertility (R-W) conditions at Bhairahawa during 2003 and 2004.

Effects of Sesbania on HLB

Effect of long-term application of Sesbania before rice on HLB disease of wheat in any nutrient combinations was not seen (Figure 4). Sesbania hadn't any effect on HLB severity when it was added on the treatments containing all the three major elements such as 100:60:50 NPK kg ha^{-1} and 100:60:100 NPK kg ha^{-1}. Similarly, the addition of Sesbania on the treatment having nitrogen and phosphorus only (100:60:0 NPK kg ha^{-1}) also hadn't any influence on HLB severity. Present results do not support the previous findings of Nikonorova (1997) and Davis et al (1996), in which green manuring decreased the infection level of some soil borne diseases. However, based on present results and previous conclusions, it can be suggested that green manures may have less impact on foliar diseases than soil borne diseases.

Likewise, the higher and at par levels of AUDPC in treatments Sesbania + 100:0:0 NPK kg ha^{-1} and only 100:0:0 NPK kg ha^{-1} suggest the lack of influence of Sesbania on HLB severity when it is applied in the field having nitrogen only. The results also supports that application of higher amount of only nitrogen either in organic or inorganic form raised the severity of HLB because application of nitrogen level above 80 kg ha^{-1} induces the foliar disease incidence due to denser crop canopy (Wall et al 1990).

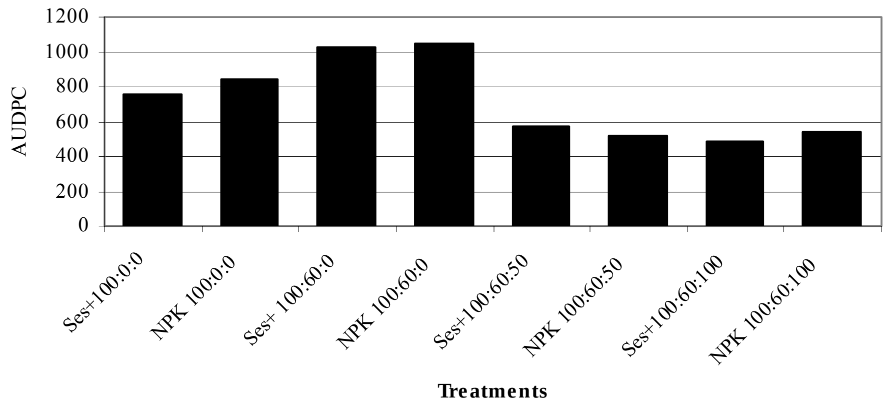

Figure 4. Effect of Sesbania on HLB of wheat in different nutrient combinations under long-term fertility (rice-wheat) conditions at Bhairahawa during 2003 and 2004.

Effects of various nutrients on yield of wheat

The yield of wheat was significantly different among the treatments (Table 2). However, the variation in yield was not solely due to the levels of HLB disease. The variations in yield were due to the combined effect of levels of nutrients and levels of HLB disease. Lower wheat yield and TGW with higher HLB AUDPC (Figure 5) confirms the previous reports which disclosed the negative correlations of HLB AUDPC with yield and TGW (Mahto 1999).

Treatments containing potash 50 kg ha^{-1} had significantly higher yield and TGW than the treatments that lack the potash. Treatments with only inorganic nitrogen and phosphorus had significantly lower yield and significantly higher AUDPC than treatments having inorganic nitrogen, phosphorus and potash. This result verifies the role of potash on wheat yield and HLB disease, which has been already explained by several previous workers (Sharma et al 2005, Regmi et al 2002, Gharti et al 2002).

Table 2. Combined mean yield and TGW on different treatments under long-term fertility condition at Bhairahawa during 2003 and 2004

SN	Treatments	Combined mean yield, kg ha^{-1} †	Combined mean TGW, g†
1	Sesbania before rice and NPK 100:60:100 kg ha^{-1}	2073ab	38.44a
2	Sesbania before rice and NPK 100:60:0 kg ha^{-1}	642c	21.77c
3	Sesbania before rice and NPK 100:60:50 kg ha^{-1}	2076ab	36.54ab
4	NPK 100:60:0 kg ha^{-1}	595c	20.98c
5	NPK 100:60:50 kg ha^{-1}	2421ab	39.36a
6	NPK 100:60:100 kg ha^{-1}	2102ab	35.21ab
7	FYM 10 t ha^{-1} in wheat and NPK 100:60:0 kg ha^{-1}	1870b	32.45b

8	FYM 10 t ha^{-1} in wheat and NPK 100:60:50 kg ha^{-1}	2601a	37.47ab
9	FYM 10 t ha^{-1} in wheat and NPK 100:60:100 kg ha^{-1}	2284ab	39.67a
10	FYM 10 t ha^{-1} in wheat and NPK 100:0:0 kg ha^{-1}	1903b	36.13ab
11	Sesbania before rice and NPK 100:0:0 kg ha^{-1}	250c	22.04c
12	NPK 100:50:0 kg ha^{-1}	640c	20.92c
13	NPK 100:100:0 kg ha^{-1}	481c	22.75c
14	NPK 100:0:0 kg ha^{-1}	342c	23.14c

† *Means in a column followed by the same letter do not differ significantly at P = 0.05 according to Duncan's multiple range tests.*

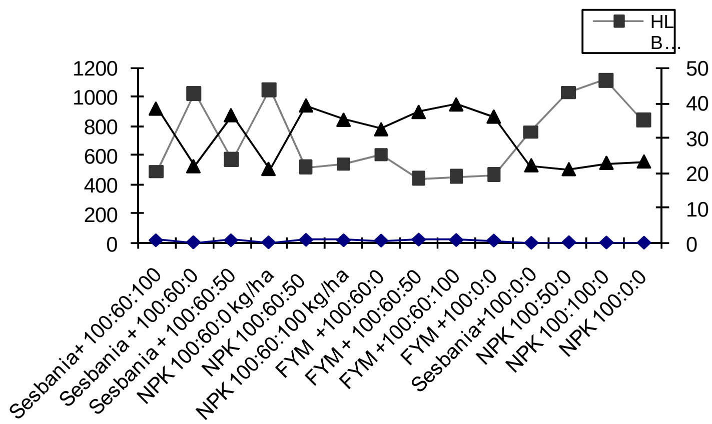

Figure 5. Relationship of HLB AUDPC with wheat yield and grain weight (TGW) in different nutrient combinations under long-term fertility (rice-wheat) conditions at Bhairahawa during 2003 and 2004.

CONCLUSION

In long-term, balanced use of inorganic and organic nutrients with special attention on regular inclusion of potash and FYM in the nutrient combinations is vital in suppression of HLB disease under rice-wheat cropping pattern. Long-term application of only nitrogen and phosphorus fertilizers boosts the HLB disease severity, where as application of 50 kg potash ha^{-1} in addition of nitrogen and phosphorus fertilizers considerably reduces the HLB disease severity. Similarly, long-term use of FYM effectively suppresses HLB disease in wheat, whereas long term applications of Sesbania couldn't suppress the intensity of HLB disease.

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REFERENCES

Abawi GS and TL Widmer. 2000. Impact of soil health management practices on soil borne pathogens, nematodes and root diseases of vegetable crops. *Appl. Soil Ecol.* 15:37-47.

Akhtar N, MF Begum, S Alam and MS Alam. 2006. Inhibitory effect of different plant extracts, cow dung and cow urine on conidial germination of *Bipolaris sorokiniana*. *Journal of Bio-Science* 14:87-92.

Anonymous. 1998. *Better Crops*. Vol. 82, No 3. Pp. 37.

Bailey LD, H Ukrainetz and DR Walker. 1980. Effect of phosphorus placement on crop uptake and yield. **In:** *Proceedings of the Western Canada Phosphate Symposium*. Calgary, Alberta. Pp. 200-229.

Bhatta MR, DR Pokhrel, RN Devkota, HJ Dubin, A Mudwari, HP Bimb, BR Thapa, BP Sah and D Bhandari. 1997. Breeding for resistance to *Helminthosporium* blights in Nepal: Strategies and genetic gains. **In:** *Helminthosporium blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico, DF. Pp. 188-195.

Bockus WW and JP Shroyer. 1998. The impact of reduced tillage on soil borne plant pathogens. *Annual Review of Phytopathology*, 36:485-500.

Conn KL and G Lazarovits. 2000. Soil factors influencing the efficacy of liquid swine manure added to soil to kill *Verticillium dahliae*. *Can. J. Plant Pathol.* 22:400–406.

Das MK, S Rajaram, CC Mundt and WE Kronstad. 1992. Inheritance of slow rusting resistance to leaf rust in wheat. *Crop Science*, 32:1452-1456.

Davis JR, OC Huisman, DT Westermann, SL Hafez, DO Everson, LH Sorensen and AT Schneider. 1996. Effects of green manures on verticillium wilt of potato. *Phytopathology* 86:444-453.

Duveiller E and L Gilchrist. 1993. Production constraints due to *Bipolaris sorokiniana* in wheat: Current situation and future prospects. **In:** *Wheat in heat stress environments: Irrigated dry areas and rice wheat farming system* (DA Saunders and GP Hettel, eds). Mexico, CIMMYT, DF. Pp. 343-352.

Duveiller E. 2002. *Helminthosporium* blight of wheat: Challenges and strategies for a better disease control. **In:** *Advances of wheat breeding in China*. Proceedings of the first National wheat breeding conference, 10-12 May, 2002, Jinan, Shandong, People Republic of China. China Science and Technology Press. Pp. 57-66.

Gharti DB, MP Sah, SK Gami and KP Bhurer. 2002. Effect of various organic and inorganic nutrients on foliar blight of wheat. **In:** *Proceedings of wheat research papers presented at 25th National winter crops research workshop.* National Wheat Research Program, Bhairahawa, Nepal. Pp. 142-147.

Lazarovits G, M Tenuta, KL Conn. 2001. Organic amendments as a disease control strategy for soil borne disease of high-value agricultural crops. *Australians Plant Pathol.* 30:111-117.

Mahto BN. 1999. Management of *Helminthosporium* leaf blight of wheat in Nepal. *Indian Phytopath.* 52(4):408-413.

Mathieoson JT, CM Rush, D Brodovsky, LE Clark and OR Jones. 1990. Effects of tillage on common root rot of wheat in Texas. *Plant Disease* 74:1006-1008.

Naitao C and W Yousan. 1997. Incidence and current management of spot blotch of wheat in China. **In:** *Helminthosporium blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico, DF. Pp. 119-125.

Nikonorova AK. 1997. Phytosanitary effect of combined application of green manure and antagonistic bacterium *Bacillus subtilis* on *B. sorokiniana*. **In:** *Helminthosporium blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico, DF. Pp. 359-363.

Regmi AP, JK Ladha, EM Pasuquin, H Pathak, PR Hobbs, LL Shrestha, DB Gharti and E Duveiller. 2002. The role of potassium in sustaining yields in a long term rice-wheat experiment in the Indo-Gangetic plains of Nepal. *Biol. Fertil. Soils.* 36:240-247.

Ruckstuhl M. 1997. Population structure and epidemiology of *B. sorokiniana* in the rice wheat cropping pattern in Nepal. **In:** *Helminthosporium blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico, DF. Pp. 88-106.

Saari EE. 1997. Leaf blight disease and associated soil borne fungal pathogens of wheat in South and South East Asia. **In:** *Helminthosporium blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico, DF. Pp. 37-51.

Sharma RC, SM Shrestha and E Duveiller. 2003. Incidence of *Bipolaris sorokiniana* and *Pyronophpora tritici repentis* on wheat in the lowlands of Nepal. **In:** *Proceedings of the fourth international wheat tan spot and spot blotch workshop* (JB Rasmusseen, TL Friesen and S Ali, eds). North Dakota State University, Fargo, USA. Pp. 122-127.

Sharma S, E Duveiller, R Basnet, CB Karki and RC Sharma. 2005. Effect of potash fertilization on *Helminthosporium* leaf blight severity in wheat, and associated increase in grain yield and kernel weight. *Field Crop Research*, 93:142-150.

Wall PC, PR Hobbs, DA Saunders, KD Sayre and DG Tanner. 1990. Wheat crop management in the warmer areas: A review of issues and advances. **In:** *Wheat for the non-traditional warm areas* (DA Saunders, ed). CIMMYT, Mexico, DF. Pp. 225-241.

Controlling Foliar Blight of Wheat through Nutrient Management and Varietal Selection

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ABSTRACT

Helminthosporium leaf blight, a complex of spot blotch caused by *Bipolaris sorokiniana* and tan spot caused by *Pyrenophora tritici-repentis*, is one of the most important foliar diseases of wheat in Nepal. It appears in almost all wheat growing areas and causes severe yield loss every year. A study was conducted at Regional Agriculture Research Station (RARS), Tarahara, Sunsari during 2004-05 and 2005-06 wheat growing seasons to elucidate role of nitrogen in wheat genotypes for management of the disease. Field experiment was laid out on split plot design with three replications. Four doses of nitrogen in six different promising genotypes were tested. Nitrogen levels higher than 50 kg ha^{-1} significantly reduced disease severity and increased grain yield in all genotypes but there was no significant differences in grain yield in the first year. In the second year, grain yield difference among the genotypes was significant. Area under disease progress curve (AUDPC) was not significant between two doses 100 and 150 kg ha^{-1}. The wheat genotypes showed different reactions to disease. Genotype BL 2047 had the lowest incidence of disease followed by BL 1887, whereas BL 2217 had the highest incidence of the disease. Genotype BL 2196 produced the highest grain yield (2172 kg ha^{-1}) and the lowest grain yield was obtained in Bhrikuti followed by BL 2089. These results suggested that fertilizer should be applied in soil at balanced dose 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}. Growing relatively resistant genotypes with the balance dose of fertilizers can reduce foliar blight severity in wheat.

Key words: AUDPC, *Bipolaris sorokiniana*, disease resistance, grain yield, Helminthosporium leaf blight, *Pyrenophora tritici-repentis*

INTRODUCTION

Wheat occupies the third position after rice and maize in Nepal representing 22% of total cultivated area. Major area of wheat production is covered by eastern terai region of Nepal. Successful production for wheat is constrained by several biotic and abiotic stresses. Among them, Helminthosporium leaf blight (HLB), a complex foliar disease of wheat caused by *Bipolaris sorokiniana* (Sacc.) Shoem. and *Pyrenophora tritici-repentis* (Died) is a serious constraint. It is considered a disease of major importance owing to its potential to cause yield loss. Globally an estimation of 25 million ha of wheat land is affected by the disease (van Ginkel and Rajaram, 1998). In Nepal the disease is widely distributed throughout the wheat growing areas particularly in terai (NWDP 1976). The magnitude of yield loss due to HLB may vary among locations and years (Mahto 1995). In South Asia, yield loss due to HLB has been reported to to 20-30% in farmers' field and experiment stations (Dubin amd Bimb 1991, Duveiller and Gilchrist 1994, Saari 1998, Duveiller et al 2005). In years when rain occurs late in the crop cycle, especially during grain filling, complete crop loss has been observed (Saunders 1988). Selection and breeding for resistant cultivars is the main disease management strategy for a sustainable agriculture. Duveiller and Gilchrist (1994) and Dubin and Rajaram (1996) reported several sources of spot blotch resistance in wheat but high yielding genotypes resistant to the disease is not yet available. Most of the improved and recommended wheat cultivars in Nepal are severely attacked by foliar blight (Shrestha et al 1998).

Crop management practices affect on the development of the disease epidemics. In the humid sub-tropics of South Asia, there is evidence of stress conditions, which favor foliar blight (Dubin and Bimb 1994). Factors such as minimum tillage or surface seeding, irrigation, late planting, or low soil fertility may be responsible for higher foliar blight severity in the wheat-based cropping systems of the Indo-Gangetic plains (Sharma and Duveiller 2003). Lower disease severity with higher nitrogen application was reported by Chaurasia and Duveiller (2006) and Sharma and Duveiller (2004). However, Singh et al (1998) reported more disease infection on higher nitrogen application.

The objective of the present study was to find out the influence of nitrogen in different wheat genotypes on the severity of foliar blight.

MATERIALS AND METHODS

A split plot experiment with three replications was conducted at Regional Agriculture Research station, Tarahara Sunsari, Nepal during wheat season of 2004-05 and 2005-06 where climatic and agro-ecological conditions favor rapid development of foliar blight pathogens. The main plot treatments were four levels of nitrogen: i) 0:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}, ii) 50:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}, iii) 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}, and iv) 150:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}. The sub plot treatments included most promising wheat genotypes: BL 2047, BL2089, BL2196, BL 2217, Gautam, and Bhrikuti. The individual plot size was 4- × 3-m and consisted of twelve rows with 25cm spacing. Seed was sown using standard seed rate of 120 kg ha^{-1}. Phosphorus and potassium were applied as basal dose. Half of N (for all three levels) was applied at basal dose and remaining half was top-dressed at tillering stage. Three irrigations were given. Plots were kept free from weeds by hand weeding. Daily rainfall, max and min temperature during wheat growing seasons were recorded from wheat emergence to harvest in the two test years.

After anthesis, the peak stage of disease development, disease severity was assessed using the double-digit scale (00-99) developed as a modification of Saari and Prescott's scale for assessing severity of foliar diseases of wheat (Saari and Prescott 1975, Eyal et al 1987). The first digit (D1) indicates disease progress in canopy height from the ground level and second digit (D2) refers to severity measured based on diseased leaf area. Both D1 and D2 are scored on a scale of 1 to 9. Three individual disease scores per plot were recorded at every 7-days interval. For each evaluation, percent disease severity was estimated using the formula: % severity = $(D1/9) \times (D2/9) \times 100$. The area under disease progress curve (AUDPC) was calculated using the percentage disease severity estimations corresponding to the three ratings as outlined by Shaner and Finney (1977).

Yield (kg/ha) and 1000-grain weight were measured after harvesting all plots. The data were analyzed using computer software MSTATC and MINITAB 11 for windows. Statistical analysis includes ANOVA test, mean separation based on Duncan's multiple range test, regression analysis for AUDPC and the grain yield over different levels of nitrogen.

RESULTS AND DISCUSSION

Weather conditions and disease severity

There was high pressure of disease in both years. However, the disease severity was significantly higher ($p < 0.05$) in the second year (Table 1). The difference in the disease might be due to climatic variations in these two years (Figure 1). Higher temperature in early stage of the crop cycle was observed in the second year. This result suggested the influence of temperature on disease development. Naitao and Yousan (1998) reported that *Bipolaris sorokiniana* resistance traits in wheat are polygenic and greatly affected by climatic factors such as rainfall, humidity and temperature. Similarly, Gilbert et al (1998) reported that humid environment resulting from high temperature and high rainfall promoted the development of the disease.

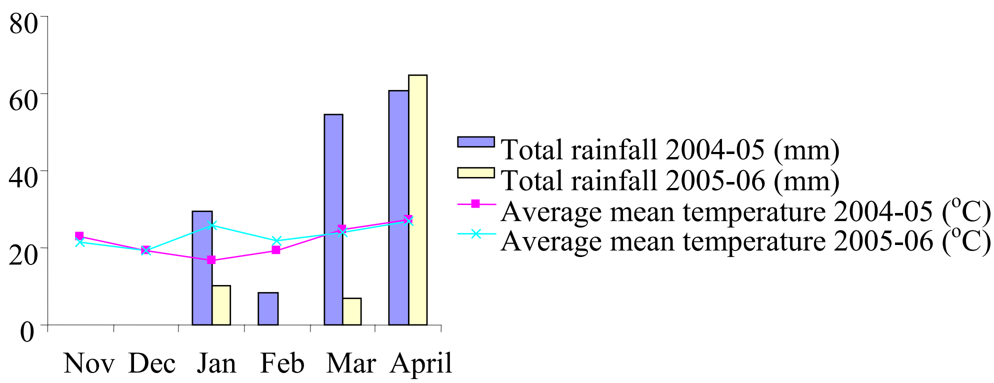

Figure 1. Monthly average climatic variables recorded throughout the wheat growing season 2004-05 and 2005-06 at Tarahara, Sunsari, Nepal.

Influence of nitrogen (N) levels on disease severity and wheat yield

N levels had a significant effect ($p < 0.01$) on AUDPC in both years (Table 1). Among four levels of N tested, the mean AUDPC value was higher for N levels 0 and 50 kg ha^{-1} as compared to 100 kg ha^{-1} and 150 kg ha^{-1}. Such variation in mean values for disease severity among the four levels of N confirmed its role in reducing foliar blight infection in wheat. Regression analysis showed a significant negative linear relation of AUDPC, $Y = 657.458 - 6.7583X$, R-Sq = 0.048** over dose of nitrogen application (0-150 kg/ha; Figure 2A). This result indicated that foliar blight severity was lowered with increased dose of N.

Mean values for grain yield differed in the test years. Average grain yield was lower in 2005 than in 2004. The lower yield with more disease in the second year suggested the effect of the disease in wheat yield reductions. The effect of N level was significant for grain yield and thousand kernel weight (TKW) in both the years. The mean grain yield was high for N levels of 100 and 150 kg ha^{-1} as compared with 0 and 50 kg ha^{-1} but the difference between the first two levels was insignificant (Table 1). Similarly AUDPC value was also not significantly different between these two N levels (100 and 150 kg ha^{-1}). Regression analysis showed that grain yield was increased as a function of nitrogen level, $Y = 521.168 + 716.125X$, R-Sq = 0.667** (Figure 2). There was sharp100 and 150 kg ha^{-1}) increment of grain yield over N application up to the dose 100 kg ha^{-1} in all the genotypes but after the level, the rate of increment decreased (Figure 3). This result suggested that nitrogen level more than 100 kg ha^{-1} was not significantly effective to lower the disease severity and to increase the grain yield. There was no specific trend for TKW over N levels but average value was the lowest in 150 kg ha^{-1}.

The results suggested that N levels had a significant influence on foliar blight development, grain yield and TKW. It was observed that low and imbalance use of nitrogenous fertilizer increased severity of the disease. Krupinsky et al (1998) noted more leaf necrosis and chlorosis caused by *Pyrenophora tritici-repentis* in the plots with no additional nitrogen and/or low level of nitrogen than higher nitrogen levels. Similarly higher tan spot severity in N deficient condition was observed by Fernandez et al (1998). In agreement with the results of Sharma and Duveiller (2004) and Chaurasia and Duveiller (2006) our results clearly suggested that higher dose of nitrogen had significant effect on reducing the disease and thereby increase the grain yield. This finding differs from the observation by Singh et al (1998) who reported higher disease infection with higher level of nitrogen.

Table 1. Means values for disease and agronomic variables at four level of nitrogen application and of six genotypes recorded in 2004 and 2005 wheat growing seasons at Tarahara, Sunsari, Nepal

Effect of nitrogen levels

	AUDPC			Grain yield, kg/ha			TKW, g		
Nitrogen dose, kg/ha	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
N0	446 a	774 a	610 a	1550 c	585 c	1068 d	46.1 a	48.9 ab	47.5 a
N50	452 a	770 a	611 a	2606 b	1600 b	2103 c	45.4 ab	48.6 ab	47.0 a
N100	378 b	671 b	525 b	3259 a	2498 a	2879 b	43 bc	50.4 a	46.9 a
N150	368 b	665 b	517 b	3474 a	2919 a	3196 a	41.7 c	47.1 b	44.4 b
Mean	441	719		2722	1901		44.1	48.8	
F-test	*	**	**	**	**	**	*	*	**

Effect of genotypes

		AUDPC			Grain yield, kg/ha			TKW, g		
Genotypes	Days to heading	2004	2005	Mean	2004	2005	Mean	2004	2005	Mean
BL 2217	76 c	473 ab	840 a	657 a	2649	2049 ab	2349	41.1 c	48.0 b	44.5 d
BL 2089	77 c	483 a	774 b	629 b	2682	1747 c	2215	49.3 a	53.3 a	51.3 a
Bhrikuti	81 b	438 b	742 b	590 c	2871	1670 c	2271	38.5 c	43.7 c	41.1 e
BL 2196	77 c	396 c	777 b	586 c	2581	2172 a	2376	47.3 a	51.5 a	49.4 b
BL 1887	80 b	332 d	632 c	482 d	2792	1883 bc	2338	43.9 b	48.1 b	46.0 c
BL 2047	86 a	346 d	555 d	450 e	2761	1881 bc	2321	44.5 b	48.0 b	46.3 c
Mean		441	719		2722	1901		44.1	48.8	
F-test		**	**	**	ns	**	ns	**	**	**

AUDPC, Area under disease progress curve, TKW= Thousand kernel weight. Means within a column followed by the same letter do not differ significantly based on least significant difference at P = 0.05.

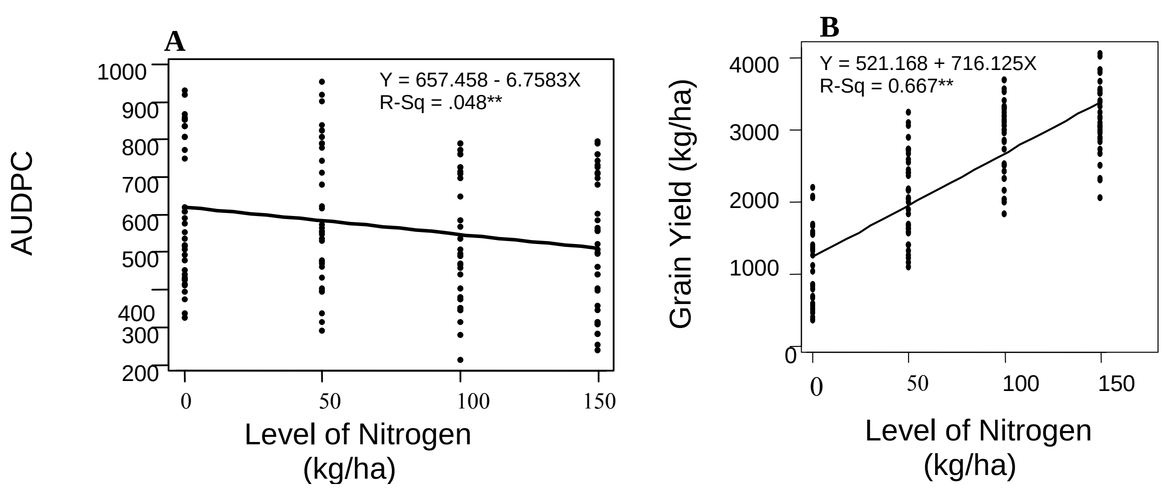

Figure 2. Regression lines indicating linear negative relation of area under disease progress curve (AUDPC; A) and linear positive relation of grain yield (kg/ha; B) over level of N in wheat grown at Sunsari, Nepal during 2004-05 and 2005-06 wheat growing seasons.

Varietal performance

Analysis of variance explicitly showed highly significant differences among genotypes ($P < 0.01$) for AUDPC in both the years (Table 1). Interaction between the fertilizer dose and genotypes was insignificant and negative linear trend for AUDPC across nitrogen levels was observed in all the genotypes (Figure 3). Among the tested genotypes no resistance reaction to the disease was observed conforming previous observations of van Ginkel and Rajaram (1998). The six genotypes showed variations in level of resistance to the disease and agronomic traits. Such variation in disease level confirmed genetic differences among the genotypes. BL 2047 showed relatively higher disease resistance characterized by lower AUDPC value than others, and was followed by Gautam. Similarly, BL 2217 had the highest AUDPC value demonstrating the most susceptible to the disease among the tested genotypes (Table 1). The genotypes were significantly different in days to heading ($P < 0.01$). Among the tested genotypes BL 2047 was relatively late and BL 2217 was early for days to heading (that foliar Table 1). This result suggested blight resistance in wheat genotypes was associated with maturity and confirmed the previous observations by Dubin et al (1998). They reported the best foliar blight resistant wheat genotypes in South Asia were late. A significant negative correlation between the days to heading and AUDPC was found by Mahto (1999).

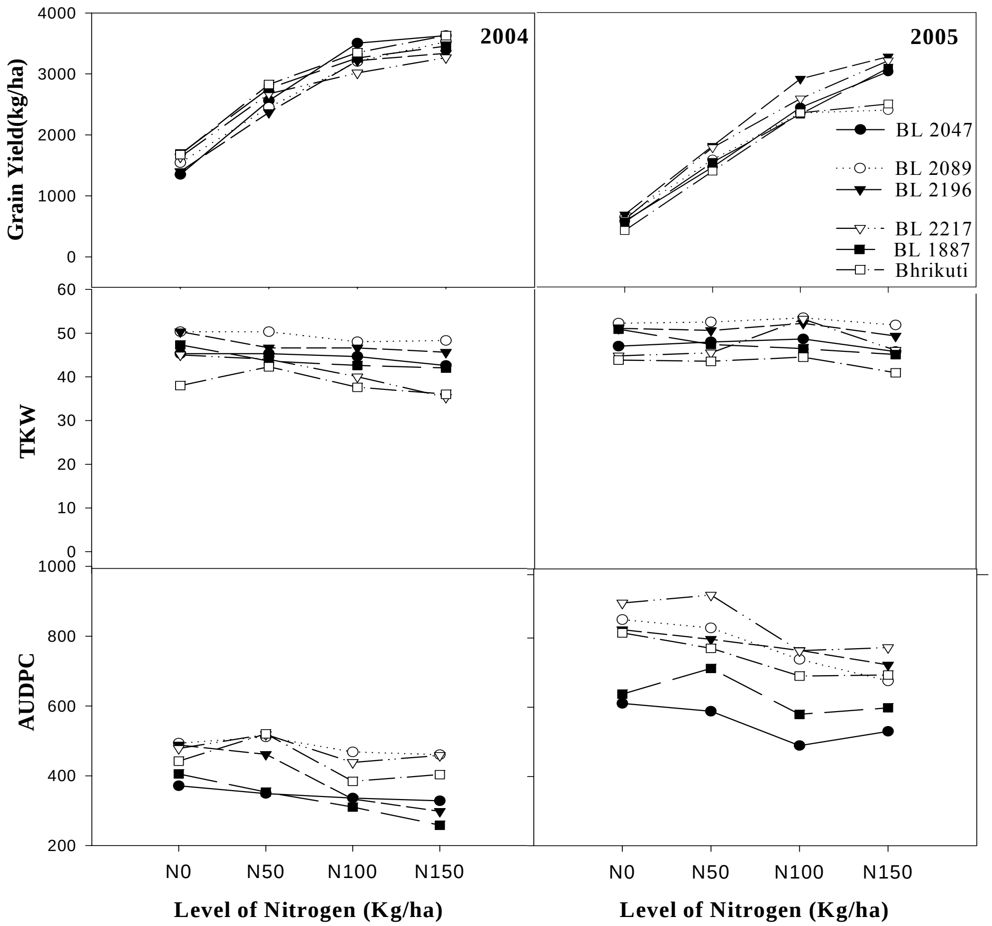

Figure 3. Changes in grain yield, thousand kernel weight (TKW), and area under disease progress curve (AUDPC) in six wheat genotypes across four level of nitrogen in the 2004 and 2005 wheat seasons at Tarahara, Sunsari, Nepal.

The wheat genotypes differed significantly only in the second year for grain yield (Table 1). In this year, genotype BL 2196 produced the highest yield (2172 kg ha^{-1}) which was followed by BL 2217 (2049 kg ha^{-1}). Despite having higher AUDPC value these genotypes produced higher grain yield suggesting they are tolerant to the disease. Among the tested genotypes thousand kernel weight was relatively high in BL 2089 followed by BL 2196.

CONCLUSION

The findings of the study have implications for integrated management of foliar blight (HLB) disease of wheat. Nutrient management in field is very critical to minimize the disease severity. Crop without or with low dose of Nitrogenous fertilizer are vulnerable to severe foliar blight attack. Genotypes BL 2047 and BL 1887 showing relatively resistance, and BL 2196 having tolerance to the disease should be promoted. These three genotypes are potential and be crossed to combine resistance and tolerance to foliar blight along with high yielding progenies. By growing the selected cultivars with balanced dose of fertilizer @ 100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}, yield loss due to the disease in warm wheat growing climate could be minimized.

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REFERENCES

Chaurasia PCP and E Duveiller. 2006. Management of leaf blight (*Bipolaris sorokiniana*) disease of wheat with cultural practices. *Nepal Agric. Res. J.* 7:63-69.

Dubin HJ and HP Bimb. 1991. Effect of soil and foliar treatments on yield and diseases of wheat in lowland of Nepal. **In:** *Wheat in hot stressed environments: Irrigated, dry areas and rice-wheat systems* (DA Saunders and GP Hettel, eds). CIMMYT, Mexico. Pp. 484-485.

Dubin HJ and HP Bimb. 1994. Studies of soil borne diseases and foliar blights of wheat at the National Wheat Research Experiment Station, Bhairahawa, Nepal. *Wheat special report* no 36. CIMMYT, Mexico.

Dubin HJ and S Rajaram. 1996. Breeding disease resistant wheats for tropical highlands and lowlands. *Ann. Rev. Phytopathol.* 34:503-526.

Dubin HJ, B Arun, SN Begam, M Bhatta, R Darai, LB Goel, AK Joshi, BM Khanna, PK Malakar, DR Pokhrel, MM Rahman, NK Shah, MA Shaheed, RC Sharma, AK Singh, RM Singh, RV Singh, M Vargas and PC Verma. 1998. Results of the South Asia Regional *Helminthosporium* leaf blight and yield experiments, 1993-94. **In**: *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 182-187.

Duveiller E and L Gilchrist. 1994. Production constraints due to *Bipolaris sorokiniana* in wheat: Current situation and future prospects. **In:** *Wheat in hot stressed environments: Irrigated, dry areas and rice-wheat systems* (DA Saunders and GP Hettel, eds). CIMMYT, Mexico. Pp. 343-352.

Duveiller E, YR Kandel, RC Sharma and SM Shrestha. 2005. Epidemiology of foliar blights (spot blotch and tan spot) of wheat in the plains bordering the Himalayas. *Phytopathology* 95:248-256.

Eyal Z, AL Scharen, JM Prescott and M van Ginkel. 1987. The septoria diseases of wheat: Concepts and methods of disease management. CIMMYT, Mexico.

Fernandez MR, RM Depauw, JM Clarke, RP Zentner and BG McConkey. 1998. Tan spot in western Canada. **In:** *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 73-79.

Gilbert J, SM Woods and A Tekauz. 1998. Incidence and severity of leaf spotting diseases of spring wheat in southern Minotoba. **In**: *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 333-338.

Krupinsky JM, AD Halvorson and AL Black. 1998. Leaf spot diseases of wheat in a conversation tillage study. **In**: *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 322-326.

Mahto BN. 1995. Wheat disease screening nurseries. **In:** Proceedings of the 1994-95 winter crop research workshop. NARC, Nepal. Pp. 289-307.

Mahto BN. 1999. Management of Helminthosporium leaf blight of wheat in Nepal. *Indian Phytopathol*. 52(4):408-413.

Naitao C and W Yousan. 1998. Incidence and current management of spot blotch of wheat in China. **In:** *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 119-125.

NWDP. 1976. *Annual Report 1975/76*. National Wheat Development Program (NWDP), Department of Agriculture, Ministry of Food, Agriculture and Irrigation, Nepal. Pp. 75-81.

Rucksthul M. 1998. Population structure and epidemic of *Bipolaris sorokiniana* in rice-wheat cropping pattern in Nepal. **In**: *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 88-106.

Saari EE and JM Prescott. 1975. A scale for appraising the foliar intensity of wheat diseases. *Plant Dis Rep*. 59:377-380.

Saari EE. 1998. Leaf blight disease and associated soil borne fungal pathogens of wheat in South and Southeast Asia. **In:** *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 37-51.

Saunders DA. 1988. Characterization of tropical wheat environments: Identification of production constraints and progress achieved in South and Southeast Asia. **In:** *Wheat production constraints in tropical environments* (AR Khatt, ed). CIMMYT, Mexico. Pp. 12-26.

Shaner G and Finney RE. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in Knox wheat. *Phytopathology* 67:1051-1056.

Sharma RC and E Duveiller. 2003. Effect of stress on *Helminthosporium* leaf blight in wheat. **In:** *Proc. 4th int. wheat tan spot and spot blotch workshop* (JB Rasmussen TL Friesen and S Ali, eds). North Dakota State University, Fargo. Pp. 140-144.

Sharma RC and E Duveiller. 2004. Effect of *Helminthosporium* leaf blight on performance of timely seeded wheat under optimal and stress levels of soil fertility and moisture. *Field Crop Research* 89:205-218.

Shrestha KK, RD Timila, BN Mahto and HP Bimb. 1998. Disease incidence and yield loss due to foliar blight of wheat in Nepal. **In**: *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 67-72.

Singh RV, AK Singh, R Ahmad and SP Singh. 1998. Influence of agronomic practices on foliar blight and identification of alternate hosts in the rice-wheat cropping systems. **In:** *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 346-348.

van Ginkel M and S Rajaram. 1998. Breeding for resistance to spot blotch in wheat: Global prospective. **In:** *Helminthosporium leaf blight of wheat: Spot blotch and tan spot* (E Duveiller, HJ Dubin, J Reeves and A McNab, eds). CIMMYT, Mexico. Pp. 162-169.

Digestibility of *Ficus roxburghii*, *Castanopsis indica* and *Ficus cunia* on Growing Buffalo from Western Hills of Nepal

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ABSTRACT

Nine buffalo calves were subjected to three fodder tree species namely; Nimaro *(Ficus roxburghii)*, Dhalne Katus *(Castanopsis indica)* and Rai Khanyu *(Ficus cunia)* for digestibility trial during November 27 and December 3, 2005 in Regional Agricultural Research Station, Lumle, Kaski, Nepal. Animals were kept 7 days for adaptation for these fodders. Weighed amount of fodder tree leaves including twigs and small branches were fed two times a day and observation on fodder offered, refused and faeces voided were recorded daily. Chemical composition of fresh matter and faeces voided were carried out for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, calcium (Ca) and phosphorus (P). The mean DM content and their dry matter digestibility (DMD) of these three fodder tree species were found 27.86, 46.02, 34.72, 73.21, 65.93 and 71.28 percent, respectively. Strong negative correlations ($r=-0.75$ to -0.78; $p<0.05$) were observed between Ca and CP with fiber fraction (NDF and ADF). A weak correlation was also observed between P and other constituents with respect to digestibility. From the results, if there could be provision of low fiber content in dry season, the three main nutrients (Ca, P and CP) may easily be absorbed by the animals.

Key words: Buffalo, digestibility, fodder tree, nutrients

INTRODUCTION

About 39.6 percent of the total land of Nepal is covered by forest and shrub. Fodder and leaf litter from forest, fodder tree from crop lands, grasses legumes available from bunds and fallow lands, crop by products from agricultural crops are the major sources of feed for ruminant animals. Fodder trees from terrace risers and marginal lands are lopped for supplementing green fodder from December to June, which is the feed scarcity period in hills and mountain of Nepal (Sherchand and Pariyar 2002). Even though the protein contents of fodder tree leaves are moderate, the animals loose their body weight and milk production drops drastically during winter months when animals are mainly provided with fodder tree leaves and rice straw. This problems may be due to seasonal rainfall, upland areas where decrease in soil moisture, deciduous plant species particularly mid hills across the country and composition and availability of nutrients present in the plant species during moisture stress condition.

Nutrient composition of fodder tree leaves, tree fodder, grasses and legumes were evaluated (Subba 1998), but studies on nutrient availability from these feeding resources to the animals are very limited. Review of literature shows very few fodder tree species have been studied for nutrient availability to the animals (Subba 1998). In this study, efforts have been made to find out the digestible co-efficient of nutrients of fodder tree foliage such as Nimaro (*Ficus roxburghii*), Rai Khanyu (*Ficus cunia*) and Dhalne Katus (*Castanopsis indica*) and side by side to point out the positive and negative relation among the constituents under fresh and digestible basis.

MATERIALS AND METHODS

Nine growing buffalo calves about one and half year age (male and female) were allotted to three treatments ie Nimaro (*Ficus roxburghii*), Dhalne Katus (*Castanopsis indica*) and Rai Khanyu (*Ficus cunia*) and replicated three times. Animals were kept under metabolic shed, weighed amount of fodder tree leaves including twigs and small branches were provided two times a day and experiment was lasted up to 7 days. Observations as fodder offered, refused and faeces voided were recorded daily.

Fodder and fecal samples were collected in morning and evening for 7 days experimental period. The average maximum and minimum temperature recoded in samples collection site was 20.61^{o}C and 12.22^{o}C, respectively and the total rainfall of the site was 5833.60 mm and average was 5303.1 mm per year (Annual Report 2001). Collected tree foliage and fecal samples were dried at constant heat in hot air oven at 72^{o}C for over night (24 hours). Dried fodder and fecal samples were ground to passes through 1 mm sieves in hammer mill and stored for chemical analysis.

After dry matter determination, nitrogen content was determined by the Micro-Kjheldal method (AOAC 1990). The crude protein (CP) was calculated as N × 6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by the method developed by Van Soest et al (1991). Calcium (Ca) and phosphorus (P) were measured by titration and spectrophometry method, respectively.

One-way analysis of variance (ANOVA) was carried out to compare the chemical composition and digestibility values with species of fodder tree as the main factor by using General Linear Model (GLM) procedure (Statistix for Windows 1996). Simple correlation analysis was used to establish the relationship between the chemical constituents as fresh and digestible basis.

RESULTS AND DISCUSSION

The mean chemical constituents are presented in Table 1, there is positive and negative relationship observed among the chemical constituents (Table 2). Protein, calcium and phosphorus content in feed are very important for milk production from milking animals, fiber content in fodder tree leaves have strong negative correlation (Table 2) with these nutrients. When commencing dry season plant tend to increase fiber content in the leaves, which lead to decrease these two minerals content during the winter or dry season.

Table 1. Chemical constituents of three different fodder tree leaves from western hills of Nepal

Name of fodder	Chemical constituents						
	DM	CP	NDF	ADF	Lignin	Ca	P
Ficus roxburghii	27.86	14.27	54.00	52.46	32.53	2.82	0.49
Castanopsis indica	46.02	11.38	65.13	64.52	21.82	0.76	0.23
Ficus cunia	34.72	13.61	43.63	41.08	20.55	2.47	0.37
Mean	36.20	13.08	54.25	52.69	24.97	2.01	0.36

DM, Dry matter. CP, Crude protein. NDF, Neutral detergent fiber. ADF, Acid detergent fiber. Ca, Calcium. P, Phosphorus.

Table 2. Correlations (Pearson) coefficients of different chemical constituents of three fodder tree leaves from western hills of Nepal

	DM	CP	NDF	ADF	Lignin	Cal
CP	0.276					
	0.473					
NDF	-0.181	-0.750				
	0.640	0.020				
ADF	-0.173	-0.752	1.000			
	0.656	0.019	0.000			
Lignin	0.197	0.602	0.076	0.073		
	0.612	0.086	0.846	0.852		
Cal	0.273	0.998	-0.786	-0.788	0.738	
	0.477	0.000	0.012	0.012	0.023	
P	0.238	0.775	-0.163	-0.166	0.564	0.453
	0.538	0.014	0.675	0.669	0.114	0.221

Digestibility of chemical constituents present in Nimaro, Dhalne Katus and Rai Khanyu were similar (Table 3). Positive correlation was observed in digestibility of all constituents except phosphorus to other constituents. Phosphorus has weak correlation to other constituents in terms of digestibility (Table 4). This low phosphorus content in fodder tree leaves may have negative effect on absorption of nutrient present in the fodder tree leaves specially lactating animals.

Table 3. Digestibility coefficients of chemical constituents from Nimaro, Dhalne Katus and Rai Khnyu found in western hills of Nepal

Name of fodder	Digestibility coefficient						
	DMD	CP	NDF	ADF	Lignin	Ca	P
Ficus roxburghii	73.21	80.22	74.58	74.55	74.94	85.34	74.14
Castanopsis indica	65.93	74.58	62.67	61.54	76.08	80.89	82.04
Ficus cunia	71.28	74.29	77.99	77.45	79.63	85.32	71.24
Mean	70.14	76.36	71.75	71.18	76.88	83.85	75.81
CV, %	8.21	5.81	17.61	19.02	8.28	3.69	12.74
SEM	1.92	1.48	4.21	4.51	2.12	1.03	3.21

Table 4. Correlations (Pearson) coefficients of digestibility of different chemical constituents of three fodder tree species leaves from western hills of Nepal

	DMD	CP	NDF	ADF	Lignin	Cal
CP	0.837					
	0.005					
NDF	0.928	0.680				
	0.000	0.044				
ADF	0.929	0677	0.997			
	0.000	0.045	0.000			
Lignin	0.728	0.502	0.863	0.856		
	0.026	0.168	0.003	0.003		
Cal	0.910	0.683	0.855	0.833	0.598	
	0.001	0.042	0.003	0.005	0.089	
P	0.066	0.054	-0.056	0.000	0.154	-0.247
	0.866	0.889	0.887	0.999	0.693	0.522

Fodder tree leaves contain high level of calcium (2.20%) and low level of phosphorus (0.25%) among 30 fodder tree species found in the hills and mountain of Nepal Osti et al (2006). Similarly, Subba 1998 analyzed over 75 tree fodder species and found 0.10 to 0.90 percent total phosphorus content and he also analyzed for calcium content ranges from 26.5 mmol/kg Bakaino (*Melia azedarach*) to 689 mmol/kg Teli bans (*Teli bans*), and most of tree fodder species found 100 + mmol/kg calcium content. This low level of phosphorus and negative correlation between calcium and phosphorus with fiber fraction may be the one factor for low milk production during dry season in the hills and mountain of Nepal. This finding is closely supported with the finding of Davies et al (1938) who reported that the presence of soils low in plant available phosphorus results in herbage with subnormal phosphorus content and occurrence of a dry period in each year when the plants are dry and mature and the seed is set accentuated or prolong this effect. Calcium and phosphorus are the major minerals required for proper milk formation in the body of milking animals, this low phosphorus contain in fodder tree leaves also have another possibility of binding to other nutrients like protein with phytate to form protein phosphorus complex which lead to low absorption of these nutrients in the animal body. The protein content of plant falls with phosphorus and also energy because all soluble carbohydrates ultimately non available with increase in dry matter content in dry season (Lapkin et al 1961). There is also quantitative ratio (2:1) between calcium and phosphorus required for proper functioning of milk secretion and 1.5 part of calcium there should be 1 part of phosphorus in the diet. If the ratio is narrower than 1:1 and wider than 2.5:1 there will be incidence of milk fever and other deficiency diseases appeared (Wattiaux 1994). From this finding the ratio between calcium and phosphorus is very weak. This low phosphorus contain in fodder tree leaves open the another rooms for further research in this area with respect to milk production in the hills and mountainous region.

Strong negative correlation was observed among fiber fraction (NDF and ADF) of fodder tree leaves with Ca, P and CP. A weak correlation was also observed between P and digestibility of other constituents. If there could be provision of low fiber content in dry season these three nutrients (Ca, P and CP) may absorbed easily by the animals.

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REFERENCES

Annual report 2001. Meteorological records. **In:** *Annual report 2000/01*. Agriculture Research Station, Lumle, Kaski, Nepal. Pp. 85.

AOAC. 1990. *Official methods of analysis*. 15th Edition. Association of Official Analytical Chemists, Washington, DC, USA. Pp. 66-88.

Davies JG, AE Scot and JF Kennedy. 1938. The yield and composition of a Mitchell grass pasture for a period of 12 months. *J. of the Council for Scientific and Industrial Research Australia* 11:127-129.

Lapkin GH, DA Howard and DA Burdin. 1961. Study on production of beef from zebu cattle in East Africa. 3. The value of phosphatic supplement. *J. of Agriculture Science*, UK, 57:39-47.

Osti NP, CR Upreti, NP Shrestha and SB Pandey. 2006. Nutrients contents in fodder trees leaves, grasses and legumes from buffalo growing areas of Nepal. In: *Proceedings of 5th Asian Buffalo Congress*, 18-22 April 2006, Naning, China. Pp. 366-371.

Sherchand L, and D Pariyar. 2002. Pasture forage and agroforestry technology and their dissemination status in Nepal. **In:** *Proceedings of the 6th National Outreach Workshop*, NARC, Kathmandu, Nepal.

Subba DB. 1998. *Chemical composition and nutritive values of feeds of East Nepal*. Pakhribas Agriculture Centre, Dhankuta, Nepal.

Van Soest PJ, JD Robertson and BA Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74:3583-3597.

Wattiaux M. 1994. *Nutrients in the feed. technical dairy guide, nutrition and feeding*. The Babcock Institute for International Dairy Research and Development, University of Wisconsin, Madison, USA. Pp. 22-24.

An Empirical Analysis of Resource Productivity of Wheat in Eastern Tarai Region of Nepal

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ABSTRACT

Different types of resource conservation technology (RCT) in wheat cultivation have been recently introduced and use of seed cum fertilizer zero till drill machine is one of them which was used in eastern terai region in wheat season of 2006/2007. A survey was carried out to study the productivity of wheat and compare the production between traditional and RCT method of cultivation. Altogether 31 farmers were interviewed with semi-structured questionnaires. Model used to estimate the productivity for both the methods was significant ($p < 0.01$) which explained 96 and 97 per cent variation due to independent variables under study in wheat production of traditional and RCT method, respectively. Farmers used 160 kg seed/ha in traditional method while in RCT method it was 122 kg/ha. Similarly, they applied 148 and 137 kg nutrients as a total of nitrogen, phosphorus and potash in traditional and RCT method, respectively. Average production of wheat grain in traditional and RCT method was 2456 and 2714 kg/ha giving average gross margin of Rs 16750.00 and Rs 23301.00/ha, respectively. This revealed 10 per cent reduction in total costs and 29 per cent increase in return by RCT method.

Key words: Gross margin, productivity, resource conservation technology

INTRODUCTION

Wheat is the third major cereal crop of the country after rice and maize. The area, production and productivity of wheat in 1968/1969 was 208000 ha, 233000 mt and 1119 kg/ha which in 2005/2006 has increased to 672040 ha, 1394126 mt and 2074 kg/ha, respectively (Chand et al 1990, ABPSD 2000, ABPSD 2006). Similarly, during 2006/2007, 1515139 mt of wheat; was produced in the country from 702664 ha of land with an average yield of 2156 kg/ha (ABPSD 2007). It indicates that the improved wheat technologies have contributed to increase more than 300 per cent in area, about 600 per cent in production and 185 per cent in yield. Use of resource conservation technology to minimize costs and increase production has become essential for economic production of wheat.

Wheat contributed to more than 23 per cent to total edible food requirement of the country during 2004/2005 (ABPSD 2006). Export and import of wheat shows that the wheat worth of Rs 4,88,000,000.00 was imported from India while equivalent to Rs 19,95,207.00 was exported to overseas countries during 2005/2006.

Resources are generally either economic or natural which are vital to determine wheat production. Technology that enhances the saving of economic and natural resources without declining production level is Resource Conservation Technology (RCT). Furthermore, either efficient use of resources to attain at least previous level of production, or to increase that level with similar dose of inputs but with applying different technology is RCT. Increasing rate of inputs like seed, labor, fertilizers, fuel and also their unavailability in time has challenged to generate technologies that require less resources to attain more production. RCT thus refers to efficient use of inputs like seed, fertilizer, irrigation, labors and money without declining yield level rather to enhance its increment. Farmers for wheat cultivation generally plough the field 2-3 times after paddy harvest and left it to dry/to bring the soil-moisture into optimum level or sometimes the plowing of field is hindered due to over moisture in the field and ultimately the wheat sowing is delayed. RCT, thus refers to the economic use of inputs for optimum production of the crops.

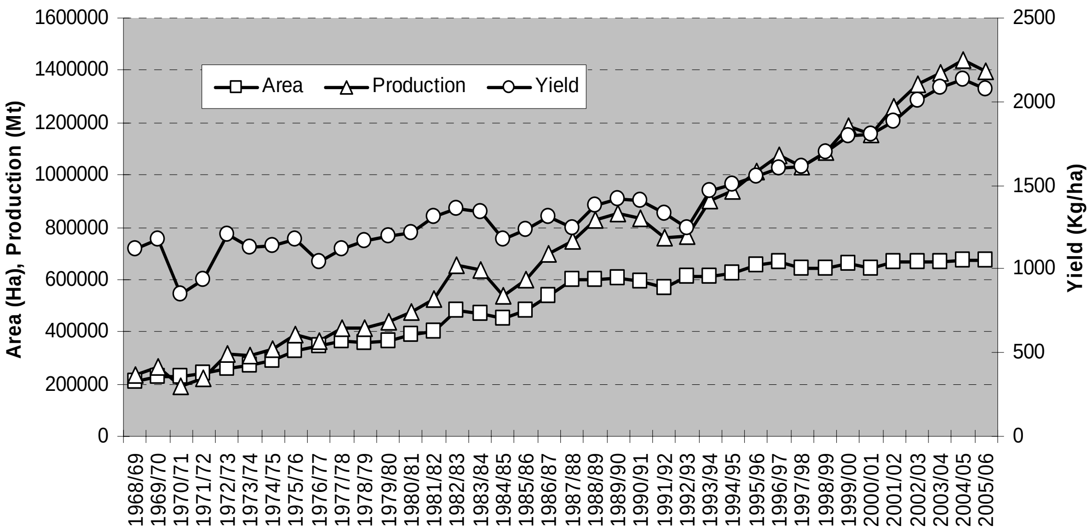

Figure 1. Trend of area, production and productivity of wheat in Nepal.

Regional Agriculture Research Station, Tarahara, Sunsari has been carrying out on-station research on wheat crop to find out high yielding varieties suitable for Eastern Terai Region (ETR). Since variety is one of the governing factors in wheat, the resource conservation technology (RCT) without decreasing the yield has also been inevitable for its sustainability. Farmers are well aware of conserving the resources right from the very beginning and they had used different methods of RCT in Nepal. Wheat cultivation using no-till technique was first started at the bank of *Ridi Khola* in Palpa district. Even before the initiation of wheat research, no-till wheat cultivation was practiced by the farmers of Bhaktapur district and the research on no-till wheat cultivation was initiated at Janakpur and Bhairahawa during mid seventies to minimize yield loss because of late planting (Giri 2001). Different tillage options such as zero tillage, surface seeding, bed planting and reduced tillage with Chinese seed drill as RCT have been found very effective to increase the production and productivity of rice-wheat system at significantly profitable level. These technologies greatly help in reducing the cost of cultivation by eliminating land preparation cost (Rs 2000.00 to Rs 2500.00/ha) and fostering timely establishment of wheat crop (Pathic et al 2003). Seed cum Fertilizer Zero Till Drill Machine in ETR was used to follow RCT in wheat cultivation during 2063/2064. This machine is also one of the technologies of resource conservation such as seed, fertilizer, labor and water. In this year, perhaps the first time in ETR, the seed cum fertilizer zero till drill machine was introduced in farmers' field for wheat sowing of Saptari, Sunsari and Morang districts.

The main objective of the study was to compare the production cost between traditional method of wheat sowing and by using seed cum fertilizer zero till drill machine. The specific objectives were:

1. to study the resource productivity of wheat,
2. to compare production of wheat between traditional method and RCT method of sowing,
3. to compare production cost and gross margin, and
4. to assess the production constraints.

MATERIALS AND METHODS

During the year 2063/2064 (2006/2007), a survey was carried out to assess the production of wheat cultivated by using seed cum fertilizer zero till drill machine and traditional method of the farmers. Farmers of Saptari, Siraha and Morang districts who used the machine to sow wheat were selected to take primary information. Altogether 31 sample farmers were selected purposefully. The same farmers had applied RCT and in some area they had grown wheat by their own traditional practices. Thus, all the selected farmers had applied both of the methodologies for wheat cultivation. A semi-structured questionnaire was developed for interview schedule. Face to face interview was scheduled with the respondent farmers. Information on traditional method of wheat sowing and RCT method was the main focus including the costs and production.

Secondary information was collected from publications, group discussions and key informants. Review was made through different reports published in journal and proceedings. The data was fed into computer and analyzed statistically using MS excel and SPSS package. Empirical analysis was focused on comparing the outputs between traditional and RCT method of wheat cultivation by the farmers. Since the variable cost is important in the short run which influence the decision making of the farmers to be considered for deriving the profits in both of the methods.

Analytical framework

In order to find out the productivity of the resources, production function approach was used for which the Cobb-Douglas production function was employed. In this production function the input coefficients constituted the respective elasticities which is the single most advantage of this production function and is mostly applied in agricultural research. The Cobb-Douglas production function was modified to include dummy variables for number of irrigation as Equation 1.

$$Y = AX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}X_7^{b7}X_8^{b8}X_9^{b9}X_{10}^{b10}D_1^{b11}\mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
Y = Gross returns from wheat cultivation (Rs.)
A = Intercept
X_1 = Area of wheat (Ha)
X_2 = Value of seed (Rs.)
X_3 = Cost on chemical fertilizers (Rs.)
X_4 = Cost on agrochemicals (Rs.)
X_5 = irrigation charge (Rs.)
X_6 = Cost on bullock labor (Rs.)
X_7 = Tractor charges (Rs.)
X_8 = Labors' cost (Rs.)
X_9 = Harvesting charge (Rs.)
X_{10} = Threshing charge (Rs.)
D_1 = Dummy for number of irrigation (1 for up to 3 irrigations, and 0 for otherwise)
b_1 to b_{11} = Elasticities coefficients

μ = Random error

Above model was estimated using Ordinary Least Square (OLS) approach after converting it into log linear form and thus, the estimation form of equation (1) was transferred into equation (2) as:

$\ln Y = \ln A + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + b_9 \ln X_9 + b_{10} \ln X_{10} + b_{11} D_1 + \mu$ ………............................ Equation (2)

The coefficient values imply their contribution to the production of wheat grown using traditional or RCT method by the farmers.

The total variable cost was estimated by using equation (3):
$Y = \sum x_i$ ………………………………..Equation (3)

Where,
Y = Total cost (Rs.)
x = Costs (Rs) incurred in i^{th} inputs.
Gross return was calculated by:
$Y = \sum x_i \times P_i$ ………………………………………Equation (4)

Where Y = Gross return (Rs.). It is the total value of total grain, husk and straw production.
X = Quantity of i^{th} products. It is quantity of grain, husk and straw production.
P = Price of i^{th} products (Rs/kg)

Similarly, the net return was estimated by using
$Y = \sum y_i - \sum x_i$ …………………………………….. Equation (5)

Where,
y_i = Value of the i^{th} products.
x_i = Total cost of inputs incurred in the cultivation.

RESULTS AND DISCUSSION

Among 31 sample farmers, 93 per cent were male while 7 per cent were female and the age of the respondent farmers was found to be 44 in average.

Land holdings and source of irrigation

Farmers were having both the irrigated and unirrigated land out of which farmers were found to be holding 4.28 ha of irrigated land in average. Farmers possessing more than 1 to 1.5 ha and more than 3 ha were equally contributed to total holdings as 29.03 per cent of each category followed by 16.14 per cent of holding more than 1.5 to 2 ha (Table 1). Similarly, the average holding of unirrigated land among the sample farmers was 0.11 ha which indicates the majority of wheat growers had irrigated land, because 84 per cent farmers had irrigated land and only 16 per cent of them operated unirrigated land too. Thus average operational holding was 4.59 ha. Majority of the farmers had more than 1 to 2 ha of total operated land including irrigated and unirrigated environment (Table 2). It was 38.71 per cent followed by more than 5 ha which constitutes 22.58 per cent among the sample farmers. The source of irrigation was mostly the irrigation canal which constituted 81 per cent. Remaining farmers had deep and shallow tube well.

Table 1. Average irrigated and unirrigated land holding of sample farmers, 2007

SN	Operational irrigated land area, ha	No. of farmers	Per cent	Operational unirrigated land area, ha	No. of farmers	Per cent
1	Up to 0.5	2	6.45	0	26	83.88
2	> 0.5 – 1	2	6.45	Up to 0.5	3	9.68
3	> 1 – 1.5	9	29.03	> 0.5 – 1.5	1	3.22
4	> 1.5 – 2	5	16.14	> 1.5 - 2	1	3.22
5	> 2 – 2.5	1	3.22			
6	> 2.5 - 3	3	9.68			
7	> 3	9	29.03			

Source: Field survey, 2007.

Table 2. Operational land holding of sample farmers, 2007

SN	Operational land area, ha	No. of farmers	Per cent
1	Up to 1	4	12.90
2	> 1 – 2	12	38.71
3	> 2 – 3	4	12.90
4	> 3 – 4	2	6.45
5	> 4 – 5	2	6.45
6	> 5	7	22.58

Source: Field survey, 2007.

Cropping intensity

Average cropping intensity of the sample farmers was 177 per cent where more than 45 per cent had up to 180 to 200 per cent followed by 38.71 per cent of farmers that had more than 180 to 210 per cent (Table 3). Similarly, more than 210 per cent cropping intensity was also found among 16 per cent of the sample farmers.

Table 3. Cropping intensity

SN	Cropping intensity, %	No. of farmers	Per cent
1	Up to 150	7	22.58
2	150 – 180	7	22.58
3	> 180 – 210	12	38.71
4	> 210	5	16.13

Source: Field survey, 2007.

Seed rate

Farmers in traditional method were found using high seed rate. The average seed rate was found to be 159.68 kg/ha and about 68 per cent farmers used more than 120 to 150 kg seed/ha (Table 4). In case of RCT method average seed used was 122.37 kg/ha and more than 87 per cent farmers used 120 kg seed/ha.

Table 4. Average seed rate used by the farmers in wheat cultivation

SN	Traditional method			RCT method		
	Seed, kg/ha	No. of farmers	Per cent	Seed, kg/ha	No of farmers	Per cent
1	Up to 120	1	3.23	120	27	87.10
2	> 120-150	21	67.74	> 120-130	2	6.45
3	> 150-180	7	22.58	> 140-150	2	6.45
4	> 180-210	2	6.45			

Source: Field survey, 2007.

Use of nutrients

The main source of nitrogen was Urea and DAP while that of phosphorus and potash was DAP and Muriate of potash. Average use of $N:P_2O_5:K_2O$ in traditional method was 72.52:43.23:20.93 kg/ha while in RCT method it was 77.70:48.46:21.71 kg/ha showing no significant difference in nutrient application. Thus total nutrient used in RCT and traditional method was 147.86 and 136.69 kg/ha respectively. More than 32 per cent farmers applied >100 to 125 kg of nutrients per ha both in traditional as well as in RCT method. Farmers were equal in applying more than 150 to 175 kg/ha in RCT method (Table 5).

Table 5. Average nutrients (nitrogen + phosphorus + potash) used by the farmers in wheat cultivation

SN	Traditional method			RCT method		
	Nutrient, kg/ha	No. of farmers	Per cent	Nutrient, kg/ha	No of farmers	Per cent
1	Up to 100	4	12.90	> 100-125	10	32.26
2	> 100-125	10	32.26	> 125-150	6	19.35
3	> 125-150	6	19.35	> 150-175	10	32.26
4	> 150-175	5	16.13	> 175-200	5	16.13
5	> 175-200	5	16.13			
6	> 200	1	3.23			

Source: Field survey, 2007.

Variable costs and production of wheat

Total variable costs incurred in traditional and RCT method was Rs 21716.25 and 19546.45/ha giving a net return of Rs 16750.06 and 23301.26/ha, respectively. Production of wheat was found different in both of the methods. The average yield in traditional and RCT method was 2455.81 and 2714.35 kg/ha respectively. The share of fertilizers was highest in both of the methods which was 24 and 29 per cent in traditional and RCT method respectively (Figure 2). The total benefit cost ratio was 1.77 in traditional method and 2.19 in machine used RCT method.

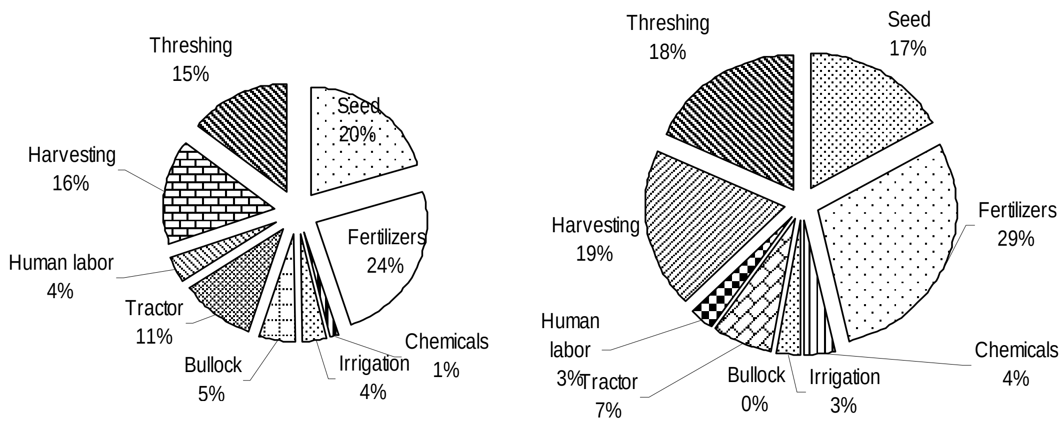

Figure 2. Share of variable costs in traditional and RCT method (left to right) of wheat cultivation.

The resource productivity of inputs used in traditional method indicated the area, chemical, number and cost of irrigation, harvesting and threshing as statistically significant (Table 6). Area has an elasticity of 1.05 which defines that 1 per cent increase in area would result in 1.05 per cent increase in production. Similarly, the cost on chemical, irrigation, harvesting and threshing is also significant. The negative value of irrigation shows that the farmers are paying high for irrigation charge while the dummy for number of irrigation has positive elasticity of 0.33 which indicates one per cent increase in number of irrigation would result 0.33 per cent increase in production. Despite significance in harvesting and threshing they have negligible value and reveals to maintain the cost in harvesting and threshing which are unbalanced. The model applied was significant ($p < 0.01$) with adjusted R^2 value of 0.96. It implies that the model is successful to explain 96 per cent variation in wheat production under traditional method due to independent variables taken under study.

Table 6. Resource productivity in wheat cultivation under traditional method

SN	Explanatory variables	Elasticities	Standard errors	T statistics
1	Intercept	10.11***	0.71	14.23
2	Area	1.05***	0.11	9.59
3	Seed	0.07	0.06	1.20
4	NPK	-0.007	0.01	-0.50
5	Chemical	0.01*	0.01	1.72
6	Irrigation	-0.13**	0.05	-2.50
7	Bullock labor	-0.0008	0.0009	-0.86
8	Tractor	-0.003	0.01	-0.32
9	Human labor	0.04	0.07	0.51
10	Harvesting	0.02**	0.01	2.29
11	Threshing	-0.02**	0.008	-2.23
12	Dummy for no of irrigation	0.33***	0.12	2.75
	Adjusted R^2	0.96***		
	F value (11,19)	67.29		
	Observations	31		

*NPK, Total of nitrogen + P_2O_5 + K_2O. ***, **, *, Denotes significant ($p < 0.01, 0.05, 0.10$).*

The model applied to explain variation in wheat production due to explanatory variables included under RCT method was significant ($p < 0.01$). It proves that the model has explained 97 per cent variation in wheat production due to independent variables under study which has been derived from adjusted R^2 value of 0.97 in the model. Cost on seed and human labor is statistically significant (Table 7). It means one per cent increase in seed and human labor would increase 0.53 and 0.05 per cent increase in production, respectively. However, the seed rate has limit to certain extent which can not be determined here. Similarly, the cost on human labor can still be considered. Other variables are non-significant that imply the similar use by the farmers and not varied significantly. Though most of the independent variables (area, NPK, chemical, irrigation, tractor, harvesting, threshing and no. of irrigation) are non-significant and have negative value (area, chemicals, tractor, harvesting, threshing and no. of irrigation), which in general indicates that a marginal increase in these inputs would not raise significantly the total value of output realized. However, the inputs applied by farmers in RCT method of wheat cultivation did not vary significantly which also reveals that they are well aware of using inputs efficiently if the technology is acceptable and economical.

Table 7. Resource productivity in wheat cultivation under RCT method

SN	Explanatory variables	Elasticities	Standard errors	T statistics
1	Intercept	2.79	3.61	0.77
2	Area	-0.09	0.42	-0.2
3	Seed	0.53*	0.31	1.68
4	NPK	0.44	0.29	1.53
5	Chemical	-0.003	0.01	-0.23
6	Irrigation	0.02	0.08	0.27
7	Bullock labor (Not used)	-	-	-
8	Tractor	-0.01	0.01	-0.90
9	Human labor	0.05***	0.02	2.70
10	Harvesting	-0.002	0.018	-0.13
11	Threshing	-0.05	0.10	-0.55
12	Dummy for no. of irrigation	-0.17	0.13	-1.27
	Adjusted R^2	0.97***		
	F value (10, 20)	118.50		
	Observations	31		

*NPK, Total of nitrogen + P_2O_5 + K_2O. ***, **, *, Denotes significant ($p < 0.01, 0.05, 0.10$).*

Production constraints

Wheat is generally grown by the farmers who are assured to supply irrigation. Farmers in discussion expressed the problems of getting quality input materials like seed and fertilizers. Timely availability of seed and fertilizers is also lacking. The demand of wheat seed is high but the supply through both the public and private sector is still not sufficient. Generally farmers did not mentioned about the loss from insects/pests and diseases, however, in RCT method they experienced more weeds which were controlled by applying herbicides. Increased price of seeds, fertilizers, fuel and lubricants, agrochemicals, labors has made the farmers to think twice whether to grow wheat or not, but they are to grow at least for their own consumption and thus can hardly escape from its cultivation. Furthermore, excess moisture in rice field has delayed wheat sowing in traditional method. Farmers having tractor can buy seed cum fertilizer zero till drill machine and all categories of farmers can not buy it.

In RCT method, farmers experienced the lack of availability of machine, high price of the machine, skilled operator of the machine and local mechanics for regular maintenance of the machine. They mentioned that the field should be well leveled which may not be in all conditions, specially the weed free (Stubbles) field after paddy harvest where the bottom part of the straw may be left at the field. In RCT method, weeds can not be controlled without herbicides application which may threat the environmental pollution.

CONCLUSION

Wheat cultivation is being expensive due to increase in labor and input price which can be solved to some extent by using resource conservation technology. Cultivation of wheat by using seed cum fertilizer zero till drill machine is one of the methods of RCT. The result has shown that by the use of this machine the costs on input variables can be reduced by 10 per cent while the return can be increased by 29 per cent which is encouraging information for wheat farmers. The benefit cost ratio was 1.77 and 2.19 respectively in traditional and RCT method of wheat cultivation. Production function showed the scope of increasing wheat yield in traditional method too. But it requires more investment and farmers can not get rid of labor problems and efficient use of seed, fertilizers and irrigation. In other hand they can not sow wheat in time if moisture is high in the field and become late to prepare the field and to bring the field into optimum moisture condition for which they have to wait. But in RCT method soil structure is not disturbed, seed and fertilizers are efficiently used, amount and time of irrigation water is less than the tilled field, timely sown and production is comparatively high. There is no need of using human labor and it is completely free from using bullocks in the current situation where raising bullocks is difficult due to lack of family labor and unavailability of feeds.

The result of the study has clearly supported the use of RCT method which is beneficial to farmers in many aspects and can cope with their existing problems of particularly the labor and inputs' use. However, every farmer can not buy the machine and those who are financially capable to buy the machine need to be encouraged by giving appropriate support services and facilities. Development of market for hiring machines in local market will help not only to owner of the machine but can provide services to all other farmers who can hire the machine and save the cost. It will have demonstration effect which is expected to be multiplied within a short span of years. Participatory research and scaling up programs need to be developed and also the training programs for local mechanics and farmers for its maintenance and availability of different machinery accessories which can be maintained by the dealers/hardware suppliers automatically on demand. Furthermore, RCT method would have chance to encourage farmers to grow wheat commercially and requires the policy support at the national level.

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REFERENCES

ABPSD. 2000. *Statistical information on Nepalese agriculture 1999/2000*. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Government of Nepal, Singh Darbar, Kathmandu. P. 114.

ABPSD. 2006. *Statistical information on Nepalese agriculture 2005/2006 (2062/63)*. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Government of Nepal, Singh Darbar, Kathmandu.

ABPSD. 2007. *Statistical information on Nepalese agriculture 2006/2007 (2063/2064)*. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Government of Nepal, Singh Darbar, Kathmandu. P. 4.

Chand SP, BD Gurung and PG Rood. 1990. Farmers' traditional wisdom, where does it stands within the present agricultural research system of Nepal. *PAC occasional paper no. 4*. Pakhribas Agriculture Centre, Dhankuta, Nepal.

Giri G. 2001. History of no-till (surface/relay) wheat planting in Nepal. **In:** *Advances in agricultural research in Nepal* (HK Manadhar, CL Shrestha, RK Shrestha and SM Pradhan, eds). Proceedings of the first SAS/N Convention, 29-31 Marg 1999, Kathmandu. SAS/Nepal. Pp. 68-76.

Pathic DS, DP Sherchan and RK Shrestha. 2003. Recent spread and impact of improved crops technologies in Nepal. **In:** *Proceedings of the 6th National Outreach Workshop* held at NARC (M Joshi and N Thakur, eds), 4 July 2002, Kathmandu, Nepal. Outreach Research Division, NARC, Kathmandu, Nepal. Pp. 62-75.

RESEARCH NOTE

PREVALENCE OF AFLATOXIN B1 AND B2 IN POULTRY FEED

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ABSTRACT

A total of 65 poultry feed samples were examined for the detection of aflatoxin (aflatoxin B_1 and aflatoxin B_2) using thin layer chromatography (TLC). Samples were collected from Chitwan and Kavrepalanchock districts. Out of those samples examined a total of 49 (75.38%) samples were found positive. Out of 49 (75.38%) samples positive, 42 (85.71%) samples were found positive both with aflatoxin B_1 and B_2 where as five (10.20%) samples were positive only with aflatoxin B_1 and two (4.08%) samples were positive only with aflatoxin B_2. Among them 13 (20%) samples were found positive having aflatoxin above permissible level. The concentration of aflatoxin in positive samples ranged from trace to 366 ppb (366 µg/kg). Likewise, out of 52 samples examined in rainy season, 40 samples (76.92%) were found positive where as out of 13 samples examined in winter season 9 (69.23%) were found positive.

Key words: Aflatoxin B_1, aflatoxin B_2, feed, mycotoxin, poultry, thin layer chromatography (TLC)

INTRODUCTION

Aflatoxins are naturally occurring highly toxic metabolites produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus* that cause detrimental effects on animal and human health. They are hepatotoxic, mutagenic, carcinogenic and immunosuppressive. According to World Health Organization – International Agency for Research on Cancer (WHO – IARC 1994, cited by Dwivedi and Patil 2005) aflatoxins are also considered to be a potential human carcinogen. These fungi are mainly found in groundnut cake, maize, wheat, pulses, beans, cotton seed, peanut and rice. However, almost any feed or grain for poultry and livestock support fungal growth and aflatoxin formation. The *Aspergillus* fungus can germinate and grow on feed grains and feed at moisture levels of 15% or above in the presence of warm (70 to 100^{o}F) temperatures. Aflatoxin production by the fungus is optimal at moisture levels above 17.5% and temperatures of 77 to 92^{o}F. Aflatoxins are relatively stable compounds in normal food and feed products. Infection can occur while grain is standing in the field, at and soon after harvest and during storage before or after the grain is processed into feed.

Aflatoxins have emerged as an important problem of economic importance in livestock and poultry industry. Aflatoxin causes clinical illness and death when consumed in high quantity (Sohane and Chaturvedi 2001). Aflatoxins in poultry feeds have long been associated with impaired performance by decreased weight gains, drop in egg production and reduced immunity (Mani and Viswanathan 1999) and vaccination failure (Sohane and Chaturvedi 2001). Aflatoxin is the most common mycotoxins, which is ubiquitous in nature and poultry feed. There are four major types of the aflatoxin molecules referred to as B1, B2, G1 and G2. Fungi invasion of poultry and livestock feeds results in production of aflatoxins, which are consumed by birds and livestock accounts for serious health hazards. These toxins are usually formed together in various foods and feeds in various proportions; however, aflatoxin B_1 is the predominant and is the most toxic. Due to their high carcinogenic and immunosuppressive properties, these toxins pose a substantial health risk to humans and animals.

Use of poor quality feed ingredients rejected for human consumption in preparing animal and poultry feed can cause serious diseases in animals (Kalorey and Ingle 1999).

Swine, other livestock and poultry are susceptible to aflatoxins at very low levels measured in parts per billion (ppb). Low levels of aflatoxin (20 to 200 ppb) in the diet of pigs can result in decreased feed intake, slower growth rate and decreased ability to resist disease. There are severe economic losses due to aflatoxins in poultry and livestock industry. Aflatoxins present in the feed have been found to interact with salmonellosis (Boonchuvit and Hamilton 1975, Singh et al 1996).

In general younger animals are more susceptible than older market animals or breeding animals. With increasing levels of aflatoxin in the diet, depressions in feed intake and growth rate become severe. If aflatoxin levels are high enough, liver damage can occur.

In Nepal, meager studies on detection and prevalence of aflatoxins in feed have been performed. Therefore this study was conducted to detect the prevalence of aflatoxin in poultry feed.

MATERIALS AND METHODS

A total of 45 poultry feed samples representing the stock batch were collected directly from farmhouses in winter and rainy seasons from Chitwan and Kavre districts, the two major poultry production pockets. The samples were kept separately in locked polyethylene packet and taken to laboratory for analysis.

Samples were analyzed by thin layer chromatography (TLC) method as described by AOAC (1984) at the laboratory of Department of Food Technology and Quality Control, Babar Mahal and at Animal Health Research Division, Khumaltar.

RESULTS AND DISCUSSION

A total of 65 samples were examined for the detection of mycotoxin (Aflatoxin B_1 and Aflatoxin B_2). Out of those 65 samples examined 45 samples were examined at the Department of Food Technology and Quality Control, Babar Mahal and 20 samples were examined at Animal Health Research Division, Khumaltar and a total of 49 (75.38%) samples were found positive (Table 1). Among them 39 (60%) samples were found traces positive where as 13 (20%) samples were found positive having aflatoxin above permissible level. In a study aflatoxin B_1 was found in 19%

groundnut, in 11% maize and in 50% maize flour whereas only few percentage of aflatoxin B_2 were found (DFTQC 1995). Out of 49 (75.38%) samples positive, 42 (85.71%) samples were found positive both with aflatoxin B_1 and B_2 where as 5 (10.20%) samples were positive only with aflatoxin B_1 and 2 (4.08%) samples were positive only with aflatoxin B_2. The concentration of aflatoxin in positive samples ranged from trace to 366 ppb (366 µg/kg). The findings of the present study are similar to those reported by Khadka et al (2000) where in Kathmandu, Chitwan and Biratnagar observed aflatoxin 300 µg/kg in livestock feeds, 500 µg/kg in poultry feed and 300 µg/kg in feed ingredients. He observed 80% of livestock feeds, 74% of poultry feeds and 72% of feed ingredients were contaminated and the average contamination percentage was observed 75 percent. The high percentage of positive feed samples in the present study may be due to the contamination of fungi *Aspergillus flavus* and *Aspergillus parasiticus* with the poultry feed in these areas due to the favorable environment for the growth of the fungi, use of suitable feed ingredients for the preparation of feed.

Table 1. Prevalence of aflatoxin B_1 and aflatoxin B_2 in poultry feed

Total number of positive samples	Types of toxin	No. of negative samples	No. of samples positive with			
			Traces	1-20 ppb	21-50 ppb	Above 50 ppb
49/65 (75.4)	B_1	5 (10.2)	15 (23.1)	6 (9.2)	13 (20.0)	12 (18.5)
	B_2	2 (4.1)	24 (37.0)	16 (24.6)	2 (3.1)	1 (1.5)

Figures in parentheses indicate percent sample.

Likewise out of 52 samples examined in rainy season, 40 samples (76.92%) were found positive where as out of 13 samples examined in winter season 9 (69.23%) were found positive (Table 2). Diener and Davis (1969) mentioned that moisture and relative humidity of the surroundings plays important role for the growth and development of fungus and production of aflatoxin. Animals and poultry consuming aflatoxin contaminated feed can develop serious health problems and pass the aflatoxin into milk, meat and eggs (Mishri et al 1999). Poor harvesting, storage and marketing facilities influence the production of aflatoxin (Sinha et al 1999). Therefore, regular monitoring of these practices and monitoring of aflatoxin could help for the protection of animals, birds and humans from aflatoxicosis.

Table 2. Seasonal occurrence of aflatoxin B_1 and aflatoxin B_2 in poultry feed

Season	No of samples +ve	Types of toxin	Samples positive with			
			Traces	1-20 ppb	21-50 ppb	Above 50 ppb
Summer (July-Oct)	40/52 (76.9)	B_1	14 (26.9)	3 (5.8)	12 (23.1)	10 (19.2)
		B_2	18 (34.6)	13 (25.0)	1 (1.9)	1 (1.9)
Winter (Nov-Feb)	9/23 (69.2)	B_1	2 (15.4)	3 (23.1)	2 (15.4)	2 (15.4)
		B_2	5 (38.5)	3 (23.1)	1 (7.7)	0 (0)

Figures in parentheses indicate percent samples.

REFERENCES

AOAC .1984. Official methods of analysis for aflatoxin determination. *Association of Official Analytical Chemists*. Washington DC, USA. Pp. 87-99.

Boonchuvit B and PB Hamilton. 1975. Introduction of aflatoxins and paratyphoid infections in broiler chicken. *Poultry Science* 54:1567-63.

DFTQC. 1995. Mycotoxin in food products. *Leaflets*. Department of Food Technology and Quality Control, Kathmandu. Pp. 1-8.

Diener UL and MD Davis. 1969. Aflatoxin formation by *Aspergillus flavus*. **In:** *Aflatoxin: Scientific Background , Control and Implication.* (LA Goldblatt, ed.). Academic Press, New York. Pp. 13-54.

Dwivedi P and RD Patil. 2005. Mycotoxicosis and their management in poultry. **In:** *National symposium on emerging and exotic diseases of poultry*, 10-11 March. Division of Avian Disease, Indian Veterinary Research Institute.

Kalorey DP and VC Ingle. 1999. Tips for control of mycotoxins in poultry and cattle. *Pashudhan* 14(7):3.

Khadka BB, BK Sinha, KCP Singh, LN Prasad and SB Verma. 2000. *Aflatixin contamination in livestock feeds and feed ingredients of Nepal* (part of MVSc Thesis). Rajendra Agricultural University, Pusa, India.

Mani K and K Viswanathan. 1999. Effect of aflatoxin on chicken production. *Poultry Punch*. Pp. 67-69.

Misri J, N Singh and VK Gupta. 1999. Mycotoxins: The unapparent source of animal feeds. *Livestock International* 3(10):7-9.

Singh B, MS Oberoi, SK Land and A Singh. 1996. Emerging diseases of poultry in India. *J. Res. Punjab Agric. Univ*. 33(1-4):391-410.

Sinha BK, KS Rajan and TN Pandey. 1999. Aflatoxin contamination of animal feed in Bihar. *Indian J. Vet. Res.* 8:31-38.

Sohane RK and VB Chaturvedi. 2001. Detoxification of aflatoxin in feed. *Pashudhan* 13(5):3.

RESEARCH NOTE

Use of Ethephone and Indigenous Plant Materials in Ripening Banana in Winter

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ABSTRACT

Post-harvest handling of banana is a crucial activity to get good quality fruit to the consumers. A post-harvest study on ripening of banana was carried out at Regional Agriculture Research Station, Khajura during winter season of 2005 to find out the effect of different materials in ripening of banana and study about shelf-life period. Dipping fruits in Kripone 2.56 ml per liter of water (ethephone 1000 ppm) for five minutes was found effective for banana ripening. Those fruits treated with ethephone 1000 ppm started to soften in three days and became ready to consume in five days with shelf-life of eight days. Fruits treated with 'Asuro' (*Adhatoda vesica*) started to become soft in five days where as fruits treated with 'Koiralo' (*Bahunia veriagata*) became soft in four days. By using these indigenous plant materials, we can prolong shelf-life of fruit by 2-3 days more than the Kripone-treated fruits. Use of ripe banana fruit also found effective to hasten ripening the banana with excellent taste. However, the shelf-life was relatively short (8 days). It is difficult to ripen the banana in winter without using any ripening materials. In untreated control, only 33% fruits started to become soft after 7-9 days of storage and were ready to consume in nine days. Rest 66% fruits were remain as such up to 11 days then after fruit started uneven softening ie some portion became soft and other portion remained hard. After 14 days fruits became black without softening and got spoiled. Overall percent weight loss was found 6.0 to 10.7 from initial to end of shelf-life period.

Key words: Banana, ethephone, plant materials, ripening, shelf-life

INTRODUCTION

In social and economical aspect banana (*Musa acuminata*) is one of the major fruits of Nepal. It occupied an area of 5732 hectare with the total productive area is 3742 hectares, which produces approximately 53257 metric of fruits (MOAC 2007). Among the major fruit crop growing area in Nepal banana stands 4th position after citrus, mango and apple. In Nepalese geophysical situation, it can be grown from terai to 1500 m altitude of mid hills, where frost does not occur usually (Gautam and Dhakal 1991). The major production areas are terai, valleys and river basins (Bhusal et al 2008).

For nutritional security banana plays significant role in human diet by supplying vitamins, minerals and dietary fiber. Banana is the rich source of energy. Hundred grams of banana pulp provides 100 kilo calories (Khader 1990).

Both qualitative and quantitative losses occur in horticultural commodities between harvests and consumption. Qualitative losses such as loss in edibility, nutritional quality, caloric value and consumer acceptability of produce are much more difficult to assess than are quantitative losses (Kader and Rolle 2004). Banana is not usually allowed to ripen on the plant as it takes long time. Moreover, the fruit peel splits, fruit ripens unevenly and fails to develop good color and aroma, hence, the marketable quality deteriorates (Khader 1990). Therefore, banana needs to be ripened artificially. Improper maturity at harvest, miss handling during transport and lack of proper ripening technique are other causes of post-harvest losses and marketable quality. Study conducted on the post-harvest losses in different market channels in India indicated total loss of 4.86 to 18.76 per cent in different varieties (Sudhakar Rao 2007). In climacteric fruit like banana uniform ripening especially in winter season is often problematic. Poor quality and uneven ripening are caused by early harvesting and late harvesting results in extremely poor shelf-life. To extend post-harvest shelf-life of the fruit its respiration rate should be reduced at minimum tolerant level as far as possible. The most striking chemical changes which occur during the post-harvest ripening of banana are the hydrolysis of starch and the accumulation of sugar (Roy 1990).

Farmers and traders of Nepal are using different chemicals and plant materials in different doses knowingly and unknowingly. With the objectives of verifying the non hazardous chemicals and their doses and possible indigenous plants materials, this study was carried out at Regional Agriculture Research Station, Khajura, Banke.

MATERIALS AND METHODS

An experiment was conducted as a part of the 'Improvement of Quality Fruit Production and Post Harvest Handling of Banana' project supported by National Agriculture Research and Development Fund (NARDF), Government of Nepal. The experiment was carried out at Regional Agriculture Research Station of Nepal Agricultural Research Council (NARC), Khajura, Banke during winter season of 2005. Cultivar used in the study was 'Jhapali Malbhog'. Room temperature recorded during study period was maximum 27-29^{o}C and minimum 20-22^{o}C.

The treatments include ethephone 1000, 2000, 3000 and 4000 ppm, 'Asuro' (*Adhatoda vesica*) 100 g/kg fruit, 'Koiralo' (*Bahunia veriagata)* 100 g/kg fruit, ripe banana four piece/kg fruit, and untreated control.

Procedure

1. To obtain 1000, 2000, 3000, and 4000 ppm ediphone 2.56, 5.12, 7.68 and 10.24 ml Kripone (ethephone 39%) per liter of water, respectively was used. Fruits were dipped in the solution for five minutes, dried in shade, kept on Jute sacs and then covered with poly bags.
2. The fresh leaves and twigs of Asuro and Koiralo 100 g each per kg of fruits were dried in sunlight for light withering and kept as mention above.

3. Four ripe bananas were used per kg of fruits to be ripened.

RESULTS AND DISCUSSION

Fruits dipped in Ethephone 1000 ppm {Kriphone 39%, 2.56 ml per liter of water} for five minutes was effective for banana ripening so there is no need of use higher dose. Fruits started to be soften in three days and became ready to consume in five days. However, shelf-life was relatively short (8 days). After eight days fingers were detached from palm and yellow fruits turned black and got spoiled (Table 1).

'Asuro' and 'Koiralo' were found effective to ripe the banana fruit. Asuro-treated fruits started to soften in five days whereas Koiralo-treated fruits became soft in four days. By using these indigenous plant materials, we can also prolong shelf-life of fruit by 2-3 days more (Table 1). After 9-10 days fruits were spoiled by detachment of finger from palm but fruit color remained yellow. Availability of plant materials may be difficult everywhere.

Use of four fingers of ripe banana per kg of fruit found effective and quick to ripen the banana fruit with excellent taste. However, shelf-life was relatively short (8 days). After eight days fruits were spoiled by detaching the finger from palm and yellow fruits turn in brown color. Practical application of this method to hasten the banana ripening might be costly.

Table 1. Effect of different materials to ripening banana in winter at Khajura, 2005

Treatment	Soften started (days)	Suitable for use (days)	Color scale	Attend completely yellow (days)	Shelf-life (days)	Brix, %	Taste
Ethephone 1000 ppm	3.00	4.00	3	-	8	11.00	Excellent
Ethephone 2000 ppm	3.00	5.30	3	8	8	13.00	Excellent
Ethephone 3000 ppm	3.00	4.00	3	-	8	11.20	Excellent
Ethephone 4000 ppm	3.00	4.67	3	7	7	13.06	Excellent
Adhatoda vesica	4.67	6.00	3	8	10	11.33	Good
Koiralo	4.00	6.00	5	7	9	10.33	Good
Ripe banana	3.00	4.33	3	7	8	9.53	Excellent
Untreated control	9.00	9.33	-	-	-	9.53	-
Grand mean	4.083	5.45	-	-	8.706	11.125	
LSD (a = 0.05)	1.159	0.946	-	-	1.576	ns	
F-test	**	**	-	-	**		
CV, %	16.14	9.89	-	-	10.33		

Color scale: 3, More green than yellow. 5, More yellow than green.

In winter season, it is very difficult to ripen the banana commercially without using any materials. In untreated control, only 33 percent fruits started to become soft after 7-9 days and ready to consume in nine days. Rest 66 percent fruits remained as such up to 11 days. Then after fruits started uneven softening i.e. some portions became soft and some portions remained hard. Fruits also failed to develop color and aroma. After 14 days fruits became black without softening and yellowing. The loss of weight was the highest in the 'Koiralo' treatment and the least in untreated control.

Table 2. Weight loss trend of ripe banana over shelf life period

Treatment	Initial weight, g	4 days of storage	8 days of storage	Total wt loss at the end of shelf-life, g	Weight loss, %
Ethephone 1000 ppm	920	903	845	75	8.1
Ethephone 2000 ppm	951	932	873	78	8.2
Ethephone 3000 ppm	902	888	831	71	7.8
Ethephone 4000 ppm	926	908	870	56	6.0
Asuro	842	840	799	79	9.3
Bahunia veriagata	914	892	849	98	10.7
Ripe banana	901	888	829	72	7.9
Untreated control	899	879	865	34	3.7

CONCLUSION

Uses of ethephone, indigenous plant materials (Asuro and Koiralo), ripe banana fingers were found effective to ripen banana. Further modification/verification for their use in large scale and studies on other indigenous materials should be explored.

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REFERENCES

Bhusal,Y.R., M.S. Ghale and H.P. Pathak 2008. Evaluation of different Varieties of Banana at Agriculture Research Station (Horticulture), Malepatan, Pokhara. Paper presented at 5th National Horticulture Seminar June 9-10, Khumaltar, Lalitpur.

Gautam DM and DD Dhakal. 1991. *Falful Tatha Audhogik Bali* (In Nepali). Pavitra and Rupa publication, Bharatpur, Chitwan.

Kader AA and RS Rolle. 2004. *The role of post-harvest management in assuring the quality and safety of horticultural produce*. FAO Agricultural Services Bulletin 152.

Khader A, JBM Md, K Chellappan, PK Chattopadhayay and O Anchanam Alagia Pillai. 1990. Banana. **In:** *Fruits Tropical and Subtropical* (TK Bose and SK Mitra, eds.). Naya Prokash, Calcutta. Pp. 132-185.

MOAC. 2007. *Statistical information on Nepalese agriculture (2006/07)*. Agribusiness Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Government of Nepal, Singha Durbar, Kathmandu, Nepal.

Roy SK. 1990. Post-harvest handling of fresh fruit. **In:** *Fruits tropical and subtropical* (TK Bose and SK Mitra, eds.). Naya Prokash, Calcutta.

Sudhakar Rao DV. 2007. Minimization of post-harvest losses of fruits and vegetables. Division of Post-harvest Technology, Indian Institute of Horticultural Research, Hessarghatta Lake, Bangalore.

RESEARCH NOTE

Hybridization Technique in Tartary Buckwheat (*Fagopyrum tataricum* Gaertn)

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Nepalese people called two cultivated species of Fagopyrum (*F. esculentum* and *F. tataricum*) collectively Phapar (Buckwheat). Common buckwheat (*F. esculentum*) is called Mithe Phapar and tartary buckwheat (*F. tataricum*), Tite Phapar in Nepali. Buckwheat is cultivated from 60 to 4200 m altitude and in 61 districts of Nepal (Baniya 1999, Vaidya et al 1999, Joshi 2008). Farmers value buckwheat as vegetable, food and medicinal crop (Baniya 1999, Vaidya et al 1999). Because of its unusual and very unique behavior as well as medicinal and economical values, its potential is very high for improving farmers' livelihoods. Buckwheat is a high value crop however, research effort has been only limited to introduction and simple phenotypic selection in Nepal. Lately hybridization followed by genotypic selection is initiated in Biotechnology Unit, Khumaltar to develop high yielding, bitterless and non-adhering hull type varieties.

Tartary buckwheat (*Fagopyrum tataricum* Gaertn, 2n = 2x = 16) is a staple food crop in Mountain regions (agroecologically, High Hill) of Nepal. It can be grown in summer season in High Hill, autumn and spring seasons in Mid Hill and winter season in Low land (Tarai). Cultivating areas of buckwheat have been increasing throughout the country because of its easiness of cultivation, high medicinal and environmental protection values. Breeding work is limited only to selection on existing natural variation mainly due to very difficult to produce F_1 seeds among the landraces of tartary buckwheat. Flower is inconspicuous, incomplete, bisexual and cleistogamy in nature. Therefore, it is extremely difficult to emasculate manually. Only Mukasa et al (2007) and Wang and Campbell (2007) produced F_1 seeds among tartary buckwheat. With the hot water aided emasculation, we produce F_1 seeds among Tartary buckwheat first time in Nepal.

Eighteen accessions of tartary buckwheat (Table 1) were taken from Gene Bank of NARC and grown in buckwheat in Greenhouse in 2008. Staggered planting, though not necessary because of indeterminant growth habit, was done for synchronized flowering. Three methods namely hand emasculation, hot water using Thermos and hot water using electric water bath (Thermo Minder SD Mini, TAITEK Corporation, Japan) were randomly used for emasculating these genotypes. Flower clusters were prepared by removing opened flower, ready to open flower and very immature and seed set flower. On an average there were 6 flowering buds in a cyme. Emasculation was done from 2-5 pm.

Mostly the shiny small flower buds which were not longer than bract length were taken to emasculate (Figure 2). For hand emasculation, top portion about 1/3rd of flowering bud were cut and in some cases, hand emasculation was done without cutting the top portion. 8 anthers were removed by needle or forceps with help of magnifying lens. Different temperatures at different time period of soaking flower buds were tested in Thermos and Water bath and these treatments are given in Table 1. Thermometer was used to check the water temperature and stop watch to check the soaking time duration. In the next day, opened flowers were marked and used for pollination. Two methods, rubbing and brushing were followed for pollination with the help of magnifier. Anthers were collected from the flowering buds ready to open in petridish and pollens were released pressing the anther by needle. These pollens were dusted to emasculated flower by brush or needle. In some cases, anther were picked by forceps and rubbed to the stigma. Open flowers from the male parent were taken by forceps and rubbed in the emasculated flowers in the morning with the help of magnifier. Pollinated flowers were regularly monitored and one week after treatment, number of seeds and dead flowers were counted.

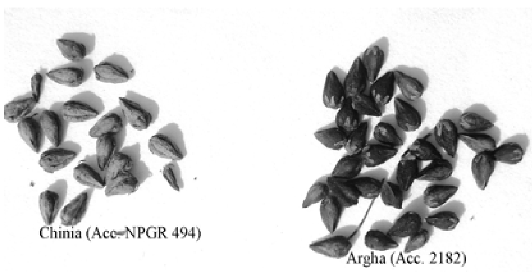
Table 1. Parental lines used in crossing (CN, crossing number) and treatment for emasculation

CN	Female parent		Male parent	Emasculation	
	Name	Accession		Method	Treatments (^{o}C-min)
1	Andheri	NPGR-5663	Kabre Tite	Hand	-
2	Argha	NPGR-2182	Bijuwar	Hand	-
3	Bijuwar	NPGR-2191	Kabre Tite	Thermos	45-3
4	Chalsa-1	NPGR-5658	Bijuwar	Thermos	44-3
5	Chinia	NPGR-494	Argha	Water bath	I. 45-3, II. 44-3
6	Chyangboche	NPGR-2237	Jumla Tite-1	Thermos	44-2
7	Dablyang	NPGR-5671	Sample#8	Thermos	43-5
8	Dolpa Tite	NPGR-11329	Kabre Tite	Thermos	42-5
9	Ghiling Tite	NPGR-11385	Argha	Water bath	I. 44-3, II. 44-2
10	Jumla Tite-1	NPGR-11358	Kabre Tite	Water bath	43-3
11	Jumla Tite-2	NPGR-11363	Kabre Tite	Water bath	I. 43-3, II. 42-4
12	Kabre Tite	NPGR-11322	Khalde-2	Thermos	45-3
13	Khalde-2	NPGR-5668	Argha	Thermos	44-3
14	Khinga	NPGR-8207	Khalde-2	Hand	-
15	Morudung	NPGR-2224	Khinga	Hand	-
16	Sample#8	NPGR-1319	Chalsa-1	Thermos	42-4
17	Sirdibas	NPGR-2214	Dolpa Tite	Hand	-
18	YDR-2-FT-19-4	NPGR-11304	Jumla Tite-1	Hand	-

Flowers emasculated by hand did not open and force pollinated (Table 2). All flowers were died. Every flower parts are very sensitive and delicate. Therefore after touching them by forceps or needles, they turned dried. After cutting the tips, flower turned dark and did not open completely. Hand emasculation is very difficult and could not successful in tartary buckwheat. Similarly flowers emerged in Thermos hot water did not open. Forced pollination was followed in such case. However, flowers could not set the seeds. It is noticed that in Thermos, temperature could not be maintained at right degree. Deeper the Thermos more the temperature. High temperature inhibit flower to open (Mukasa et al 2007).

Most of the flowers opened next day after treating in water bath. This is because; the temperature in the water bath is constant. Very few F_1 seeds have been produced using hot water in water bath for emasculation. This method is seemed very useful and simple for producing F_1 seeds. After crossing, different characters can be used for testing F_1 seeds. Cotyledon color in just after emergence, seed shape, maturity, hull color, etc will be useful but the inheritance patterns of these characters are necessary. In addition to this morpho type of F_1 seeds or plant, segregation pattern in F_2 supplement the successful of crossing. For example, dark red cotyledon color is controlled by single recessive gene. Non adhering hull is the output of single recessive gene and independent with hull color. Dark hull color is controlled by dominant gene (Mukasa et al 2007).

F_1 seeds were successfully produced first time in Nepal by crossing two landraces {Chinia (NPGR 494) / Argha (NPGR 2182)} using hot water method for emasculation. F_1 seeds were produced only from the flower treated at 44^{o}C for 3 minute.



Seeds of two parents used in crossing

Flower cluster after removing unnecessary flowers and seeds

Apical part soaking in hot water for emasculation

Flower opened in the following day of hot water treatment

Figure 2. Seeds of parents and emasculation process.

Table 2. Emasculation and pollination details along with seed set

CN	Flower/bud, n		Pollination		Seed set, n
	Emasculated	Opened	Method	Flower pollinated , n	
1	3	-	Rubbing	3	0
2	4	-	Brushing	4	0
3	35	0	Brushing	0	0
4	45	0	Brushing	0	0

5	I. 44, II. 56	I. 0, II. 11	Rubbing	I. 0, II. 6	I. 0, II. 2
6	60	0	Rubbing	0	0
7	56	0	Brushing	0	0
8	34	2	Brushing	2	0
9	I. 34, II. 16	I. 8, II. 3	Rubbing	I. 3, II. 1	I. 1, II. 0
10	60	14	Rubbing	5	0
11	I. 20, II. 25	I. 4, II. 5	Rubbing	I. 2, II. 2	I. 0, II. 0
12	24	0	Brushing	3	0
13	15	0	Rubbing	4	0
14	6	-	Rubbing	6	0
15	7	-	Rubbing	7	0
16	24	1	Rubbing	3	0
17	4	-	Brushing	4	0
18	2	-	Brushing	2	0

Refer Table 1 for crossing number.

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REFERENCES

Baniya BK. 1999. Buckwheat genetic resources in Nepal. **In:** *Status reports on genetic resources of buckwheat. East Asia: China, South Asia: India and Nepal* (M de Zhou and RK Arora, eds). IPGRI APO, Malaysia. Pp. 1-27.

Joshi BK. 2008. *Buckwheat genetic resources: Status and prospects in Nepal. Agric. Development Journal* 5:13-30.

Kreft I, N Fabjan and M Germ. 2003. Rutin in buckwheat-protection of plants and its importance for the production of functional food. *Fagopyrum* 20:7-11.

Mukasa Y, T Suzuki and Y Honda. 2007. Emasculation of tartary buckwheat (*Fagopyrum tataricum* Gaertn.) using hot water. *Euphytica* 156:319-326.

Vaidya ML, BK Baniya, HP Bimb, SR Upadhyay, D Sharma and D Dongol. 1999. On - farm conservation of bitter buckwheat in the mountain of Nepal: A feasibility study. Agriculture Botany Division, Nepal Agricultural Research Council, Lalitpur, Nepal. **In**: *IPGRI project report on on-farm conservation of bitter buckwheat in the Mountains of Nepal*. Nepal Agricultural Research Council, Lalitpur, Nepal. Pp. 1-40.

Wang Y and C Campbell. 2007. Tartary buckwheat breeding (*Fagopyrum tataricum* L. Gaertn.) through hybridization with its rice-tartary type. *Euphytica* 156: 399-405.

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Joshi BK, S Gyawali and DS Poudyal. 2002. Regression analyses and multiple comparison procedures: Uses and misuses. *J. Institute Sci. Tech.* 12:69-81.

Book

Cochran WG and GM Cox. 1968. *Experimental designs.* 2nd ed. John Wiley and Sons, Inc., New York. 490pp. Lewis WH, ed. 1980. Polyploidy: Biological relevance. Plenum Press, New Yrok.

Contribution to Book/Proceedings

Yuan LP, ZY Yang and JB Yang. 1994. Hybrid rice in China. **In:** *Hybrid rice technology: New development and future prospects* (SS Virmani, ed). IRRI, the Philippines. Pp.143-147.

Joshi BK, KP Shrestha, KD Joshi, A Mudwari, SP Khatiwada, P Chaudhary, RB Yadab, D Pandey, PR Tiwari, BK Baniya and BR Sthapit. 2003. Process documentation on deployment of rice and buckwheat diversity through participatory varietal selection for specific adaptation. **In:** *On farm management of agricultural biodiversity in Nepal* (BR Sthapit, MP Upadhyay, BK Baniya, A Subedi and BK Joshi, eds). Proceedings of a National Workshop, 24-26 April 2001 Lumle-Nepal, NARC, LIBIRD and IPGRI. Pp. 229-232.

Annual Report

NWRP. 1980. Rice-wheat system: Opportunities and constraints. **In:** *Annual report-1980*. National Wheat Research Program (NWRP) - Nepal Agricultural Research Council, Bhairahawa – Rupandehi - Nepal. Pp.60-65.

ABD. 2003. *Annual report 2058/59 (2001/02).* Agriculture Botany Division - NARC, Khumaltar - Kathmandu.

Serials

Hodges EM, WG Kirk, FM Peacock and JR Neller. 1964. Forage and animal response to different phosphatic fertilizers on pangobgrass pastures. *Fla. Agric. Expt. Sta. Bull.* 6(8):28.

Web material

Pretty J. 2003. *Genetic modification: Overview of benefits and risks*. Accessed in 5 June 2005 from http://www2.essex.ac.uk/ces/.

Thesis/Dissertation

Joshi BK. 2000. Assessment of the potential of Nepalese rice cultivars and landraces for hybrid production. *Master Thesis*. Institute of Agriculture and Animal Science, Rampur - Nepal. 104pp.

Paper Presented in Workshop or Seminar

Upadhyay MP, BK Baniya, RB Rana, J Bajrachayraya, A Subedi, A Mudwari, S Gywali, DK Rijal, BK Joshi, HB KC, D Gauchan, BR Sthapit. 2003. On farm management of

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