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Contents

Genetic Base of Wheat Cultivars Recommended in Nepal

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ABSTRACT

Plant breeding success is dependent, in part, upon the genetic diversity found within genetic resources. The genetic base of wheat (*Triticum aestivum* L.) cultivars recommended in Nepal is not well characterized. Therefore this study was carried out to quantify the genetic base of Nepalese wheat cultivars by coefficient of parentage (COP). Analysis of pedigree information was based on International Wheat Information System of the International Center for Maize and Wheat Improvement (CIMMYT), which consists of WCOP for calculation of COP and WPDEND for generating Mendelgram with contribution of ancestors to the cultivar if fully expanded. One hundred eighteen ancestors from 23 countries were identified in the pedigree of 24 recommended Nepalese cultivars. Of these, 32 ancestors contributed at least 1% each to the genetic base of Nepalese cultivars, with a total contribution of 79%. Ancestors originating from USA contributed 19.8% of the genes, India 11.2%, Japan 9.5%, Argentina 7.5%, Kenya 7.5% Australia 6.2%, Brazil 5.6%, Canada 5.5%, Italy 4.1% and remaining from other countries. At 30% similarity, 18 clusters were formed with largest cluster of five members. None of Nepalese landraces were traced in the pedigree of these cultivars. Relatively large amount of diversity in Nepalese cultivars exits based on their genetic background although small number of cultivars is recommended for cultivation.

Key words: Coefficient of parentage, diversity, *Triticum aestivum*, wheat breeding

INTRODUCTION

Genetic variation is required in a breeding program to achieve genetic gains. Breeders require information on the magnitude of variation in the genetic material. Originally developed by Wright (1922), the coefficient of parentage (COP) for two genotypes estimates the expected percentage of alleles identical by descent at loci which are polymorphic within a population, is commonly used measure to assess the genetic composition of cultivars developed through hybridization. The COP between two wheat genotypes is the inbreeding coefficient of their offspring. St. Martin (1982) adapted the COP analysis to inbred crops by assuming that each genotype is completely homozygous, that genotypes without common parentage are unrelated and that parents contribute equally to the offspring, despite inbreeding and selection. Highly selected, qualitative loci would not follow the assumption of random transmission of a large number of alleles. However, in a general sense, a COP is a measure of overall common ancestry of two genotypes and estimates latent genomic diversity that is not obvious until a crop is challenged by the appropriate biotic or abiotic stress. Breeders can use COP to increase genetic diversity by selecting lines for crossing with divergent parentage.

Using COP, one can quantify pattern of relatedness among cultivars, magnitude and importance of genetic drift, and the genetic base for crop breeding. COP has been used to estimate the genetic diversity among cultivars and parental germplasm (St. Martin 1982, Joshi et al 2004, Cowen and Frey 1987, van Beuningen and Busch 1997). COP has also been used to predict breeding behavior of the progeny of crosses (Cowen

and Frey 1987), to summarize regional crop diversity (Souza et al 1994), genetic base of cultivars and to identify parents contributing to increased yield (Beer et al 1995).

CIMMYT software, WCOP calculates the COPs among genotypes. A mainframe version was used to study wheats in the 17th to 27th International Spring Wheat Yield Nurseries (ISWYNs) (Fox et al 1994). Pedigree analysis identified genotypes with excellent industrial quality among germplasm that is genetically distant from major gene pools. Long-term trends in genetic diversity were compared using COPs for wheat in the Pakistani, Punjab and in the Yaqui Valley of Mexico (Souza et al 1994). There was no evidence of genetic erosion and patterns in varietal adoption were more important for diversity than varieties released per se. Researchers from India (Jain 1994), Canada (Thomas 1996), USA, Australia (Brennan and Fox 1995) and CIMMYT (Smale and McBride 1996) have used WPMS to examine the genetic base and gene flows in wheat. Landraces from certain regions do not appear in the genealogies of modern wheats. Generally, this seems to indicate that these materials have not been tried in breeding and thus represent novel sources of variation. Braun et al (1992) calculated the genetic variance of entries for grain yield in many environments in the first 19 ISWYNs. The relationship between these parameters and the average COPs for the entries (without distinguishing among sister lines) in individual ISWYNs was investigated (Fox and Skovmand 1996). The significant correlation suggests that both measures, one from yield data from international trials and the other from genealogical information, support each other and are useful measures of genetic diversity. In Nepal wheat cultivars are recommended for cultivation starting from 1960 (Morrin et al 1992). The major part of wheat breeding in Nepal is mostly screening of cultivars and lines from India and CIMMYT. Information on size of genetic diversity and genetic base in wheat in Nepal is limited. This study was carried out to assess the diversity on cultivars based on their pedigrees and contribution of ancestors to Nepalese cultivars.

MATERIALS AND METHODS

Twenty-four cultivars among all 35 cultivars recommended for cultivation in Nepal were used in the study (Table 1). The cultivars were not included in the study whose pedigree information was incomplete. Two international cultivars; Marquis and Pavon and three South Asian cultivars; Chirya 3, PBW 343 and Kanchan were also used for comparative analysis. All of the pedigree information and analysis were based on International Wheat Information System (IWIS ™, Version 4) (Payne et al 2001). IWIS consists of WCOP to retrieve parentage information from CIMMYT pedigree management system (Fox and Skovmand, 1996). Specific Cross Identification (CID) numbers and Selection Identification (SID) numbers were used for all unique cultivars. WCOP use the CID to retrieve from the Pedigree Management System, a pedigree history that traced back to at least grand parents but often to ancestral landraces. WCOP formats the pedigree history into a file and then calls the FORTRAN program RCL to calculate COP values between pair wise combinations. A total of 29 (24 cultivars and 5 additional reference cultivars) were included in the final similarity matrix. The COP matrix of Nepalese recommended cultivars and reference cultivars was used as a similarity matrix for cluster analysis in NTSYS (Rohlf 1990), with SHAN clustering option using UPGMA method.

The parental contribution of an ancestral genotype to a modern cultivar was determined in following way. Ancestors were defined as founding stocks with no known pedigree. Contribution of an ancestor was defined as the fraction of genes in modern cultivars that could be traced from the progeny of that ancestor through pedigree analysis. COP between ancestors (landraces, treated as unrelated) and Nepalese recommended cultivars were computed from pedigree information using WPDEND (Wheat PMS Dendogram V2.0 CIMMYT 1997). When a genotype is fully expanded (so that all ancestors were landraces ie lines with unknown parentage), Mendelgram were generated using the same software. The Mendelgram

presents the theoretical percentage contribution of ancestors to a pedigree assuming equal contribution from both parents in a cross. The average contribution of ancestors to the 24 cultivars under study was determined as average of all coefficients between the ancestors (landraces) and the Nepalese cultivars.

Table 1. Wheat cultivars included in the study for analysis of diversity and genetic base

SN	Cultivar	Pedigree	CID	SID	Origin	Area of adoption
1	Annapurna 1	KVZ/BUDHO//KAL/BB	7691	394	Mexico	Hills
2	Annapurna 2	NAPO/TOB//8156/3/KAL/BB	141626	-1	India	Hills
3	Annapurna 4	KVZ/3/CC/INIA//CNO/ELGAU/SN64	162497	-1	Mexico	Hills
4	Bhrikuti	CDO/COC/3/PLO//FURY/ANA	251774	0	Mexico	Plains
5	BL 1022	PVN/BUC	541	7	Nepal	Western Tarai
6	BL 1135	QTZ/TAN	558	1	Nepal	Plains
7	BL1473	NL352/Nepal 297	166468	0	Nepal	Plains and Hills
8	HD 1962	E5557/HD845	122538	0	India	Western Plains
9	Kalyansona	Pj"S"/Gabo 55	6831	1	Mexico	Plains
10	Kanti	LIRA/FFN//VEE#5	22966	105	Mexico	Hills
11	Lerma 52	Mentana/Kenya 324	3011	7	Mexico	Hills
12	Lerma Rojo 64	Y50/N10B//L52/3/2*LR	6846	0	Mexico	Hills
13	Lumbini	E4871/PJ62	3117	1	India	Plains
14	Nepal 251	WH147/HD2160//2*WH147	142563	0	India	Plains
15	Nepal 297	HD2137/HD2186//HD 2160	142566	0	India	Plains
16	Nepal 30	HD832-5-5-OY/BB	142562	0	India	Western Plains
17	Pasang Lahmu	PGO/SERI	9368	198	Mexico	Hills
18	Pitic 62	YT54/N10B 26.1C	6674	7	Mexico	Hills
19	R 21	Sonalika= I53.388/AN/3/YT54/N10B/3/LR/4/B4946. A.4.18.2.IY/Y53//3*Y50	6977	3	Mexico	Hills and Plains
20	Rohini	PRL/TONI//CHIL	111639	5	Nepal	Plains
21	Siddhartha	HD2092/HD 1962//E4870/3/K65	84638	-1	India	Plains
22	Triveni	KAL/JANAK	85879	0	India	Plains
23	UP 262	S308/BAJIO 66	5435	1	India	Plains
24	Vaskar	TZPP/PL//7C	7401	9	Mexico	Mid-western Plain
International cultivars						
25	Marquis	HRC/RF	794	1	Canada	-
26	Pavon	VCM//CNO 67/7C/3/KAL/BB	7624	0	-	-
South Asian popular cultivars						
27	Chirya 3	CS/TH.CV//GLEN/3/ALD/PVN/4/NINMMAI NO.4/OLESON//ALD/YANGMAI NO.4	54384	0	Mexico	-
28	PBW 343	ND/VG 9144//KAL/BB/3/YACO/4/VEE#5	8890	1549	India	-
29	Kanchan	UP 301/SUJATA	2565	3	Bangladesh	-

CID, Cross identifier. SID, Selection identifier. The pedigree of Triveni is widely denoted by HD1963/HD1931 in Nepalese literatures, but based on CIMMYT pedigree database it was KAL/JANAK.

Source: CIMMYT 1997, NARC 1997.

RESULTS AND DISCUSSION

The contribution revealed that genetic base of recommended cultivars included in the study was fully defined by 119 ancestors. These ancestors' contribution to the genetic base of wheat were unequal, ranged from 0.0001 to 7.5%. It seems that large numbers of ancestors appear in pedigree of Nepalese wheat cultivars although more than half of the genetic base of Nepalese recommended cultivars constituted by only 14 ancestors (Table 2). Pedigree tree of Sonalika has shown how the genes of interest were combined (Figure 1). It indicates that efforts have been made in selecting landraces and hybridization. Agriculture Botany Division, NARC has conserved 390 accessions of wheat (Upadhyay and Joshi 2003). However,

these landraces were not traced out in breading history of these cultivars. Only 4 cultivars, which were not included in this study, were bred and developed using foreign landraces (Joshi and Mudwari 2003). Thirty-two ancestors contributed at least 1% each to the genetic base of Nepalese cultivars. The contributions of these 32, taken together, amount to 79% of the total genetic base of Nepalese wheat cultivars.

Table 2. Landraces (genotypes with unknown parents) with their contribution to Nepalese cultivars

SN	Landrace	Origin	Contribution, %	Cumulative, %	Number of cultivars with contribution
1	Akagomughi	Japan	7.5	7.5	24
2	Red Fife	Canada	4.6	12.1	-
3	Kenya 324	Kenya	4.5	16.6	24
4	Turkey Red	USA	4.0	20.6	23
5	Rieti	Italy	3.8	24.4	24
6	Steinwedel	Australia	3.7	28.1	20
7	Hd 845	India	3.1	31.2	2
8	Hard Red Calcutta	India	3.0	34.3	23
9	Oro	USA	3.0	37.3	23
10	Kanred	USA	2.8	40.1	23
11	Polyssu	Brazil	2.6	42.8	-
12	Red Egyptian	South Africa	2.6	45.4	17
13	Iumillo	Spain	2.5	47.9	23
14	Gaza	Egypt	2.5	50.3	20
15	Kenya Bf4-3b.10.V.1	Kenya	2.3	52.7	18
16	Egypt Na101	Argentina	2.3	55.0	19
17	Fultz	USA	2.2	57.2	23
18	Alfredo Chaves 6.21	Brazil	2.1	59.3	18
19	Daruma	Japan	2.0	61.3	23
20	Squarehead	USA	1.9	63.2	24
21	Improved Fife	USA	1.5	64.8	23
22	Ladoga	USSR	1.5	66.3	23
23	Fife	Poland	1.5	67.8	23
24	White Naples	Australia	1.5	69.2	23
25	Maria Escobar	Argentina	1.5	70.7	-
26	Jacinth	-	1.3	72.0	22
27	Turkey	USA	1.3	73.9	23
28	Americano 25e	Uruguay	1.2	74.5	18
29	Mediterranean	USA	1.1	75.6	23
30	Barleta	Argentina	1.1	76.7	18
31	Chino	Argentina	1.1	77.8	18
32	Purple Straw	Australia	1.0	78.8	23

Joshi et al (2004) have reported 77 ancestors originated from 22 countries used for 26 Nepalese cultivars. Introduced genotypes along with landraces and wild relatives have made Nepal a wheat genes rich country (Mudwari 1999, Bhatta et al 2000, Joshi and Mudwari 2003). This diversity should be characterized systematically and utilized effectively for long-term food security in the country.

Most of the cultivars released in Nepal are from CIMMYT source, directly or indirectly. COP was estimated with 8 CIMMYT most popular lines/crosses because COP was used by many national programs worldwide (Bayerlee and Moya 1993). The COP values show moderate to high relation with newly released and some old cultivars and it ranges from 0 to 1 (Table 3). Joshi et al (2004) showed that the most closely related cultivars were Annapurna 3 and 2 and some of the highest dissimilarity was between Kalyansona and HD 1982, and L52 and HD 1982 based on the COP.

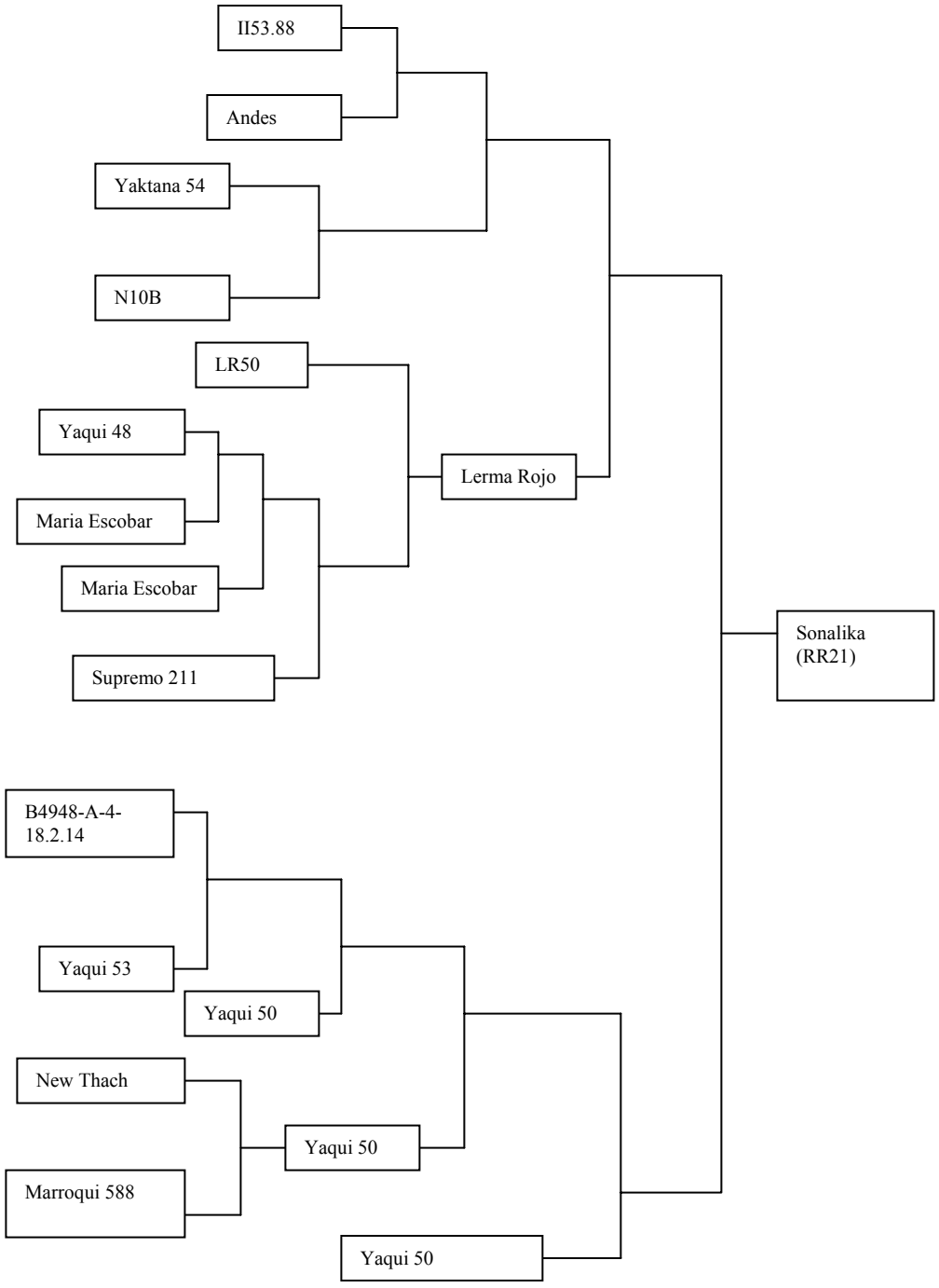

Figure 1. The pedigree tree for Sonalika (RR21) expanded to reasonable label. Fully expanded to level of all landraces include the contribution of 39 landraces.

The origin of most of the ancestors for Nepalese cultivars were from USA (13%), India (13%), France (12%), Argentina (6%), and Italy (6%) (Table 4). None of the ancestors were of Nepalese origin. On the basis of contribution, ancestors from USA (19.8%), India (11.2%), Japan (9.5%), Argentina (7.5%), Australia (6.2%), Brazil (5.6%), Canada (5.5%) and Italy (4.1%) constitute approximately 70% of the total

contribution. Only two of Japanese ancestors, Akagomughi (7.5%) and Daruma (2.0%) contributed almost ten percent.

Table 3. Coefficient of parentage between recommended Nepalese wheat cultivars with six internationally popular wheat lines/crosses developed by CIMMYT

SN	Cultivar	Blue Bird	II8156	Pavon	Bobwhite	Bluejay	Ciano	Buckbuck	Veery
1	Annapurna 1	0.446	0.264	0.297	0.231	0.177	0.172	0.192	1
2	Annapurna 2	0.494	0.353	0.437	0.276	0.252	0.182	0.229	0.32
3	Annapurna 4	0.190	0.074	0.165	0.164	0.096	0.32	0.152	0.18
4	Bhrikuti	0.237	0.118	0.159	0.117	0.106	0.165	0.132	0.14
5	BL 1022	0.383	0.252	0.425	0.228	0.212	0.251	0.622	0.25
6	Bl 1135	0.309	0.168	0.293	0.180	0.168	0.252	0.195	0.19
7	BL1473	0.219	0.159	0.215	0.156	0.146	0.201	0.193	0.15
8	HD 1962	0.046	0.044	0.062	0.051	0.057	0.063	0.057	0.05
9	Kalyansona	-	-	-	-	1	-	-	0.38
10	Kanti	0.289	0.162	0.206	0.167	0.132	0.144	0.141	0.35
11	Lerma 52	0.056	0.036	0.095	0.098	0.12	0.092	0.089	0.08
12	Lerma Rojo 64	0.054	0.044	0.12	0.094	0.106	0.079	0.076	0.1
13	Lumbini	0.196	0.297	0.200	0.146	0.196	0.139	0.207	0.17
14	Nepal 251	0.11	0.164	0.111	0.084	0.111	0.074	0.093	0.09
15	Nepal 297	0.105	0.079	0.108	0.102	0.105	0.16	0.115	0.06
16	Nepal 30	0.547	0.216	0.267	0.175	0.137	0.185	0.243	0.26
17	Pasang Lahmu	0.414	0.258	0.361	0.230	0.195	0.211	0.407	0.42
18	Pitic 62	0.185	0.156	0.183	0.152	0.151	0.347	0.242	0.14
19	Rohini	0.484	0.269	0.467	0.289	0.198	0.379	0.276	0.3
20	Siddhartha	0	0	0	0	0	0	0	0.09
21	Sonalika	0.088	0.070	0.101	0.091	0.10	0.145	0.11	0.07
22	Triveni	0.181	0.282	0.241	0.158	0.175	0.108	0.138	0.21
23	UP 262	0.135	0.088	0.133	0.124	0.14	0.214	0.141	0.25
24	Vaskar	-	1	-	-	-	-	-	0.18

Table 4. Origin of ancestors and their contribution to Nepalese cultivars

SN	Country	Number of ancestors contributing	Cumulative contribution of ancestors
1	USA	15	19.8
2	India	14	11.2
3	Japan	2	9.5
4	Argentina	7	7.5
5	Kenya	5	7.5
6	Australia	5	6.2
7	Brazil	5	5.6
8	Canada	5	5.5
9	Italy	7	4.1
10	Zaire	1	2.6
11	Egypt	2	2.5
12	Spain	1	2.5
13	Uruguay	3	2.4
14	USSR	3	2.2
15	Poland	1	1.5
16	Mexico	4	1.2
17	Germany	3	0.9
18	Chile	1	0.5
19	China	4	0.3
20	France	13	0.3
21	Zimbabwe	1	0.02
22	Sweden	1	0.1
23	United Kingdom	1	0.001
24	Unknown origin	13	4.1

Cluster analysis was done to group cultivars with similar genealogies (Figure 2). At 30% similarity level 18 clusters were formed. Cluster 7 was the largest which include Annapurna-2, Kalyansona, Rohini, BL 1022, Pasang Lahmu and Pavon. Some cultivars that are closely related were Nepal 297 and BL 1473 (COP = 0.55), Sonalika and UP 262 (COP = 0.55), Triveni and HD 1962 (COP = 0.52), Annapurna 2 and Kalyansona (COP = 0.47), Lerma 52 and Lerma Rojo 64 (COP = 0.45), Pasang Lahmu and BL 1022 (COP = 0.43) and Annapurna 1 and Kanti (COP = 0.35). Among reference cultivars, three South Asian cultivars PBW 343, Kanchan, Chirya 3 and International cultivar Marquis had low COP values with the studied genotypes. PBW 343 was related with Annapurna 1 (COP = 0.38). The assumption of the COP calculation may also bias the conclusions for sets of the cultivars within the study. A specific example is the assumption of lack of genetic similarity between cultivars without demonstrable ancestry (St. Martin 1982).

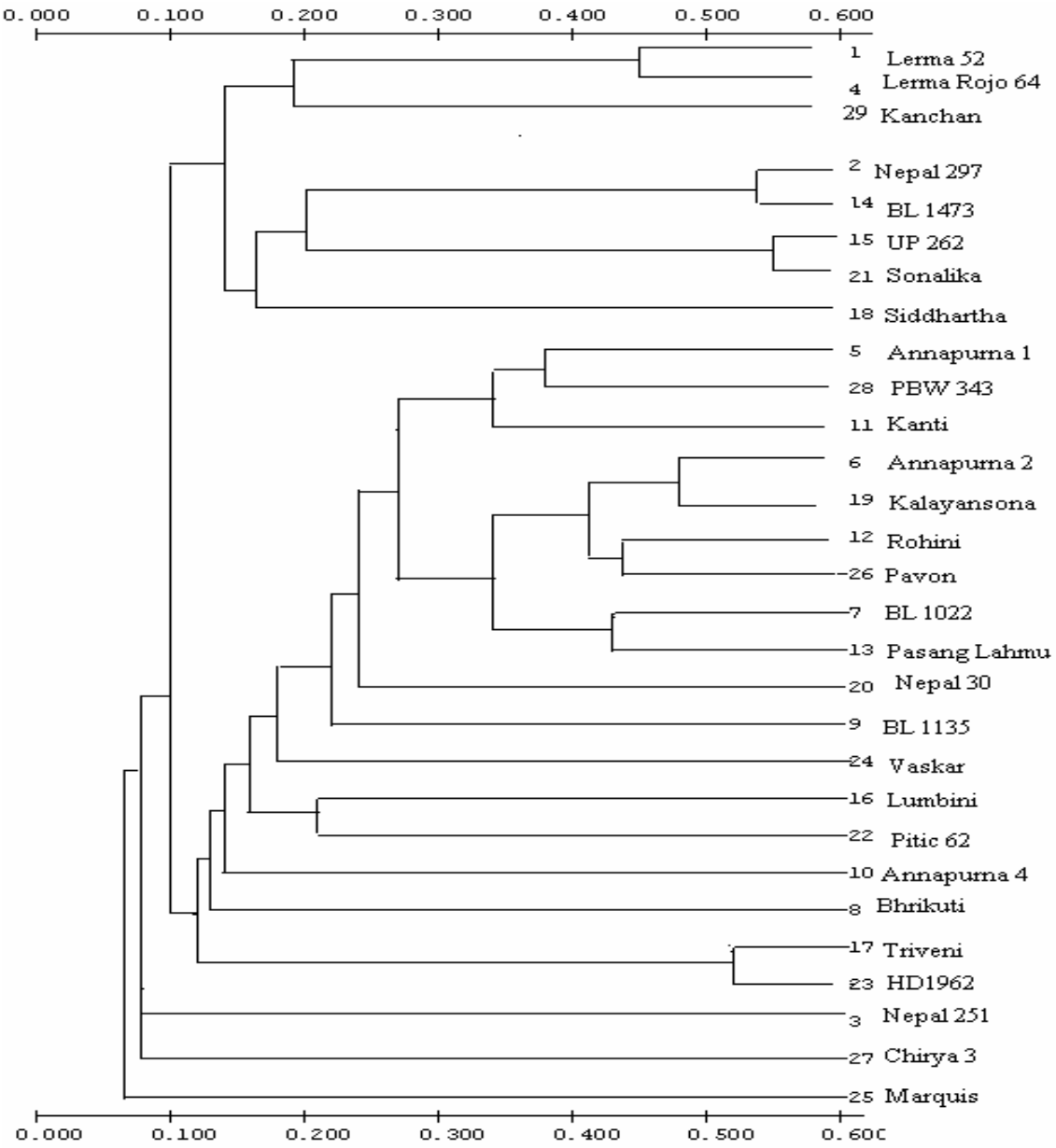

Figure 2. Cluster analysis of wheat cultivars released for cultivation along with national and international checks based on coefficient of parentage.

Results of cluster analysis show weak relatedness among the cultivars forming a large number of clusters of genotypes, often single member cluster at low level of similarity. This shows considerable diversity exists in the recommended cultivars. So, crossing programs aimed to cross two recommended cultivars may be less restricted in selection of parents. The gain may be further widened if the COP values were considered in account. Breeders making cross should consider COP values and selection of parents should be done from distantly related genotypes. For example, Bhrikuti has unique genetic base than other genotypes.

This study show that there is large amount of diversity in Nepalese cultivars based on their genetic background even though relatively smaller number of cultivars is recommended in Nepal. The origin of the diversity is not native one rather due to introduction from time to time. Thus, cultivars recommended in Nepal are internally diverse. That's why, these are adopted to diverse environments of Nepal. Improved wheat cultivars cover more than 93% of total wheat area (Bhatta et al 2000). Recently, a participatory approach is taken to increase adoption rate (Mudwari et al 2005). This helps to develop site-specific variety faster (Mudwari et al 2004) and management of existing diversity should be continued

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Rice Gene Pool for Tarai and Inner Tarai Areas of Nepal

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ABSTRACT

Knowledge on crop gene pool helps to develop varieties, to know the potential sources for breeding materials and to develop strategy for sustainable use and conservation. The amount of genetic diversity presents depends on the number and diversity of the original ancestors involved in the creation of a germplasm pool, existing landraces and wild species. The objective of this research was to study the diversity of rice gene pool present in the Nepalese improved rice cultivars and landraces adapted to Tarai and Inner Tarai (<1000 m). Pedigrees of 28 Nepalese rice cultivars were examined and surveyed the literature for distribution of landraces and wild relatives of rice. Crosses among *indica* rice gene pool are more common and use of *japonica* and *nivara* species were less common. There are 28 improved rice cultivars, >500 landraces, and 6 wild species and relatives of rice adapted to Tarai and Inner Tarai. Eight countries are the origins for 28 cultivars. In Nepal 4 cultivars were bred and developed using a local landrace and exotic genotypes. A total of 35 ancestors originated in 11 different countries were used to develop these 28 cultivars. Highest number of ancestors was from India. Use of ancestors of both *sativa* and *nivara* species having *indica* and japonica types indicated the collection of wide gene pool. Most of the ancestors were *sativa* (60.00%) and *indica* (65.71%). Genetic erosion is observed in rice diversity therefore, *in situ*, on farm and *ex situ* conservations are necessary for maintaining the genetic variation. Utilization of local landraces in breeding program may be the good way of genetic resources conservation. Gene pool from these landraces along with international gene pool could make towards success in developing high yielding cultivars with wide adaptability and/or site specific. In this study, cultivars and landraces surveyed represent a wide range of variation for different areas of origin and adaptation. This genetic diversity is very useful for further rice improvement and should be conserved both *ex situ* and *in situ*.

Key words: Ancestor, Landrace, Nepalese rice cultivar, Rice gene pool, Tarai and Inner Tarai

INTRODUCTION

Rice is a staple food crop and plays an important role in Nepal's economy. Different kinds of landraces and wild rice in Nepal are reported by Mallick (1981/82), Sherchand et al (1998), Joshi et al (1998), Shrestha and Upadhyay (1999), Rana et al (2000a, 2000b, 2000c), Adhikari et al (1995) and Gupta et al (2000). About 2000 rice landraces are reported in Nepal growing from 60 to 3050 m altitude (Mallick 1981/82). Rice samples of 500 years ago are found at Simraungardh, Bara (Mallick 1981/82) which support the statement that Nepal is one of the centers of rice diversity. During mid 1960s the yield potential of semi dwarf high yielding varieties initiated a scope for raising rice production in the country. Several exotic varieties were obtained through IRRI and Taiwan (NRRP 1997a). Rice research was initiated in 1951 (Mallick 1981/82) and National Rice Improvement Program was established in 1972 at Parwanipur to organize the research and development works on rice as a commodity crop. So far there are 48 improved rice cultivars recommended for cultivation. Among them 28 are recommended for Tarai, Inner Tarai and Foot Hills of Nepal.

Genetic diversity is necessary to derive different transgenic segregants suitable for different agro-ecology and to meet the needs of farmers. The main source of the diversity for development of modern varieties is the traditional varieties that have been grown and selected for generations by rice farmers. All modern varieties can be traced back to landraces. Both the potential for long term genetic gain and the reduction of genetic vulnerability may depend on the genetic diversity present in the genetic base of the crop. The amount of genetic diversity presents depends on the number and diversity of the original ancestors involved in the creation of a germplasm pool, existing landraces and wild rice and their relatives. The level of genetic variation present in gene pools of most important crops has been analyzed by studying the pedigree relationship between cultivars. Kinship coefficients estimation of cultivars of oat (Souza and Sorrells 1989), soybean (Cox et al 1985a), wheat (Joshi et al 2004), winter wheat (Cox et al 1985b), rice (Dilday 1990) and barley (Martin et al 1991) has shown that a restricted number of ancestral genotypes account for a large proportion of the variation present in released cultivars. The pedigrees of IRRI varieties upto 1994 have been traced back to 40 landraces from 12 different countries (de Leon and Carpena 1995). Diversity of rice considering ancestors of cultivars, wild relatives and landraces should be assessed for effective conservation and utilization of rice gene pool. Information on cultivars diversity based on pedigrees is useful for risk assessment on concern cultivar. Equally, such types of analysis explain how the breeders are able to capture genetic diversity in a cultivar. Therefore study was focused here on landraces and wild rice diversity and its distribution in Nepal and countries from where genes were introduced through improved cultivars in Nepal particularly in Tarai and Inner Tarai areas.

METHODOLOGY

In this study basically diversity on landraces in terms of their name, improved cultivars in terms of their ancestors and origin and wild rice in terms of species distribution were assessed. Literature related to rice exploration, improved cultivars recommended for Tarai and Inner Tarai and Nepalese landraces adapted to Tarai and Inner Tarai and wild rice and their relatives were reviewed. Three sites, National Rice Research Program (NRRP), Haridnath; Regional Agriculture Research Station, Parwanipur, and Plant Genetic Resources (PGR) Unit, Khumaltar were visited. PGR Unit has collected and conserved many rice landraces. Rice genotypes available in Nepal were categorized under four groups 1. Landraces, 2. Improved cultivars, 3. Ancestors of these cultivars and 4. Wild rice and their relatives. Unique and endangered rice landraces were compiled. Based on collection data, landraces and wild species distribution were indicated in Nepal map. Landrace diversity based on different name was compiled with respect to districts. It is assumed to estimate the landrace richness that rice landrace is different if the name given by farmer was different. Frequency of rice accessions collected from different districts and conserved in PGR Unit was computed. Altogether 28 cultivars had been released for Tarai and Inner Tarai and Foot Hills in Nepal from 1959 to 2002. Here in this study the pedigrees of these 28 cultivars were examined. Study shows that most of the cultivars were introduced either from IRRI or India. The pedigrees of these rice cultivars were traced back to their ancestors that had no known relationship with each other. One example of the cultivar back to ancestors is given in Figure 1. The source of improved cultivars, their pedigree and release dates were Mallick (1981/82), IRRI (1970, 1987, 2000a, 2000b), NRRP (1992, 1997a), NRRP (1997b) and IRRI (GEU). Origin of ancestors, their group and species were identified. Diversity was studied on improved cultivars based on their origin, types and number of ancestors and ancestors' types. Countries from where the genes introduced in Nepal were located in world map based on the origin of ancestors of Nepalese improved rice cultivars.

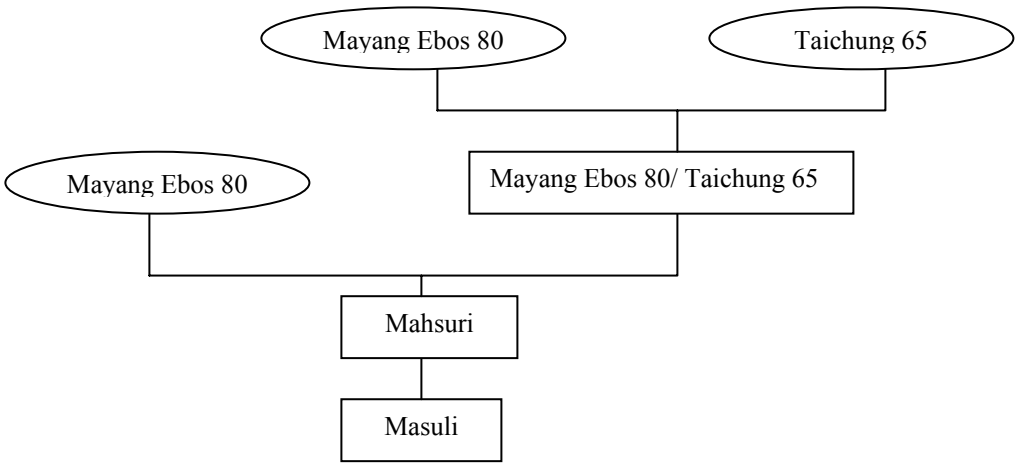

Figure 1. Pedigree tree of Masuli rice cultivar. This helps to study inheritance pattern. Ancestors are kept in oval shape (For pedigree trees of all Nepalese improved rice cultivars, contact author).

RESULTS AND DISCUSSION

The land in Nepal has the largest variations in altitude in the world. Three types of land *Bari*, *Khet* and flat and fertile with good soil depths produce rice indicating the diverse rice genotypes adopted to different production environments. Rice is grown mainly as *Barkhe* crop sown in June/July and harvested in Sept/Oct. It is also grown as *Hiunde* (winter rice popularly known as Boro rice) and Chaite dhan. Due to the varied agroecological diversity of the country, it is possible to plant same cultivar in *Barkhe*, *Hiunde* and *Chaite* seasons. Nepal posses many diversity in rice however, under the CGIAR system Nepal received a lot of rice genotypes. Landraces are diverse in maturity period, photoperiodism, growing seasons, adaptation to different cropping systems and cultural practices and dormancy. Rice can be observed in the field all year round somewhere in Nepal.

Exploration and collection

Ten international exploration missions have targeted cultivated and wild rice species in Nepal (Upadhyay and Joshi 2003). Forty exploration programs were carried out in different parts of Nepal to collect different crops species by international organizations from 1937 to 2000. The countries/ organizations involved in exploration missions are Germany, Japan, UK, IRRI, FAO, IBPGR and USAID. A total of 1550 different rice varieties from Nepal have been collected from altitude of 60-3050 m and conserved at IRRI, Philippines (Shrestha and Vaughan 1989). National organizations mainly by Agriculture Botany Division (ABD), Khumaltar had explored different crop species 22 times in different parts of Nepal. They have targeted 7 times to rice both cultivated and wild from 1981 to 2000 (Gupta et al 2000). There are 615 landraces, which are differed by name collected from Tarai and Inner Tarai and conserved in ABD. These are collected from different altitude ranging from 65 to 1000 m. There may be many landraces that are genetically same but differed only by name or vise versa. These need to verify. ABD has 2963 accessions of rice landraces and 144 accessions of wild rice collected from all over the country (Gupta et al 2000). These are conserved ex situ at medium term storage facility in Khumaltar.

Landrace gene pool

ABD has representative rice landraces from 73 districts of Nepal (Table 1). Highest number of rice accessions among the 33 Tarai and Inner Tarai districts was collected from Sunsari (3.88% of total accessions) followed by Dhanusha (3.37%), Parsa and Bara. Collection sites of 197 accessions were not known. Sunsari, Dhanusha, Parsa and Bara may be the focal area in term of rice landraces diversity in Tarai and Inner Tarai. Lumle Agriculture Research Station (LARS) and NRRP, Hardinath have also maintained some landraces and ABD has 1608 accessions of rice adapted to Tarai and Inner Tarai. There may be duplicate accessions in these three places. Removing duplicate accessions and adding new one should be made continuously. Extensive survey and duplication study of accessions could help to control genetic erosion and conservation cost. Many of these landraces are still grown by farmers. These landraces have a wide range of natural adaptation to withstand varied abiotic and biotic conditions. In addition, these landraces have high tillering ability, withstand severe drought stress, have good quality grains and adapted to marginalized areas.

Table 1. Total rice accessions and frequency collected from different districts of Tarai and Inner Tarai of Nepal and conserved *ex situ*

SN	District	Accession, n	%	SN	District	Accession, n	%
A. Tarai and Inner Tarai districts				**B. Districts fall in both ecoregions**			
1	Banke	58	1.96	22	Arghakhanchi	28	0.94
2	Bara	84	2.83	23	Dandeldhura	33	1.11
3	Bardiya	12	0.4	24	Dhankuta	72	2.43
4	Chitwan	16	0.54	25	Doti	39	1.32
5	Dang	36	1.21	26	Ilam	56	1.89
6	Dhanusha	74	2.5	27	Makwanpur	22	0.74
7	Jhapa	100	3.37	28	Palpa	18	0.61
8	Kailali	23	0.78	29	Pyuthan	13	0.44
9	Kanchanpur	44	1.48	30	Sallyan	21	0.71
10	Kapilvastu	40	1.35	31	Sindhuli	20	0.67
11	Mahottary	74	2.5	32	Surkhet	31	1.05
12	Nawalparasi	28	0.94	33	Tanahun	74	2.5
13	Parsa	85	2.87		Sub total	427	14.41
14	Rautahat	74	2.5	**C. Mid and high hill districts**		1158	39.04
15	Rupandehi	38	1.28		Unknown	197	6.65
16	Saptari	62	2.09		Total	2963	100
17	Sarlahi	36	1.21				
18	Siraha	82	2.77				
19	Sunsari	115	3.88				
20	Udaypur	50	1.69				
21	Morang	50	1.69				
	Sub total	1181	39.84				

Source: Gupta et al 2000.

Nepal has many locally adapted rice genotypes but only one has been used or improved for developing Nepalese Tarai and Inner Tarai rice cultivar. Trends of using local landraces are now increasing which help to check genetic erosion (B Chaudhary, Personal communication). Due to agro ecological differences Nepalese genotypes may contain unique genes (Table 2). These genes if conserved properly could be enough to fulfill rice grain demand in Nepal for next century. Diverse ethnic groups have great knowledge about the genotypes possessing unique characters. The possibility of starting a three lines heterosis breeding using local landraces was reported (Joshi et al 2003b). Among the 14 rice genotypes tested for their ability to restore fertility and maintain sterility, two landraces (Kature and Ratodhan) are restorers and other two (Deharadune and Chiunde) are maintainers (Joshi 2000a). Great potential of exploiting heterosis is possible using landraces and improved cultivars (Joshi 2000b, Joshi and Subedi 2001, Joshi 2003b). A set of 183 landraces were characterized and evaluated over space and time (1998-2000) (Sharma et al 2001). There was wide variation in maturity. Landraces were comparable

with the improved cultivars. There is a possibility of breeding for new levels of grain yield and other economical characters using these landraces. Blast resistance was widely available in these landraces. More important genotypes should be identified and developed a strategy to use them. These genotypes may have potential role in developing suitable varieties and/or increasing national production. Clear advantages were indicated in using locally adapted parents and selection in the target environment compared to introduction from international nurseries, which usually perform poorly (Sthapit 1992). Characterization, evaluation and utilization of these landraces in breeding program by LARS, NRRP and ABD could certainly enhance the rice gene pool conservation. Landraces were mostly collected from western and eastern Nepal (Figure 2). The distribution pattern of rice could help to locate diverse rice areas and to implement in situ and on farm conservation and exploration program. This pattern suggests that there are diverse rice landraces adapted to different environments. Characterization and improvement of these landraces are necessary for long-term conservation and utilization. Due to the expansion of modern varieties these landraces are under threats of extinction. In addition, some of the landraces are under threat or extinct (Table 3) due to natural and human factors. Chang (1984) estimated more than 100,000 rice cultivars existed in Asia earlier in the 20th century. But with the advent of modern, high yielding varieties and intensive cultivation, a small number of productive and relatively uniform cultivars now dominate commercial production (Chang 1994).

Table 2. Some of the unique rice genetic resources cultivated in Tarai, Inner Tarai, mid and high hills of Nepal

SN	Genotype	Uniqueness
1	Amaghauj	Multiple spikelets per node
2	Anati or Anadi	Festival rice/ sticky rice/ medicinal value
3	Bhati, Silhat	Deep water rice
4	Chainon 2, Taichung 176	Japonica type
5	Chhommrong dhan, Jumli marshi	Cold tolerance rice, *andilo*
6	Ekle rice	Zn deficiency tolerance
7	Gamadi, Sathi	Panicle matured within flag leaf, early rice
8	Ghayia	Upland rice
9	Gurdi	Lodging susceptible
10	IR 8, Jaya	Indica type
11	Jarneli, Kathe Gurdi	Drought tolerance, secure grain yielder
12	Jhinuwa	Good eating quality
13	Kalanimak	Photo period sensitive
14	Khera	God preferred landrace
15	Laila Majnu or Jhodi dhan	Two grains in a lemma and palea
16	Lalka basmati	Improtant for party
17	Mansara, Mutmur, Anga	Adopted to very marginalized land
18	Nal tumme	Shade loving rice
19	Nakhisaro, Sathi, Laltenger	Pest resistance
20	Pahele	Vitamin A content landrace (?)
21	Pakhe Masino, Radha-4, Taichung, Lahure Sahila, Gori Sahila, Makar Kandhu	Hiunde (winter) rice
22	Parwanipur 1	Ratoon rice
23	Patle dhan	Good for pregnant women
24	Samundaphinj	Swampy land rice
25	Sokan dhan, Bageri	Resistance to BB and GLH‡
26	Wild rice	Festival rice/ perenniality gene

Hiunde rice (seeding at December and harvesting at May) has been cultivated since 35 years ago at Taruwa VDC, Nawalparasi. This rice was extensively cultivated after 2042 BS (1984) in these areas. Farmer of this area, Khadka Narayan Mahato has more knowledge on Hiunde rice. BB, Bacterial blight. GLH, Green leaf hopper.
Sources: Mallick (1981/82), NRRP (1997), Rijal (1998), Upadhyay and Joshi (2003).

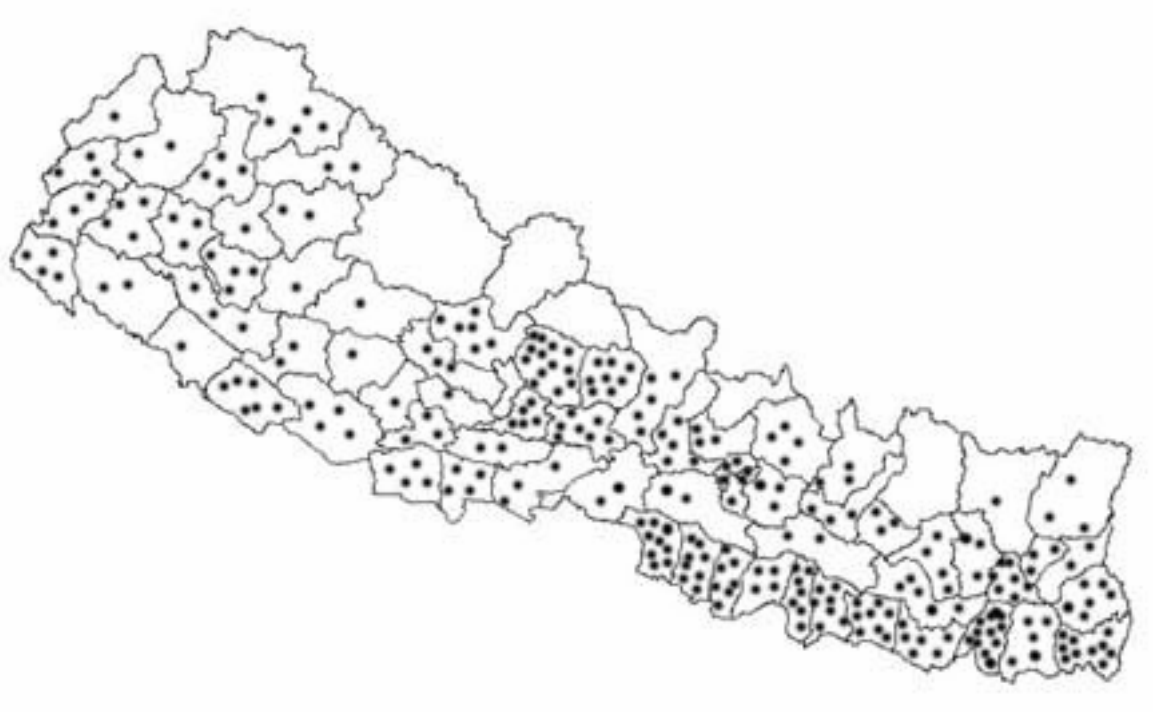

Figure 2. Distribution of rice diversity (more the number of dots more the diversity).

Table 3. Endangered and lost rice landraces in Tarai, Inner Tarai, mid and high hills of Nepal†

Endangered (48)	Lost (105)
Tauli, Thapachinia, Marsi, Mansara, Siraunla, Masind, Nathani, Khalte Kolo, Biramphool, Samundaphinj, Jhinuwa, Bayarni, Ramani, Pahenle Ghaiya, Bichare, Basmati, Dudhe Marange, Pakhe Masino, Sindhuli, Pakhe Sali, Jabaka, Charinangre, Pakhe Jhinuwa, Basaune Jhinuwa, Pahenle, jhinuwa, Gudura, Bardari, Battisara, Pokhreli Jhinuwa, Pagate Jhinuwa, Phente silange, Lalka Basmati, Soka, Sarho, Satraj, Lajhi, Rango, Gajargul, Ratrani, Katuash, Latongad, Masura, Dudhisaro, Lalka Kartik, Ghuthani, Anadi, Khera, Mansari and Anga	Lahure Sahila, Gori Sahila, Makar Kandhu, Timaha, Darmali, Germani, Koili, Budho thakale, Ghote, Salidhan, Jhauri, Bhamger, Lalka Pharam, Lajhi, Lohasaran, Parewa Pankha, Handiphul, Karma, Golabachhi, Dudhi Kariya, Bachhi, Devsar, Dudhraj, Sikhichanda, Galphuli Dutha, Rjana, Madhukari, Habsa, Ratin, Bansbarcli, Kanakjira, Ramjamai, Ratan, Tulasiprasad, Mahajogi, Ramini Katika, Sankharika, Sokan, Baramphusi, Ghiukumari, Anandi, Manshara, Satraj, Barkhabahadur, Pokhraj, Sankharika, Gondan, Maturi, Bhulani, Kuriya, Surkamiti, Satraj, Najhi, Golarato, Rajala, Megadoot, Dudhraj, Maturi, Parweapankhe, Kariyakamod, Gaddar, Kanajira, Babadudhi, Bhulani, Barkha Bahadur, Nakhi, Karma, Rati, Horinlduri, Gokulchanda, Maturi, Jhali, Gangaur, Dhudi, Katausi, Tulsi Prasad, Kanakjira, Gokulchan, Sukhichand, Pakhar, Bansnareli, Karma, Silan, Akhidudhi, Jhabri, Jajagaur, Satawa, Bangaluwa, Dudhisaro, Borch Bahadur, Mutari, Amaghaur, Barbasaru, Jhali, Mashura, Gokhul, Handa, Kudiya, Ramjamai, Kasturi, Dudha Kariya, Satariya, Changol, Golabati, Madhusar, Manshari

† not exhaustive. This information is mostly from western development region.
Sources: Upadhyay 1995, Rijal et al 1998, Joshi et al 1998, Sherchan et al 1998, Rana et al 2000c.

Improved rice gene pool

Twenty-eight improved rice varieties suitable to Tarai, Inner Tarai and Foot Hills of Nepal (Table 4a, 4b) are real efforts of researchers to be released during the period from 1959 to 2002. More numbers of crosses involving many parental lines in cultivars like Sabitri, Laxmi and Chaite 4 indicate the effort of scientists to collect value genes in single genotype. Use of different landraces in crossing program is a

good strategy to increase yield (Joshi 2004). Six cultivars were released in 1987. The earliest released cultivar is China 45 in 1959. Shuttling of generation lines during winter season is also possible in Nepal, which helps to develop more rice cultivars within short period of time.

Table 4a. Improved rice varieties recommended for Tarai, Inner Tarai and foot hills of Nepal in *Barkhe* season

SN	Variety	Abb	Pedigree	Parentage	Year released
1	Barkhe-2	BKH2	B441b-126-3/2/2001	C4-63GB/B531b -TK39	1987
2	Durga	DGA	IET 2938	Jaya//IR8/Latisail	1979
3	Ghaiya-2	GHA2	MW 10	MTU15/Waikakku	1987
4	IR20	IR20	IR 532E-576	IR 262-24-3/TKM6	1972
5	IR22	IR22	IR 579-160-2	IR 8/Tadukan	1972
6	IR8	IR8	IR 8-288-3	Peta/DGWG	1968
7	Janaki	JNK	BG 90-2	Peta*3/TN1//Remadja	1979
8	Jaya	JAYA	-	TN1/T141	1973
9	Khajura-2	KAJ2	PAU41-262	RP72/Mutant65	1987
10	Makwanpur-1	MKN	BG 400-1	Ob678/IR20//H4	1987
11	Masuli	MAS	Mahsuri	Mayang Ebos 80*2/Taichung 65	1973
12	Radha Krishna-9	RA9	NR 15016-24-1-3	IR 42/Masuli	1991
13	Radha-11	RA11	TCA 80-4	Local selection	1995
14	Radha-12	RA12	OR 142-99	TNI/T141//Annapurna	1995
15	Radha-4	RA4	IR 8423-156-2-2-1	BG 34-8/IR 2071-625-1	1995
16	Radha-7	RA7	NR 15013-40-1-1	Janaki/Masuli	1991
17	Rampur Masuli	RAMSULI	-	Lal Nakanda/IR30	1999
18	Sabitri	SAB	IR 2071-124-6-4	IR 1561-228-1/IR 1737//CR 94-13	1979

Source: NRRPa 1997.

Table 4b. Improved rice varieties recommended for *Chaite* season or first rice crop in the double rice cropped areas of Nepal (Recommended to Tarai and Inner Tarai)

SN	Variety	Abb	Pedigree	Parentage	Year released
1	Bindeswari	BND	IET 1444	TN 1/Co29	1981
2	China-45	CH45	China 45	Selection at CRRI	1959
3	Chaite-2	CHT2	IR7151-1260-3-3	BG34-8/IR2061-522-6-9	1987
4	Chaite-4	CHT4	IR9729-67-3	BG34-8/IR28//IR2071-625-1-252	1987
5	Chaite-6	CHT6	NR 274-7-3-3-1	NR6-5-46-50/IR28	1991
6	Chandina	CND	IR532-1-176	Peta* 3/TN1//TKM6	1978
7	IR24	IR24	IR661-1-140-3	IR8/// Century Patna/SLO//Sigadis	1975
8	Laxmi	LAXMI	IR2061-628-1-6-4-3	IR833-6-2-1-1//IR1561-149-1/IR1737	1979
9	Malika	MALI	Mala/J15 (IR272)	CP/SLO*2//Sigadis	1982
10	Parwanipur-1	PWP1	IR400-29-2-73	Peta* 4/TN1	1973

Source: NRRPa 1997.

A total of 35 ancestors originated in 11 different countries were used to develop 28 rice cultivars (Table 5). Eight countries are the origins for 28 cultivars (Figure 3). These genes were mainly from Asian countries (Figure 4). Maximum ancestors were from India followed by Taiwan and Indonesia. Involvement of ancestors from 11 countries indicates the introduction of genes adapted to different geographic locations. A single landrace of each of seven countries (Figure 4) have been used in developing rice cultivars probably because of having value genes with them. Evidence shows that breeders can develop best varieties by reshuffling the genes from these wide collections. In Nepal 4 cultivars had been originated. Use of ancestors of both *indica and japonica* groups of *sativa* and *nivara* species indicated the collection of wide gene pools. Relatively more ancestors originated in more different countries were used for Nepalese wheat cultivars and mid and high hill rice cultivars development (Joshi and Mudwari 2003, Joshi 2003a) than Tarai and Inner Tarai rice cultivars. Evidence

suggests that some modern varieties have a narrow genetic background. Lin (1991) has shown a narrow genetic background of japonica varieties released in Taiwan between 1940 to 1987. Dilday (1990) documented similar pattern for US rice cultivars. Concerns were raised about the narrow genetic diversity present among IRRI varieties (Hargrove 1979, Hargrove et al 1980, Chang 1994). All semidwarf cultivars have the *sd1* gene for short plant stature. Most semidwarf cultivars derived from IR8 and other early IRRI releases carry the cytoplasm of Cina. All *indica* type rice hybrids in China share the *sdl* gene and the wild abortive (WA) source of cytolasmic male sterility (Chang 1994).

Table 5. Ancestors used for developing Nepalese rice cultivars for *Chaite* and *Barkhe* Season for Tarai, Inner Tarai and foot hills of Nepal

SN	Ancestor	Abb	Origin	Abb	Group	Species
1	ANNAPURNA	ANNA	?	?	?	?
2	B531B-TK39	B531B	?	?	?	?
3	C4-63-GB	C4	?	?	?	?
4	CENTURY PATNA	CP	USA	USA	INDICA	SATIVA
5	CHINA-45	CH45	CHINA	CHN	?	SATIVA
6	CINA	CINA	CHINA	CHN	?	SATIVA
7	CO-18	CO18	INDIA	IND	INDICA	SATIVA
8	CO-29	CO29	INDIA	IND	INDICA	SATIVA
9	DEE-GEO-WOO-GEN	DGWG	TAIWAN	TWN	INDICA	SATIVA
10	GEB-24	GEB24	INDIA	IND	INDICA	SATIVA
11	GP-15	GP15	?	?	?	?
12	H4	H4	CEYLON	CLN	INDICA	SATIVA
13	H501	H501	CEYLON	CLN	INDICA	?
14	LALNAKANDA	LKD	INDIA	IND	INDICA	?
15	LATISAIL	LAS	PAKISTAN	PAK	INDICA	SATIVA
16	MAS	MAS	INDONESIA	IDO	INDICA	?
17	MAYANG EBOS-80	ME80	MALAYSIA	MAL	INDICA	SATIVA
18	MTU15	MTU15	INDIA	IND	INDICA	SATIVA
19	MUTANT-65	MTNT 65	?	?	?	?
20	SHANKARA	SKR	NEPAL	NPL	INDICA	SATIVA
21	O. NIVARA	ON	?	?	?	NIVARA
22	OB678	OB678	SRILANKA	SRI	?	?
23	PP	PP	?	?	?	?
24	PTB 18	PTB 18	INDIA	IND	INDICA	?
25	PTB 21	PTB 21	INDIA	IND	INDICA	?
26	REMADJA	REM	INDONESIA	IDO	INDICA	SATIVA
27	RP72	RP72	INDIA	IND	INDICA	SATIVA
28	SIGADIS	SGO	INDONESIA	IDO	INDICA	SATIVA
29	SLO	SLO	INDIA	IND	INDICA	SATIVA
30	T141	T141	INDIA	IND	INDICA	SATIVA
31	TADUKAN	TDKN	PHILIPPINES	PHL	INDICA	SATIVA
32	TAICHUNG NATIVE1	TN1	TAIWAN	TWN	INDICA	SATIVA
33	TAICHUNG-65	T65	TAIWAN	TWN	JAPONICA	SATIVA
34	TCA-80-4	TCA80	INDIA	IND	INDICA	SATIVA
35	WAIKAKKU	WKU	?	?	?	?

? Not known

Use of 35 ancestors from 11 different countries for tropical and sub tropical rice cultivars represent the great diversity in built in 28 Nepalese rice cultivars. The origins of 8 ancestors are not known. Ancestors were with different groups eg *indica* (65.71%) and japonica (2.86%). Groups and species of 31.43% and 37.14% ancestors respectively are not known. There were 60.00% sativa and 2.86% *nivara* ancestors species (Figure 5). Such diversity in species, origin and groups of ancestors have certainly enriched Nepalese rice biodiversity.

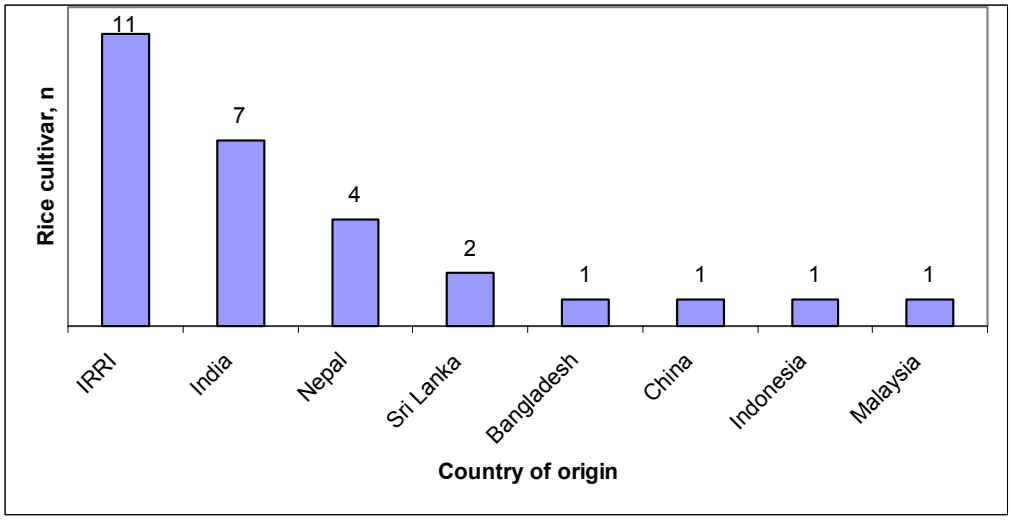

Figure 3. Countries of origin of 28 Tarai and Inner Tarai improved rice cultivars in Nepal.

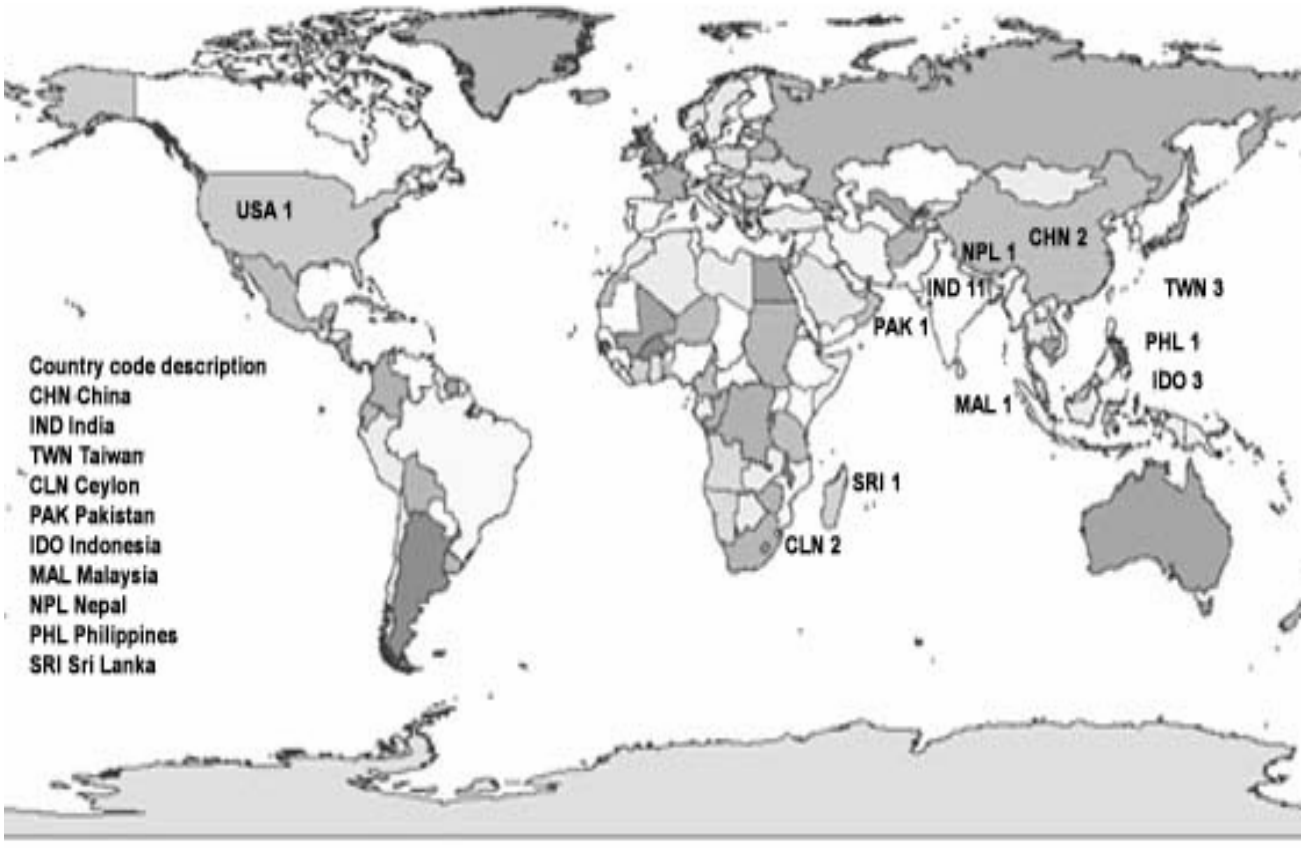

Figure 4. Countries where the ancestors of Nepalese improved rice cultivars recommended for Tarai, Inner Tarai and foot hills were originated. Origins of 8 ancestors are not known.

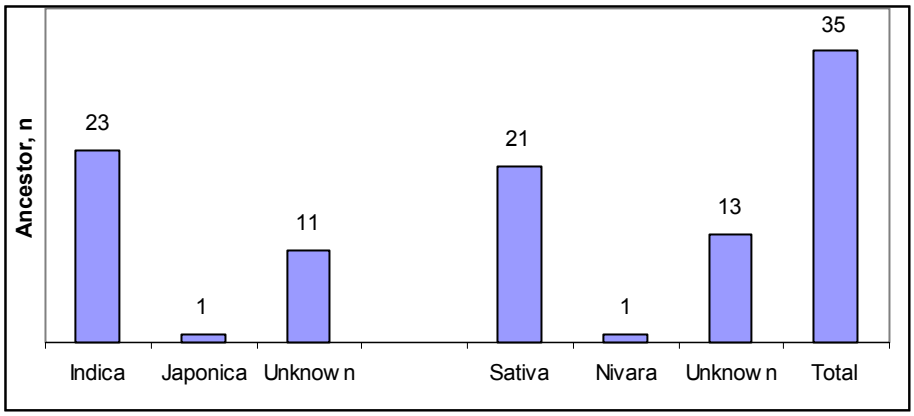

Figure 5. Ancestors' group used to develop Nepalese rice cultivars for Tarai and Inner Tarai.

Wild rice gene pool

Nepal being the center of diversity of rice, harbor the wild rice and its relatives in addition to diverse forms of landraces. Four wild rice species, *Oryza nivara*, *O. rufipogan*, *O. granulata* and *O. officinalis* are found in different areas of Nepal (Figure 6). Some of these areas are Ghodagodhi tal, Ajigara tal, Lothar, Jhapa, Illam, Sundarpur, Surkhet, Nijgada, Janakpur, Nepalgungj, Bara, Dang, Kapilbastu, Rupendehi, Birendranagar, Kaski, Palpa, Banke, Bardiya, Kancanpur etc (Table 6). Weedy rice, *O. sativa* f. *spontanea* is found in rice field across the country. *Hygrooryza aristata* and *Leersia hexandra* are other two species in related genera found in Nepal. These species are adapted to different ecological conditions in terms of altitude and water requirements, and distributed across the Tarai and mid hill. *O. rufipogan*, one of the natural parents of the present day cultivated rice is reported to have found in the northern most limit and the highest altitude in Nepal in the world (Shrestha and Upadhyay 1999). This extraordinary biological diversity in Nepal is due to geological, geographical and cultural factors. Very little attention has been given to wild rice diversity in Nepal. Nepal was considered as area of potentially new and useful genes for rice breeders (Shrestha and Upadhyay 1999). Wild species represent a rich pool of diversity particularly for their ability to withstand pests and diseases (Jackson 1995). Since wild germplasm is a valuable source for improving rice productivity and durability, explorations on those wild relatives are suggested followed by their proper characterization and utilization in the breeding program.

Table 6. Wild rice and wild relatives of rice found in different districts of Nepal

SN	Wild /relative	Local name	Districts†
1	*Oryza nivara* Sharma et Shastry	Tinna, Jhara	**Banke, Kapilbastu, Lumbini, Bardiya, Kailali, Kanchanpur,** Kaski, **Dang, Rupandehi**
2	*O. rufipogon* Griff. (*O. perennis* Moench.)	Nabo ghans, Anga, Salidhan	**Banke, Kapilbastu, Kailali, Kanchanpur,** Surkhet, Kaski, Palpa, **Rupendehi, Dang**
3	*O. granulata* Nees et Arn. ex Watt.	Ban dhan, Jangali dhan, Sitarani dhan	**Chitwan, Jhapa,** Ilam, Makawanpur
4	*O. officinalis* Wall ex Watt.	-	**Kancahnpur, Bara, Janakpur**
5	*O. sativa* f. *spontanea* (weedy rice)	Navo, Thima, Jara	Most of the rice growing districts, **Rupandehi, Kapilbastu, Banke, Bardiya, Kanchanpur,** Lamjung
6	*Hygroryza aristata*	-	Kaski, **Kailali**, Kathmandu
7	*Leersia hexandra*	-	Kaski, Lamjung, Kathmandu

† Bold districts lie in Tarai and Inner Tarai of Nepal.
Sources: Shrestha and Updhyaya 1999, Sthapit 1999.

Figure 6. Distribution of wild rice and related species in Nepal.

Contributions of Nepalese PGR at national and international level have not been well documented. A total of 48 improved rice cultivars certainly have significant contributions at National economy. There are many more rice genotypes that have potential to make the Nepal difference. National and international organizations have explored and collected many rice genotypes from different parts of Nepal but their value and uses are very little known.

Despite high yielding attributes of improved cultivars compared to those of local types improved varieties were found to be susceptible to diseases and lodging (Shrestha 1976). There are many examples of improved varieties gaining popularity within a short period of time but later become susceptible to biotic stresses. Such trend was not reported in landraces. In this study, cultivars surveyed represent a wide range of variation for different areas of origin and adaptation. This genetic diversity may be useful for further rice improvement. The results of this study may help in the selection of the most diverse cultivars and greatly expand genetic variation for rice improvement. Cultivated landraces of *indica* and *japonica* type, wild rice and wild relatives of rice are found in Nepal. Gene pool from these landraces along with international gene pool could make to success in developing high yielding cultivars with wide adaptability. Developing cultivars possessing desired period of maturity, height and yield is seemed possible using this gene pool. However, modern varieties have been replacing the landraces and improved old varieties resulted in the genetic erosion. Therefore, in situ, on farm and ex situ conservations are necessary for maintaining the genetic variation. Government, semi governmental and private agencies should take action to conserve and utilize rice genetic diversity present in Nepal.

There is need of identifying least cost *in situ* and *ex situ* conservation for rice landraces and wild rice gene pools and policy instruments most suitable for supporting conservation of this gene pool (D. Gauchan, personal communication). Participatory varietal selection (PVS) methodology has been selected to increase diversity in addition to increase the adoption rate of variety (Joshi et al 2003a). A

prerequisite of conservation is genetic assessment of rice populations in the area that are likely to constitute rare, unique and distinctive genetic resources. Based on available information and genetic analysis, prediction of the future value of these genetic resources is needed in the extent to which they have high genetic value in improving yield potential and sustaining future rice productivity in the changing pest endemics, climate change and changes in market demand. We don't have favorable policy and legal for the protection of wild rice habitats. Molecular study is necessary to assess the diversity among ancestors (if possible) and cultivars derived from these ancestors. For effective conservation least cost methodologies for *in situ*, on farm and ex situ systems should be developed. Utilization of local landraces should be the first priority to conserve them in addition to increase the yield. Crossing program should be designed based on pedigrees information and local landraces. Potentiality of native genotypes should be made available. Varieties developed using local landraces will perform and adapt better than others. Duplicate accessions of ABD and LARS should be removed and gene bank must be updated through regular exploration program. To release cultivar, ancestors and number of crosses for that cultivar should be considered. For the conservation of wide gene pool, site-specific trial rather than coordinated trial is recommended. Conservation work be initiated after genetic assessment of rice populations in the area that are likely to constitute rare, unique and distinctive resources. Specific technological options (plant breeding, biotechnology) for utilization of genes and appropriate economics instruments for providing incentives to community are suggested for conservation and utilization of rice diversity. For recommendation of any varieties microenvironment effects be considered. For Nepalese agro biodiversity conservation and utilization, plant breeding work should get first priority. Nepal has still many traditional farming systems. Based on the locality needs, these systems should be improved through participatory approach for overall plant genetic resources management.

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Correlation and Path Coefficient Analyses in Sugarcane

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ABSTRACT

This study was conducted to determine the contribution of different traits to cane yield in sugarcane (*Saccharum officinarum* L). Sixty-five clones were evaluated in a replicated field experiment at Sugarcane Research Programme, Jitpur, Nepal in 2003 for six morphological characters under irrigated conditions. Analysis of variance revealed significant differences for all the characters studied. Cane yield showed positively and highly significant correlation with single cane weight, stalk length and millable cane number. There was also positively significant correlation of cane diameter and number of internode with cane yield. Length of internode had positive non-significant correlation with cane yield. Single cane weight had the highest positive direct effect on cane yield followed by millable cane number. Stalk diameter and stalk length was positively and significantly correlated with cane yield, which was due to indirect effect of single cane weight. Results indicate that the genotypes should be selected on the basis of single cane weight and millable cane number for getting higher sugarcane yield.

Key words: Cane yield, correlation, path coefficient, sugarcane

INTRODUCTION

Sugarcane is one of the most important crops in the world (Dagar et al 2002). In Nepal it is the third largest agro industry crop next to grain and oil mills (Shakya 2001). Sugarcane is being cultivated in around 59477 ha, producing 2.2 million tons of cane with approximately 37.79 tons per hectare during 2001 in Nepal (Chaudhary 2002). Sugarcane breeding involves the production and evaluation of several thousand seedlings from different crosses every year and selection of the superior seedlings for further evaluation in clonal stages (Sundaresan et al 1979). The subsequent selection in successive clonal generations require considerable amount of labour and fund.

Path coefficient is an excellent means of studying direct and indirect effects of interrelated components of a complex trait (Kang et al 1989). Path-coefficient analysis measures the direct influence of one variable on another. Each correlation coefficient between a predictor variable and the response variable is partitioned into its component parts: the direct effect or path coefficient (a standardized partial-regression coefficient) for the predictor variable and indirect effects, which involve the product of a correlation coefficient between two predictor variables with the appropriate path coefficient in the path diagram (Dewey and Lu 1959). By determining the inter-relationships among grain yield components, a better understanding or both the direct and indirect effects of the specific components can be attained. Effects of stalk number, stalk diameter, stalk length and single cane weight on cane yield have been reported by Hogarth (1971), Chaudhary et al (1994) and James (1971). Plant breeders generally select for only a few traits and it is very important to know the effects of this on other important characters as well. Therefore, this experiment was conducted to study the relations of certain morphological characters with sugarcane yield.

MATERIALS AND METHODS

Sixty-five clones of sugarcane developed at different research stations of India and local cultivars collected from different parts of Nepal that belonged to different maturity groups were planted in a randomized block design with two replications at Sugarcane Research Programme, Jitpur during 2003. The plot size was 4- × 1.8-m with 2 rows and row-to-row distance was 90 cm. The seed was planted on 07 Feb 2003 and crop duration was 360 days. Three budded setts of cane were planted at the rate of 12 buds per meter in furrow method. The fertilizers were used at the rate of 75:60:40 kg N:P:K ha^{-1} at the time of planting and 75 kg N ha^{-1} in two equal split, first at 90 and second at 120 days after planting. Regarding interculture operations, 3 hand weedings and one earthing up were done. The observations were recorded for millable cane number, stalk length, stalk diameter, number of internode, length of internode and cane yield. Pearson correlation coefficient were estimated among these variables as suggested by Steel and Tori (1980). Correlation coefficient was calculated using INSTAT software. The total correlation coefficients of various yield contributory characters with regard to cane yield was partitioned into components of direct and indirect effects following the method adopted by Dewey and Lu (1959).

RESULTS AND DISCUSSION

There were significant differences among the genotypes for all characters under studied (Table 1). This can be attributed to the fact that these clones were derived from parents having different genetic and geographic backgrounds.

Table 1. Means of sum of square for stalk characters in 65 sugarcane clones

Source	df	No of millable cane	Stalk length	No of internode	Length of internode	Cane diameter	Single cane weight	Cane yield
Replication	1	59.57	4.8	0.069	2.4923	0.000443	0.004923	76.34
Genotypes	64	393.15**	708.7**	15.266**	2.8043*	0.036384**	0.018574**	206.56**
Error	64	32.04	104.7	3.160	0.8113	0.004990	0.001235	10.81

**, ** Significant at 0.05 and 0.01 probability levels, respectively.*

Correlation

The pair wise simple correlation coefficient (r) among various characters are presented in Table 2. Cane yield was positively and highly significant correlation with single cane weight (r = 0.68**), stalk length (r = 0.61**) and millable cane number (r = 0.37**). There was also positive significant correlation of cane yield with cane diameter (r = 0.31*) and number of internode (r = 0.27*). A positive value of r shows that the changes of two variables are in the same direction, ie high values of one variable are associated with high values of other and vice versa. A positive and highly significant correlation between cane yield and its components, viz single cane weight, stalk length and millable cane number was reported by Brown et al (1969), Balasundarum and Bhagyalakshmi (1978) and Punia et al (1983). Hooda et al (1979) also observed cane diameter having significant positive correlation with cane yield. Length of internode had positive non-significant correlation with cane yield. Millable cane number was negatively significant correlation with cane diameter (r = -0.36**) and single cane weight (r = -0.26*). Balasundarum and Bhagyalakshmi (1978) also reported similar results. Negative correlation indicated their inverse relationship with each other. Single cane weight was positively and highly significant correlation with stalk length and cane diameter. Stalk length was positively and highly significant correlation with number of internode and length of internode. Whereas, number of internode had positive but non-significant correlation with length of internode (r = 0.15) and single cane weight (r =

0.23). Length of internode had also non-significant correlation with cane diameter (r = 0.091) and single cane weight. It is obvious that single cane weight, stalk length, millable cane number, stalk diameter and number of internode can be considered together in a positive direction towards an ultimate aim of developing high yielding sugarcane clone.

Table 2. Correlation coefficients among different characters in 65 sugarcane genotypes grown at Jitpur

SN	Character	1	2	3	4	5	6
1	Number of millable cane						
2	Stalk length	-0.0021					
3	Number of internode	0.1309	0.4104**				
4	Length of internode	0.0075	0.3448**	0.1584			
5	Cane diameter	-0.3621**	0.4767**	0.3533**	0.091		
6	Single cane weight	-0.2584*	0.6173**	0.2337	0.199	0.5983**	
7	Cane yield	0.3735**	0.6059*	0.2691*	0.1866	0.3092*	0.6836**

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

Path coefficient analysis for cane yield

Path coefficient analysis unfolds whether the association of cane yield with its components is due to the direct effects of component characters on cane yield or is a consequence of its indirect effects via some other traits. The highest positive direct effect on cane yield was exerted by single cane weight (0.728) followed by millable cane number (0.576) (Table 3). The direct effect of single cane weight on cane yield was also reported by Punia et al (1983), Reddy and Reddy (1986) and Hooda et al (1988). A direct effect of millable cane on cane yield was similar to the findings of Balasundarum and Bhagyalakshmi (1978), Kang et al (1989), Punia et al (1983) and Chaudhary and Singh (1994). It was observed that stalk length and stalk diameter was positive significant correlation with cane yield. Their direct effects on cane yield were positive but low and negligible. Significant correlation was due to indirect effects of single cane weight. Internode number and internode length had negative negligible direct effects on cane yield. This implied that selection of sugarcane genotypes on the basis of stalk weight and millable cane number would be beneficial for increasing sugarcane yield.

Table 3. Path coefficients showing direct (diagonal) and indirect effects of 6 components on cane yield

SN	Characters	1	2	3	4	5	6
1	Number of millable cane	**0.576**	-0.0003	-0.007	-0.0001	-0.007	-0.188
2	Stalk length	-0.001	**0.176**	-0.021	-0.006	0.009	0.449
3	Number of internode	0.075	0.072	**-0.052**	-0.003	0.006	0.170
4	Length of internode	0.005	0.061	-0.008	**-0.017**	0.002	0.145
5	Cane diameter	-0.209	0.084	-0.018	-0.002	**0.018**	0.435
6	Single cane weight	-0.149	0.109	-0.012	-0.003	0.011	**0.728**

**, ** Significant at 5% and 1% respectively. Residual = 0.43.*

Correlation study indicates that stalk length and single cane weight are most important for cane yield improvement. Selection based on number of millable cane and single cane weight are directly increased cane yield. During selection indirect effect of stalk length via single cane weight should also be considered. Three characters viz stalk length, millable cane number and single cane weight are very important that can be considered during breeding programme. For more reliable information, these coefficients should be separated in environmental, genotypic and phenotypic parts.

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Performance of Different Size True Potato Seed Seedling Tubers at Khumaltar

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ABSTRACT

A field study was carried out at Khumaltar-Lalitpur, during 2002-2004 to evaluate and compare the performance of different sizes of seedling tubers (1-5 g, 5-10 g, 10-20 g and 20-40 g) of true potato seed (TPS) with whole and half cut seed tubers of Desiree of 20-40 g size at 60- × 25-cm spacing. Percent emergence, plant height, ground cover by foliage, stems/plant, number of tubers per plant, marketable and total yields were significantly increased with the increase in seedling tubers weight as compared to whole and half cut seed tubers of Desiree. Late blight (*Phytophthora infestans* L.) disease was quite low in the TPS crops than Desiree. Both whole and half cut seed tubers of Desiree produced significantly higher average per tuber weight. Uniformity of the tubers harvested from different sizes of seedling tubers was statistically similar and tubers from Desiree were statistically uniform as compared to seedling tubers. The three years result suggests that more than 1 g size seedling tubers can be successfully used for potato production as from the seed tubers of any standard variety.

Key words: Desiree, seedling tuber, tuber size, tuber yield

INTRODUCTION

It has long been the tradition of majority of farmers in Nepal to use left small seed tubers, and sometimes even slice pieces with only one eye as seed for growing the potato crop to cover large area as much as possible with the minimum input of seed by using smaller seed pieces or very small seed tubers. This practice may be considered as one of the factors responsible for the low productivity. In such situation true potato seed (TPS) are the best with lower seed cost and higher yield potential. By using TPS as planting material about 18 percent of total edible potato production in developing countries can be saved for food (CIP 1982). Moreover viral, bacterial and other plant pathogens can be transmitted through tubers to succeeding generation, subsequently reducing plant health and yield. TPS minimizes both of these limitations, because no portion of the usable harvest needs to be diverted for seed and diseases are much less prevalent in the botanical seed as compared to vegetative propagated materials (Sadik 1983). These factors in TPS are matter of interest especially to resource poor farmers in developing countries like Nepal. Potato propagation by true seed (Wiersema 1986) has resulted in an increasing use of seedling tubers derived from TPS at the farmer's level. TPS is usually used to produce small seedling tubers (<20 g/tubers) that are used as seed to produce a ware potato crop.

High quality first generation seedling tubers (F1C1) can be obtained by seeding TPS in the nursery at high plant density (Nayar 1992, Wiersema 1985, Wiersema 1986) or by planting seedlings directly in the field. In small nursery beds, the adverse conditions can be managed well than in the field. Seedling tubers above 1 g size can be used for potato production (Adhikari and Rai 2004). Wiersema (1986) reported that the yield increases were significant with >5 g size tubers. It has been widely reported that both growth and yield of individual stems are largely dependent on the seed tuber size (Allen and Scoot 1980, Wiersema 1986).

Generally higher proportion of small size (<10 g) seedling tubers derived from TPS can be obtained in the nursery at high plant density. So far no systematic study has been done in Nepal to find out the differential yield performance of seedling tubers in terms of size. Thus the present study was undertaken to compare the performance of four grades of seedling tubers, 1-5 g, 5-10 g, 10-20 g and 20-40 g with a seed weight of 20-40 g whole and half cut seed tubers of Desiree.

MATERIALS AND METHODS

An experiment was carried out during 2002-2004 at Hattiban Research Farm of Potato Research Program, Khumaltar-Lalitpur (1350 masl.). Before starting the experiment, the land was used for growing rice in summer (rainy season). Plants from seedling tubers of different weights (1-5 g, 5-10 g, 10-20 g and 20-40 g) were evaluated and compared with whole and cut half seed tubers of Desiree variety (20-40 g) under partial irrigation condition.

Seedling tubers of TPS family HPS II/67 derived from the nursery beds in the field during 2001, 2002 and 2003 crop seasons at Hattiban Research Farm, were used in the experiment. After harvesting, the graded seedling tubers were kept in cold store till middle of Jan 2002, 2003 and 2004. Seedling tubers and seed tubers of Desiree were taken out from the cold store on 15 January and spread on diffused light store for sprouting. Well sprouted seedling tubers (all sizes), whole and half cut seed tubers of Desiree were planted in the field on 5 Feb 2002, 7 Feb 2003 and Feb 5, 2004. Just before planting, whole tubers of 40-80 g were cut longitudinally to make tuber half of 20-40 g. Randomized complete block design was used with four replications in plot of 3- × 2.4-m size consisted of four rows with 12 plants each. Distance between rows was 0.6 m, and spacing between plants was 0.25 m. A basal dose of N, P and K fertilizer was applied at the rate of 50:100:60 kg/ha respectively. Nitrogen was applied through DAP (18:48:00) and urea (46:0:0), phosphorus through di-ammonium phosphate (18:48:0) and potassium through muriate of potash (0:0:60). In addition, farmyard manure (FYM) at the rate of 20 t/ha was also used in the plots. Additional nitrogen at the rate of 50 kg/ha was top-dressed as urea at the time of first earthing-up ie 45 days after planting (DAP). Insecticides and fungicides were not used at all. Weeds were controlled by hand pulling at 45 and 60 DAP.

Measurement on growth parameters such as stem number per hill, percent ground cover, plant height and late blight disease infection at 1-9 scales (1 = no symptoms, 2 = up to 5% affected, 3 = 5-15% affected, 4 = 15-35% affected, 5 = 35-65% affected, 6 = 65-85% affected, 7 = 85-95% affected, 8 = above 95% affected and 9 = dead) were taken. Disease severity was estimated weekly and expressed as the fraction of the foliage infected. For accurate determination of stem numbers, the number of stems at soil level (above ground stems) was counted just before hilling. Ground cover by foliage was determined at 60 days after planting using wooden frame of 1 m by 0.6 m. The frame was divided into 1- × 1-cm grid cell by double strings (one directly above the other). The frame was placed above two plants and the area below each intersection scored as green (cover by foliage) or not greens (not covered by foliage). Crop raised from true potato seed was dehaulmed after 110 days of planting and harvested 10 days later. Desiree was dehaulmed at 90 days and harvested at 100 days after planting. Tuber germination after 30 days of planting, marketable (fraction>20 g size) (Kadian et al 1988) and total tuber yield, number of tuber per hill, average tuber weight and tuber uniformity was recorded at harvesting.

Analysis of variance was performed by MSTATC (1986) to investigate the treatment effects. Duncan Multiple Range Test was used for comparison of means. The data analysis procedures were followed as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Field emergence

Percentage of final emergence was significantly increased with higher seedling tuber weight during 2002 and 2004 (Table 1). Although three years emergence means of plants from seedling tubers size of >10 g and whole and half cut seed tubers of Desiree were similar. Emergence was delayed in seedling tuber of 1-5 g. Plants from 1-5 g tubers required an average of 3 days more to reach 90% emergence than plants from larger tubers. Emergence of 5-10 g seedling tubers was a day later than the larger tubers. Wiersema and Cabello (1986) reported that there was little difference in time to emergence between 5-10 g tubers and those from larger tubers.

Table 1. Effect of seedling tuber weight, whole and half cut seed tuber of Desiree on plant emergence and plant height at Khumaltar-Lalitpur during 2002-2004

Tuber weight, g	Emergence, %				Plant height, cm			
	2002	2003	2004	Mean	2002	2003	2004	Mean
Seedling tuber 1-5	89.50b	93.13	87.50c	90.04 b	49.10b	44.30b	51.90b	48.43c
Seedling tuber 5-10	95.00a	94.38	90.00bc	93.13 b	50.55b	49.80a	52.05b	50.80b
Seedling tuber 10-20	98.75a	96.25	95.00b	96.67 a	52.15b	50.90a	53.90b	52.30b
Seedling tuber 20-40	100.00a	100.00	98.33a	99.44 a	57.15a	53.00a	58.80a	56.32a
Desiree whole seed 20-40	100.00a	100.00	99.17a	99.72 a	53.75a	44.25b	51.50c	49.68d
Desiree half cut seed 20-40	98.75a	98.75	99.17a	98.89	53.00ab	43.80c	49.90d	48.90e
CV, %	5.38	4.16	3.15	4.10	4.75	4.71	3.51	4.42
F test	**	ns	**	**	**	**	**	**

*** Significant difference at 1% level. ns, Non significant. Means followed by the same letter within columns are not significantly different according to Duncan's Multiple Range Test at P = 0.05.*

Plant height

Plant height increased with increasing seedling tuber weight in all the years (Table 1). Considerable differences were seen in the height of plant from seedling tubers and whole and half cut seed tubers of Desiree. Maximum mean plant height (56.32 cm) was recorded where seedling tubers of 20-40 g were planted. Batra et al (1992) also reported increase in plant height with the increase in seedling tuber weight. Plants from 5-10 g and 10-20 g seedling tubers had statistically similar plant height but the plants from whole and half cut seed tuber of Desiree were significantly taller than plants from 1-5 g size seedling tubers. The variation in plant height may be due to food reserve for early growth of seed tubers and varietal characters and interactions of planting materials and environment. Wiersema (1986) and Batra et al (1992) have reported similar findings.

Table 2. Effect of seedling tuber weight, whole and half cut seed tuber of Desiree on ground cover and late blight infection at Khumaltar-Lalitpur during 2002-2004

Tuber weight, g	Ground cover, %				Late blight infection, 1-9 scales			
	2002	2003	2004	Mean	2002	2003	2004	Mean
Seedling tuber 1-5	59.75c	67.50b	60.25b	62.50 c	2.00b	3.00	2.00b	2.33b
Seedling tuber 5-10	66.75b	75.00a	67.25a	69.67 b	2.00b	3.00	2.00b	2.33b
Seedling tuber 10-20	77.50a	77.50a	66.50a	73.83 a	2.00b	3.00	2.00b	2.33b
Seedling tuber 20-40	80.50a	78.75a	70.00a	76.42 a	2.00b	3.00	2.00b	2.33b
Desiree whole seed 20-40	63.00bc	57.50c	60.25b	60.25 cd	7.00a	6.00	4.00a	5.67a
Desiree half cut seed 20-40	62.50bc	52.50c	57.75b	57.58 d	7.00a	6.00	4.00a	5.67a
CV, %	4.57	5.88	5.27	5.27	10.47	12.31	11.48	11.70
F test	**	**	**	**	**	**	**	**

*** Significant difference at 1% level. Means followed by the same letter within column are not significantly different according to Duncan's Multiple Range Test at P = 0.05.*

Ground cover

The ground covers by foliage among the treatments were statistically significant in all the years. The mean ground cover by foliage of three years showed that 20-40 g size seedling tubers had the maximum ground cover (76.42%), whereas minimum in half cut seed tubers of Desiree (57.58%) (Table 2). Plants from 10-20 g and 20-40 g had statistically similar ground cover. This may be due to emergence and plant height (Table 1).

Ground cover by foliage indicates the size of the photosynthetic system and is therefore an indication of intercepted radiation (Kloos 1986). Allen and Scoot (1980) have shown that there is a close relationship between total intercepted light and tuber yield. Ground cover by foliage was significantly increased with increasing seedling tuber weight and number of stems per plant (Tables 2, 3). In general greater the number of stems, the earlier the ground cover by foliage. Lateral stems on the main stem near or in the ground cover can help to achieve a close canopy and so enhance light interception. This suggest a positive effect of the amount of tuber reserve per stem on plant growth at early stage which is also reported by Moorby (1967), Wiersema (1986), Iritani et al (1972).

Late blight infection

Late blight incidence recorded in the 1-9 scales indicated that diseases build up in the seedling tubers was significantly lower than whole and cut seed tuber of Desiree (Table 2). Late blight infection in the treatments was slightly higher in 2003 as compared to 2002 and 2004. The variation in late blight infection may be due to the not conducive environment in 2003 for late blight pathogens (Table 2). TPS seedling tubers represent genetic variability, which are genetically not uniform and hence each plant acted as different genotype, which needed different matching race of *Phytophthora infestans* L. Under such situation accumulation of higher genes of virulence by a pathogen become difficult. This phenomenon not only delayed the infection but also check the build up of late blight. Singh and Bahal (1997) also indicated that disease build up in the TPS crops were lower than the clonal variety Rose through seed tubers of variety Kufri Jyoti.

Table 3. Effect of seedling tuber weight, whole and half cut seed tuber of Desiree on number of main stems per plant and number of tubers per plant at Khumaltar-Lalitpur during 2002-2004

Tuber weight, g	Number of main stems/plant				Number of tubers/plant			
	2002	2003	2004	Mean	2002	2003	2004	Mean
Seedling tuber 1-5	2.45d	1.65d	2.80d	2.30 e	10.82c	11.08b	7.16cd	9.68 d
Seedling tuber 5-10	3.30c	1.85d	3.00c	2.72 c	10.81c	13.58a	7.68c	10.69c
Seedling tuber 10-20	3.55b	2.25c	3.50b	3.10 b	12.43b	13.77a	9.35b	11.85 b
Seedling tuber 20-40	3.80a	2.60b	3.70a	3.37 a	14.35a	13.82a	10.11a	12.76 a
Desiree whole seed 20-40	2.50d	2.95a	3.10c	2.85c	6.66d	8.03c	6.74de	7.14e
Desiree half cut seed 20-40	2.35d	2.35c	2.80d	2.50d	6.15d	7.04d	6.17e	6.45e
CV, %	4.92	6.95	3.24	4.92	4.03	4.81	6.08	4.91
F test	**	**	**	**	**	**	**	**

*** Significant difference at 1% level. Means followed by the same letter within column are not significantly different according to Duncan's Multiple Range Test at P = 0.05.*

Stem number

If high yields per plant are desired, stems/plant should be low, where as it should be high when high yields per hectare are required (Beukema and Van Der Zaag 1990). The number of stem per plant increased with increasing seedling tuber weight (Table 3). It is attributed to increase in number of eyes. Batra et al (1992) and Iritani et al (1972) also reported increase in stems per plant with increases in seed size. The maximum stems/plant (3.37) was recorded in plants from seedling tubers 20-40 g size and minimum in 1-5 g seedling tubers. Plants from whole seed tubers of Desiree produced significantly

higher stems/plant due to higher eyes in the tubers. In all the sizes of seedling tubers stems/plant was lower in 2003 as compared to 2002 and 2004.

Tuber number

Tuber number is a function of stem population (Cho and Iritani 1983), but is also influenced by cultivars and several other factors, which control vegetative growth. There was significant effect of tuber sizes on tuber number per plant in all the years (Table 3). All the sizes of seedling tubers produced significantly higher tuber per plant compared to whole and half-cut seed tubers of Desiree. Tuber numbers per plant were not consistent across years. Tubers/plant was similar in 2002 and 2003 but it was low in 2004 due to unavailability of irrigation during growth period in 2004. TPS seedling tubers have tendency to produce more number of tubers per plant than Desiree seed tubers. The three years mean showed that plants from whole and cut seed pieces of Desiree produced similar tuber number per plant. Plants from increasing weight of seedling tubers significantly increased the tuber number per plant. This result agree with the data from Batra et al (1992) indicated that tuber number per plant increased with increase in seedling tuber size. The highest tuber number per plant was recorded in 20-40 g size seedling tuber planted crop. The data indicate that the number of main stems per plant has positive bearing on number of tubers per plant. The results corroborate with the findings of Wiersema (1986) and Kadian et al (1988).

Table 4. Effect of seedling tuber weight, whole and half cut seed tuber of Desiree on marketable yield and total yield at Khumaltar-Lalitpur during 2002-2004

Tuber weight, g	Marketable yield, t/ha (>20 g)				Total yield t/ha			
	2002	2003	2004	Mean	2002	2003	2004	Mean
Seedling tuber 1-5	21.93c	21.07c	11.50e	18.17 d	24.90cd	24.24c	13.28d	22.82d
Seedling tuber 5-10	23.33bc	24.62b	15.28c	21.08c	26.60c	28.14b	17.18c	23.97c
Seedling tuber 10-20	24.11b	26.83ab	19.28b	23.41b	28.81b	30.67a	21.45b	26.98b
Seedling tuber 20-40	31.45a	27.51a	22.45a	27.14 a	37.17a	30.85a	24.78a	30.93a
Desiree whole seed 20-40	24.01b	16.83d	13.63d	18.16d	25.13cd	18.13d	14.78d	19.35e
Desiree half cut seed 20-40	22.03c	14.76d	13.00d	16.60e	23.44d	15.84d	14.55d	17.94f
CV, %	4.42	7.55	6.09	6.12	4.33	4.67	5.78	5.62
F test	**	**	**	**	**	**	**	**

** *Significant difference at 1% level. Means followed by the same letter within columns are not significantly different according to Duncan's Multiple Range Test at P = 0.05.*

Tuber yield

Weight of the TPS seedling tubers, whole and half-cut seed tubers of Desiree significantly affected the total and marketable tuber yields per hectare in all years (Table 4). The significantly maximum total and marketable (>20 g) tuber yield was obtained when larger seedling tubers were planted. Seedling tuber 20-40 g size produced the highest total and marketable yield (30.93 t/ha and 27.14 t/ha, respectively). The overall performance of three years means showed that relative yield difference between plants grown from all the sizes of seedling tubers was greater than whole and half cut seed tubers. This may be explained on the basis of photosynthates in large size seedling tubers that helped in early emergence, better growth, high ground cover by foliage, tubers/plant and positive effect on the amount of tuber reserve per stem on growth (Tables 1, 2, 3). The results are in conformity with the findings of Wiersema (1986), Kadian et al (1988) and Iritani et al (1972). The data presented in Table 4 indicate the production of marketable and total tuber weight was high in 2002 and 2003 as compared to 2004 probably due to unavailability of irrigation in the early bulking stage. The yield of whole and half cut seed tubers of Desiree is higher in 2002 the 2003 and 2004. The variation may be due to better haulm growth and average tuber weight (Tables 2, 5). The whole seed tuber of Desiree produced statistically higher marketable and total yields in 2002 than half-cut seed tuber of Desiree. But it was similar in 2003 and 2004. In most of the developing countries especially in Nepal the tuber size of 20 g and above is

usually accepted as marketable. The seedling tuber size less than 20 g can successfully be used as seed tubers for next season planting which would give the same potential yield from seed tubers of standard variety.

Table 5. Effect of seedling tuber weight, whole and half cut seed tuber of Desiree on average tuber weight and tuber uniformity at Khumaltar, Lalitpur during 2002-2004

Tuber weight, g	Average tuber weight, g				Tuber uniformity, 1-5 scales			
	2002	2003	2004	Mean	2002	2003	2004	Mean
Seedling tuber 1-5	34.31cd	31.14	27.80d	31.08c	4.00c	4.00b	4.00c	4.0 b
Seedling tuber 5-10	36.88cd	32.94	33.56bc	34.46c	4.00c	4.00b	4.00c	4.0 b
Seedling tuber 10-20	34.80d	33.46	34.45abc	34.24c	4.00b	4.00b	4.00b	4.0 b
Seedling tuber 20-40	38.90c	33.51	36.88a	36.43b	4.00b	4.00b	4.00b	4.0 b
Desiree whole seed 20-40	61.27a	33.96	36.00ab	43.74a	5.00a	5.00a	4.80a	4.93a
Desiree half cut seed 20-40	52.91b	33.76	32.55c	39.74a	5.00a	5.00a	4.80a	4.93a
CV, %	5.47	8.06	5.02	6.22	2.63	4.67	2.67	3.43
F test	**	ns	**	**	**	**	**	*

** *Significant difference at 1% level. ns, Non significant. Means followed by the same letter within columns are not significantly different according to Duncan's Multiple Range Test at P = 0.05. Tuber uniformity scales: 1 = least uniform and 5 = Most uniform.*

The overall three years mean showed that average tuber weight from all the sizes of seedling tubers was statistically lowest as compared to the whole and half-cut seed tubers of Desiree (Table 5). The average tuber weight among the treatments was significantly different in 2002 and 2004 and insignificant in 2003. Tuber weights of 1-5 g, 510 g, 10-20 g seedling tubers were statistically similar. Whole seed tubers of Desiree gave highest average tuber weight (43.74 g) followed by half cut seed tuber of Desiree (39.74 g) and 20-40 g seedling tubers (36.43 g) and minimum in 1-5 g size (31.08 g). Kadian et al (1988) also reported similar results. Short duration (90 days) Desiree matured earlier than crops grown from TPS seedling tubers. Although no systematic ratings on maturity were taken, it was observed that plants from smaller seedling tubers mature later than the larger. This may explain the average tuber weight differences between plants from the different seedling tuber weights.

The produce from the four sizes of seedling tubers could not be distinguished morphologically in terms of tuber shape, color and depth of eye but statistically distinguished from seed tuber of Desiree (Table 5). The tuber of Desiree was most uniform in color, shape and size compared to seedlings and seedling tubers.

Seedling tubers of TPS family HPS II/67 have shown the potential of giving significantly higher yield of potatoes than Desiree. In Mid Hill condition like Kathmandu valley, the cost of seed tubers is high and good quality disease free seed tubers are not easily available at reasonable cost. Hence, use of above 1 g size seedling tubers can successfully be used for potato production as from the seed tubers of release cultivars.

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Response of Wet Seeded Rice Varieties to Sowing Dates

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ABSTRACT

The experiment was conducted at Regional Agriculture Research Station, Parwanipur in two consecutive years to find out the suitable rice varieties for wet seeding conditions in relation to sowing dates. Yield components like tillers number/$m^{2,}$ number of filled grains/panicle and 1000-grain weight were found in the decreasing trend from the seeding of 15 of June onward. The percent decrease in the grain yield was 14.1, 31.8 and 50.6 in 1998/99 where as 4.8, 7.9 and 49.6 in 1999/00 on June 29 to July 14 seeding dates respectively as compared to 15 June seeding date. Radha 4 in the first and Chaite 2 in the second year recorded the highest grain yield of 3757 and 4197 kg/ha respectively. Interaction effect of the sowing dates and varieties was highly significant. Radha 4 produced the highest grain yield of 5039 kg/ha in 1998/99 where as Radha 4 and Chaite 6 were found at par in 1999/2000 seeded on 15 June. Radha 4 was the best variety for wet seeded conditions when seeded on 15 June. Chaite 2 had been observed good yielder in all seeding dates among the tested varieties.

Key words: Grain yield, seeding dates, wet seeding rice

INTRODUCTION

There are three principal methods of rice establishment; dry seeding consists of sowing dry seeds on dry soil; wet seeding, involves sowing pre-germinated seeds in wet puddled soils; transplanting involves, re-planting of rice seedlings grown in nursery to puddled soils. The both dry and wet seeding methods are often referred as direct seeding because the seeds are sown directly. These traditional methods either in irrigated or rainfed ecosystem are labour intensive. Pandey and Velasco (1999) reported that the high labour cost and high requirement of labour for rice transplanting have narrowed the profit margin. Generally water availability and opportunity cost of labor are the major determinants of crop establishment methods. Adequate water supply and low wage rate favor for transplanting. When the water supply is adequate and wage rate is high, the wet seeding is favorable provided the low cost of weed control; thus economy incentives for direct seeding increased under such situation. As a result of rising wage rate the direct seeding method is popular in Southeast Asian countries. The total direct seeded area is about 15 million hectare in Asia only in rainfed lowland and irrigated ecosystem. The importance of direct seeding in irrigated and rainfed lowlands increased during the past three decades mainly in Malaysia, Thailand and Macon Delta (Pandey and Velasco 1999) and continued to expand in South and Southeast Asia where farmers are mostly concerned to lower the cost of rice production through labor saving technology.

It was reported that 23 percent of the total rice growing area in Nepal was under irrigated conditions (Adhikari and Khatiwada 1996/97). Labor scarcity during transplanting period had been realized from many years due to development in the industrial sectors or seasonal migration to Punjab. Mechanization is very costlier as the size of holding is small. Keeping in account the availability of adequate water, high yielding short duration varieties, chemical weed control methods and high wage rate can make a major shift from transplanting to wet seeding. Number of high yielding varieties suitable for transplanting conditions is available, but there was no information on the performance of varieties

grown under wet seeding conditions. Therefore, efforts had been made to evaluate the performance of rice varieties sown on various dates under wet seeding conditions.

MATERIALS AND METHODS

The field experiment was carried out at Regional Agriculture Research Station, Parwanipur ($27^0$04' latitude and $84^0$58' longitude) at an elevation of 115 masl in two consecutive years (1998/99-1999/00). Four seeding dates at 15 days interval starting from June 15 to July 29 were compared to evaluate the yield potentials of rice varieties Chaite 2, Radha 4, Chaite 6 and Radha 11 under wet seeding conditions. The experiment consisting of two factors (dates and varieties) were laid out in a 4^2 factorial experiment in randomized complete block design, replicated three times. Seeds were soaked in water for 24 hours and incubated for 48 hours; and sown on puddled soil @100 kg/ha as per treatment in the plot size of 5- × 2.35-m. Net harvest was done in a plot size of 4.5- × 1.8-m. N:P:K @ 40:40:30 kg/ha were applied as basal and 40 kg N/ha was top dressed at 30 days after seeding. Butachlor 50 EC @ 2 l/ha was sprayed as pre-emergence to control the weeds. Irrigation was given as per need of the crop for both the years. One hand weeding was done before topdressing. Data were recorded on tillers number/m^2, number of filled grains/panicle, 1000-grain weight and grain yield (kg/ha). Statistical analysis was done using MSTATC.

RESULTS AND DISCUSSION

Effect of sowing dates on grain yield and yield components

Results for two years (1998/99-99/00) recorded on yield and yield components are presented in Table 1. Highly significant effect of sowing date was detected on grain yield and yield attributing characteristics like tillers number/m^2, filled grains/panicle and 1000-grain weight in both the years. June 15 seeding had the highest tillers number/m^2 (240 and 316 in 1998/99-99/00 respectively) whereas the lowest in July 29 seeding. More number of filled grains/panicle was visualized in the early seeding and declined gradually in the successive seeding dates. Early seeding (June 15) had the highest 1000-grain weight and decreased as sowing delayed. June 15 seeding date recorded significantly the highest grain yield in 1998/99 whereas June 15 to July 14 seeding date had statistically the similar yield in 1999/00.

The reason for low yield on July 14 seeding in first year might be due to brown plant hopper infestation. The percent decline in grain yield was 14.1, 31.8 and 50.6 in 1998/99 and 4.8, 7.9 and 49.6 in 1999/00 when seeded on June 29, July 14 and 29 respectively as compared to June 15 seeding. The decreasing trend in the grain yield in delayed seeding might be associated with significantly lower number of panicle/$m^{2,}$ less number of filled grains/panicle and low 1000-grain wt in both the years. Similar results were reported by Koirala (1983), Kunwar and Shrestha (1979) and Bhurer et al (1990). It was also reported that the reason for decline grain yield might be due to delayed panicle formation and grain filling in the season where temperature and solar radiation are less (IRRI 1993). The earlier sown crop benefited from better sunshine and appropriate temperature that resulted into a more vigorous and extensive root system leading to increased vegetative growth means more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the spikelets and longer leaf area index during grain filling period, thus resulted to high yields in early seeding.

Table 1. Effect of sowing dates on grain yield and yield components

Sowing date	Tillers/m^2		Grains/panicle, n		1000-grain wt g		Grain yield, kg/ha	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
15 June	240	316	100	99	22.2	24.2	4357	4497

29 June	186	277	105	81	21.9	23.9	3746	4282
14 July	166	258	92	86	21.1	23.9	2972	4146
29 July	169	199	71	65	20.7	23.7	2154	2266
CV, %	15.4	14.3	20	14.5	4.6	4.5	17.2	17
LSD (0.05)	24.8	33	15	9.8	0.82	-	476	592

Effect of varieties on grain yield and yield components

Chaite 6 gave significantly higher number of tillers/m^2 in both the years, but at par with Radha 4 in 1998/99 (Table 2). Chaite 2 had the highest number of grains/panicle whereas Chaite 6 had the lowest in both years. Radha 4 had the heaviest grains (24.8 and 27.8 g in 1998/99 and 1999/00 respectively) whereas minimum was noted from Radha 11 in both the years. The differences in the grain yield, obtained in Chaite 2, Radha 4 and Chaite 6 in 1999/00 were insignificant whereas in 1998/99 Chaite 2 and Radha 4 and Radha 11 had the same yield. Chaite 2 yielded the highest grain of 4197 kg in 1999/00 whereas in 1998/99 Radha 4 had the highest (3757 kg/ha). Radha 11 was the lowest yielder in both the years among the tested varieties. This was mainly influenced by the lowest 1000-grain weight.

Table 2. Effect of varieties on grain yield and yield components regardless of sowing dates

Varieties	Tillers/m^2		Grains/panicle, n		1000-grain wt, g		Grain yield, kg/ha	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
Chaite 2	172	259	106	91	20.6	24.0	3366	4197
Radha 4	197	245	86	80	24.8	27.8	3757	3769
Chaite 6	213	302	78	72	20.9	22.8	3154	3777
Radha 11	180	245	97	87	19.6	21.1	2953	3447
CV, %	15.4	14.3	20	14.5	4.6	4.5	17.2	17
LSD (0.05)	24.8	33	15	9.8	0.82	0.89	476	592

Interaction effect of sowing dates and varieties on grain yield

The interaction effect of the sowing dates and varieties on grain yield was highly significant (Table 3). Radha 4 produced statistically the highest grain yield of 5039 kg/ha in 1998/99 whereas Chaite 2, Radha 4, Chaite 6 and Radha 11 were at par in 1999/00 seeded on June 15. The reduction in grain yield was noted in all tested varieties as seeding was delayed from June 15 onwards. But the reduction in the grain yield was comparatively minimum on second and third date of seeding than that of other dates. Chaite 2 gave fairly a good yield amongst the tested varieties in all seeding dates in both the years.

Table 3. Interaction effect of sowing dates and varieties

Sowing date	Yield, kg/ha (1998/99)				Yield, kg/ha (1999/00)			
	Chaite 2	Radha 4	Chaite 6	Radha 11	Chaite 2	Radha 4	Chaite 6	Radha 11
15 June	4472	5039	4398	3521	4140	4681	4847	4319
29 June	3571	4045	3516	3845	4935	4035	4129	4028
15 July	3177	3868	2456	2388	4754	3978	4133	3720
29 July	2243	2068	2248	2058	2960	2383	2001	1720
CV, %	17.2				17			
LSD (0.05)	945 (Two varieties at the same date)				1160 (Two varieties at the same date)			

Early wet seeding (June 15) had a considerable effect on grain yield. In case if time is not permitted to sow earlier, seeding could be done up to July 14. Radha 4 was found the best variety for wet seeding condition if sown earlier. Chaite 2 performed better under delayed conditions as compared to other varieties.

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Planting Materials Seed Systems of Finger Millet, Rice and Taro in Jumla, Kaski and Bara Districts of Nepal

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ABSTRACT

Formal and informal seed supply systems of rice (Jumla, Bara and Kaski), finger millet and taro (Kaski) were studied in three ecosites of Nepal during 1999-2001 to understand the processes of seed flow, seed production, seed selection and storage systems. A survey was conducted at 48 to 96 households. Informal seed supply was the only system in Jumla and Kaski and formal system existed only in Bara. The main sources of seed were farmer's own saved seed (67-91%), seed from neighbors and relatives. Exchange of germplasm was the main basis of fulfillment from other sources. All farmers obtained seed from their own village, while farmers introduced materials occasionally from outside village. Most of the farmers followed seed selection before or after crop harvest. Rice field selection and plant selection based on a fixed set of criteria was the common practice. Non lodged plants with more grain per panicle, bold grains, well-matured and uniform plants, long panicle, true to type, good looking grains, free from diseases and insects were the main rice seed selection criteria. All farmers from both sites stored rice seeds by local methods in the locally available containers. *Mor* and *Mudkothi* are the special straw containers to store rice seed in Bara. *Dhara* is a special mud structure used to store rice seeds in Jumla. Finger millet seed supply system was mostly similar to that of rice seed system. Ninety one percent farmers saved seed for their own use; however, many of them changed finger millet seeds lots or varieties regularly for their particular plot. Ears selection during harvest by set criteria for seed purpose was the common practice. Farmers stored finger millet seed carefully in small locally available containers and tried their best to maintain the quality of seed during different stage of seed production. Taro has diverse planting materials: cormels, corms with eyes, suckers and corm with small cormels. Taro planting materials management is totally informal and almost 89% farmers saved these materials for their use and replaced them mostly after 3 years. Farmers had fixed criteria of corms and cormels selection for planting purpose and focus and more on disease free. Storage of planting materials was locally by using local materials and methods. Understanding of seed system in various crops helps to develop conservation strategy.

Key words: Seed flow, seed production, seed selection, seed storage, seed system

INTRODUCTION

Seed is the genetic material, which is the first link in the food chain, source of life, future plant and even source of culture (Shiva et al 1995). Both formal and informal seed supply systems exist in Nepal, but informal system is playing major role to fulfill the seed need (Baniya et al 1999). Traditional seed supply system is an important source of diversity for majority of farmers (Shrestha 1998). An understanding of farmers seed supply system is prerequisite to understand the on-farm germplasm conservation. Seed production, seed selection, seed flow and seed storage practices followed by farmers have the high impact on the genetic diversity. Similarly, some farmers procure seeds of different crops and their varieties from formal and informal systems and ultimately increase the diversity at species and

variety levels. Bellon and Smale (1998) clarified the concepts of seed flows, varietal choice, seed selection and seed management. The units of seed flow are often referred to as seed lots (Louette and Smale 1996). The seed supply system of landraces is totally informal, which has not well understood and after the CBD - 1992 agreement, it is getting priority from national and international levels.

To study the seed supply system in Nepal, 3 sites were selected one site each at high hill in Jumla, mid hill in Kaski and plain area in Bara districts. Jumla site is situated in the altitudinal range of 2240 to 3000 m on both sides of Tila river. The climate of Jumla site is cool temperate to sub-alpine and the average annual rainfall is 886 mm. The altitudinal range of Bara is 80 to 90 m, its climate is tropical to subtropical and the average annual rainfall is 1515 m. The Kaski site is situated at Begnas and Rupa lake watershed areas whose altitudinal range is 600 to 1600 m; its climate is subtropical with average rainfall 3979 mm (Paudel et al 1999). Rice is the main crop of Jumla site and 17 rice landraces are reported from there. Similarly, 53 (33 local + 20 modern) rice varieties were reported from Bara. Finger millet is the important food crop in hills, but it is neglected crop and Nepal is rich in finger millet diversity (Baniya et al 1992). A total of 24 landraces were reported (Rana et al 2000b) from Kaski site. Taro is a clonally propagated crop and common vegetable in Kaski site. In taro also 24 landraces were reported from the study site. The main objective of this study was to understand the informal seed supply system of finger millet, rice and taro grown at different ecological zones of Nepal; and suggest to improve the local seed system.

MATERIALS AND METHODS

A questionnaire with 21 questions was prepared for rice seed supply system in Jumla and Bara. Some information of site selection and base line survey of in-situ project were used to select the particular household (Rana et al 2000a, 2000b, 2000c). Out of the rice growing HHs, 48 houses were surveyed based on the criteria of wealth rank, rich, medium and poor (Table 1) and gender groups, male and female. Thus six categories consisting of rich male and female; medium male and female; poor male and female were formed and eight houses were randomly selected from each group. To estimate the sources of seed, seed production techniques, seed selection methods, seed storage system, seed flow, seed counseling etc.

Table 1. Status of rice, finger millet and taro growing households (HH) in Jumla, Kaski and Bara, 1998

SN	Variable	Jumla	Kaski		Bara
		Rice	Finger millet	Taro	Rice
1	Total number of HH's	759	941	941	914
2	No. of HH's used in baseline survey				
	1) Rich	40	77	77	21
	2) Medium	59	74	74	73
	3) Poor	81	55	55	108
	Total	180	206	206	202
3	No. of HH's growing crops				
	1) Rich	40	60	66	21
	2) Medium	59	53	49	73
	3) Poor	81	33	32	103
	Total	180	146	146	197
4	No. of HH's used in seed supply system				
	1) Rich	16	32	32	16
	2) Medium	16	32	32	16
	3) Poor	16	32	32	16
	Total	48	96	96	48

Source: Rana et al 2000a, 2000b and 2000c.

In case of finger millet, the questionnaire developed for rice was modified to suite the finger millet. The basic data and information of site selection and base line survey were used for selecting specific household (Rana et al 2000a, 2000b, 2000c). Out of 146 finger millet growing farmers in Kaski, 60 were rich, 53 medium and 33 poor. Each group was divided into male and female. After putting the farmers into 6 cells, 16 farmers were randomly selected from each cell and 96 households were surveyed (Table 1).

In case of taro also the questionnaire developed for rice was modified. Taro growing farmers (Pandey et al 1998) were divided into six categories. Out of 146 taro-growing farmers, 65 were rich, 49 medium and 32 poor. Each group was divided into male and female and 16 farmers were randomly selected from each cell. So, 96 households were surveyed to collect information on different aspects of taro planting material supply system. The data were analyzed with the help of SPSS package.

RESULTS

Seed flow

Rice in Jumla

About 79 percent farmers saved rice seed by themselves. Similarly, relatives and neighbors also were supplying rice seed to the farmers. Few farmers even received seed from extension agents, however there was no formal rice supply system in Jumla (Table 2). Most of the farmers from Jumla had no practice of changing seed. About 33 percent farmers followed seed change in the regular interval (Table 3).

Table 2. Number and percentage of households in receiving seed and planting material of rice, finger millet and taro in Jumla, Kaski and Bara, 2000

Source of seed	Rice				Finger millet		Taro	
	Jumla		Bara		Kaski		Kaski	
	N	Percent	N	Percent	N	Percent	N	Percent
Own	42	79	31	67	87	91	85	89
Neighbour	6	11	5	11	21	22	21	23
Relative	4	8	3	7	3	3	8	8
Formal	-	-	6	13	-	-	-	-
Others (extension)	1	2	1	2	-	-	-	-

Some farmers have more than one source.

Table 3. Number and percentage of households in replacing seed of respective crops in Jumla, Kaski and Bara, 2000

Period	Rice				Finger millet		Taro	
	Jumla		Bara		Kaski		Kaski	
	N	Percent	N	Percent	N	Percent	N	Percent
No change	32	67	1	2	17	18	16	17
Every year	11	23	1	2	2	2	1	1
Every 2-3 year	3	6	28	58	17	18	18	18
More than 3 year	2	4	18	38	60	62	62	64

Rice in Bara

In Bara, about 67% farmers saved their own rice seed. Formal system was the second main source of seed and followed by neighbours and relatives (Table 2). Almost all farmers replaced seed in the regular interval (98%). Changing rice seed in every three year was very common practice (Table 3). Neighbors, relatives, market and public sector were the sources of seed and exchange, gift, purchase and free

distribution were the main bases of rice seed flow. Rice seed flow took place inside and outside the village.

Finger millet in Kaski

Majority of farmers (91%) saved their own seed for their use. Some of the farmers managed finger millet seed from their neighbors and relatives (Table 2). Purchase, exchange, gift and free collection of seed are the bases of seed flow. Almost 82% farmers had the practice of changing seed in the regular interval (Table 3). About 62% farmers changed seed lot in more than 3 years period. This was done mostly either by female or both sexes.

The surveyed 96 farmers cultivated finger millet in about 18.5 ha area and used 371 kg of seed (seed rate 20 kg/ha). The recommended seed rate of finger millet is 10 kg/ha, so the farmers are using almost double the required amount of seed, which might be due to the difficulties in managing finger millet seedlings in dry and stress conditions. So, farmers are using more seed in obtaining sufficient seedlings even in adverse climatic conditions.

Taro in Kaski

About 89% farmers used their own source of planting materials, 23% bring these from their neighbors and 8% from their relatives. Some farmers mentioned more than one sources of cormels. Nobody was bringing the seed from formal system (Table 2). When the sources of cormels for seed purpose is from neighbors, the farmers either purchase the cormels or receive them freely. Exchange was negligible and generally they provide cormels to the relatives as gift. Almost 83% farmers changed the seed lot or even variety regularly. Majority of farmers (64%) followed this practice after 3 years only.

The main planting material of taro is cormel and corm and suckers in some cases. The surveyed 96 farmers cultivated taro in about 0.906 ha and used about 1141 kg cormels as planting material. The seed rate of taro is about 1260 kg/ha, which seems that farmers are using the required seed rate (recommendation 1000 to 1600 kg/ha and spacing is 50- × 30-cm). Estimated area and planting materials of taro is vague for farmers, because area is small and generally seed is not measured as in rice or finger millet.

Seed production

Rice in Jumla

Most of the farmers (about 96%) followed seed selection process either before or after harvesting the crop, and some farmers followed seed selection before and after harvesting the crop. About 58% farmers selected the best patch of rice field, harvested the crop separately and keep for the seed (Table 4). Some farmers simply harvested the crop, threshed and kept separately the required amount of seed from the whole harvest. Farmers had fixed a set of criteria for seed selection from standing crop. Well matured plants, free from insects and diseases, bold and big grain, uniform plants, better panicle, etc were the main selection criteria before harvesting and free from diseases and insects, clean and better grain, bold grains, long panicles, etc were the main criteria after harvesting (Table 5).

Rice in Bara

The farmers of this site had not separate place for seed production but about 40% farmers fixed better area in the rice field and followed seed selection only before or after and both before and after harvesting. Some farmers practiced panicle selection in the standing crop. However, the very common method of seed selection in Bara was that first, farmers harvested the crop of the previously fixed area, dried few days in the field, prepared the bundles from the crop, transported to the threshing flour and removed off types from the bundles and threshed separately for seed purpose (Table 4). Free from

diseases and insects, bold seed, non lodged plants, uniform plants and panicles, true to type, bright and better panicles, etc were rice seed selection criteria before harvesting and true to type, free from insects and diseases, uniform plants and panicles, big and bold seeds, etc were the criteria of seed selection after harvest (Table 6).

Table 4. Number and percentage of households following the seed and planting material selection of rice, finger millet and Taro in Jumla, Kaski and Bara, 2000

SN	Process	Rice				Finger millet		Taro	
		Jumla		Bara		Kaski		Kaski	
		N	Percent	N	Percent	N	Percent	N	Percent
1	Selecting panicles or plants from the whole area	-	-	6	13	40	42	1	1
2	Selection of panicles or plant from the best patch of area	28	58	1	2	52	54	2	2
3	Harvesting all and selecting seed from the whole lot after threshing	12	25	4	8	-	-	-	-
4	Selection of better ears/panicles/cormels after harvesting the crop	6	13	30	63	-	-	75	78
5	Planting the left over after using for food	-	-	1	4	-	-	2	2
6	No response	2		6		4		16	

Table 5. Number and percentage of households in seed selection criteria of rice before and after harvesting in Jumla, 2000

SN	Selection criteria	Before harvest		After harvest	
		N	Percent	N	Percent
1	Well matured plant	28	38	-	-
2	Bold and big seed	13	18	18	26
3	Free from insects and diseases	11	15	15	22
4	Uniform plants with better panicles	7	9	-	-
5	Clean and better plant type/seed	4	5	12	17
6	True to type	3	4	-	-
7	Long panicle	2	3	3	4
8	Free from weed plants/seeds	2	3	1	1
9	Cleaner than food grain		-	8	12
10	Others (less shattering, less moisture, etc.)	4	5	13	18

Same farmers practiced more than one criteria.

Finger millet in Kaski

Majority of farmers followed seed selection practices. Many farmers followed seed selection during the harvesting of finger millet and the some did this activity before harvest. The general practices of seed selection was that during harvesting some experienced farmers first harvest some ears for seed purpose and keep separately for each variety. This is very common practice in case of finger millet, because varietal mixture is common, and few ears will be sufficient for seed purpose. The farmers either select the better ears from the whole field or first select better area and select the better ears from the fixed area only (Table 4). Farmers had their own selection criteria and followed accordingly. Big ear size, free from finger blast, well matured ears, big grain size, free from insects and non lodged plants were the major seed selection criteria (Table 7). About 88% female make decision to fix the criteria and the decision of male was negligible (Table 7).

Farmers are very much careful in maintaining of seed quality during harvesting, threshing, drying, storing and planting of finger millet. The main strategy of maintaining seed quality was keeping the seed lot separately from other seed or food purpose finger millet grains. Harvesting earlier than others, threshing without heaping the ears, threshing by hand and leg, more drying than food grain, store in air tied container, were other regular activities to maintain seed quality.

Table 6. Number and percentage of households in seed selection criteria of rice before and after harvesting in Bara, 2000

SN	Selection criteria	Before harvest		After harvest	
		N	Percent	N	Percent
1	Free from diseases and insects	10	26	14	16
2	Big and bold seeds	8	21	13	15
3	Uniform plants, panicles and grains	5	13	12	14
4	Non lodging plants	4	10	4	5
5	True to type	3	8	16	19
6	Long and better panicles	3	8	7	8
7	Bright and better panicles	3	8		-
8	Removal of off types (Rouging)	1	3		-
9	Panicum with more grains	1	3	1	1
10	Removal of off type grains	-	-	5	6
11	Uniform grain colour	-	-	2	2
12	Not damaged by rain	-	-	2	2
13	Well matured plants	-	-	3	4
14	Others (not wet grain, plants from the center of heap, protects from mixing, etc)	-	-	7	8

Same farmers practiced more than one criteria.

Taro in Kaski

About 81% farmers followed seed selection procedures (Table 4). 93% farmers followed cormel selection during or after the harvest of the crop. Due to the underground nature of the crop, selection before harvest is difficult and very few farmers followed cormel selection before harvesting. Few farmers followed cormels selection even during planting time. Less eyed, non damaged, diseases and insects free and big sized cormels were the main seed selection criteria (Table 8). Either female (72%) or both male and female (27%) were the decision maker to fix taro cormels selection criteria (Table 8). Few farmers kept cormels intact with its mother corm for seed purpose. Farmers had no plan to select seed from better crop area, however they harvest the crop from the whole field and select cormels from the harvested lot. Few farmers did not bother for seed selection. Taro is generally cultivated in association with ginger, cowpea, sweet potato and maize in upland. It was not understood the effect of other crops on cormel production by this cultivation practice.

Table 7. Number and percentage of households with the decision makers in adopting major criteria of finger millet seed selection in Kaski, 2000

SN	Selection criteria	Decision makers, n			Total	
		Male	Female	Both	N	Percent
1	Big ear size	2	69	9	80	83
2	Free from finger blast	1	63	5	69	72
3	Well matured ears	-	38	6	44	46
4	Big grain size	-	23	1	24	25
5	Free from insects	-	18	1	19	20
6	Non lodged plants	-	16	1	19	20
7	Disease free plants	1	12	2	15	16
8	Non dried leaves and stems	-	4	1	5	5
9	True to type	-	3	3	6	6
10	No finger branching ears	-	2	-	2	2
11	No response	-	3	-	3	3
Total	Number	2	84	10	96	-
	Percent	2	88	10	-	100

Some farmers followed more than one criteria.

Table 8. Number and percentage of households with the decision makers in adopting major criteria of taro planting materials selection in Kaski, 2000

SN	Selection criteria	Decision makers, n			Total	
		Male	Female	Both	N	Percent
1	Less eyed cormels	1	24	8	33	34
2	Non diseased and damaged cormels	-	20	12	32	33
3	Free from insects and diseases	-	23	8	31	32
4	Not mechanically damaged cormels	1	23	6	30	31
5	Bigger cormels on time	-	22	5	27	28
6	Not damaged by white grub	1	18	7	26	27
7	Small size cormels for seed economy	1	15	6	22	23
8	Planting the sprouted ones	-	6	4	10	10
9	Better looking cormels	-	6	4	10	10
10	Storing in better place	-	5	4	9	9
11	Not wrinkled cormels	1	2	2	5	5
12	Storing in Tauwa	-	1	2	3	3
13	Others (less dried, cormels intact with corm, etc.)	-	2	1	3	3
14	No response		16	1	17	18
Total	Number	1	69	26	96	-
	Percent	1	72	27	-	100

Some farmers followed more than one criteria.

Seed storage

Rice in Jumla

Earthen *Dhara*, wooden *Bhakari*, drum and small pots were the main containers for rice seed storage (Table 9). Farmers took extra care to store rice seed by adopting special methods and approaches (Table 10). Separate harvesting, threshing, cleaning, drying and storing in closed containers and more drying were the strategies to keep seed pure and high quality. Storing the seed in bright, cold and dry places in the raised portion, insects and diseases free places were common practices (Table 10).

Rice in Bara

Mud-kothi, jute sacks, plastic bags, drum, *Mor* etc are the seed storage structure and containers. *Mud-kothi or Kothi* was the very common structure made for seed storage of different crops (Table 9). *Mud-kothi* is a temporary structure placed outside or inside the house, which is made by local materials and plastered by mud. *Mor* is another special type of container made from rice straw by tying long and strong straw together. It is especially made for rice seed, storing capacity of which ranges from 20 to 40 kg. Farmers reported that the seed stored in *Mor* will remain fresh and dry easily. *Mor* is kept inside or outside house in the raised portion. Some people put mud on the outside of the *Mor*. The seed containers are either kept at the raised portion or *Machan* or above bricks bed inside the room.

Finger millet in Kaski

The requirement of finger millet seed for the individual farmers is less, where average quantity was about 3.9 kg/household, minimum 0.44 kg and maximum 14 kg. So, farmers had not devised any container for finger millet storage. However, they stored finger millet seed in small earthen pots (*Ghaito*, *Gagri*), wooden vessel (*Theki*), bamboo container (*Dalo*), tin vessel, small plastic bags, etc. (Table 9). Farmers were careful to cover the mouth of the containers and some farmers mixed millet seed and black gram seed together and stored. Perhaps this is followed to store black-gram seed safely than finger millet seed. For seed purpose, the grain is dried 2 to 3 times more and is stored in smoking place in air tied containers (Table 10).

Table 9. Number and percentage of households using different containers/structures in storing rice and finger millet seeds and taro planting materials in Jumla, Kaski and Bara, 2000

SN	Containers/Structures	Rice				Finger millet		Taro	
		Jumla		Bara		Kaski		Kaski	
		N	Percent	N	Percent	N	Percent	N	Percent
1	Earthen Dhara	34	71	-	-	-	-	-	-
2	Wooden Bhakari	8	17	-	-	-	-	-	-
3	Lead drum	2	4	-	-	7	7	-	-
4	Mudkothi	-	-	18	38	-	-	-	-
5	Jute bag	-	-	10	21	8	8	-	-
6	Bag + Mudkothi	-	-	7	15	-	-	-	-
7	Plastic bag	-	-	5	10	20	21	-	-
8	Bag + drum	-	-	4	8	-	-	-	-
9	Small earthen pot (Ghaito)	-	-	-	-	68	71	-	-
10	Water vessel (Gagri)	-	-	-	-	19	20	-	-
11	Big basket (Doko)	-	-	-	-	-	-	48	0.5
12	Wooden structure (Khol)	-	-	-	-	-	-	23	24
13	Straw Tauwa	-	-	-	-	-	-	16	17
14	Others (wooden Dhara, small pot, Mor, earthen pot, Theki, dalo, etc.)	4	8	4	8	29	30	16	17
15	No response	-	-	-	-	2	2	10	10

Some farmers used more than one containers.

Some local storage

Khol = Special structures made from small pieces of woods.
Doko = Big basket made from the bamboo which is used to carry bulk material like grasses, fodders etc.
Mach (Machan) = Temporary structure made by locally available materials which is above the ground.
Tauwa = Small structure like Mach where the straw or other agriculture materials are kept.
Ghaito = Small earthen pot made for carrying water.
Gagri = Medium earthen or metal pot used to transport water by a person.
Theki = Wooden vessel made for handling milk and curd.
Dalo = Small bamboo container made for keeping things.
Bhakari = Big bamboo container for storing grain.
Kotho = Small bamboo container for storing grain.
Dharo = Special small structure made by mud and kept either above stone or wood.
Mudkothi = Temporary structure made by local material and plastered by mud which is placed inside or outside the house.
Mor = Special container made from rice straw itself by tying long and strong straw together.

Taro in Kaski

Storing in big bamboo basket (*Doko*) was the most common method followed by wood structure (*Khol*), *Tauwa (heap of straw)* and so on (Table 9). Cormels for seed purpose were buried inside the soil for sprouting before planting. While storing for the seed purpose, farmers stored cormels in separate places and materials, some stored in wet places even inside the locally made pits. However, some farmers store the seed and food cormels in the same place and even in the same container (Table 10). Cormels for seed purpose was dried less and store them in the better places, The leaves, petioles, corms and cormels are the edible parts of taro and these are used for making varieties of foods. The seed storage methods for different crops in different places were not the same, which might be due to diverse nature of the crops and studied places.

Table 10. Number and percentages of households in paying special attention in storing seed and planting material of rice, finger millet and Taro in Jumla, Kaski and Bara, 2000

SN	Methods	Rice				Finger millet		Taro	
		Jumla		Bara		Kaski		Kaski	
		N	Percent	N	Percent	N	Percent	N	Percent
1	Storing in bright, cold and dry place	37	55	-	-	-	-	-	-
2	Storing on wood, stone and mud raised places	8	12	-	-	-	-	-	-
3	Storing in insects, rats and diseases free places	7	10	-	-	-	-	-	-
4	Storing in dark and hot place	6	9	-	-	-	-	-	-
5	Keeping in the mouth closed structures above raised portion inside the room	9	13	-	-	-	-	-	-
6	Containers are kept above brick inside room	-	-	28	59	-	-	-	-
7	Keep in Machan	-	-	12	25	-	-	-	-
8	Containers above floor	-	-	4	8	-	-	-	-
9	Storing in smoky place	-	-	-	-	6	6	-	-
10	Storing in air tied container	-	-	-	-	3	3	-	-
11	Seed mixed with other grains	-	-	-	-	1	1	-	-
12	Storing in small containers	-	-	-	-	52	54	-	-
13	Drying more than food grain	-	-	-	-	16	17		
14	Keeping in separate place	-	-	-	-	3	3	12	13
15	Storing in separate containers	-	-	-	-	-	-	37	39
16	No different from food	-	-	-	-	-	-	29	30
17	Storing in separate structure (*Khol*)	-	-	-	-	-	-	13	15
18	Planting cormels buried in pits	-	-	-	-	-	-	2	2
19	Others (Away from children, dry more, keep on woods, wet place etc.)	1	1	4	8	4	4	8	8
20	No response	-	-	-	-	11	12	5	5

Some farmers fallow more than one methods.

DISCUSSION

The rice seed production system in Bara was well-managed and advanced as compared to that of Jumla. Farmers of Bara managed seeds from different sources, changed the seed lot more frequently and followed fixed criteria of seed selection. The seed supply system of finger millet had many similarities with rice seed system and much dissimilarity as compared to that of taro. Kaski farmers are trying their best to produce better quality finger millet seed by practicing extensive seed selection procedures, careful performance of agronomical practices and storage processes for pure seed. Farmers are paying extra attention to select blast free finger millet seed. Taro is different crop from the other crops in terms of uses, propagation, cultivation practices and bulkiness of its cormels. So, the seed flow pattern, seed production and storage practices of taro were very much different than other crops. There is need to control borer in taro. It is expected that the indigenous knowledge and practices related to seed and planting material supply system of rice, finger millet and taro will be helpful to formulate their conservation strategies in future. Again, findings of this study will be useful to the development agents to intervene in the seed system for improvement and thereby developing the agriculture system.

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Resistance in Rice Breeding Lines to the Blast Fungus in Nepal[1]

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ABSTRACT

A total of 36 rice breeding lines including checks were evaluated for resistance to blast at Rampur during 2000-2001. The experiments were conducted under both field condition and greenhouse inoculated condition. Qualitative resistance in rice to blast was assessed based on lesion type, whereas quantitative resistance was assessed based on area under disease progress curve (AUDPC) in the upland field condition. The number of sporulating lesions and the number of leaves with at least one sporulating lesion per plant were considered as measures for evaluation of quantitative resistance in the greenhouse assay. The lesion type, neck blast percentage and AUDPC data suggest that most of the rice lines possess higher level of resistance to leaf and neck blast. The rice lines varied for the number of sporulating lesions and the number of leaves with sporulating lesion per plant. Some lines were incompatible to virulent blast isolates, showing major resistance genes. NR 1558, NR 601-1-1-9, BW306-2 and CN 836-3-10 were promising lines for quantitative resistance to both leaf and neck blast. Radha 12, Sabitri, Janaki possess higher level of quantitative resistance to blast, hence these could be promoted for cultivation in blast-prone environments. These genotypes could also be utilized as donor parents for breeding durable blast resistant varieties. The most virulent blast isolate could be used for evaluation of both qualitative and quantitative resistance to blast in early generation in the greenhouse so that workload could be cut down in future works.

Key words: Blast resistance, field condition, greenhouse assay, *Pyricularia grisea,* rice lines

INTRODUCTION

Blast, caused by *Pyricularia grisea* Sacc., has been a continuous threat to rice production in Nepal (Manandhar 1987, Manandhar et al 1992, Chaudhary 1999). Blast epidemics result in a complete loss of seedlings in the seedbed (Manandhar 1984, Thapa and Manandhar 1985, Adhikari and Shrestha 1986, Pradhanang 1988, Sah 1989, Chaudhary et al 1994, Chaudhary and Sah 1997, Chaudhary and Sah 1998). The farmers often transplant blast infected seedlings that might serve as sources of inoculum for further out-breaks of leaf and neck blast disease in the field (Teng et al 1991). Panicles infected near the base (neck) may break and cause complete yield loss (Ou 1985).

In general, the disease causes 10-20% yield reduction in susceptible varieties, but in severe cases the loss may go up to 80% (Manandhar et al 1992). For 1% increase in the neck blast, a reduction in grain yield had been estimated between 21 to 51 kg ha^{-1} in rice cultivar 'Sankharika' (Manandhar et al 1985). More recently, a grain yield loss of 38.5 and 76.0 kg ha^{-1} was reported in the rice cultivars: 'Masuli' and 'Radha-17', respectively, due to one percent increase in neck blast (Chaudhary 1999).

Seed treatments with systemic fungicides and fungicidal foliar sprays had been demonstrated to be effective in minimizing blast disease (Manandhar 1984, Manandhar et al 1985, Sah and Karki 1988,

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Chaudhary and Sah 1998, Chaudhary 1999). However, the resource-poor farmers are reluctant to use the chemicals prior to occurrence of the disease. The use of chemical is also neither practical nor environment-friendly. Utilization of host resistance has been the best way to manage the disease (Ou 1985, Bonman 1992, Bonman et al 1992). However, blast resistance, especially governed by major genes, is often broken down under field conditions (Kiyosawa 1982, Bonman and Mackill 1988). Therefore, identification of new sources of resistance especially partial resistance and their deployment are necessary for blast management. In this study, 36 advanced rice breeding lines including checks (standard, resistant and susceptible) were evaluated for qualitative and quantitative resistance to blast at Rampur under both field condition and greenhouse inoculated condition during 2000-2001.

MATERIALS AND METHODS

Experiment 1

A total of 35 advanced rice breeding lines promoted for farmer's field trials including resistant and susceptible checks (Table 1) were planted in the upland field conditions. The trial was laid down in a randomized complete block design with three replications. Each genotype was planted in five rows of 0.5 m long as an experimental unit to evaluate for qualitative resistance to blast.

Table 1. Lesion type and percent infection by neck blast in rice genotypes evaluated in the field trials at Rampur, Nepal during the wet season of 2000

SN	Genotype	Lesion type†	Neck blast, %‡	SN	Genotype	Lesion type†	Neck blast, %‡
1	BG 1165-2	0.0	0.08e	19	MLT 119	0.0	0.18e
2	BG 1442	0.1	0.25e	20	NR 1249	0.2	0.40e
3	Bindeshwari	0.7	0.59de	21	NR 1487	0.0	0.53de
4	BR 4684	0.0	0.10e	22	NR 1488	0.1	0.26e
5	BW 306-2	0.0	0.38e	23	NR 1558	2.4	3.74c
6	Chaite 2	0.8	0.66cde	24	NR 1736-4-6	0.0	1.72cde
7	Chaite 4	0.0	0.25e	25	NR 601-1-1-5	0.1	2.02cde
8	Chaite 6	1.4	0.53de	26	NR 601-1-1-9	0.0	0.37e
9	CN 836-3-10	1.5	0.00	27	Radha 11	4.4	15.63b
10	Ghaiya 2	1.0	0.86cde	28	Radha 12	2.5	3.13cd
11	IR 51672	0.0	0.00	29	Radha 32	0.1	0.19e
12	IR 56382	0.0	0.10e	30	Radha 4	0.0	0.29e
13	IR 58115	0.0	0.37e	31	Radha 7	3.6	66.45a
14	IR 59624	0.0	0.13e	32	Radha 9	2.9	11.42b
15	Janaki	0.1	0.12e	33	Rampur Masuli	0.1	0.12e
16	Kalinga 3	1.2	1.29cde	34	Sabitri	1.6	0.00
17	Makwanpur-1	0.1	0.98cde	35	TOX 4004	0.0	0.00
18	Masuli	4.8	20.73b				

† *Lesion type was measured on a 0-5 scale; 0-2 = R, 2.1-3 =MR and 3.1-5 = S.*

‡ *Values followed by the same letter within the column are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.*

To create blast congenial environment, windbreaks around the experiment and inoculum plots inside the windbreak were managed as per international specifications (Jennings et al 1979). The seedbeds were raised up to 15 cm high above the ground to avoid flooding. The fertilizers were applied at the rate of 150 and 50 kg ha^{-1} of N and P_2O_5, respectively, at the time of planting. Five-gram seed of each line was seeded in a row of 0.5 m long. Weed management was done as needed. Disease evaluation was started 28 days after seeding and continued for three observations at 3-day interval. Six randomly selected

seedlings from each plot were rated using a 0-5 scale (Mackill and Bonman 1992). The final data was used to classify the genotypes as resistant (R), moderately resistant (MR) and susceptible (S) types.

The same genotypes were evaluated for resistance to neck blast under transplanted field conditions. The trial was laid down in a randomized complete block design with three replications. The plot size consisted of 10 rows of 1 m length. Single seedling per hill was planted at a spacing of 20- × 15-cm. The fertilizers were applied at the rate of 150 and 50 kg ha^{-1} of N and P_2O_5, respectively. Half N and all P_2O_5 were used as basal at the time of transplanting. The half of the rest nitrogen was uniformly broadcasted at 25 days after transplanting (DAT) and the rest on 40 DAT. Neck blast observation was done 7-10 days before harvesting. Individual panicles were rated as percentage of panicle infected in the neck. Analysis of variance was performed after logarithmic transformation to compare the genotypes for percent neck damage.

Experiment 2

Since the genotypes with 3 or 4 lesion types may have implications on partial resistance (Villareal et al 1980), the genotypes with MR and S lines of experiment 1, along with CO39 as international susceptible check, were re-evaluated for their relative partial resistance under the upland field conditions. Genotypes Chaite 6, Chaite 2, CN 836-3-10 and Kalinga 3, on an average with resistant reaction, also received 3 rating in a few plants in the experiment 1, therefore they were also included in experiment 2.

Five-gram seed of each genotype was planted in 0.5 m long row and each genotype was replicated thrice in randomized complete block design. The planting of spreader rows and fertilizer management was similar to the other upland experiments except windbreak and inoculum rows. Pieces of freshly blast infected leaves collected from the nearby rice fields were spread over the bed uniformly at 20 day after seeding in the evening. The trial bed was routinely sprinkled with water in between 0900 to 1000 h and 1700 to1800 h if it did not rain. After inoculation with freshly infected leaves, the bed was kept covered with polyethylene sheet from 1800 to 0900 h daily until the final observation.

Disease scoring was started from 28 day after seeding. Percentage of diseased leaf area was recorded as the procedure described by Kim et al (1988) and continued for five observations at the 3-day interval. The area under disease progress curve (AUDPC) was calculated using the formula outlined by Shaner and Finney (1977) and analyzed after logarithmic transformation and compared for levels of partial resistance among the genotypes.

Greenhouse Assays

The same 35 advanced rice lines used in experiment 1 (Table 1) along with CO39 as international susceptible check were seeded in the aluminium tray as described by Chaudhary (2001). The experiment was laid out in a randomized complete block design with two replications. The seedlings were inoculated at 21 day after seeding (3-4 leaf stage) with three representative virulent isolates. Inoculum preparation and inoculation were done as described by Chaudhary (2001). Spore suspension of 150 ml for 4 trays was used for inoculation. Disease scoring was done on the seventh day of inoculation on a 0-5 scale as outlined by Mackill and Bonman (1992). The sporulating lesions were counted in each leaf of individual seedlings. The number of sporulating lesions per seedling and the number of leaves at least with one sporulating lesion were calculated.

The rice genotypes were grouped into three categories; R, MR and S based on lesion types, as mentioned in experiment 1. The number of sporulating lesions and the number of leaves at least with one sporulating lesion are the measures for partial resistance to blast (Villareal et al 1981, Yeh and Bonman 1986, Bonman and Mackill 1988, Roumen 1992a, 1992b). These components were analyzed after logarithmic transformation to compare the genotypes for relative partial resistance to blast.

RESULTS AND DISCUSSION

Experiment 1

The rice genotypes varied for qualitative resistance to blast, as measured by lesion type (Table 1). The mean lesion type ranged from 0.0 to 4.8, with Masuli having the highest rating. Twenty-nine of the 35 genotypes showed R to blast. Three genotypes were MR and the rest were susceptible to blast under the field conditions.

The 35 genotypes also differed for neck blast resistance, as measured by percentage of neck infected (Table 1). Neck blast infection varied from 0.0 to 66.45 percent. Radha 7 showed the highest neck blast, whereas Masuli, Radha 11 and Radha 9 had higher percentage of neck blast. Sabitri, TOX 4004 and CN 836-3-10 were completely free from neck blast. Radha 12 had 7-folds less neck blast than that of Masuli. Similarly, NR 1558 and NR 601-1-1-5, the two promising rice lines had, respectively, 6 and 10 times less neck blast than that of Masuli. Other genotypes had lower neck damage due to blast (about > 20 times less) as compared to that of Masuli.

Experiment 2

The AUDPC values ranged from 1.6 to 410 and differed significantly among the 11 genotypes (Table 2). Masuli, CO39 and Radha 11 had higher AUDPC, indicating the higher level of susceptibility to leaf blast. Radha 7 and NR 1558 showed one-third and one-sixth of AUDPC, respectively, in comparison to CO39. The rest genotypes exhibited the AUDPC even significantly lower than NR 1558 suggesting that they have higher level of partial resistance to leaf blast.

Table 2. Area under leaf blast disease progress curve of the rice genotypes tested in upland field at Rampur, Nepal during the wet season of 2000

SN	Genotype	AUDPC[†]
1	BG 1165-2	17.2de
2	BG 1442	79.0bc
3	BW 306-2	5.0ef
4	Chaite 2	43.4cd
5	Chaite 6	1.6f
6	CN 836-3-10	16.4de
7	CO39	288.7a
8	Masuli	410.2a
9	Radha 11	12.0e
10	Radha 7	13.1e
11	Radha 9	153.9ab

[†] *AUDPC, Area under disease progress curve. Values followed by the same letters within the column are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.*

The rice genotypes differed significantly for leaf blast disease severity for all dates (Figure 1). Initially, the differences in blast severity among the rice genotypes were not so pronounced, but over time, it progressed faster in Masuli and CO39 compared to other genotypes (Figure 1). The blast progress in Radha 11 was slower than Masuli and CO39, but faster in comparison to other genotypes, which was reflected by its lower AUDPC than Masuli and CO39 but higher than other genotypes (Table 2). Radha 7 and NR 1558 exhibited intermediate disease progress over time. The rest of the genotypes had 5.0% terminal disease severity values, indicating their higher level of partial resistance.

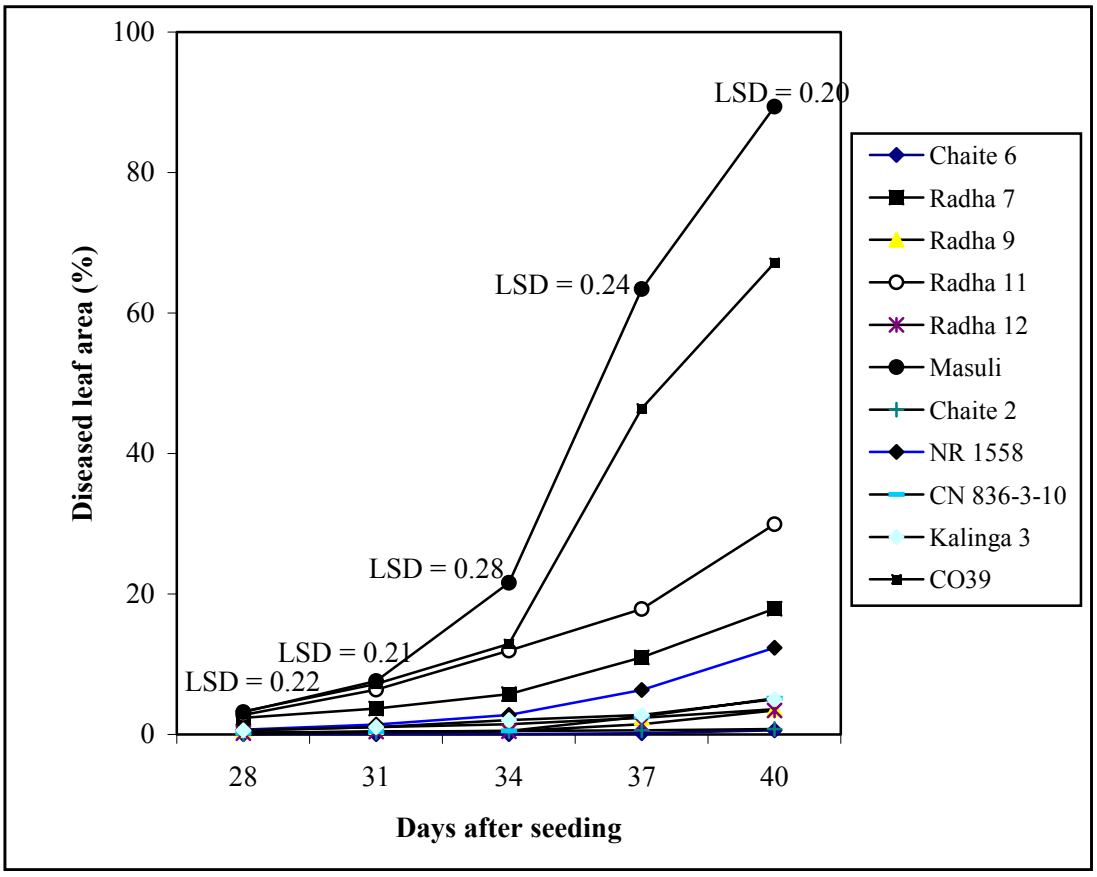

Figure 1. Leaf blast progress curves on rice genotypes evaluated under the upland seedbed conditions at Rampur, Nepal during September to October 2000.

The lesion type, neck blast percentage and AUDPC data suggest that Radha 7, Radha 9, Radha 11 and Masuli are susceptible genotypes. Under field conditions, all the advanced breeding lines possess higher level of resistance to leaf and neck blast. The genotypes having higher rating of leaf blast scored higher percentage of neck blast too; suggesting that compatible inoculum from leaf blast could serve for neck blast infection. A similar finding was reported by Hwang et al (1987). However, there was an exception that statistically, Radha 7 had the highest neck infection, although it had significantly less leaf blast than that of Masuli. This indicates that resistance to neck blast may be expressed in some genotypes of rice independently of that to leaf blast. Gangopadhyay and Padmanabhan (1987) and Chaudhary (1995) reported the similar results. Hence, evaluation of genotypes for both leaf and neck blast is required in field condition before recommendation for release.

Greenhouse assays

The rice genotypes differed for lesion type within and between isolates (Table 3). The lesion type varied from 0.0 to 5.0 in rice seedlings inoculated with different isolates. Isolate K59-1L produced sporulating lesions on 18 rice genotypes, N 22-1L on 13 and Kanto 51-11R on 11.

Table 3. Assessment of blast resistance in rice genotypes as measured by lesion type, the number of leaves at least with one sporulating lesion and the number of lesions per plant under inoculation with three isolates of *Pyricularia grisea* in the greenhouse at Rampur, Nepal during the dry season of 2001

SN	Genotype	K59-1L			N22-1L			Kanto51-11R		
		Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§	Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§	Lesion type†	Leaf with lesions/plant‡	Lesion number/plant§
1	BG 1165-2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	BG 1442	2.0	0.0	0.0	2.0	0.0	0.0	0.5	0.0	0.0
3	Bindeshwari	5.0	1.8ab	14.4abcd	3.5	1.0bcd	3.5def	1.5	0.0	0.0
4	BR 4684	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	BW 306-2	4.0	0.5c	1.5e	0.0	0.0	0.0	1.0	0.0	0.0
6	Chaite 2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	Chaite 4	1.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
8	Chaite 6	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	CN 836-3-10	4.5	1.5ab	10.5cd	4.0	0.9cde	2.4f	3.0	0.9c	1.7cd
10	CO39	5.0	2.5a	25.7ab	5.0	2.1a	12.1a	4.5	1.9b	17.4 a
11	Ghaiya 2	5.0	1.6ab	7.8d	4.0	1.3bc	4.2cde	3.0	0.5de	0.9de
12	IR 51672	1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
13	IR 56382	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
14	IR 58115	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
15	IR 59624	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
16	Janaki	4.0	0.4cd	0.9ef	0.5	0.0	0.0	0.0	0.0	0.0
17	Kalinga 3	3.0	0.6c	1.1ef	3.0	0.2fg	0.4h	3.0	0.4e	0.5 ef
18	Makwanpur-1	2.0	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0
19	Masuli	5.0	2.5a	27.1a	5.0	2.0a	7.8ab	5.0	2.6a	24.8a
20	MLT 119	3.0	0.3cd	1.0ef	0.0	0.0	0.0	0.5	0.0	0.0
21	NR 1249	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	NR 1487	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
23	NR 1488	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	NR 1558	4	0.5c	1.3e	3.5	1.1bc	2.5ef	3.0	0.8cd	3.6c
25	NR 1736-4-6	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
26	NR 601-1-1-5	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
27	NR 601-1-1-9	3.5	0.6c	1.6e	0.0	0.0	0.0	1.0	0.0	0.0
28	Radha 11	5.0	2.2a	18.7abc	4.0	1.9a	6.6bc	5.0	2.3ab	22.3a
29	Radha 12	4.5	1.3b	9.7cd	5.0	0.7d	4.0def	4.0	1.1c	6.7b
30	Radha 32	2.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
31	Radha 4	3.5	0.7c	2.6e	3.5	0.5ef	1.1g	0.0	0.0	0.0
32	Radha 7	5.0	1.9ab	13.9bcd	4.5	1.3b	7.5ab	4.5	1.7b	19.8a
33	Radha 9	5.0	2.4a	15.4abcd	4.0	1.3b	5.4bcd	4.5	2.0ab	27.0a
34	Rampur Masuli	3.0	0.6c	0.9ef	3.0	0.3f	0.3h	3.0	0.5e	0.9de
35	Sabitri	3.0	0.5c	1.4e	1.5	0.0	0.0	0.0	0.0	0.0
36	TOX 4004	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

† Lesion type measured on a 0-5 scale; 0-2 = R, 3 = MR and 3.5-5 = S.

‡ The average number of leaves per plant at least with one sporulating lesion; values followed by the same letters are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

§ The number of sporulating lesions per plant; values followed by the same letters are statistically similar at $P \leq 0.05$ level by Duncan's multiple range test.

The three isolates produced sporulating lesions in Ghaiya 2, Radha 7, Radha 9, Radha 11, Radha 12, Masuli, Rampur Masuli, NR 1558, CN 836-3-10, Kalinga 3 and CO 39. Isolate N22-1L produced sporulating lesion in Bindeswari and Radha 4 in addition to that of 11 genotypes. Isolate K59-1L produced sporulating lesions in Janaki, Sabitri, NR 601-1-1-9, BW 306-2 and MLT 119 in addition to the genotypes showing the sporulating lesions when inoculated with N22-1L.

The rice lines varied for the number of sporulating lesions per plant and the number of leaves with sporulating lesion per plant for an isolate (Table 3). Masuli and CO39 had always the highest number of lesions and leaves with at least one sporulating lesion.

Comparable to Masuli and CO39, Radha 7, Radha 9 and Radha 11 consistently exhibited lower number of sporulating lesions per plant and leaves with such lesions per plant inoculated with each of the isolates. Under field conditions, Radha 7 and Radha 9 showed lower leaf blast but similar or higher neck blast compared to Masuli. This indicated that greenhouse inoculation assays could precisely identify or

assess level of blast resistance in the genotypes; hence, greenhouse inoculation assays should be adopted for such works.

Ghaiya 2, Radha 12 and Rampur Masuli had significantly less number of lesions and fewer leaves with lesions compared to Masuli, indicating that they have a good level of partial resistance. Radha 12 had also significantly less percentage of neck blast and the slower disease development in the field conditions (Table 1 and 2).

Janaki and Sabitri had the lowest leaves with sporulating lesions. They also produced the least number of lesions per plant among the genotypes. This explains why these varieties have been observed consistent in the farmer's field. NR 601-1-1-9 and BW 306-2 also had significantly lower number of leaves having less number of lesions per plant compared to Masuli (Table 3). In most cases, the genotypes having higher number of sporulating lesions had the higher number of leaves with lesion, indicating positive association between them similar to that of earlier report (Roumen 1992a, Roumen 1996). This suggests that the number of leaves with sporulating lesions could be used as the easier and faster criterion for selection and improvement of partial resistance in rice to blast.

Majority of the rice lines possess major blast resistance genes. Among the recommended genotypes Chaite 2, Chaite 4, Chaite 6 and Makwanpur 1 showed hypersensitive reaction to all the three isolates, indicating that they have major genes for resistance to the blast pathogen.

All isolates produced sporulating lesions on seedlings of NR 1558, CN 836-3-10 and Kalinga 3. However, these lines had significantly fewer leaves with lower number of sporulating lesions as compared to Masuli. This indicates that these lines possess quantitative resistance according to report of Van der Plank (1968) that varieties with quantitative resistance are equally effective against all isolates.

The results suggest that evaluation for partial resistance in rice to blast could be done by the inoculation with a single virulent isolate. The similar recommendation was proposed by Imbe et al (2000). Due to high association between partial resistance and durable resistance to blast (Bonman and Mackill 1988), selection for partial resistance might help extend longevity of resistance in rice genotypes to blast. Also, the number of leaves with sporulating lesions could be used as a component of partial resistance to blast.

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Economic Management of Late Blight (*Phytophthora infestans* L.) of Potato in Eastern Tarai of Nepal

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ABSTRACT

Field experiments were carried out at Regional Agriculture Research Station, Tarahara in three consecutive years (1997-2000) during winter season to know the economic sprays of different fungicides to manage late blight disease of potato. Late blight susceptible cultivar of potato Kufri Sindhuri was used for the experiment. Krinoxyl gold (metalaxyl 8% and mancozeb 64%) at the rate of 1.5 g/l, Dithane M- 45 (mancozeb 75%) @ 0.3% and Bordeaux mixture @ 10 g copper sulfate and 10 g lime/l of water and their different combinations were tested in randomized complete block design with three replications. Terminal disease severity was the highest (7.9) on 0-9 scale disease rating in unsprayed check and it was significantly higher than those of other fungicides sprays. Plots with three sprays of Dithane M- 45 @ 0.3% recorded the lowest (2.4) terminal disease severity. Disease development was the fastest in the unsprayed plot compared to all other treatments. Similarly apparent infection rate was the highest in unsprayed treatment. Area Under the Disease Progress Curve was also the highest in unsprayed plot and it was significantly higher than those of other treatments. Tuber yield was the lowest (3.93 kg/4.5 m^2 plot in unsprayed and the highest (6.08 kg), in the plot receiving four sprays of Dithane M-45 @ 0.3 % and this was at par with the tuber yield of plots receiving two and three sprays of Dithane M-45. Benefit cost ratio was the highest (1.54) in case of two sprays of Dithane M-45 @ 0.3% at 10 days intervals. All others fungicide spays were uneconomical under Eastern Tarai condition.

Key words: Eastern Tarai, economic spray, Dithane M-45, late blight management, potato

INTRODUCTION

Potato (*Solanum tuberosum*) is an important stable food in high hills and is the best vegetable crop in mid hill and Terai (plain area) of Nepal (ABPSD 2000). Late blight of potato, caused by *Phytophthora infestans* (Mont) de Barry is the most important disease of potato worldwide (Hardy et al 1995). It is the most destructive disease of potato in India (Singh 1996). The disease causes heavy losses in susceptible cultivar of potato annually in mid and high hills of Nepal but its occurrence in Tarai is restricted to every third year when weather is conducive to the disease development. Many fungicides, contact and systemic are available to manage the disease and farmers are using them many times to protect their crops. There is a tendency of development of resistant fungal races against use of systemic fungicides (Singh 1996). Josepovits and Dobrevalszky (1985) reported that the use of fungicides with different modes of action is the best strategy to delay build up of resistance. Farmers of this area are not aware of economic number of sprays of different fungicides. Singh (1996) reported that one spray of Ridomil MZ @ 0.25% plus six sprays of Dithane M-45 @ 0.2 % gave the highest cost benefit ratio in northwestern hills of India. Farmers in this area spray four to five times Dithane M- 45 to manage the disease. This study was undertaken to determine economic number of sprays of different fungicides to manage late blight disease of potato in the Eastern Tarai condition of Nepal.

MATERIALS AND METHODS

Field experiments were conducted in three years (1997/98-1999/2000) during the winter season at Regional Agriculture Research Station (RARS), Tarahara, situated at 100 masl in the Tarai of Eastern Development Region of Nepal. In all the experimental seasons trials were planted during the first week of Nov. Kufri Sinduri was used as susceptible check test variety of potato. The trial was carried out in complete randomized block design with three replications and individual plot size of 3- × 3-m. The trial was fertilized at the rate of 100:100:60 kg NPK/ha. Net plot was 1.8- × 2.5-m. Three fungicides Krinoxyl gold @ 1.5 g/l (metalaxyl 8% and mancozeb 64%), Dithane M-45 @ 3 g/l (mancozeb 75%) and Bordeaux mixture 10 g of copper sulfate and 10 g of lime/l of water were used in different combinations. All fungicides were used when first symptoms of late blight disease was observed (first week of January). Fungicides were sprayed at 10 days interval. Disease severity was scored using CIP 1-9 scale Hardy et al 1995). Terminal disease score (observed first week of February), tuber yield per net plot and Area Under the Disease Progress Curve (AUDPC) were analyzed using MSTAT-C computer program. Apparent infection rate (Vander Plank 1963), which is given by formula $!/t_2\text{-}t_{1x}$ loge $x_2(1\text{-}x_1)/x_1(1\text{-}x_2)$ where t_2 and t_1 are date of disease observations and x_1 and x_2 are percent disease score divided by hundred and Area under the Disease Progress Curve (Shaner and Finney 1997) given by $(t_1+t_2)x\ (x_1+x_2)/2$ where t_1 and t_2 are same as in apparent rate of infection and x_1 and x_2 are disease score value of that date, were calculated. Benefit cost ratio of number of sprays of each treatment was calculated by taking the ratio of total values in term of money of additional tuber yield of a treatment over unsprayed check and total cost of spray of fungicide involved in that treatment.

RESULTS AND DISCUSSION

Effect of fungicides on disease severity and disease development curves

All the treatments were significantly superior to unsprayed check in reducing terminal disease severity. Plot receiving three sprays of Dithane M-45 @ 0.3% was able to record the lowest disease severity, 2.4 on CIP scale compared to unsprayed check, 7.9 (Table 1). It was superior to all other fungicides spray treatments in reducing terminal disease severity. Two sprays of Dithane M-45 @ 0.3% had mean terminal disease severity of 3.2 on CIP scale and this was at par with two sprays of Krinoxyl gold @ 1.5 g/l, four sprays of Krinoxyl gold, one spray of Krinoxyl gold plus three sprays of Dithane M-45, two sprays of Krinoxyl gold plus two sprays of Dithane M-45, one spray of Krinoxyl gold plus three sprays of Bordeaux mixture, two sprays of Krinoxyl gold plus two sprays of Bordeaux mixture and three sprays of Bordeaux mixture. Three sprays of Krinoxyl gold, four sprays of Dithane M-45, three sprays of Krinoxyl gold plus one spray of Dithane M-45 and four sprays of Bordeaux mixture were superior to all other treatments in reducing mean terminal disease severity (Table 1).

Table 1. Effect of fungicide sprays on disease severity, AUDPC, apparent infection rate (r), tuber yield and benefit cost ratio (1997/98-99/2000)

TN	Description	Terminal disease score	AUDPC	r	Tuber yield, t/ha
1	Control (water spray only)	7.9	123.9	0.275	8.52
2	Krinoxyl gold @ 1.5 g/lit - 2 sprays	3.0	50.9	0.065	12.52
3	Krinoxyl gold @ 1.5 g/lit - 3 spray	2.9	51.2	0.081	11.58
4	Krinoxyl gold @ 1.5 g/lit - 4 sprays	3.0	53.6	0.064	10.54
5	Dithane M- 45 @ 3 g/lit - 2 spray	3.2	58.7	0.072	12.98
6	Dithane M- 45 @ 3 g/lit - 3 sprays	2.4	53.3	0.042	12.75
7	Dithane M- 45 @ 3 g/lit - 4 sprays	2.9	54.2	0.086	13.50
8	Krinoxyl gold 1 spray plus Dithane M-45 - 3 sprays	3.4	55.2	0.072	11.60
9	Krinoxyl gold 2sprays plus Dithane M-45 - 2 sprays	3.0	52.1	0.081	9.50

TN	Description	Terminal disease score	AUDPC	r	Tuber yield, t/ha
10	Krinoxyl gold 3 sprays plus Dithane M-45 - 1 spray	2.9	58.3	0.055	10.54
11	Krinoxylgold-1spray+ Bordeauxmixture - 3 sprays	3.0	61.4	0.055	10.42
12	Krinoxyl gold 2 spray + Bordeux mixture - 2 sprays	3.0	52.5	0.098	12.25
13	Krinoxyl gold3sprays + Bordeaux mixture - 1 spray	3.0	57.4	0.068	10.98
14	Boredeaux mixture - 2 sprays	3.9	73.7	0.098	12.0
15	Bordeaux mixture - 3 sprays	3.3	62.7	0.071	10.51
16	Bordeaux mixture - 4 sprays	2.9	51.9	0.046	11.85
	F test	**	**		**
	CV, %	25.8	21.12		23.85
	SED	0.29	4.27		0.41

Late blight disease was developed faster in unsprayed check compared to all other treatments. It was very fast after 3rd week of January and reached a maximum at first week of Feb. All the treatments except unsprayed check had similar type of disease development curves (Figure 1). This indicated that all the fungicides under test were equally effective in managing late blight disease of potato under Tarai condition.

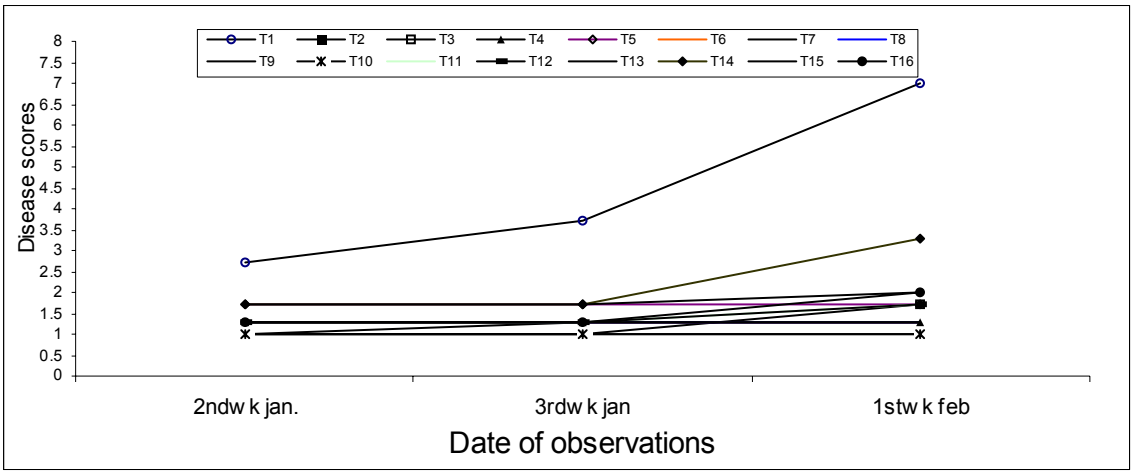

Figure 1. Disease development curves of different fungicide sprays.

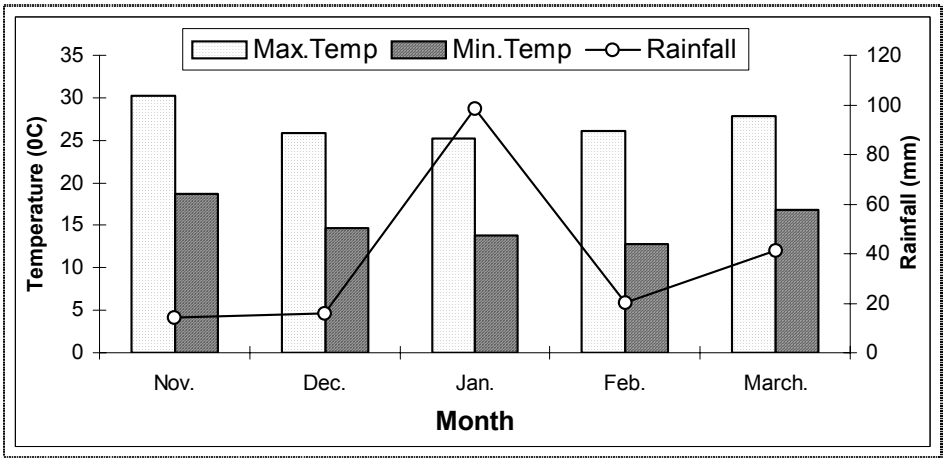

Figure 2. Mean weather parameter of three years during potato growth period.

Prevailing weather during potato growth period influences relative humidity inside the crop canopy and hence favor the disease spread and development in the crop. The canopy of crop growth was medium and that helped in quicker drying of relative humidity and dew presence on leaf surface in the plot. This had considerably reduced the number of sprays of different combinations of fungicides in reducing terminal disease severity. Rainfall received in January had enhanced the disease development. In Jan and Feb minimum temperature was around 15^{o}C and maximum temperature 25^{o}C (Figure 2). Disease development and number of protective fungicide sprays in potato depend on canopy of the crop growth and weather conditions of crop growth period.

Table 2. Benefit cost ratio analysis

TN	Tuber yield, kg/plot	Additional tuber yield, kg/plot	Value of additional tuber yield, Rs	Additional cost of spray/plot, Rs	Benefit cost ratio
T1	3.833	0.0	0.0	0.0	-
T2	5.633	1.8	9.0	13.23	0.68
T3	5.211	1.378	6.09	19.92	0.35
T4	4.744	0.911	4.56	26.56	0.17
T5	5.844	2.011	10.06	6.52	1.54
T6	5.756	1.923	9.62	9.78	0.98
T7	6.078	2.245	11.23	13.04	0.86
T8	5.256	1.423	7.12	16.42	0.43
T9	4.278	0.445	2.23	19.8	0.11
T10	4.744	0.911	4.56	23.58	0.19
T11	4.689	0.856	4.28	23.59	0.18
T12	5.511	1.678	8.39	24.58	0.34
T13	4.944	1.111	5.56	25.57	0.22
T14	5.4	1.576	7.84	11.3	0.69
T15	4.733	0.9	4.5	16.95	0.27
T16	5.333	1.5	7.5	22.6	0.33

Potato, Rs 5.00/kg. Dithane M-45, Rs 420/kg. Krinoxyl Gold, Rs 232/100g. Copper sulfate, Rs 170/kg. Lime, Rs 25/kg. Labor charge, Rs 60/8 hrs.

Effect of fungicides on apparent infection rate and AUDPC

Three sprays of Dithane M-45 had the lowest apparent infection rate followed by four sprays of Bordeaux mixture, three sprays of Krinoxyl gold plus one spray of Dithane M-45 and one spray of Krinoxyl gold plus three sprays of Bordeaux mixture. Two sprays of Krinoxyl gold, four sprays of Krinoxyl gold and three sprays of Krinoxyl gold plus one spray of Bordeaux mixture had similar apparent infection rates (Table 1). However, their AUDPC differ significantly. The highest apparent infection rate was in the case of unsprayed check (0.275). Two sprays of Dithane M-45, one spray of Krinoxyl gold plus three sprays of Dithane M-45 and three sprays of Bordeaux mixture had similar apparent infection rates but their AUDPC differed significantly among themselves (Table 1).

Area Under the Disease Progress Curve (AUDPC) was the highest in case of unsprayed check and all other treatments had significantly lower AUDPC compared to unsprayed check (Table 1). AUDPC of the plots receiving two sprays of Krinoxyl gold, three sprays of Krinoxyl gold, four spray of Krinoxyl gold, three sprays of Dithane M-45, four sprays of Dithane M-45, one spray of Krinoxyl gold plus three sprays of Dithane M-45, two sprays of Krinoxyl gold plus two sprays of Dithane M-45, two sprays of Krinoxyl gold plus two sprays of Bordeaux mixture and four sprays of Bordeaux mixture were statistically at par. AUDPC of plot receiving two sprays of Dithane M-45 was significantly higher to all above mentioned treatments but significantly lower to the AUDPC of plot receiving two and three sprays of Bordeaux mixture Krinoxyl gold one spray plus three sprays of Dithane M-45 and unsprayed

check. This indicates that the fungicides under test were equally good in managing the late blight disease of potato.

Effect of fungicides on tuber yield

Unsprayed plot yielded significantly the lowest (8.52 t/ha) compared to all other treatments ranging the tuber yield of 9.5 to 13.5 t/ha (Table-1). However tuber yields of plots receiving four spray of Dithane M-45 was the highest but at par with plots receiving two sprays of Krinoxyl gold, two sprays of Dithane M- 45 and three sprays of Dithane M- 45. All other treatments were inferior in respect to tuber yield to above three mentioned treatments. This indicates that Dithane M-45 had effect on increasing tuber yield in addition to lowering the late blight disease severity. Results of this experiment showed that use of Dithane M-45 for the management of late blight of potato was beneficial for the potato growers of Eastern Tarai.

Benefit cost ratio of sprays of fungicides

The benefit cost ratio of different combinations of fungicide sprays indicated that two sprays of Dithane M-45 @ 0.3% gave the highest ratio (1.54), followed by three (0.98) and four sprays (0.86) of Dithane M-45. Singh (1996) reported that one spray of Ridomil MZ plus six sprays of Dithane M-45 gave the highest cost benefit ratio in north-western hill of India. The weather condition of north-western hill of India during potato growing period is different than that of Eastern Tarai. All other fungicide sprays tested in this study proved uneconomical in managing late blight disease of potato. However efficacy of fungicide treatment combinations in controlling disease were at par (Table 2) Even three and four sprays of Dithane M-45 were uneconomical in managing late blight disease of potato. Late blight severity did not reach at even 8 score. This is mainly because of medium crop canopy and that might lead to relatively slow disease development in all the years of experimentation.

Under the condition of Tarahara two sprays of Dithane M-45 @ 0.3% will be the most economical fungicide spray schedule for the management of late blight disease of potato in the first week of Nov planted potato in most years of potato cultivation. However, in certain year, three sprays of Dithane M-45 may be needed to manage late blight disease of potato. All other fungicides available in the market are effective in managing the late blight disease of potato but would not be of cost effective in managing late blight disease of potato in Eastern Tarai condition of Nepal.

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Role of weather on *Alternaria* Leaf Blight Disease and its effect on Yield and Yield Components of Mustard[1]

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ABSTRACT

Alternaria leaf blight disease caused by *Alternaria brassicae* in mustard (*Brassica juncea* (L) Czern and Coss) was studied in two crop seasons, 1992 and 1993 in Nepal at Nawalpur, Sarlahi (Tarai**)** and Khumaltar, Lalitpur (mid hill). At Nawalpur, epidemics of the disease was recorded for both seasons. Weather conditions like humidity, temperature and frequent rainfall played key role for the epidemics. In experimental fields, the disease appeared first in mid-December when the relative humidity was more than 80% with maximum temperature ranging between 18-25^{0}C and minimum between 10-14^{0}C. At Khumaltar, incidence of the disease was low in both seasons due to low average temperature from December to February. Among cultivars, Krishna and Pusabold were less susceptible than Varuna. Both mancozeb and iprodione had effectively reduced disease in the sprayed plots and increased seed yield by 48% and 130% respectively. The correlation between disease severity and yield, and yield components was negative and highly significant. Average yield loss was estimated to be in the range of 32 to 57%. Seed infection was also significantly higher in non sprayed treatment than sprayed one. The disease showed a negative effect on oil content causing losses on oil between 4.2 to 4.5%.

Key words: *Alternaria brassicae*, epidemics, iprodione, mancozeb, mustard, oil content

INTRODUCTION

Leaf blight caused by *Alternaria brassicae* (Berk.) Sacc. is an important disease of mustard (*Brassica juncea* (L.) Czern and Coss) and rapeseed *(B. campestris* L. var Toria*)* in the Indian sub-continent. In Nepal, our observations show that the disease occurs as a regular feature in the plains (Tarai and inner Tarai) causing heavy damage to the crops but in the midhill, the disease incidence is low. Severe infection causes substantial yield loss as a result of early defoliation, flower-bud abortion, premature ripening, siliquae dehiscence and seed shriveling (Seidle et al 1995). Yield losses of 20 to 30% were recorded in Canada (McDonald 1959, Conn et al 1990). In India, losses of 15 to 71% were reported (Kadian and Saharan 1983; Singh and Bhowmik 1985, Kumar 1986, Ram and Chauhan 1998). Kolte et al (1987) reported the losses in 1000-seed weight of yellow sarson and mustard of 23% and 24% respectively. No factual data on yield loss due to the disease on rapeseed or mustard is available in Nepal. However, losses in yield of both rapeseed and mustard due to *A. brassicae* have been arbitrarily estimated between 20 and 50% from Chitwan (Tarai) district of the country (ATSP, USAID/HMG-NARC 1993) but the data on effect of the disease on different yield components are not available. The disease reduces the oil content of mustard. In Canada, losses in oil content up to 4.8% have been reported (Degenhardt et al 1974) but higher losses (14.6-36 %) were recorded in India (Ansari et al 1988).

[1] The paper is based on PhD Thesis of the first author submitted to Royal Veterinary and Agricultural University (KVL), Copenhagen, Denmark.

The effect of environmental factors, temperature (15-25^{O}C), relative humidity (>80%) and leaf wetness (rain or dew) for 4-24 h, for the disease development and its epidemics have been reported from some countries like Canada (Degenhardt et al 1982), United Kingdom (Humpherson-Jones and Phelps 1989, Mridha and Wheeler 1993, Hong and Fitt 1995) and India (Ansari et al 1989). No such information is available in Nepal. The present investigation was therefore, undertaken to study the effect of environmental factors on *Alternaria* leaf blight and its effect on seed yield, yield components and oil content of mustard cultivars commonly grown in Nepal.

MATERIALS AND METHODS

Field experiments were conducted during two growing seasons, 1992 and 1993 at two locations, one in the mid hill (Khumaltar, Lalitpur, 27^{O} 42' N and 85^{O}20' E) and the other in the plain (National Oil Research Program (NORP), Nawalpur, Sarlahi, 27^{O} 48' N and 85^{O} 57' E). These two different geographical regions were chosen because of their different climatic conditions. Besides, in these regions many different brassicaceous crops including mustard are grown intensively. Three commonly grown mustard cultivars, Pusabold, Varuna and Krishna were used in the experiments. In the first year, seeds received from National Bureau of Plant Genetic Resources (IBPGR**),** India were used, as the seed lot was found free from infection of *Alternaria* species. In the subsequent year, seeds of treated plots from Khumaltar were used. Prior to sowing, the seeds were tested by blotter method (Limonard 1966) and found free from infection of *Alternaria* species. A susceptible yellow sarson cultivar, Psy-6 (*B. campestris* var. *sarson)* was used for border planting in which, seed-infection level of *A. brassicae* was 8-10%.

The experiments were carried out in factorial Randomized Complete Block Design (RCBD) with 6 replications. The factorial combination was 2 × 3 (treatments × cultivars). Each cultivar had two plots in each replication, one was fungicide-treated and the other untreated. Each plot was 3.75 x 4 m with 10 rows, 40 cm space between rows, 60 cm distance from plot to plot and 75 cm between replications. The whole experimental block was surrounded by a single border row of yellow sarson at a distance of 60 cm. At both locations and years, seeds were sown at 6 kg/ha in the last week of October. Chemical fertilizers (NPK) were applied as per recommendation 60:40:40 kg/ha (NARC 1988). After 2-3 weeks of emergence, seedlings were thinned to 25 per row, each at a distance of 15 cm. Weeding, irrigation and other cultural practices were done during the cropping period.

Two fungicides were applied: Dithane M-45 (mancozeb) @ 1.2 kg/ha ai in 1992 and Rovral 50 WP (iprodione) 0.6 kg/ha ai in 1993. A hand compression sprayer 'Marut' of 9 l capacity (American Spring & Pressing Works Ltd, Mumbai, India) was used for spraying. The first spraying was done in the 2nd week of December when the disease first appeared in the experimental plots. Subsequent sprays were done at an interval of 10-12 days. Total number of sprayings was 5 at Nawalpur and 2 at Khumaltar. At both locations, each plot, except the controls, received about 600-700 l/ha of fungicide solution each time. The control plots were sprayed with plain water. The disease was assessed once a week from the date of first appearance in the leaves and the assessments continued until total defoliation in the untreated plots. Pod infection was scored at 15 days intervals up to mid February. Disease scoring in the leaves and pods was done in 25 randomly tagged plants in each plot using a 0-5 scale (0 = no infection, 1 = 1-5% area covered by the disease, 2 = 6-10% area covered, 3 = 11-20% area covered, 4 = 21-30% area covered, 5 = 31-100% area covered). A set of pictorial disease scale 0-5 in the leaves and pods are also shown in Figure 1A and B.

The percentage of disease for each plot was calculated using the formula of Townsend and Heuberger (1943) as,

$$P = \frac{\Sigma (n \times v)}{5N} \times 100$$

P = disease percent, n = number of plants in each index, v = numerical value of each index, N = total number of plants.

Area under the disease progress curve (AUDPC) was calculated according to Shaner and Finney (1977),

$$AUDPC = \sum_{i=1}^{n} [(Y_{i+1} + Y_i)/2][X_{i+1} - X_i]$$

In which, Y_i = disease index (per unit) at ith observation, X_i = time (day) and n = total number of observations.

One day before harvest, approximately 300-400 siliquae were collected from each plot from different heights (lower, middle and top) of racemes of 10 tagged plants. These siliquae were used for measuring 100-siliquae weight and for counting average number of seeds per siliquae. In the second year, the number of siliquae and the height of the tagged plants were also recorded. Harvest was done from net area of 3 × 2.75 m of each plot. Total yield and 1000-seed weight were measured. The relationship between seed yield and disease severity was calculated using a linear regression model. Yield loss in percent was calculated according to Walker (1990),

$$W = \frac{(m - y)}{m} \times 100$$

Where, W = yield loss (%), m = yield in sprayed plot, y = yield in unsprayed plot.

Four hundred seeds of each plot were examined for infection of *A. brassicae* by the blotter method. Seed samples of 16 g per plot were used for measuring oil content by the Near-Infrared Reflectance Spectroscopy (NIR), InfraAlyzer 2000, Bran + Luebbe GmbH, Norderstadt Germany (Rahman et al 2001).

Daily air temperature and relative humidity were recorded with a thermohygrograph installed 2 meters above ground level and about 20 meters away from the experimental field. The recording sheet was replaced every week. Rainfall data was also collected from the nearest meteorological station. Data were analyzed statistically using ANOVA for factorial experiment in the MSTAT-C (Freed et al 1988).

RESULTS

Disease and weather factors

At Khumaltar, during December-February, maximum temperatures were 15-20^{O}C, minimum temperatures 1- 5^{O}C, relative humidity >80% and total rainfall was 49.8 mm in 1992 and 27.4 mm in 1993 (Table 1). In both years, *Alternaria* leaf blight incidence was very low. Only a few spots were observed in the lower leaves in the third week of January, which increased slightly in February. For both seasons, the disease severity did not exceed 5%. No symptom was observed in the siliqua, and the difference in yield of sprayed and unsprayed plots were quite less. Therefore, only the data from Nawalpur were discussed.

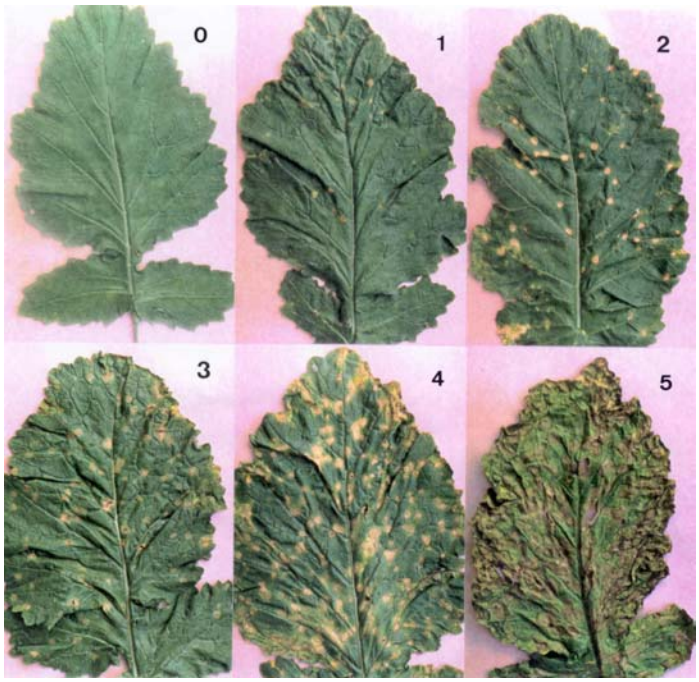

Figure 1A. *Alternaria* leaf blight disease index on leaves of mustard cv Krishna, 0 = no symptom, 1 = 1-5% area covered by disease, 2 = 6-10% area covered, 3 = 11-20% area covered, 4-21-30% area covered, 5 = 31-100% area covered.

Figure 1B. *Alternaria* leaf blight disease index on pods of mustard cv Krishna, 0 = no disease spots, 1 = 1-5% area covered by spots, 2 = 6-10% area covered, 3 = 11-20% area covered, 4 = 21-30% area covered, 5 = 31-100% area covered.

Table 1. A comparison of meteorological data between Khumaltar-Lalitpur and Nawalpur-Sarlahi, 1992-93

Location	Time period	Temperature range, °C		Relative Humidity range, %	Rainfall, mm
		Maximum	Minimum		
Khumaltar	Oct - Nov	20.6 - 24.1	4.1 - 12.5	74.5 - 82.6	0
	Dec - Feb	15.5 - 19.8	1.4 - 4.8	78.2 - 94.3	27.4 - 49.8
Nawalpur	Oct - Nov	31.1 - 33.6	16.1 - 25.4	65.3 - 72.1	0
	Dec - Feb	18.4 - 26.6	10.3 - 14.5	60.5 - 95.6	8.6 - 46.7

At Nawalpur, symptoms of *Alternaria* leaf blight were first observed on cotyledonary leaves of a few border plants of yellow sarson (cv Psy-6) during the second week of November. However, the disease did not progress further until early December. After emergence of seedlings, the weather was slightly warm and dry with mean daily temperatures between 20 and 30^{O}C and average relative humidity was less than 70% during October-November.

In the experimental plots, the disease appeared as necrotic spots on the lower leaves of the stage GS3 (Harper and Berkenkamp 1975) in the second week of December. The disease increased rapidly as daily temperature gradually decreased and relative humidity increased steadily during December-February. In this period, daily maximum temperature ranged from 18 to 27^{O}C, minimum temperature 10-14^{O}C and relative humidity 60-96%. Total rainfall during those three months in 1992 was 46.7 mm (Table 1) and 8.6 mm in 1993. The rainfall along with heavy dew deposition provided wetness on leaves for about 14-15 h a day.

In both years, the disease progress was much faster in unsprayed plots than in fungicide-sprayed plots (Figure 2). In unsprayed plots, the disease severity reached high in the lower leaves followed by defoliation within two weeks of infection. A vertical gradient of disease infection was developed in the plants. As the disease progressed, spots appeared on the leaves of middle and upper levels of plants and the defoliation continued. After five weeks, leaves of all plants were shed in the unsprayed plots. In the sprayed plots, disease progress was much slower and the leaves remained attached to the plants for a longer period until senescence. Disease severity was slightly higher in the first season than in the second season that might be due to rainfall for 3 consecutive days in the last week of December 1992. In both years, disease progress in the cv Varuna was slightly faster than in the other two cvs, Pusabold and Krishna (Figure 2) indicating that cv Varuna is more susceptible than the other two. On pods, the disease appeared by mid January in both years. The weather conditions continued to be favorable for the disease development. The disease gradient in racemes followed the one observed in the foliage. In the early stage of infection, the spots were more frequent in the lower pods, lesser in the middle and much less in the upper pods. After the second week of February, disease development was slow in the unsprayed plots, probably due to gradual decrease in the relative humidity (60-65%) and rise in the day temperatures (26-27^{O}C). Disease symptoms on the pods in sprayed plots were lower than in unsprayed plots (Table 2).

The ANOVA showed that there was no significant interaction between cultivars and treatments indicating that the cultivars differences were not significantly affected by the treatments and the treatments effect did not differ significantly with the cultivars tested. Main effects, both of cultivars and of treatments were significant. Hence the overall main effects of the cultivars and the treatments were compared.

Table 2. Area under disease progress curve (AUDPC), seed yield and yield loss due to *Alternaria* leaf blight for three mustard cultivars at National Oilseeds Research Program, Nawalpur in 1992 and 1993

Cultivar/Treatment	1992				1993			
	AUDPC in leaf	AUDPC in pod	Seed yield, kg/ha	Seed yield Loss, %	AUDPC in leaf	AUDPC in pod	Seed yield, kg/ha	Seed yield Loss, %
Pusabold								
Sprayed	67.57	43.42	746.90		30.30	16.20	1270.00	
Unsprayed	142.89	74.88	474.30		120.83	69.49	505.70	
Average	105.23 b	59.15 b	610.60 a		75.56 b	42.85 b	887.85 b	
Varuna								
Sprayed	71.55	52.53	532.80		36.17	21.78	1142.00	
Unsprayed	148.63	85.15	392.12		130.96	81.36	487.70	
Average	109.99 a	68.84 a	462.46 b		83.56 a	51.57 a	814.85 b	
Krishna								
Sprayed	65.59	38.45	749.50		28.57	14.77	1394.00	
Unsprayed	137.70	70.80	498.80		114.49	62.65	654.90	
Average	101.65 b	54.63 b	624.15 a		71.53 b	38.71 b	1024.45 a	
Sprayed (Av over 3 cvs)	68.64 b	44.80 a	676.40 a	32	31.68 b	17.58 b	1268.50 a	57
Unsprayed (Av over 3 cvs)	143.07 a	76.94 b	455.07 b		122.09 a	71.17 a	549.43 b	
P-value								
A (Cultivar)	(0. < 001)	(0. < 001)	(0. < 001)		(0 <. 001)	(0. < 001)	(0.002)	
B (Treatment)	(0. < 001)	(0. < 001)	(0. < 001)		(0. < 001)	(0. < 001)	(0. < 001)	
AB (Interaction)	ns	ns	ns		ns	ns	ns	
$LSD_{(0.05)}$ for cultivars	3.585	4.99	65.91		4.259	4.34	109.2	
$LSD_{(0.05)}$ for treatment	2.927	2.91	53.81		3.477	3.12	89.18	
CV, %	4.04	13.34	13.85		6.59	8.04	14.29	

Means in a column with different letters are significantly different at P = 0.05.

Effect of disease severity on seed yield and yield components

Disease measured using Area Under Disease Progress Curve (AUDPC) for both leaves and pods was significantly higher in all cultivars in the unsprayed plots than in sprayed plots (Table 2). The disease severity in the leaves and pods of cv Varuna was higher than in cvs Pusabold and Krishna. The average seed yield of all cultivars was significantly higher in sprayed than in unsprayed plots. In the first year, the yields of cvs Pusabold and Krishna were similar but that of Varuna was significantly lower. In the second year, however, cvs Pusabold and Varuna were similar but the yield of Krishna was significantly higher than that of Varuna. The average seed yield loss was 32% in 1992 and 57% in 1993 (Table 2). The correlation between seed yield and disease severity was negative and highly significant. Furthermore, the regression line was y = 919 - 6.9 x in 1992 and y = 1548.5 - 16.9 x in 1993. Based on a regression analysis, it was calculated that for 1% increase of *Alternaria* leaf blight, the yield losses ranged from 6.87 to 16.88 kg/ha in 1992-1993. Spraying with mancozeb, the average yield increase was 48% in 1992 and by spraying iprodione, 130% in 1993 (data not sown).

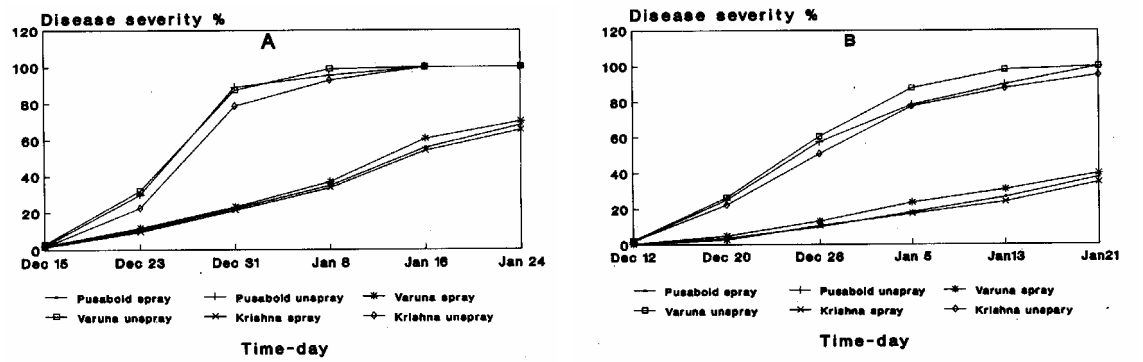

Figure 2. Disease Progress Curves of *Alternaria* leaf blight in the leaves of mustard cvs Pusabold, Varuna and Krishna at National Oilseeds Research Program, Nawalpur, Sarlahi (A, 1992 and B, 1993).

Alternaria leaf blight affected yield components of mustard considerably (Table 3). In comparing sprayed and unsprayed treatments, the disease significantly reduced 1000-seed weight, 100-siliqua weight, number of seed per siliqua for both years and number of siliqua per plant and plant height in the second year. The simple correlation coefficients between various yield components and disease severity in leaf and siliqua were negative and significant (Table 4**)**. Disease severity of both leaf and sliliqua was negatively correlated to 1000-seed weight and 100-siliqua weight and less to the other components indicating that the effect of *Alternaria* leaf blight is closely associated with these components.

Table 3. Effect of *Alternaria* leaf blight on yield components of three mustards cultivars grown under field conditions at National Oilseeds Research Program, Nawalpur in 1992 and 1993

Cultivar/Treatment	1992			1993				
	1000-seed weight, g	100-siliquae weight, g	Number of seeds/siliqua	1000-seed weight, g	100-siliquae weight, g	Number of seeds/siliqua	Number of siliqua/plant	Plant height, cm
Pusabold								
Sprayed	4.30	9.86	11.85	6.57	12.26	12.62	112.48	188.66
Unsprayed	3.33	7.76	10.72	4.57	9.09	11.72	77.49	173.66
Average	3.82 a	8.81a	11.28 b	5.57 a	10.67 a	12.17 a	94.99 ab	181.16 a
Varuna								
Sprayed	2.78	7.69	11.00	4.37	8.76	11.58	98.97	184.83
Unsprayed	2.13	5.84	10.08	3.37	6.86	10.57	71.99	168.33
Average	2.46 b	6.76 c	10.54 c	3.87 b	7.81 c	11.08 b	85.48 b	176.58 b
Krishna								
Sprayed	4.38	8.69	11.90	4.56	9.80	12.52	125.83	195.66
Unsprayed	3.04	6.74	11.06	3.48	7.45	11.73	82.59	180.00
Average	3.71 a	7.71 b	11.48 a	4.02 b	8.63 b	12.13 a	104.21 a	187.83 a
Sprayed (Av over 3 cvs)	3.82 a	8.74 a	11.58 a	5.17 a	10.27a	12.24 a	112.43 a	189.72 a
Unsprayed (Av over 3 cvs)	2.83 b	6.78 b	10.62 b	3.81 b	7.80 b	11.34 b	77.36 b	173.99 b
P-value								
A (Cultivar)	(0. < 001)	(0. < 001)	(0.05)	(0. < 001)	(0. < 001)	(0. < 001)	(0.01)	(0.005)
B (Treatment)	(0. < 001)	(0. < 001)	(0.02)	(0. < 001)	(0. < 001)	(0. < 001)	(0. < 001)	(0. < 001)
AB (Interaction)	ns	ns	ns	ns	ns	ns	ns	ns
$LSD_{(0.05)}$ for cultivars	0.298	0.837	0.059	0.275	0.614	0.559	17.80	6.747
$LSD_{(0.05)}$ for treatment	0.244	0.683	0.049	0.224	0.501	0.456	14.53	5.509
CV, %	10.69	12.81	7.40	7.28	8.05	5.64	22.33	4.42

Means in a column with different letters are significantly different at P = 0.05.

Table 4. Simple correlation coefficients for seed yield, yield components and disease severity of mustard grown at National Oil Research Program, Nawalpur, 1992 and 1993

Seed yield and yield components	1992		1993	
	Leaf disease severity	Siliquae disease severity	Leaf disease severity	Siliquae disease severity
Seed yield	- 0.738***	- 0.760***	- 0.937***	- 0.936***
1000-seed weight	- 610***	- 0.711***	- 0.636***	- 0.675***
Number of siliqua/plant	-	-	- 0.564***	- 0.601***
Number of seeds/siliqua	- 0.458**	- 0.466**	- 0.550***	- 0.630***
100-siliquae weight	- 0. 655***	- 0.690***	- 0.686***	- 0.737***

, *, Significant at 1% and 0.1% respectively.

Seed infection and oil content

In the first year, average seed infection in cvs Puseabold and Varuna were similar but in cv Krishna, it was significantly lower than other two cultivars. However in the second year, the cultivars did not differ with respect to seed infection. Moreover, average seed infection of three cultivars from sprayed plots was significantly lower than in the seeds from unsprayed plots in 1992 and highly significantly in 1993. Average percent of oil content in the seeds of Pusabold was lower than other two cultivars in the first year but in the next year its level was high. However, in the seeds of Varuna and Krishna the level of oil content was remained same in both years (Table 5). Among treatments, average percent of oil content in the seeds of all cultivars from sprayed plots was significantly higher than in the seeds from unsprayed plots in both years. The average oil reduction was calculated as 4.5% in the first year and 4.2% in the second year. The coefficient of correlation between seed infection and oil content was significantly negative in 1993. Similarly, relationship between oil and protein content in the seeds of mustards of 1993 was negative (Figure 3).

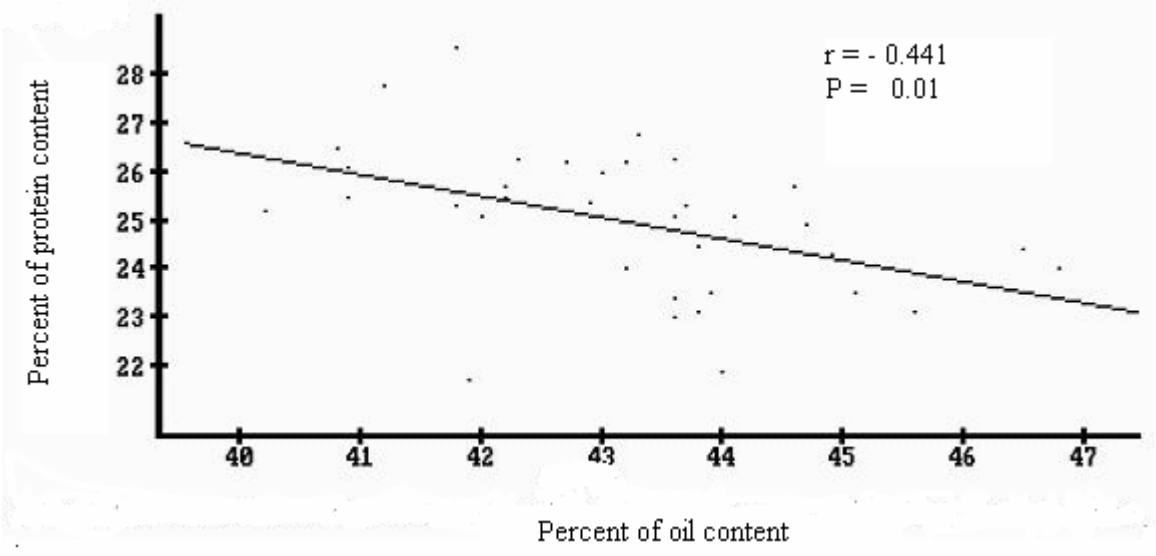

Figure 3. Relationship between oil and protein content in the seeds of mustard, 1993.

Table 5. Seed infection of *Alternaria brassicae* and oil content of three mustard cultivars grown at National Oilseeds Research Program, Nawalpur, 1992 and 1993

	1992			1993		
Cultivar/Treatment	Seed infection, %	Oil content, %	Average oil loss, %	Seed infection, %	Oil content, %	Average oil loss, %
Pusabold						
Sprayed	32.26	44.10		5.53	44.42	
Unspray	33.48	40.12		19.87	42.30	
Average	32.87 a	42.11 c		12.70 a	43.36 a	
Varuna						
Sprayed	31.82	44.22		6.29	44.72	
Unsprayed	34.05	43.17		22.74	43.12	
Average	32.93 a	43.69 a		14.51 a	43.92 a	
Krishna						
Sprayed	29.10	43.45		6.23	43.38	
Unsprayed	33.66	42.47		19.38	41.53	
Average	31.35 b	42.96 b		12.80 a	42.46 b	
Spraye (Av over 3 cvs)	31.06 b	43.92 a		6.01 b	44.17 a	
Unsprayed (Av over 3 cvs)	33.73 a	41.92 b	4.55	20.66 a	42.32 b	4.20
P-value						
A (Cultivar)	0.05	0.<01		0.04	0.01	
B (Treatment)	0.05	0.<01		0.01	0.<01	
AB (Interaction)	NS	NS		NS	NS	
$LSD_{(0.05)}$ for cultivars	1.02	0.37		1.20	0.86	
$LSD_{(0.05)}$ for treatment	1.96	0.31		1.48	0.71	
CV, %	10.80	1.04		21.35	2.37	

Means in a column with different letters are significantly different at P = 0.05.

DISCUSSION

Mustard is grown in many parts of Nepal but the major belt for production of seed for oil extraction is the Tarai (plain), which extends all along the length of the country bordering India. The crop is attacked by *Alternaria brassicae* causing leaf blight all over the country, but the severity of the disease is much higher in Tarai (Shrestha and Shrestha 1992**).** That is why the experiments were conducted at Nawalpur, Sarlahi.

The second experiment site was Khumaltar, which represented the mid hill of the country. The experiments conducted with 3 popular cultivars clearly show that environmental conditions recorded at the two locations were very different. The environmental conditions, which were prevalent at Nawalpur during two years of experiments, favored the disease development of *Alternaria* leaf blight. These conditions were 80-90% relative humidity, maximum temperature ranging from 18-25^{O}C, minimum from 10-14^{O}C and 14-15 h wetness period daily with dews from 6 pm. to 9 am during the months of December and January.

Our assessments show that the critical period for disease development in the foliage was from 2nd week of December to the 3rd week of January. During this period, the disease appeared in severe form in the both years causing heavy damage to the plants in the unsprayed plots. At first the disease was observed as small grayish–brown necrotic spots on leaves, which later coalesced each other causing leaf blight. At Nawalpur there was a rapid and steep progression of the disease on the leaves until total defoliation and the initiation of black spot disease on the pods. Favorable weather conditions continued until the 2nd week of February and at this time the pods were severely infected. After the 2nd week of February there was no increase in the disease severity. This may have been due to gradual decline in relative humidity and rise in temperature. Similar observations on the progression of disease in relation to climatic factors have been made in United Kingdom (Humpherson-Jones and Phelps 1989, Mridha and Wheeler 1993) and India (Duhan and Suhag, 1990). We believe that the period between mid December and the 3rd week of January when maximum foliage infection was seen, is the most critical period for the epidemics of the *Alternaria* leaf blight of mustard. During this period the fungus sporulated profusely in the necrotic areas of diseased leaves. At Khumaltar, disease level was very low, usually in the form of a few leaf spots on the lower leaves. No blight symptoms were observed.

Alternaria brassicae is known to cause seed infection and the infected seeds have already been shown to act as main source of recurrence of the disease in the field (Shrestha et al 2000). Besides, *A. brassicae* was found to survive for 8 months in the seeds of rapeseed stored in local containers in the farmhouse at Nawalpur (Shrestha and Chaudhary 1999). At room temperatures (11-25^{O}C) the fungus survived in the seeds for more than 6 months (Shrestha et al 2003). In general, the farmers store the seeds of rapeseed and mustard for 6-7 months before sowing. Although *Alternaria* disease-free seeds were sown in the experimental plots in both years, the border rows were planted with infected seeds of **y**ellow sarson. The infected plants of border rows might act as primary source of inoculum. Since the disease was more severe at Nawalpur, seeds produced by the farmers in the Tarai should not be used for sowing without seed treatment. We recommend that mid hill of the country should be chosen for seed production because seeds produced in these areas will be less infected by *Alternaria brassicae*. Sowing of such seeds will give healthier crops and the production of oil in the country will be increased. The negative correlation between seed yield and disease severity of leaf and pod stress the importance of keeping the crop disease-free. Shrestha and Chaudhary (2001) showed that seed infection has a direct effect on 1000-seed weight and ultimately on seed yield. One of the ways to control leaf blight in the field is spraying with effective fungicides during the critical phase of disease development. This was achieved in the present study by the use of mancozeb, which is available easily in Nepal. Five applications of this fungicide from mid December to early February controlled the disease significantly, with an increase in seed yield of 48%. The cost benefit ratio was 1:2. However, more experiments are needed to establish the optimal number of fungicidal applications. The authors advise that fungicides should be applied judiciously by the farmers during the critical period of disease development, as no resistant cultivars against *Alternaria* leaf blight are available. Although iprodione gave better control of the disease in our experiments, with an increase in yield by 130%, it is slightly expensive than mancozeb**.**

Oil extracted from rapeseed and mustard in Nepal is the main source of edible oil. Therefore, these crops are of great economic value. Our results clearly demonstrate that the increase in seed yield will result in the increase of oil production if the disease is controlled adequately. In Nepal, there is no separate statistical

information on area and production of these rapeseed and mustard crops. However, MoAC (2004) states that area, production and productivity of the oilseeds are 1,88, 455 ha, 1,24,930 mt and 669 kg/ha respectively. By controlling the disease with mancozeb alone, there can be an increase of 20,988 mt of oil on national basis. The figure can even increase up to 58,155 mt, if the leaf blight disease is controlled with iprodione**.** However, increasing percent of oil content in the seeds of oilseeds reduces percentage of protein and vice versa. This fact is supported by Ward et al (1985). Therefore, breeders should select genotypes jointly for oil and protein content than for either factor alone. This may help to increase oil content with minimum loss in protein.

Varuna is more susceptible than the other two cultivars. At Khumaltar, the yield of all three cultivars was not significantly different for both years. But at Nawalpur, where the disease severity was high, the yield of Krishna was significantly higher than the yield of Varuna in both years and with Pusabold, the yield was at par. It is recommended to use *Alternaria* free seed for sowing, choose the least susceptible cultivars and spray with effective fungicide at critical periods during the disease development. These factors will be important in an integrated *Alternaria* leaf blight management programme of Nepal.

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Yield Loss and Economic Threshold Level of Soybean due to Leaf Roller (*Apoderus cyaneus* Hope) in Nepal

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ABSTRACT

Yield loss in soybean due to leaf roller (*Apoderus cyaneus* Hope) was studied at Khumaltar during 1985 and 1986 seasons. Field experiments were conducted during vegetative as well as reproductive stages of soybean. Rolled leaves of soybean with eggs, grubs and pupae were collected from the field and reared in the laboratory for adults. Adults were introduced into nylon cages installed at the central rows of each plot just after germination of soybean. Insects were maintained at population density of 25, 50 and 100 per m^2. At maximum (100) adult density, the potential grain yield loss of cultivar, Ransom soybean in its vegetative and reproductive stages were 103 and 48 mg per day respectively from each adult of *A. cyaneus*. Percentages of yield losses were 36.2, 45.2, and 58.0 during vegetative and 37.5, 48.5 and 66.0 during reproductive stages from the insect population of 25, 50 and 100, respectively which, was not in accordance with the level of two and four fold increased population density of insect. Yield reduction was higher (260 and 108 mg per day) from each adult beetle at lower population level (25) in both vegetative and reproductive stages of soybean.

Key words: Economic threshold level, leaf roller, physiological growth stages, yield loss

INTRODUCTION

Soybean occupies 21245 ha and average yield is only 731 kg/ha (ASD 1999). The potential yield of cultivar, Ransom is 3.79 t/ha. The country's average yield is very low due to several factors and one of them is invasion of insect pests. Pre-harvest loss from insect pests has not been estimated, but damage was observed and reported (Gyawali 1982, 1986). The yield loss from the leaf roller (*Apoderous cyaneus* Hope) was not previously studied in Nepal and has not been reported anywhere in the world. The threshold estimate is the population level that would cause damage equal to the cost of control at a given application rate of pesticide. It was assumed that the use of an insecticide at the given rate would prevent the yield loss.

The objectives of this study were (i) to establish a relationship between insect population density and yield loss in vegetative and reproductive stages of the soybean plant, and (ii) to determine the economic threshold levels of *A. cyaneus* in both the physiological stages of the crop.

MATERIALS AND METHODS

The pH of the experimental plot ranged from 5.44 to 5.52 and 5.26 to 5.36 for vegetative and reproductive stages respectively. A basal dose of chemical fertilizers (20:20:40 kg/ha NPK) was incorporated into the soil at the time of seeding (3 June 1985). Similarly, in 1986 seeding was done on

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17 June for the vegetative stage and on 18 June for the reproductive stage. Seeds germinated on 9 June 1985 and 23 and 24 June 1986 for vegetative and reproductive stages, respectively. The plot size used was 4- × 3-m. There were five replications per treatment. Row to row and plant to plant spacing was 50 and 5 cm respectively. A cage measuring 32 cm in diameter and 1 m in height was installed at the center of 4 m long row just after germination of soybean. Each cage occupied an area of 804 cm^2. Four vertical wires (each 80 cm long) and three circular galvanized wires of 14 gauze were used to hold the cage upright. At each intersection, fine wires were used to tighten the others. One-meter long 40-mesh nylon was used to cover the wire framework and thread was used to stitch the nylon mesh. Both ends of the cage were open at the upper end having 20-cm long sleeve. A thick-waxed thread was used to close the upper end in order to trap caged insects. No extraneous insect feeding was allowed other than test insects.

Rolled leaves of soybean with eggs, grubs and pupae of *A. cyaneus* were collected from the field and reared in the laboratory for adults. Adult insects of both sexes were introduced into the cages with a density of 0, 2, 4 and 8 per cage (0, 25, 50, and 100/m^2) for both the vegetative and reproductive stages. Insects were checked on alternate days and the dead ones were replaced by reared stock. A control cage with no insects was also maintained in vegetative and reproductive stages of soybean.

Separate statistical analysis was carried out for vegetative and reproductive stages. Stages of development for soybean were followed according to the criteria identified by Fehr and Caviness (1977) and reported by Gyawali (1988).

Adults of *A. cyaneus* were introduced on 7 July at V4 stage and removed from the cages on 26 July in 1985 at V6 stage. In case of 1986 beetles were introduced on 18 July at V3 stage and removed on 6 August at V5 stage. The duration of feeding was the same (18 days) for both the years.

A. cyaneus was introduced on 26 July at R2 stage and removed from the cages on 26 Sept in 1985 at R7 stage. In case of 1986, it was introduced on 5 August at R1 stage and removed on 6 October at R7 stage. Feeding duration was 61 days for both the years.

Computational procedures for economical threshold level (ETL) have been based on Liapis et al (1984) and Gyawali (1985). The damage and yield loss relationship together with information on the price of soybean and the cost as well as effectiveness of control measures were used to imply treatments for insect species for a given period. This was done for situation where statistical analysis suggested susceptibility of soybean to become damaged. Solving the following equation derived the threshold population: $P - Y.\ X - I - A = 0$

Where, P is soybean price, Y is yield loss due to insect pest at population X, I is the cost of insecticide, A is the application cost and X is the threshold population measured at density per unit of land.

The market price of soybean was estimated from 1987 to 1999 as Rupees per kilogram. Cost of insecticide (Endosulfan) was also estimated as Rupees/liter. This was averaged for the two vegetative and reproductive stages of soybean. Application costs were based on Rupees/hour.

RESULTS AND DISCUSSION

The mean grain yield of Ransom soybean in control cage produced significantly more yield than infested cages at vegetative and reproductive stages (Table 1). *A. cyaneus* introduced on vegetative and reproductive stages with a population densities of 2 insects per cage produced significantly more yield than at population density of 8 insects per cage.

Table 1. Mean grain yield (g) and yield loss of Ransom soybean at vegetative and reproductive stages due to feeding of adults of *A. cyaneus*, combined data for wet- season (upland) of 1985 and 1986 Khumaltar

Crop stage	Feeding duration, days	Population density of A. cyaneus adults per cage				Yield loss per cage		
		0	2	4	8	2	4	8
Vegetative	18	25.8a	16.5b	14.2bc	10.9c	9.34	11.6	14.9
Reproductive	61	35.3a	22.1b	18.2b	12.0c	13.2	17.1	23.3

Means in a row followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Mean grain yield loss of Ransom soybean due to infestation of *A. cyaneus* at a population density of 100/m^2 showed significantly more than densities at 25 in vegetative and at 50 and 25 population densities in the reproductive stage (Table 2).

Table 2. Mean grain yield loss (g and %) from *A. cyaneus* adults during vegetative and reproductive stages of Ransom, combined data for wet- season (upland) of 1985 and 1986 Khumaltar

Crop stage	Feeding duration, days	Population density per m^2		
		25	50	100
Vegetative	18	117.0b (36.2%)	146.1ab (45.9%)	187.3a (58.0%)
Reproductive	61	165.6c (37.5%)	214.1b (48.5%)	291.4a (66.0%)

Means in a row followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

A. cyaneus tested on the vegetative stage with a population density at 25/m^2 produced the mean grain yield loss of 117.0 g/m^2. On the other hand, the same insect at a population density of 50/m^2 caused 146.1 g yield loss. Also, the same insect at a population density of 100/m^2 produced 187.3 g yield loss. When *A. cyaneus* was tested on reproductive stage at 25 populations density/m^2 produced 165.6 g yield loss. The same insect at population densities of 50/m^2 caused 214.1 g yield loss. Similarly, the same insect at population densities of 100/m^2 made 291.4 g yield loss.

Mean grain yield loss from *A. cyaneus* was more than 260 mg per insect per day at lower population density (2 per cage or 25/m^2) than at higher level of crowding (4 per cage or 50/m^2 and 8 per cage or 100/m^2) 162 and 103 mg per insect per day in vegetative stage (Table 3). Similarly, in reproductive stage of Ransom soybean, the loss was more than 108 mg per insect per day at lower population density (2 per cage or 25/m^2) than at higher density (4 per cage or 50/m^2 and 8 per cage or 100/m^2) 70 and 48 mg per insect per day.

Table 3. Mean grain yield loss (mg) of Ransom soybean per day per *A. cyaneus* adult during vegetative and reproductive stages during 1985 and 1986

Crop stage	Population density			Compensation		
	25	50	100	Loss	2 fold loss	4 fold loss
Vegetative	260	162	103	260	520-162 = 358	1040-103 = 937
Reproductive	108	70	48	108	216-70 = 146	432-48 = 384

The yield loss was much higher in vegetative stage than in reproductive stage for the same population densities, 2 per cage or 25 insects/m^2. This could be because the vegetative stage is more susceptible than the reproductive stage. Or compensation was initiated to 358 and 937 mg per day per individual as the population increased from 2 per cage or 25 to 4 per cage or 50 and 8 per cage or 100 /m^2 densities in vegetative stage of Ransom soybean. Similarly, in reproductive stage of soybean the compensation was initiated to 146 and 384 mg per day per insect as the population increased from (2 per cage) 25 to (4 per cage) 50 and (8 per cage) 100 densities, respectively. In other words compensation by the Ransom

soybean in vegetative stage is much higher than the reproductive stage. Environmental interaction between cultivar and the location might have played a significant role in compensation or possibly there is a relationship between population density and the magnitude of compensation by the cv Ransom as well as the physiological stages of soybean. As the population density increases compensation by the plant also seems to be increase. As the percentage of loss was increased, the yield loss was also found to increase.

The economic threshold level (ETL) of *A. cyaneus* for vegetative and reproductive stages is given in (Table 4). It is necessary to decide at which population density the pests have to be controlled. When the population density reaches the quantified numbers (2 and 1) in vegetative and (7, 6, 5, and 4) in reproductive stages in the corresponding years as shown in Table 2 helps the farmer not to apply chemical insecticides for control of this insect when the population is lower (eg 9 insects/10 m^2).

Table 4. Economic threshold level (ETL) of *A. cyaneus* for a period of thirteen years in vegetative and reproductive stages of Ransom soybean 1999 Khumaltar

Year	Population density per m^2	
	Vegetative stage	Reproductive stage
1987	2	6
1988	2	7
1989	2	6
1990	1	5
1991	1	5
1992	1	4
1993	1	4
1994	1	5
1995	1	4
1996	1	4
1997	1	4
1998	1	4
1999	1	4
2000	1	4
2001	1	4
2002	1	4
2003	1	4
2004	1	4

Increased insect population density caused more yield loss but the proportionate increase in insect population did not show proportionate loss. The insect caused more yield loss in reproductive stage than in vegetative stage but the yield loss per insect per day was higher in vegetative stage than reproductive stage. This might be due to compensation of the plants to the increased level of insect population.

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Development and Evaluation of Improved Feeders for Goats Suitable to Stall-fed Management System

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ABSTRACT

Five different types of feeders were designed and tested on goats to find out their effectiveness in reducing feed wastage and cost fabrication. Experiment was conducted at Agriculture Research Station (ARS)-Bandipur for two years. Tested feeders were hexagonal, rectangular, hay rack, chain barrel and conventional wooden Tatnu. Feeders were fabricated using iron bars and woods. They were tested with the adult goats for feed wastage and feed contamination. Experimental feeds were fodders twigs (Tanki), forage (Stylo, Napier), crop residue (straw from black bean) and commercial concentrate. Chain barrel type of feeder was also tested at farmer's field at Baradi. Rectangular feeders have significantly lower ($P<0.01$) feed wastage (6.61% for fodders) compared to other tested feeders. The fabrication cost was NRs 3200, 1700, 700, 900, and 150 for hexagonal, rectangular; hay rack, chain barrel and conventional wooden Tatnu respectively. The rectangular feeder is suitable for goats feeding in Tarai and in the hills of Nepal. It has provision for feeding fodders, grasses, crop residues and concentrates together at the same time. Chain barrel type had comparatively higher wastage (10.7% for fodder) than the rectangular but was preferred by the farmers due to its low fabricating cost, portable in size, small space required and easy to handle. Therefore, the rectangular feeder is recommended for middle level farmers and chain barrel for small farmers who rear few goats.

Key words: Contamination, cost effective, feed saving, small farmer, stall-feed, suitable feeders

INTRODUCTION

Goats are one of the most important livestock commodities in Nepalese rural farming system. They are the main economic sources in the rural farming communities. The main purpose of goat keeping is for household income, manure, meat and pack use. Although the goats are fed on locally available feed resources, the cost of production is still high. High cost is due to unscientific conventional feeding practices adopted by the farmers in the rural area. Contamination of feeds with feces, urine and stamping is commonly found in conventional feeding practices that normally causes considerable wastage of offered feeds. Goats naturally prefer to eat at the height of about 20 to 120 cm above the ground (Peacock 1996). They can stand on their hind legs for long period. Goats find it difficult to eat directly off the ground. As goats are selective feeders by natural habit, they do not eat once the feed is dropped on the ground and stamped (Peacock 1996). This problem can be solved if suitable low cost feeder could be fabricated and used for goats feeding. Feeders can be fabricated using different materials such as metal, bamboo and wood but it is important to use the cheaper and durable materials. Feeders should be portable which can be easily transported in mountain terrain. Therefore this work was done to develop the suitable feeders for goats feeding under the stall feed management system.

MATERIALS AND METHODS

Feeder fabrication

Five different types of feeders namely hexagonal, rectangular, hay rack, chain barrel and traditional Tatnu were designed and fabricated using iron bars, GI sheets, galvanized mesh for improved feeders, and wood and bamboo for Tatnu. These feeders were fabricated as adopted by Mishra et al (1992) and Singh et al 1992). Some of these feeders were further fabricated using wood to reduce the cost. Following were the dimension and procedure for fabricating different feeders. Experiment was conducted at ARS-Bandipur during 1999-2001.

Hexagonal feeder

Hexagonal feeders consisted of 6 legged stand on which a hexagonal bottom trough was fitted with a six faced central hexagonal – shaped pyramid rack mounted with iron bar over the table. The lower portion of the rack had vertical slanting iron bars outwards. The feet paddles were fixed at 37 cm height from the ground to prevent stamping on feeding trough, as goats prefer to eat raising two front legs. The height of the feeding trough was based upon the average wither height of the goat. The depth and width of the feeding trough were 10 cm and 15 cm, respectively. Feeder had a 4 legged iron stand, a GI rectangular feeding trough with a triangular pyramid in the middle and a vertical and slopping hay rack mounted on the feeding trough as shown in Figure 1. The upper portion (20 cm) of the rack was covered with GI sheet and lower portion consisted of iron bars at 7 cm interval. It has provision of feeding concentrate, green fodder (ground forage and fodder twigs) and dry roughage simultaneously. The rack portion was used for dry roughage and green fodder and the feeding trough for the concentrate (Figure 1). The dimension of hexagonal feeder is presented in Table 1.

Rectangular feeder

Rectangular feeder had 4 legs iron stands, a rectangular shaped feeding trough of GI sheet, a triangular pyramid in the middle and vertical and slopping hay rack mounted on the feeding trough. The upper portion (20 cm) of the rack was covered with GI sheet and lower portion consisted of iron bars. The height of the feeding trough and the distance between the 2 iron bars (7 cm) of rack were based on the various dimension of the mouth/ jaw of the goats. The feeder has provision of feeding concentrates, green fodder (forage and fodder twigs) and dry roughages. Provision for drinking water could be made by hanging a water bucket at both sides, which could be anchored with feeder by a circular iron ring. The rack portion was used for dry roughage and green forage and the feeding trough for the concentrate (Figure 2). The dimension of the rectangular feeder is presented in Table 1. The height of the feeding trough could be changed by digging the feeders in the floor to adjust the optimum height for large and medium size breeds of goats.

Table 1. Dimension and measurements of different types of feeders

Measurement	Hexagonal	Rectangular	Hay rack	Chain barrel	Conventional Tatnu
Total length, cm	150	150	145	130	145
Height up to hopper, cm	55	47	52	48	74
Height up to top of the hopper, cm	87	87	89	90	70
Width of feeding trough, cm	15	15	-	-	-
Depth of feeding trough, cm	10	10	-	90	70
Circumference, cm	378	302	-	245	-

Hay rack

Hay rack was developed using 4 legged angle iron structures. A vertical and slopping hay rack was mounted on the table. Flat GI sheet replaced the pyramids of Hexagonal feeders. This feeder was

designed for dry rough and green fodder (Figure 3). The height of the feeder table (height of the stand) was related to wither height of goats.

Chain barrel feeder

Chain barrel type of feeder was fabricated from galvanized wire mesh and iron rods. Feeder had 4 legged circular feeder having two circular iron rings joined with legs at the bottom and with iron rods at the top. The circumference of lower circular iron ring was 215 cm on top of which a galvanized wire mesh with iron rods was vertically attached. The circumference of feeder at the top was 245 cm. The vertical rod and circular ring at the top were attached with the lower ring and legs. Inside this dome shaped feeder four iron bars of 48 cm were attached in slanting position with bottom ring in lower side and with an iron ring of 15 cm circumference at the top. The galvanized wire mesh also covered the inside rods. The height of legs from ground was 48 cm. This type of feeder has provision for feeding fodder, green grasses and crop residue but has no provision for feeding concentrate (Figure 4).

Conventional Tatnu

This type of feeder is being used in rural area of Nepal. Y – shaped tree branches were used to make the feeder. Wooden pole was used to hold the fodder. The bases of the U- part of the Y shape was at 57 cm ie of shoulder point height of the goats (Figure 5a, 5b). Feeder was fixed at open plain ground in 10- × 10-m enclosure.

Feeder testing

Fabricated feeders were tested using 6 adult Khari and 50% Crossbred (Khari × Jamunapari) goats of similar age, weight and body condition score (3 - 4) to each feeder. Observations were made to compare different types of feeders in respect to feed wastage and contamination of concentrates, straw, green fodder and fodder twigs with the use of hexagonal, rectangular, hay rack, chain barrel and conventional Tatnu. Different parts of feeder were adjusted to make comfort to the goats. The animal were fed with concentrate @ 1% body weight in the morning 7 am, and then grasses (stylo) after 2 hours and again after 2 hours fodders twigs were offered. Feed wastage in each type of feeder for feed/ forage was recorded at the end of each feeding. The percentage of wastage was determined as below:

$$\% \text{ feed wastage} = \frac{(\text{Amount of feed wasted})}{(\text{Amount of feed offered})} \times 100$$

This feeder testing experiment was carried out for 15 days after 7 days of adjustment period for each feed type. After analysis of variance means were compared using LSD.

RESULTS AND DISCUSSION

The highest floor space required was found in rectangular feeder, followed by hexagonal, hay rack, and chain barrel (Table 2).

Table 2. Floor space occupied by different types of feeders

Type of feeder	Length, cm	Breadth, cm	Area, m^2
Hexagonal	120.0	120.0	1.44
Rectangular	150.0	150.0	2.25
Hay Rack	140.0	75.0	1.05
Chain Basket	90.0	90.0	0.81
Conventional Tatno	135.0	-	-

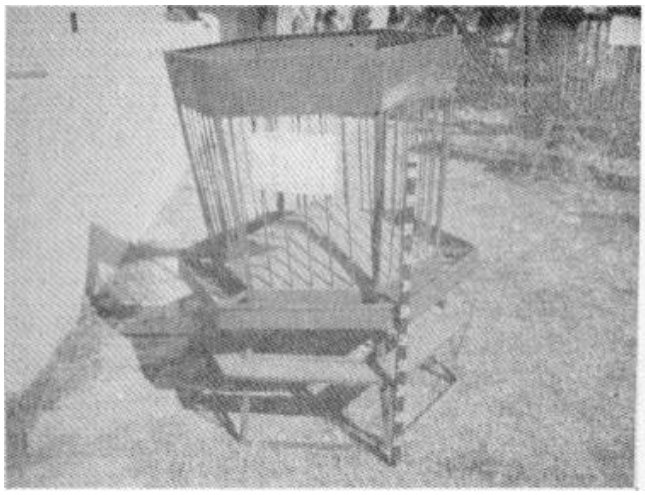

Figure 1. Hexagonal Feeder

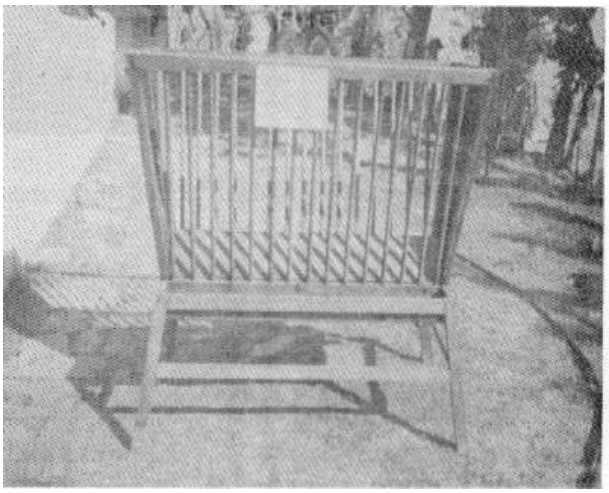

Figure 2. Rectangular Feeder

Figure 3. Hay Rack Feeder

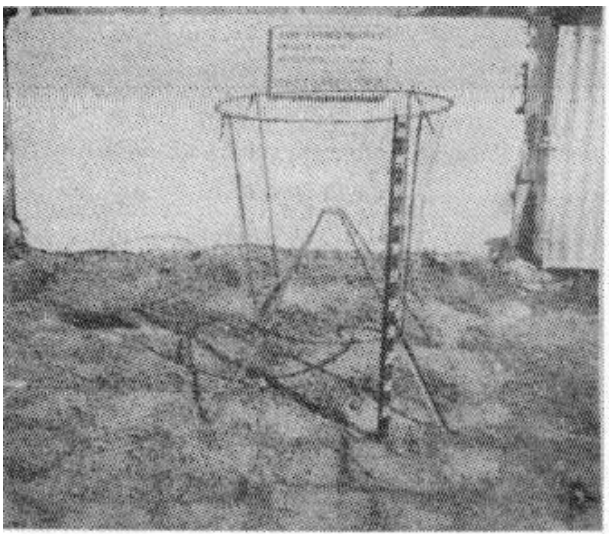

Figure 4. Chain Barrel Feeder

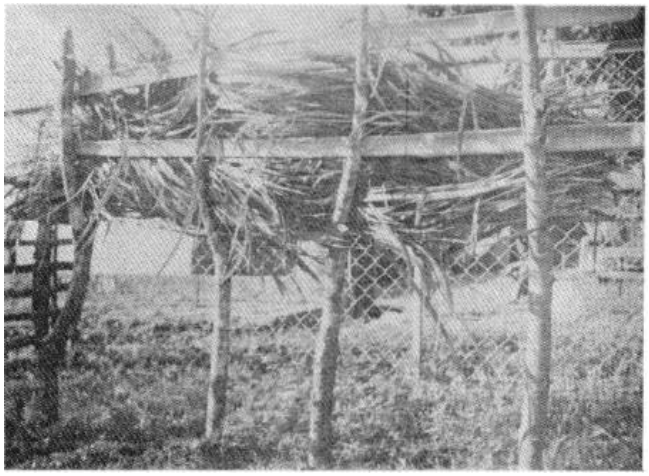

Figure 5a. Conventional Tatnu Feeder

Figure 5b. Traditional feeding system

Wastage of feed

The mean feed wastage of different types of feeders is given in Table 3. The wastage of concentrate is lower in rectangular feeder (0.61%) compared to hexagonal feeder (2.53%). For the hay rack, chain barrel and conventional Tatnu there was no provision for feeding concentrates therefore, a separate round feeder was used to feed concentrate in which maximum wastage of 4.30% was found. This wastage of concentrates in hexagonal and rectangular feeder were comparatively lower than reported by Mishra et al (1992) which were 1.43% and 2.03% respectively.

Table 3. **Feed wastage in different types of feeders (mean of 6 adult goats)**

Feed type	Feed utilization	Hexagonal	Rectangular	Hay Rack	Chain Barrel	Conventional Tatnu
Concentrate	Offered, g/d	350.0	316.0	0.0	0.0	0.0
(HC feed)	Refused, g/d	8.88 ± 1.9	1.94 ±1.2	0.0	0.0	0.0
	Wastage, %	2.53[a]	0.61[b]	0.0	0.0	0.0
Green forage (stylo)	Offered, g/d	250	250	250	250	250
	Refused, g/d	51.24 ± 10.5	19.37 ±11.74	74.79 ± 25	43.25 ± 2.3	84.16
	Wastage, %	20.49a	7.74b	29.61c	17.3d	33.66e
Straw	Offered, g/d	250.0	250.0	250.0	250.0	250.0
(Black bean)	Refused, g/d	38.12a ± 26.02	26.24b ± 18.89	64.58c ± 36.55	40d ± 4.2	119.99e ± 55.83
	Wastage, %	15.24	10.49	25.83	16.0	47.99
Green Forage	Offered, g/d	2500.0	2500.0	2500.0	2500.0	2500.0
(Napier)	Refused, g/d	687.49 ± 62	346.66 ± 176	416.66 ± 68	487.5 ± 65	723.74 ±62.54
	Wastage, %	27.49	13.86	16.66	19.5	28.94
Fodder (Tanki)	Offered, g/d	2500.0	2500.0	2500.0	2500.0	2500.0
	Refused, g/d	532.91 ± 21	165.41 ± 56	201.66 ± 93	268.2 ± 25	458.74 ± 38
	Wastage, %	21.31a	6.61b	8.06b	10.73bc	18.34ad

Means within a row followed by common letter/s do not differ significantly at the 0.05 probability level.
HC Hetaunda cattle feed.

Wastage of green forage (stylo) was substantially low (7.74%) in rectangular feeder compared to hexagonal (20.49%), hay rack (29.91), chain barrel (17.3%) and conventional Tatnu (33.66%). The rectangular feeder had lowest losses of straw (10.49%), Napier (13.86%) and fodder (6.61%) compared to other feeder types (Table 3). The main reason for the comparatively higher feed losses in hexagonal feeder compared to rectangular was due to the loose pieces of green fodder coming out of the rack portion while animals pull the green fodder. These findings of concentrate, fodder and grass in hexagonal feeder are contrary to the Indian studies (Singh et al 1992) however in agreement for wastage of straw. Straw feed wastage in hexagonal feeder was reported to be 15% (Singh et al 1992), which was similar in this study. Straw wastage in rectangular feeder was also higher (10.9%) in this experiment compared to the wastage (8.84%) reported by Mishra et al (1992), which could be due to use of chaffed straw (8 cm long) in the present trial.

Feed contamination

The contamination of concentrate, green forage, straw and fodder twigs with faeces and urine was almost totally prevented with the use of hexagonal and rectangular feeders. Similarly contamination of green forages, straw and fodder twigs were prevented in chain barrel and hay racks. In hexagonal, rectangular, chain barrel and hay rack, the animals were not able to void faeces or urine in the feeding trough and animals were not able to enter in the feeding trough. However in feeder without the provision for concentrate feeding, concentrate was supplemented in a separate wooden round feeder on

ground near by the rack. Concentrate feed in the wooden round feeder was stepped by the goats and got contaminated with faeces and urine.

Forage cost saved by different feeders

The feeder that involves lowest feed wastage and lowest cost of wastage feed was considered economic feeder (Singh et al 1992). Here, in the rectangular feeder there was lowest feed wasted and the cost of wastage feed was lowest (Rs 10.38) therefore it was the best and highest economic feeder among others (Table 4). This was followed by hay rack (Rs 14.08) and chain barrel (Rs 15.82). By looking feed wastage to all different feeds in different feeders, rectangular feeder was found more suitable for simultaneous feeding of all types of feeds and could be used in hills and Tarai of Nepal. Though hay rack ranked second in the saving of feed wastage, chain barrel type is more accepted by the farmers as it is portable and take smaller space in the shed.

Table 4. Cost of wasted feed in each feeder (six adult goats/ feeder)

Feeder	Fodder tree			Napier			Stylo			Black gram straw			Total cost, Rs
	Waste, kg	Rate, Rs/kg	Cost, Rs	Waste, kg	Rate, Rs/kg	Cost, Rs	Waste, kg	Rate, Rs/kg	Cost, RS	Waste, kg	Rate, Rs/kg	Cost, Rs	
Hexagonal	3.19	3.50	11.16	4.12	3.0	12.37	0.3	3.5	1.05	0.23	2.0	0.46	25.04
Rectangular	0.99	3.50	3.44	2.08	3.0	6.24	0.11	3.5	0.38	0.16	2.0	0.32	10.38
Hay rack	1.21	3.50	4.23	2.5	3.0	7.5	0.45	3.5	1.57	0.39	2.0	0.78	14.08
Chain barrel	1.61	3.50	5.63	2.9	3.0	8.8	0.26	3.5	0.91	0.24	2.0	0.48	15.2
Tatnu	2.75	3.50	9.63	4.34	3.0	13.02	0.50	3.5	1.75	0.72	2.0	1.44	25.84

For the calculation of cost, price of concentrate was considered Rs 12/kg, Stylo, Rs 3.5/kg, Black bean straw Rs 2/kg, Napier Rs 3/kg and fodder Rs 3.5/kg.

Different types of feeders were developed and compared for the amount of feed wastage and contamination. The finding indicated that the rectangular type of feeder was better in feed saving, economic and low in feed contamination compared to other types. This type of feeder was found more suitable for simultaneous feeding of all types of feedstuff and could be used to feed goats managed under stall-fed condition in the Hills and Tarai of Nepal. Due to the lower space required in the shed and portable in size, small farmers at outreach site preferred chain barrel type of feeder. Chain barrel type is suitable for small farmers as it is handy and cheaper.

Rectangular feeder in which tree leaves, grasses, concentrates and crop residues could be fed simultaneously, has lowest feed wastage and contamination, and hence is suitable for feeding goats in the Hills and Tarai under stall-fed management system. However, chain barrel type of feeder in which tree leaves, grasses and crop residue could be fed, is suitable for small farmers. Fabricated dimension of these feeders are suitable to feed 6 adult goats with their followers.

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Growth, Efficiency of Feed Utilization and Economics of Different Rearing Periods of Turkeys

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ABSTRACT

The present study on body weight and feed efficiency for growth was carried out on 112 turkey poults from day of hatch to 28 weeks of age during May to November 2002 at Poultry Research Unit of Regional Agricultural Research Station (RARS)-Parwanipur. Layer starter ration supplemented with 6% fish meal + 0.3% lysine + 0.125% methonine was fed up to 8 weeks of age, then after layer finisher diet was fed. The body weight, feed consumption was observed at 4 weekly interval and feed efficiency and economics of rearing period in terms of income over feed and poults cost was calculated. Significant increase in body weight was recorded up to 28 weeks in male and 20 weeks in female. Male turkey had significantly higher body weight than that of female in all ages. Feed efficiency is best at earlier age but up to 16 weeks it is 3.77 for male after that it detoriates progressively. Male turkey exhibited better feed efficiency than that of female for all weeks. Significantly higher return per bird was obtained from male than that of female in all age. The profit per bird for both male and female was found maximum in 16 weeks of rearing, followed by 20 weeks and 24 weeks. Therefore, instead of waiting for highest body weight, it is better to sell turkey at 16 to 20 weeks of age to take maximum advantage of higher weight gain, higher efficiency of feed utilization and higher profit.

Key words: Economics, feed utilization, growth, rearing period, turkey

INTRODUCTION

Turkey, native of North America, is an important poultry species reared for meat production. It is one of the favored white meat famous for its leanness and delicacy. It is famous for festival especially during X-mas and New Year. Turkey production is growing globally with an average annual growth rate of 3% (Terry 2003). The consumption of turkey and broilers as white meat is increasing worldwide and a similar trend is existed in developing countries. The bird was introduced in January 2001 in Nepal. The aim was to diversify meat production from different avian species in Nepal.

Sharma (1997) reported that turkey production is possible under wide range of climatic condition and are relatively more resistant to some of the common diseases. Turkey is easy to rise with similar management as chicken and can also be reared in free-range system (Khaddakar 2001). A large variety turkey, Broad Breasted Bronze Tom could achieve a body weight of 24 pound in 24 weeks and hen reach 17.5 pound in 17 weeks while consuming 3.5 pound or less feed per pound of body weight (Austic and Neshein 1990). Singh and Moore (1972) observed a slow growth and poor feed efficiency for small variety turkey. The most economical marketing age for turkey was observed at 16 weeks in the study carried out at Haryana Agriculture University, India (Prasad 2000) whereas Singh and Moore (1972) suggested selling turkey at 20 weeks of age for maximum profit.

In preliminary observation carried out at RARS, Parwanipur, average mortality was recorded 5.35% up to 16 weeks and average body weight at maturity (43 week) was 11.34 kg and 5.98 kg for male and

female respectively (RARS 2003). Increase in age of turkey is associated with a marked increase in the proportionate yield of desirable breast part and decline in the yield of bony parts (Karki and Sah 2004). They further observed that consumers preferred turkey meat for its less fat content, high meaty parts and good taste and selling price was Rs 170-200 per kg of flesh. In general, feed consist about 65-70% of the total input in poultry farming so that saving in feed cost per kg of weight gain should be the first concerned of poultry raiser to increase the net profit. However, no works has been done on growth rate, feed utilization and economics of rearing periods of turkey in Nepal and hence, the present study was undertaken.

MATERIALS AND METHODS

A total of 112 day-old turkey poults were used in the study. The experimental birds obtained from Poultry Research Unit, RARS, Parwanipur were randomly divided into four groups and kept in cage up to 8 weeks of age. After 8 weeks, the poults were sexed and divided into male and female groups and were housed in separate compartments in deep litter housing. The observation was carried out for 28 weeks during May to November 2002. Layer starter ration supplemented with 6% fishmeal + 0.3% lysine + 0.125% methonine was fed up to 8 weeks of age, followed by layer finisher diet. All the experimental birds were raised under ordinary managements ie more or less similar to chicken. Body weight, feed consumption was recorded at 4 weekly intervals and relative growth rate percentage, feed conversion ratio was calculated. Besides growth parameters, economics of rearing period was also calculated in terms of income over poults and feed cost per bird. The cost of poults and feed was considered to be Rs 40 per birds and Rs 16 per kg of feed respectively. All the data collected from the experiment were analyzed using MINITAB statistical package.

RESULTS AND DISCUSSION

Mean body weight of both male and female turkey showed a tendency to increase from the date of hatch up to the 28 weeks of age (Table 1). Significant increase in body weight was recorded up to 28 weeks in male and 20 weeks in female. The body weight of male was significantly higher than that of female in all the ages and the difference of weight increased progressively with the subsequent period of rearing. At 20 weeks of age, the body weight of male and female was 4.525 kg and 3.3 kg respectively, which is less than reported by Austic and Neshein (1990), Waibel et al (2000) and Prasad (2000).

Table 1. Body weight and feed conversion ratio at different rearing periods for male and female turkey

Age, weeks	Body weight, kg (mean ± SE)			Feed: gain ratio (mean ± SE)		
	Male	Female	Difference	Male	Female	Difference
4	0.376 ± 0.007g†	unsexed	-	3.137 ± 0.067d	unsexed	-
8	1.068 ± 0.029f	unsexed	-	3.973 ± 0.094c	unsexed	-
12	2.330 ± 0.155e	1.832 ± 0.095d	0.498*	3.609 ± 0.200cd	4.298 ± 0.181d	-0.689*
16	3.727 ± 0.160d	2.638 ± 0.130c	1.090**	3.776 ± 0.079cd	4.589 ± 0.148d	-0.813**
20	4.525 ± 0.137c	3.300 ± 0.147b	1.225**	4.791 ± 0.275b	5.337 ± 0.136c	-0.547ns
24	5.385 ± 0.141b	3.653 ± 0.224b	1.732**	5.446 ± 0.205ab	6.055 ± 0.211b	-0.609ns
28	7.080 ± 0.210a	4.270 ± 0.244a	2.810**	6.027 ± 0.231a	7.087 ± 0.249a	-1.061*

*† Means with different alphabet in a column differ significantly (P<0.05). * significant at 5% level. ** significant at 1% level. ns non significant.*

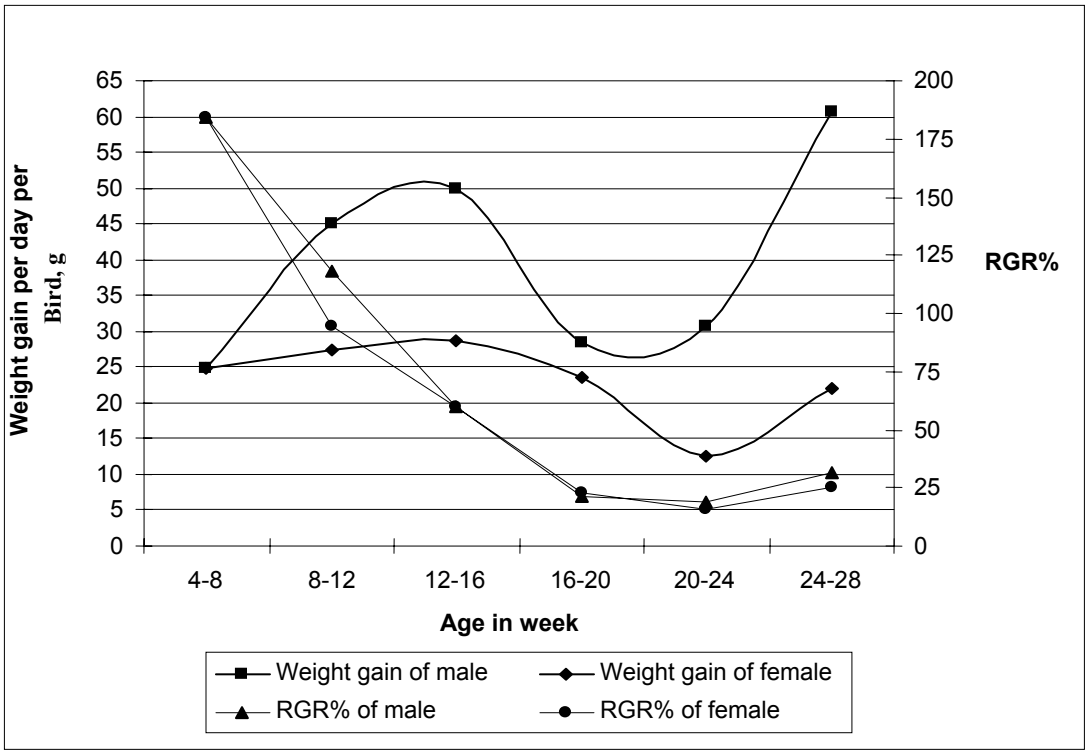

Figure 1. Sexwise weight gain and relative growth rate (RGR) of male and female turkey.

The Figure 1 clearly revealed that maximum gain in weight of male turkey was obtained between 24-28 week (60.54 g/day), followed by 12-16 weeks (49.9 g/day) whereas in case of female, it was observed in 12-16 weeks (28.75 g/day), followed by 8-12 weeks (27.29 g/day). However, relative growth rate (RGR) percentage was maximum in the early period and declined progressively in the subsequent periods of rearing. Feed intake of male was significantly higher than that of female at all age (Table 2). Irrespective of sex, feed intake per day was increased progressively with subsequent period of rearing.

Table 2. Economics of different rearing periods for male and female turkey

Parameter	Sex	Age				
		0-12 week	0-16 week	0-20 week	0-24 week	0-28 week
Feed intake per day per bird, g	Male	96.71	123.57	152.18	172.82	215.94
	Female	90.39	105.36	123.46	129.02	151.79
	Difference	6.35*	18.21**	28.82**	43.6**	64.2**
Weight gain per day per bird, g	Male	27.09	32.79	31.93	31.73	35.84
	Female	21.17	23.06	23.18	21.42	21.51
	Difference	5.92*	9.73**	8.75**	10.31**	14.34**
Total feed cost, Rs†	Male	129.98	221.44	340.88	464	677.28
	Female	121.44	188.8	276.32	346.8	476
Meat cost, Rs ‡	Male	291.25	465.87	565.62	673.13	885
	Female	229	329.75	412.5	456.63	533.75
Profit over chicks and feed cost, Rs	Male	121± 17b§	204 ± 14a	185 ± 26ab	169 ± 19ab	168 ± 27ab
	Female	68 ± 10ab	101± 12a	96.2 ± 13a	69.8 ± 17ab	17.8 ± 18b
	Difference	53.6*	103.6**	88.6*	99.4**	150.1**

** Significantly difference at 5% level. ** Significant difference at 1% level. † Feed price @ Rs 16 per kg. ‡ Meat price @ Rs 125 per kg of live weight. § Means followed by different alphabet in a row differ significantly (P<0.05).*

The feed conversion efficiency for growth of male turkey was better than female for all weeks. However, no significant difference was observed in 20 and 24 weeks of age. Cumulative efficiency of feed utilization was deteriorated with advancement of age for both male and female. This clearly indicated that there is a steady increase in feed cost for per kg weight gain of turkey with age. Male and female turkey consumed 3.776 kg and 4.589 kg of feed for per kg live weight gain up to 16 weeks of rearing whereas they required 6.027 kg and 7.087 kg of feed respectively for per kg of live weight when reared up to 28 weeks. In this experiment, the feed version efficiency for growth was very poor than reported by Austic and Neshein (1990), Waibel et al (2000) and Prasad (2000). Waibel et al (2000) observed feed to gain ratio of 2.729 up to 20 weeks of age for large white male turkey in experiment carried out at University of Minnesota. The poor feed efficiency might be due to the small variety of turkey, ordinary housing and poor feed quality offered to them in this experiment. Tyagi (2001) suggested that turkey diet needs to have a narrower energy to protein ratio as compared to chicken diet and he further reported that turkey require properly balanced diet for sustaining rapid growth and better feed efficiency. Bhanja and Majumdar (2001) reported that Turkey needs high protein diet at early stage ie 28% protein with 2800 kcal ME (metabolic energy) up to 4 weeks, 25% protein with 2900 kcal for 5-8 weeks, 22% protein with 3000 kcal for 9-12 weeks and slowly step-down of protein and gradual increase in the dietary metabolic energy with age.

At 4 weekly intervals, feed conversion ratio of both male and female increased with each subsequent period of rearing and after 16-20 weeks, it is almost double for female as compared to male. Hence to keep the birds especially female after 16 -20 weeks of age, in which the growth rate becomes slow and feed efficiency deteriorated, is not economically advisable.

The detail of economics of rearing period of male and female turkey in terms of income over poults and feed cost is given in Table 2. Male had significantly higher saving per bird at all age. Significantly higher saving per bird was obtained for male at 16 weeks of rearing (Rs 204), followed by 20 weeks (Rs 185) and 24 weeks (Rs 169) and 28 weeks (Rs 168) whereas in case of female it was also significantly higher in 16 weeks (Rs 101), followed by 20 weeks (Rs 96.2), 24 weeks (Rs 69.8) and 12 weeks (Rs 68) of rearing. This result is also in agreement with Prasad (2000), Singh and Moore (1972). Prasad (2000) reported the cost of meat production of turkey was about 1.5 times higher than the cost of chicken broilers. The maximum profit per bird over poults and feed cost was found in 16 weeks of rearing period, followed by 20 weeks and 24 weeks of rearing for both male and female turkey.

Turkey could be raised under more or less similar feed and management as chicken but slow growth with poor feed efficiency was associated with advancement of age while rearing under ordinary feed and management. Therefore, instead of waiting for highest body weight up to 28 weeks of age, it is better to sell turkey at 16 to 20 weeks of age to take maximum advantage of higher weight gain, higher efficiency of feed utilization and higher profit while rearing under ordinary feed and management conditions. Turkey is gaining popularity among farming community for its higher meat production potential and for its meat preference over chicken with a change of taste and as a festive food. So, it could be the alternate choice of farming community for higher meat production and extra cash income.

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Socioeconomic and Agroecological Determinants of Conserving Diversity On-farm: The Case of Rice Genetic Resources in Nepal

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ABSTRACT

Conservation of crop genetic resources presents a challenge of identifying specific determinants driving maintenance of diversity at farm and agroecosystems. The objectives of this study were to identify socioeconomic, market and agroecological determinants of farmers' maintenance of rice diversity at the household level and derive implications for policies in designing on-farm conservation programs. We assess spatial rice diversity at farm level using household survey data. A household decision making model is conceptualised using microeconomic theory to assess and identify factors influencing on-farm rice diversity. The model is then tested econometrically by using various factors affecting farmers' variety choice and diversity decisions. The findings show that household-specific socioeconomic, agroecological and market factors are important in determining on-farm rice diversity. The significant variables in explaining richness and evenness of rice diversity include distance to the nearest market, subsistence ratio, modern variety sold, land types and adult labour working in agriculture. The statistical signs of the factors determining rice diversity are consistent in explaining the richness, dominance and evenness among rice varieties. Finally, the study implies that the cost-effective means of promoting and sustaining on-farm conservation programmes is to target them in market isolated geographic locations of high crop diversity where farm households have more heterogeneity of agroecological conditions and more active family adult labour working on-farm.

Key words: Diversity indices, dominance, evenness, on-farm conservation, rice diversity, richness

INTRODUCTION

On-farm conservation is the outcome of farmers' decisions to select, modify and maintain diversity. It involves farmers' decisions to continue cultivating and managing landraces in the agro-ecosystems and communities where they have evolved (Bellon et al 1997). Farmers choose to conserve particular crop varieties by sowing the seed of the varieties they demand, selecting the seed and replanting. The choices they make today not only affect their welfare but that of future society. Various socioeconomic, market and agroecological factors are known to play important role in farmers' choices and management of crop genetic diversity at the farm, agroecosystems and community levels. Targeting on farm conservation efforts, therefore presents a challenge of identifying specific social, economic and agroecological determinants driving on-farm maintenance of diversity and minimizing the cost to farmers and to society of forgoing the opportunity to plant modern varieties.

The genetics and ecological literatures offer a range of sophisticated options particularly the use of diversity indices for calculating level of diversity (Magurran 1991). The objectives of the diversity

indices are to determine which populations to target for conservation to maximize diversity or to model the services provided by diversity. Diversity could be measured spatially or in time (Duvik 1984). Temporal diversity (diversity in time) could be measured using indices such as the average age and weighted (by area) average age of varieties grown by farmers (Brennan and Byerlee 1991). Spatial diversity is calculated using cultivated area share indices of the different varieties of the farmers (Van Dusen and Taylor 2003, Smale et al 2003, Benin et al 2003, Gauchan 2004). This approximates a measure of the diversity of the planted landscape. Crop genetic resource conservationist and applied scientists have used these measures as strategies and decision tools to conserve genetic resources both in *in situ* and *ex situ* genebanks. One of the advantages of using such indices is that the data can be condensed into a scalar measure for use in an analytical application (Meng et al 1998). Richness, evenness and dominance are the popular measures of spatial diversity commonly applied in ecological, genetic and agronomic literatures of plant genetic resources conservation. The measurement of "richness" looks at the total number of variants or count of varieties. The varietal "evenness" is the equality in the distribution of the named varieties or area share planted to each of the varieties. "Dominance" is defined as the proportion of the sample occupied by the most abundant species or variety (Smale et al 2003).

In Nepalese context, we lack empirical socioeconomic studies that are useful for measuring on-farm crop diversity using such spatial diversity indices in order to design strategies for on-farm conservation programs. Through the use of several spatial diversity indices that represent different diversity concepts, this study aims to compare diversity trade-offs among conservation objectives, such as maintaining numbers of distinct farmer named variety types versus the evenness and dominance in the distribution of those types. Though the presence of genetic diversity among or within crop populations is not necessarily observable in physical characteristics of the plants growing in the field, this study defines crop diversity as the observable variation in a particular plant feature (phenotypic) or a set of features either within or distinct set of populations of the same species locally identified and recognised by the farmers or scientists. Employing regression models, it aims to test the significance of the various socioeconomic, farm-specific agroecological and market factors affecting farmer's management of spatial rice diversity at farm-household level.

The purpose of the research was to provide economic explanation of farmer decision-making in the choice and maintenance of rice genetic diversity and inform policy decisions by identifying appropriate economic policies to support on-farm conservation in Nepal. The specific objectives are to apply an analytical framework from microeconomic theory to (i) identify farm-specific agroecological and socioeconomic factors that significantly influence rice diversity maintained by farmers positively and negatively; (ii) analyse possible diversity trade-offs between different measures of spatial diversity and (iii) suggest ways for on-farm conservation for rice genetic resources.

MATERIALS AND METHODS

Site selection and descriptions

This research focuses on two of the three "ecosites" of the *in situ* agrobiodiversity conservation on-farm project (Sthapit et al 2000) where farmers grow both landraces and modern varieties. They are Kachorwa village in Bara district (Tarai) and Begnas village in Kaski (Hill) district representing two distinct agroecosystems (Table 1). Bara ecosite in Tarai has better access to market and technologies as compared to Hill agroecosystem in Kaski ecosite. Farmers grow rice crop in small family-based subsistence to semi-commercialised farms with sizes varying from less than 0.1 to 1.0 hectare and hence the marketed ratio is very small. Rice is cultivated in a variety of micro-agroecological niches (defined here as "land types"), with lowland, mid-land, upland and swampy environments (*Pokhari*) often found

within the same farm (Table 1). These rice land types are classified and recognised by farmers depending on the surface hydrology (moisture availability), topography and soil types (Gauchan 2000). Farmers often plant several local cultivars to match a range of land types, soils, moisture conditions and cropping sequences.

Table 1. Landraces cultivated in micro-ecological niches in two agroecosystems

Agroecosystem	Land types (micro-ecological niche)	Local name for land types	Local name of adapted landrace
Tarai (Bara)	Upper wet land	*Uchha khet*	*Mutmur*
	Mid-wet land	*Samtal khet*	*Mansara*
	Lower wet land	*Nicha khet*	*Basmati*
	Deep water	*Ghol khet*	*Bhathi*
Hill (Kaski)	Lower river basin	*Sinchit khet/Phant*	*Jetho budho, Anadi*
	Hillside rainfed terrace	*Tari khet*	*KatheGurdi, Mansara*
	Seasonal stream irrigated terrace	*Kulo khet*	*Ekle*
	Swampy land	*Dhab khet*	*Anadi, Jarneli Dhave*
	Unbunded terrace (upland)	*Ghaiya bari*	*Set Ghaiya, Rato Ghaiya, Kunchhale Ghaiya*

Sample survey

A survey of farming households was carried out employing random sampling framework in Tarai (Bara) and Hill (Kaski) ecosites by listing actual farming households from the available records in the local administrative offices (village development council and municipality). A random sample of 307 households (148 in Bara, 159 in Kaski) representing about 17% of actively farming households was drawn using list census frame from a total list of 1785 households, with 860 households in Bara and 915 in Kaski. The survey instrument was a structured household questionnaire administered in personal interviews. Survey questions covered social, demographic, and economic characteristics of the farm households, as well as physical characteristics of their farms, economic aspects of rice production and market access. Both men and women farmers that are involved in rice production and consumption decisions were interviewed. Households were revisited immediately for missing information and inappropriate responses during the survey period. Peer review of the questionnaires was undertaken in regular intervals to check for measurement errors, ambiguities and missing information. Descriptive statistical analysis was carried out in SPSS package, whilst econometric analysis of the survey data was accomplished in LIMDEP econometric package (Greene 1998), designed specifically for models with discrete and limited dependent variables.

Farm household model

The genetic diversity in crops that are grown in farmers' fields is the outcome of farmers' allocation of crop area among several varieties. The conceptual approach of the model presented here is based on the theory of the agricultural household models (Singh et al 1986), as applied to variety choice and analysis of crop biodiversity by Van Dusen and Taylor (2003). Other related models and applications include Brush et al (1992), Meng (1997), Smale et al (2001) and Benin et al (2003). The reduced form equations given below express optimal area allocations (α) among crops and varieties as functions of a vector of prices (p) (including wage), farm size (A), exogenous income (Y), and vectors of farm household socioeconomic (Ω_{HH}), farm physical (Ω_F) and market characteristics (Ω_M:). Diversity (D) on household farms is an outcome of the choices made in a constrained optimisation problem rather than an explicit choice. Equations estimated econometrically take the following conceptual form of the model, as in Van Dusen and Taylor (2003).

$$D = D(\alpha^*(p, A^0, Y^0, \Omega_{HH}, \Omega_F, \Omega_M)) \quad \text{.....(i)}$$

Regression models and specifications

The reduced form of the household model presented above in equation (i) is the conceptual basis for econometric analysis and hypothesis testing. Significance of the various household-specific socioeconomic, agroecological and market factors affecting farmers variety choice and diversity decisions are tested by specifying regressions with diversity indices as the dependent variables. Two sets of regressions, Poisson and Tobit regression models were used as outlined below.

Poisson regression model: The preponderance of small values and the clearly discrete nature of the dependent variable (variety count data) with non-negative integer suggest the use of a Poisson maximum likelihood regression (Greene 2000). The log-linear regression in the Poisson model naturally accounts for the non-negativity of the Poisson distribution dependent variable (Winkelmann and Zimmermann 1995). The count data specification for richness measure was utilised because of the way it gives the model flexibility to explain cultivar diversity within a crop. The Poisson regression model is given as:

$$D_i = \beta_o + \beta_1 X_H + \beta_2 X_F + \beta_3 X_M + \boldsymbol{\varepsilon}$$

Where, D_i = Measure of rice diversity-richness (count of rice varieties) of household i,
X_H = Socioeconomic characteristics (age of production decision maker, education of production decision maker, percent female working adult, adult labour in agriculture, livestock assets, exogenous income, subsistence ratio)
X_F = Agroecological characteristics (number of land types, percent rice area irrigated, plot dispersion)
X_M = Market characteristics (total distance to market, landraces sold, MV sold)
ε = Disturbance term

Tobit regression model: For modelling values of Shannon and Berger-Parker indices as the measure of evenness and inverse dominance respectively, Tobit model appears to be appropriate since some households had censored values with Shannon evenness index taking a value of 0 in some cases and the Berger-Parker index assuming a value of 1, both values being the lower limits. According to Ammemiya (1974), censoring takes place when the dependent variable takes a limiting value. A reduced form equation is used in this paper to shed light on the underlying factors influencing households to maintain diversity (D_i) in terms of evenness and inverse dominance indices of rice varieties. The general formulation for Tobit specification is usually given in terms of index function (Greene 2000),

$$D_i^* = \beta' X + \varepsilon_i$$
$$D_i = 0 \text{ if } D_i^* \le 0,$$
$$D_i = D_i^* \text{ if } D_i^* > 0.$$

Where, D_i^* is a censored variable of the diversity indices. β' is a vector of parameters to be estimated and X is a vector of explanatory variables which includes household socioeconomic variables (age, education of decision makers, adult family labour working in agriculture, percent female adult, subsistence ratio, livestock assets), market variables (market distance, landraces sold, modern variety sold) and farm agroecological variables (number of land types, percent irrigated area, plot dispersions). ε is the disturbance term.

Dependent variables: The dependent variables for the regression tests are household level diversity indices (Table 2) based on variety area shares and farmer named varieties (count). This study uses a

simple count of farmer cultivated rice varieties as a measure of richness. Though in principle standardising by area (as in the Margalef index) may be preferred to a simple count; the small rice areas farmed in Nepal led to use of simple count as a measure of richness. Shannon index captures a combination of richness and equality or evenness in distribution across areas and it is also recently being used in economics research as measure of evenness for diversity measurement (see Van Dusen 2000, Benin et al 2003). The Berger-Parker index is employed to represent the relative dominance of one variety versus another. It is defined as the inverse of the proportion of the sample occupied by the most abundant species or variety (Smale et al 2003). Therefore, an increase in its value accompanies an increase in diversity and reduction in dominance.

Table 2. Definition of dependent variables for Poisson and Tobit regression models

Index	Concept	Construction †	Explanation	Model
Count	Richness	D = S	S = number of rice varieties	Poisson
Shannon	Evenness (richness and relative abundance)	$D_{sh} = -\sum_i \alpha_i \ln \alpha_i$	α_i = variety area share , i = 1,...s	Tobit
Berger-Parker	Inverse dominance (relative abundance)	$D_{bp} = 1/\text{Max}(\alpha_i)$	Where α_i = variety area share, i = 1,...s	Tobit

†, D=Diversity index. Construction adapted from Magurran (1991). When one variety is grown, the lower limit of the Shannon index is zero and count and Berger-Parker indices are equal to one.

Explanatory variables and hypothesised effects: Explanatory variables and their hypothesised effects are shown in Table 3. These explanatory variables are grouped into household, farm-physical (agroecological) and market characteristics, as in the farm household decision-making model presented in equation (i). Household characteristics affect crop diversity both through preferences and the household-specific costs of market transaction, as well as through labour stocks and opportunity costs. Age, education and the gender composition of households affect diversity through their effect on preferences for consumption and production and experience level of cultivation. Subsistence ratio, exogenous income and livestock assets are all wealth-related variables and they affect diversity through their association with larger farm sizes and ability to bear risk.

Table 3 Definitions of explanatory variables and hypothesised effects on diversity

Variable name	Variable definition	Hypothesised effect
Household characteristic		
Age	Age of the production decision-maker (years)	(+)
Education	Education of the production decision-maker (years)	(+, -)
Adult labour	Active family adult labour working on-farm (number)	(+)
Female adult	Per cent female of actively-working adults	(+)
Livestock assets	Value (NRs) of large animals (bullocks, dairy animals)	(+)
External income	Average monthly household expenditure (NRs) since last harvest preceding this season (exogenous income)	(+, -)
Subsistence ratio	Ratio of 5-year average of rice produced to rice consumed (kg)	(+, -)
Farm-physical characteristic (agroecological)		
Irrigation	Per cent rice area irrigated or with source of water	(+,-)
Land types	Number of rice land types (lowland, mid-land, upland)	(+)
Plot dispersion	Total walking distances (minutes) from the house to the rice plot(s), divided by cultivated hectares	(+)
Market characteristic		
Market distance	Total walking distance from the house to the local market (minutes)	(+)
Landrace sold	Landrace grain sold by household in preceding season (KGs)	(+)
MV sold	Grain of modern variety sold by household in the preceding season (KGs)	(-)

All prices and values are in Nepali Rupees (NRs).

Relevant physical farm or agroecological characteristics include farm fragmentation and land heterogeneity measured by the number of land types, distances among rice plots, and the percent of rice area irrigated (or assured source of water). The more heterogeneous the conditions in which farmers cultivate the crop, the higher the expected level of diversity since such heterogeneity leads farmers to choose a broader set of varieties to suit multiple classes of farm land and seasonal niches.

Market variables affect diversity through the extent to which households trade their rice crop and purchase inputs, foods and other household needs in the market. The distance of the market from the homestead and farm plot is a major component of the cost of engaging in market transactions. The more removed a household is from a local market centre, the more likely that it would rely on its own production to meet its consumption needs. Past sales of grain of landraces are expected to relate positively to provide incentives for cultivating them. Past grain sales from production of modern varieties may relate to specialisation in fewer varieties. Market prices are not included here because they are fixed for all households in each ecosite and because rice markets are incomplete, the shadow prices govern farm households' decisions.

Tests of hypothesis: The null hypothesis that parameters are equal between the Bara (Tarai) and Kaski (Hill) ecosites (Ho = $B_b = B_k$) was rejected with a log-likelihood ratio test (Greene 2000: pp 152-153). This test result confirms the statistical significance of ecosite-specific factors both in terms of levels of diversity and the marginal effects of explanatory factors on these levels. The likelihood ratio (λ) test is carried out by comparing the values of the log-likelihood function with and without the restrictions imposed. A separability test of the model was carried out to investigate whether the model used in this study is separable or not, with a joint test of the significance of the group of variables. The test of the hypothesis for separability was: $H_o = \beta_{HH} = 0$, $\beta_M = 0$. The significance of likelihood ratio (λ) test for a group of variables (eg household, market) with and without restriction imposed led us to conclude that model is non-separable. This indicates that there is simultaneity in production and consumption decisions of rice farmers in the study sites and household and market factors do influence farmers' optimal varietal choices and diversity outcome.

RESULTS AND DISCUSSION

Cultivation pattern and rice diversity

Sample farmers in the study agroecosystems maintain a total of 50 and 23 rice cultivars in the hill and lowland agroecosystems, respectively (Table 4). Farmers cultivate both the highest number of total rice varieties (local and improved) (n = 50) and rice landraces (n = 39) in the hill agroecosystem. At the household level, farmers also cultivate higher mean number of total varieties and landraces and allocate larger area for landraces in hill agroecosystem. Though both modern varieties and landraces coexist in both agroecosystems, higher number of modern varieties and larger mean area on modern varieties are cultivated in lowland in Bara (Kachorwa). Variety area share index as estimated from Shannon index is also higher in hill agroecosystem (Kaski) indicating that farmers are maintaining higher level of rice diversity at the household level.

Regression results

The results (marginal effects) of Poisson and Tobit regression models for factors explaining variation in the richness, evenness and dominance among rice varieties grown by farm households in the study ecosites (Bara and Kaski) are presented in Table 5. The age and education of decision-makers are significant factors explaining rice diversity in Tarai (Bara) but not in the Hill (Kaski). Significance of age variable in Terai indicates that older farmers are more likely to allocate rice area more equally

among varieties, perhaps due to their experience and because they are not as receptive to adopting and specialising in a single modern variety. Higher education levels among production decision-makers (usually men) in Bara are positively related to both evenness and inverse dominance. This indicates that education may expand the variety choice options for the rice farmers. More active household labour in agriculture generally contributes positively to rice diversity, and the marginal effects are particularly large in Hill (Kaski) where there are fewer non-farm employment opportunities and rice production requires more labour time. However, insignificance of female adult labour variable indicates that the gender composition of adult agriculture labour is of no apparent importance.

Table 4. Rice varietal diversity maintained at ecosite and farm household level

Cultivation pattern and rice diversity	Agroecosystems		
	Tarai (Bara)	Hill (Kaski)	All
Ecosite level diversity			
Total number of cultivars	23	50	77
Total number of landraces	5	39	44
Total number of modern varieties (MVs)	18	11	29
Household level diversity			
No of rice growing households	148	159	307
Mean number of varieties grown	2.11*	3.53	2.85
Mean number of landraces grown	0.118*	2.71	1.55
Mean number of modern varieties grown	1.98*	0.73	1.33
Mean percent area planted in landraces	3*	74	61
Mean percent area planted in MVs	97*	26	39
Variety area share index (Shannon)	0.54*	0.82	0.68

** Pair wise t tests show significant difference of means between agroecosystems at 5%, level with one-tailed test.*
Source: Gauchan (2004).

Irrigation (water availability) has positive effect on the maintenance of evenness of rice varieties in Tarai (Bara) but it has no effect in Hill (Kaski). As expected, distance from market centres is positively related to rice diversity. The further the distance of farm plots and households from markets, the higher the likelihood of maintaining evenness diversity. In Kaski, varietal richness and in Bara inverse dominance diversity was also positively related with market distance. While sales of the grain of landraces is of no importance, sales of the grain of modern varieties is associated with less evenly distributed varieties in either site and in Bara ecosite, with greater dominance by any single or few varieties. The more heterogeneous agroecological conditions (measured by number of land types and plot dispersion) in which the farmers cultivate the crop, the greater the numbers of rice varieties grown and the greater is the evenness in their area distribution in Kaski. Rice plots are more widely dispersed per unit area in Hill (Kaski) compared to Tarai (Bara), and within the Kaski ecosite, their dispersion is positively related to the richness, inverse dominance and equality among rice varieties on farms.

Similarly, surplus production (subsistence ratio) and market distance are positively related to the inverse dominance measure of diversity in Bara, whilst active adult agricultural (farm) labour, livestock assets and dispersion of plots are related to inverse dominance measure in Kaski. In Kaski (Hill), livestock assets contribute to less dominance by a single rice variety. Though outside sources of cash income are not significantly related to the diversity of rice varieties grown in these sites, surplus households also grow more varieties that are more evenly distributed. Higher sales of grains of modern varieties reduce evenness measures of diversity.

Table 5. Factors explaining variation in the diversity of rice varieties grown by farmers in two ecosites (marginal effects of Poisson and Tobit regression models) †

	Tarai (Bara) ecosite (N = 148)			Hill (Kaski) ecosite (N = 159)		
Variables	Richness	Evenness	Inverse dominance	Richness	Evenness	Inverse dominance
Constant	-0.5533	-0.816***	0.3927	0.1917	-0.2253	0.6457
Age	0.0038	0.0052**	0.0064	-0.0068	-0.00157	-0.0061
Education	0.0405	0.0193*	0.0331*	0.0243	0.00076	-0.0087
Female adult	-0.6165	-0.2571	-0.4569	-0.5358	-0.07935	-0.6042
Adult labour	0.1896	0.0781***	0.0214	0.4853***	0.14407***	0.1243*
Livestock assets	0.000007	0.000005	0.000004	0.00001	0.000005	0.00002*
External income	0.00003	0.00002	0.00008	0.00004	-0.000003	-0.000008
Subsistence ratio	0.2940	0.2163***	0.2584*	1.2590*	0.31802**	0.4851
Irrigation	0.2537	0.1203*	0.2436**	0.4486	0.04772	-0.1327
Land types	0.4198*	0.1937***	0.1233	0.4138	0.1141*	-0.1292
Plot dispersion	-0.0003	-0.0002	-0.0003	0.0026**	0.00072***	0.00151**
Market distance	0.0012	0.0009***	0.0012***	0.0013***	0.00027**	0.0003
Landrace sold	-0.0002	-0.0002	-0.0003	-0.00061	0.00002	-0.0002
MV sold	-0. 00005	-0.00009*	-0.00014*	-0.00057	-0.0003*	-0.0006
Log likelihood function	-204.6	-78.63	-157.15	-263.34	-85.72	-250.75

†, Regression model for richness is Poisson; for evenness Tobit censored at zero; and for inverse dominance Tobit censored at one. One tailed Z-tests significant at P < 0.01(***), 0.05 (**), 0.1 (*) percent level. Z-statistic is relevant for maximum likelihood estimation. Marginal effects are computed at the means of explanatory variables.

Though genetic studies (molecular and agromorphological) of landraces grown by the farmers as reported by Bajracharya (2003) has revealed that both Kaski and Bara ecosites grow more genetically diverse landraces based on selected genetic analysis of sample of landraces, this economic study has shown that farmers in Kaski ecosite as compared to Bara are more likely to maintain and sustain diversity given the economic opportunity they face. Diversity indices presented in this study also serve as proxies for public values for the set of crop populations. No trade-offs appear to be associated with public investments that promote richness, evenness or equality in the distribution of rice varieties on farms in either ecosite. The direction of a statistically significant effect is the same across diversity concepts, though there was some difference in the magnitude of the effects and significance of the factors in each ecosite. This result appears to be similar to the findings of Benin et al (2003) for cereal diversity in Ethiopia. The agroecological heterogeneity (farm-physical) and market distance which have been found to play important roles in the maintenance of rice diversity in this study are supported by the earlier works of Meng (1997) for wheat landrace diversity in Turkey and Van Dusen (2000) from *Milpa* cultivation and diversity in Mexico. The fact that households with an active family labour on-farm have greater crop diversity is also supported by previous research. Benin et al (2003) studied the diversity of cereal crops in Ethiopian highlands and found that maize diversity is related to availability of larger stocks of family labour.

Different socioeconomic, market and agroecological factors are significant in explaining the richness and evenness among rice varieties grown in both Tarai (Bara) and hills (Kaski) but they are consistent in sign. Farmers' choices and cultivation of rice varietal diversity and their possible implications on conservation policy are indicated by the significance of marginal probabilities of the explanatory variables. These significance variables are farm adult labour, subsistence ratio, market distance and land types in both of the ecosites. No diversity trade-offs are observed with public investment policy promoting different measures of diversity such as richness versus evenness. This indicates that a program designed to conserve the richness of varieties of rice crop is not likely to have a negative

impact on the evenness among them. Thus, a policy whose goal is to augment one conservation goal would not conflict with another.

Regression results (marginal probabilities) suggest that Kaski (Hill) ecosite has higher marginal probabilities for many of variables that have shown positive significance for on-farm diversity. This finding also shows that on-farm conservation programs need to be targeted in market isolated locations with high farm agroecological heterogeneity since, in such locations, it will be cost-effective to intervene and more likely to be sustained for longer term provided these locations harbour genetic resources that are of high conservation interest. The study also infers that policies that affect the supply of adult household farm labour working in agriculture are likely to have a major impact on the varietal diversity. If the opportunities for non-farm employment increase and fixed adult agricultural labour stocks are drawn out of farm production, it may have a negative impact on prospects for on-farm conservation. However, the feasibility and costs of implementing such a program would require further investigation. Clearly, rice-growing household in the hill (Kaski) ecosite with better possession of farm labour, land and livestock assets and those cultivating diverse land types and more dispersed plots that are located farther away from market centres are more likely to maintain richness and evenness measures of diversity.

Indices of genetic diversity employed here are based on area shares and variety counts. Better results on diversity may be obtained by combining household socio-economic information with an accurately measured genetic data at the molecular level that may probably shed more light on where the most diverse genetic resources are found within the study locations, communities and specific group of households (poor or rich). As constructed, the diversity indices treat all material as equally important for conservation. That is, these goals are related to the numbers, evenness or equitability of varieties grown in communities without regard to the nature of the varieties or the social value of the diversity conserved. A study that links with social valuation and that covers households located across a large range of diverse communities and locations will provide better pictures of cultivation of socially valued landraces and capture dynamics of wider variations of locations and communities.

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Data analysis methods adopted under *in situ* global project in Nepal

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ABSTRACT

Synthesizing data analysis methods adopted under in situ global project in Nepal along with variables and nature of study could be guiding reference for researchers especially to those involved in on farm research. The review work was conducted with the objective to help in utilizing and managing in situ database system. The objectives of the experiment, the structure of the treatments and the experimental design used primarily determine the type of analysis. There were 60 papers of this project published in Nepal. All these papers are grouped under 8 thematic groups namely 1. Agroecosystem (3 papers), 2. Agromorphological and farmers' perception (7 papers), 3. Crop population structure (5 papers), 4. Gender, policy and general (15 papers), 5. Isozyme and molecular (6 papers), 6. Seed systems and farmers' networks (5 papers), 7. Social, cultural and economical (11 papers) and 8. Value addition (8 papers). All these papers were reviewed basically for data type, sample size, sampling methods, statistical methods and tools, varieties and purposes. Descriptive and inferential statistics along with multivariate methods were commonly used in on farm research. Experimental design, the most common in on station trial was least used. Study over space and time was not adopted. There were 5 kinds of data generated, 45 statistical tools adopted in eight different crop species. Among the 5 kinds of data under these eight subject areas, categorical type was highest followed by discrete numerical. Binary type was least in frequency. Most of the papers were related to rice followed by taro and finger millet. Cucumber and pigeon pea were studied least. Descriptive statistics along with χ^2, multivariate analysis and regression approaches would be appropriate tools. Similarly SPSS and MINITAB may be good software. The best one among a number of statistical tools should be selected and utmost care must be exercised while collecting data.

Key words: Data analysis methods, on farm research, on station research, subject areas

INTRODUCTION

Several statistical methods have been developed, tested and routinely used in on station research system. Analysis of variance is the most common way of data management among NARC scientists (Joshi and Shrestha 2003). Limited literatures are available for analyzing and interpreting the on farm and in situ research data. In 1995, International Plant Genetic Resources Institute (IPGRI) together with national partners from nine countries covering five regions, Sub Saharan Africa, Central and West Asia and North Africa, Asia the Pacific and Oceania, the Americas and Europe formulated a global project to strengthen the scientific basis of in situ conservation of agricultural biodiversity on farm. Achievements made on the method of data handling from this project are valued among researchers especially those involved in on farm trials (Jarvis et al. 2000, Jarvis and Hodgkin 1998). The project research team have used many statistical tools in different subject areas and interpreted accordingly. Synthesizing this method along with variables and nature of study could be guiding reference for researchers especially to those involved in on farm research. There are many statistical methods whose purpose is to help understand data. Care should be taken during walking in the road from the experimentation to publication. A bad design implemented in field would result in the death of the experiment. If however, an experiment is well designed and executed, a subsequent bad analysis can be corrected .The objectives of the experiment, the structure of the treatments and the experimental design used primarily determine the type of analysis. In many journals authors (Baker 980, Carmer and Swanson 1971, Carmer 1976, Carmer et al 1979, Joshi et al 2002) pointed out the errors in the use of statistical techniques. Utilization and management of in situ data

base system is necessary for developing in situ conservation methods and models. Therefore the methods and models of data handling under in situ global project-Nepal component was assessed. Basically we have synthesized and discussed statistical tools, sample size, variables, software used, and nature of study of on farm research in Nepal. Besides additional statistical tools are given with respect to subject area of study.

METHODOLOGY

All 60 papers of in situ global project-Nepal component (1999-2000) were reviewed and interpreted data analysis methods. All these papers are grouped under 8 thematic areas ie 1. Agroecosystem (3 papers), 2. Agromorphological and farmers' perception (7 papers), 3. Crop population structure (5 papers), 4. Gender, policy and general (15 papers), 5. Isozyme and molecular (6 papers), 6. Seed systems and farmers' networks (5 papers), 7. Social, cultural and economical (11 papers) and 8. Value addition (8 papers). Three site selection reports (Sherchand et al 1998, Poudyal et al 1998, Rijal et al 1998) and three baseline survey reports (Rana et al 2000a, 2000b, 2000c) were included under social, cultural and economical group. All other papers were from two proceedings ie Sthapit et al (2003) and Sthapit et al (2000). All these papers were reviewed basically for data type, sample size, sampling methods, statistical methods and tools, varieties and purposes. Frequency was used to interpret the findings. Statistical tools were analyzed in depth and appropriate tools and interpretation are suggested. A training manual written by Jarvis et al (2000) and Mutsaers et al (1997) were consulted for listing additional potential statistical tools.

RESULTS AND DISCUSSION

Data collecting, processing and analyzing methods along with purposes and nature of study are given in Table 1. There were some differences on data handling methods among subject area of study. Descriptive statistics along with multivariate methods were the common in on farm research and experimental design which is most common in on station trial was least used. Study over space and time was not adopted. With respect to subject area, frequency of data type collected, statistical tools used and crop studied are given in Table 2. There were 5 kinds of data generated, 45 statistical means adopted in eight different crop species. These methods and crops were used for answering 4 research questions, i. What is the amount and distribution of genetic diversity maintained by farmers over space and time, ii. What are the processes used to maintain genetic diversity on farm, iii. Who maintain diversity on farm and iv. What are the factors that influence farmer's decision making to maintain diversity. In addition to these tools used by on farm researchers, there are many other tools that help to interpret data. Some of them are listed in Annex 1. Farmers are major source for data collection in on farm trials. Therefore, farmers must be cooperative and clear about objectives of the study.

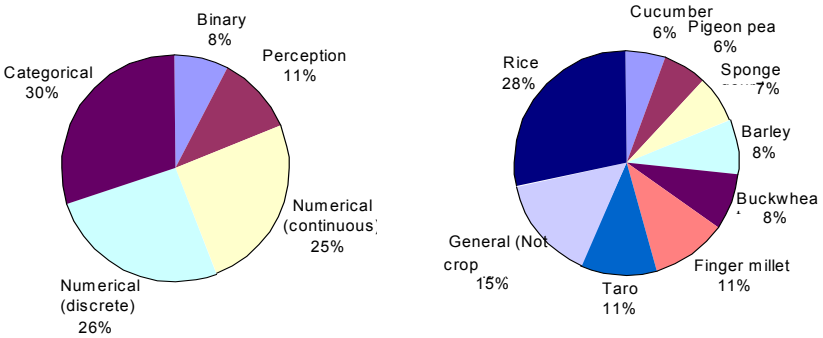

Figure 1. Total use percentage of data types (A) and total times of crop species (B) considered in 60 papers

Table 1. Statistical related parameters adopted by on farm researchers in Nepal during 1998-2003 (Refer Table 2 for full description)

Data type	Sample size	Sampling methods	Data generating methods	Statistical tools	Software	Purposes	Crops	Variables	Nature of study	Authors
1. Agro-ecosystem										
Categorical, Numerical (Discrete, Continuous)	206 (HH), 19 (Landraces)	Purposive, Random	Survey (PRA†, FGD, LRS, HHS), On-Farm (Observation), On-Station, Demonstration	%, fi, Mean, Scoring, Richness, r, Rating, χ^2, Distribution	-	Agroecosystem, Diversity	Rice, Finger millet, Barley, Cucumber, Buckwheat, Taro, Sponge gourd, Pigeon pea	Agroecosystem factors, Distribution, Use value	Exploratory, Characterization, Evaluation, Distribution	A (Paudel et al. 1999), B (Rijal et al. 2003a, Joshi et al. 2003a)
2. Agromorphological and Farmers' Perception										
Categorical, Numerical (Discrete, Continuous)	1 (Plant/Taro, Sponge gourd), 3, 5 (Plants/landrace), 30 (Plants/group), 147, 292, 207, 36, 97 (Accessions), 10, 30, 60 (Plants/accession), 19, 6, 23 (Landraces), 18 (Farmers), 327 (Plants)	Random	Survey (LRS, HHS, FGD, PRA), On-Farm (Observation), On-Station	%, Cluster, Coding, CV, Distribution, fi, H', Mean, PCA, Proportion, Range, Richness, SD, S	EXCEL, MINITAB	Locating diversity, Characterization, Diversity	Rice, Pigeon pea, Sponge gourd, Taro, Barley, Finger millet	Farmers, Agromorphological traits	Characterization, Distribution, Diversity, Exploratory, Evaluation, Grouping	A (Bajracharya et al. 1999), B (Gupta et al. 2003, Yadav et al. 2003a, Rijal et al. 2003b, Pandey et al. 2003a, Yadav et al. 2003b, Tiwari et al. 2003a)
3. Crop Population										
Categorical, Numerical (Discrete, Continuous)	2 (Landraces), 30 (Plants/population), 30 (Populations/landrace), 80, 15, 11 (Populations), 4 (Sub populations), 67 (Accessions), 5-10 (Hills/accession)	Random, Census, Purposive	Survey (PRA, LRS), Demonstration, On-Farm (Observation, RCBD-2 rep)	Mean, Distribution, Richness, SD, fi, CV, SE, Range, % PCA, Cluster, Ratio, ANOVA, LSD	EXCEL, MINITAB, MSTAT	Population structure, Diversity, Characterization	Rice, Finger millet, Barley, Buckwheat, Cucumber, Taro, Pigeon pea	Crop landraces, Agromorphological traits, Farmers	Diversity, Distribution, Structure, Evaluation, Characterization	A (Khatiwada et al. 1999), B (Pandey et al. 2003b, Baniya et al. 2003a, Khatiwada et al. 2003, Tiwari et al. 2003b)
4. Gender, Policy and General										
Perception, Categorical, Numerical (Discrete, Continuous), Binary	2, 18 (Groups), 6, 4, 17 (People), 96, 42 (Finger millet), 62 (Pigeon pea), 528, 383 (HH), 8 (Crops), 4-5 (Food)	Random, Purposive	Conceptual, Survey (FGD, LRS, KII, HHS, PRA), Demonstration, On-Farm (RCBD, Observation), Village lab (Observation)	fi, %, Richness, Mean, SD, D, H', Genetic erosion, Distribution, Trend analysis, Ratio, Proportion	SPSS, EXCEL	Institutional arrangement, Farmers' decision on seed management, National policy for agrobiodiversity conservation, Process of implementation of in situ conservation, Good practices for in situ management, CBO strengthening, Public awareness, Diversity fair, National policy, Gender on on-farm	Rice, Finger millet, Pigeon pea, Taro	Gender, Practices on rice, Policy issue, Approaches, Agricultural operations, Varieties, CBOs, Activities, Crosses, Green manure, Pesticidal plants, Crop products, Markets	Exploratory, Grouping Path study, Characterization, Methodology, Sensitization	A (Upadhyay and Subedi 1999, Subedi et al. 1999, Gauchan et al. 1999, B (Sthapit and Jarvis, 2003, Upadhyay and Subedi 2003, Rana et al. 2003a, Chaudhary et al. 2003a, Upadhyay et al. 2003, Sapkota et al. 2003, Subedi et al. 2003a, Chaudhary

Data type	Sample size	Sampling methods	Data generating methods	Statistical tools	Software	Purposes	Crops	Variables	Nature of study	Authors
						diversity, Genetic erosion CBOs role, Achievements, Local crop improvement, Cooperatives for in situ conservation				et al. 2003b, Adhikari 2003, Sah and Sah 2003, Adhikari and Adhikari 2003, Thapa 2003)
5. Isozyme and Molecular										
Binary	35, 24 (Accessions), 10 (Seeds/accession), 22 (Farmers), 10, 19, 4 (Landraces), 2 (Plants/landrace), 15, 197 (Populations), 5-10, 20 (Plants/population), 10 (Seeds/population)	Random	Lab (Observation),	Cluster, A, Ap, P, H, Ht, Hs, Dst, Gst, %, Zymotype, PCA, Range, Goodness of fit, Range, Mean, fi, r, SD, Dice coefficient, Tukey PIC, Mantel test, SE, Cophenetic correlation	NtSys, GeneStat	Evaluation, Verification, Diversity, Genetic relationship	Rice, Buckwheat, Taro, Barley	RAPD, Farmers, Isozyme, Microsattelite	Verification, Diversity, Evaluation, Relationship, Structure	A (Bajracharya et al. 1999), B (Bajracharya et al. 2003a, Bajracharya et al. 2003b, Bimb et al. 2003, Bajracharya et al. 2003c, Bajracharya et al. 2003d)
6. Seed Supply and Farmers' Network										
Categorical, Numerical (Discrete), Binary	48, 78, 96 (HH)	Purposive, Random	Survey (LRS, FGD, HHS, PRA)	Richness, %, fi, Trend analysis, Richness	SPSS	Seed supply and storage system, Diversity maintenance, Planting materials	Rice, Finger millet, Taro	Seed exchange, Seed sources and storage system, Management of planting materials	Exploratory, Distribution, Characterization	A (Baniya et al. 1999), B (Subedi et al. 2003b, Baniya et al. 2003b, Baniya et al. 2003c, Baniya et al. 2003d)
7. Social, Cultural and Economical										
Categorical Numerical (Continuous Discrete), Binary	12, 16, 22 (Villages), 2 (Varieties), 34 (Farmers), 66 (Farms), 18 (KI), 180, 206, 202, 40, 197 (HH)	Census, Random, Purposive	Survey (PRA, FGD, KII, HHS, LRS) On-Farm (CRD, Observation)	Rating, %, Maximum, Minimum, Median, fi, Richness, Matrix ranking, Genetic erosion, Mean, Ratio, SD, χ^2, ANOVA, Cluster, r, Distribution, Pair-t, Range	SPSS, MINITAB, EXCEL	Area and community identification, Information collection on crop genetic resources and farming systems, Cultural and socioeconomical factors, Assessment of economic valuations of rice landraces diversity, Understanding farmers' management of landraces, Market incentive for on-farm conservation, Traditional production	Rice, Barley, Buckwheat, Cucumber, Finger millet, Sponge gourd, Taro, Pigeon pea	Castes, Land types, Crops, Cropping patterns, CBOs, Accessibility, Agro-ecology, Socio-economic, Livestock, Agri-inputs, Market, Household characteristics, Opportunity cost, Cost benefit, Constraints, Soil characteristics, Farmer management of rice, Cost benefit, Cultivation patterns, Market price, Desired traits, Producers, Traders	Characterization, Comparison, Evaluation, Distribution, Diversity, Relationship, Path study, Grouping	Sherchan et al. 1998, Poudyal et al. 1998, Rijal et al. 1998, Rana et at 2000 K, Rana et at 2000 J, Rana et at 2000 B, A (Rana et al. 1999, Gauchan 1999), B (Rana et al. 2003b, Gauchan et al. 2003, Chaudhary et al. 2003c)

Data type	Sample size	Sampling methods	Data generating methods	Statistical tools	Software	Purposes	Crops	Variables	Nature of study	Authors
						and marketing systems				
8. Value Addition										
Categorical Numerical (Discrete, Continuous) Perception	18 (People), 16, 2 (Landraces), 57, 2, 338 (Farmers), 78, 34 (HH), 25, 5 (Panicles/HH), 7 (Locations), 30 (Plants/accession)	Random, Purposive	Survey (FGD, PRA, KII, LRS, HHS), On-Station (Screening), Conceptual (FGD, LRS, Demonstration), On-Farm (FGD, Observation, PRA, KII), Lab (HHS)	% Distribution Trend analysis Organoleptic test Matrix ranking fi, distribution Range, Mean SE, SD, Ratio, r, CV	-	Adding benefit, PGR documentation, Linking crop diversity with traditions, Enhancement, Diversity	Rice, Taro, Buckwheat, Finger millet	Awareness, PPB process, Incentives, Market, Selection, CBR, Agromorphological traits, Food traditions	Diversity, Improvement, Characterization, Distribution	A (Joshi et al. 1999, Rijal et al. 1999), B (Rijal et al. 2003c, Joshi et al. 2003b, Rijal et al. 2003d, Pant et al. 2003, Joshi et al. 2003c, Joshi et al. 2003d)

† PRA, Other than listed.

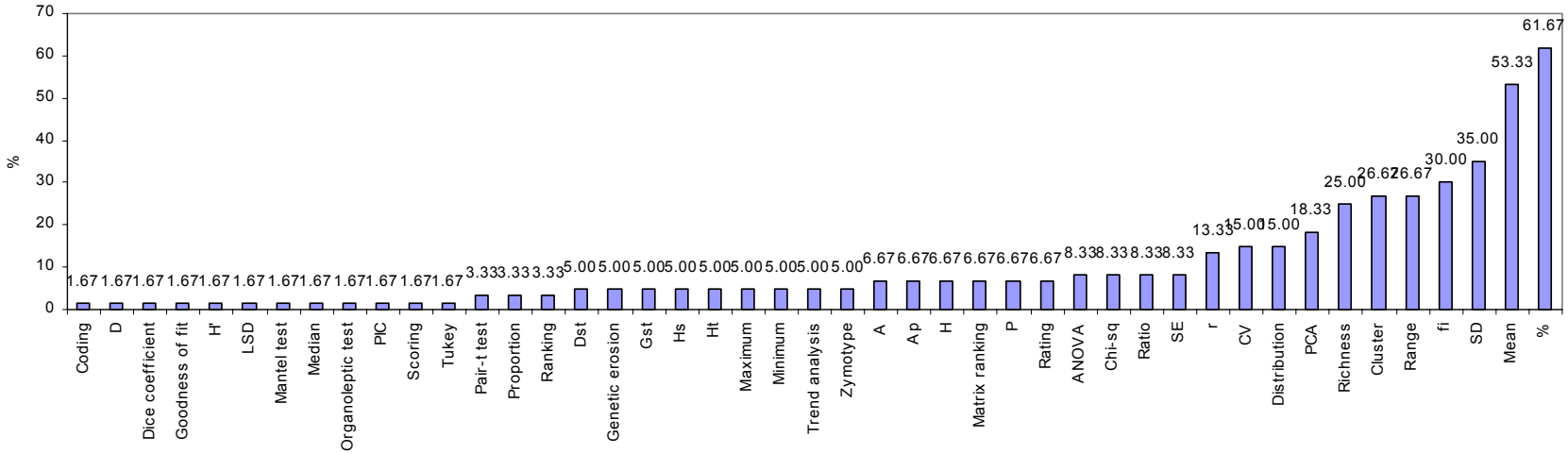

Figure 2. Total use percentage of statistical tools in 60 papers (Refer Table 2 for full description).

Table 2. Frequency of data type and statistical tools used in 60 papers under 8 different research subjects

Variables	Sectors																Total
	AE		AFP		CP		GP		IM		SS		SCE		VA		
	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi
A. Data type																	
Binary	-	-	-	-	-	-	1	6.67	6	100	1	20	1	9.09	-	-	9
Categorical	3	100	7	100	5	100	2	13.3	-	-	5	100	11	100	2	25	35
Numerical (continuous)	2	66.7	6	85.7	5	100	2	13.3	-	-	-	-	11	100	3	37.5	29
Numerical (discrete)	3	100	6	85.7	5	100	4	26.7	-	-	1	20	10	90.9	1	12.5	30
Perception	-	-	-	-	-	-	10	66.7	-	-	-	-	-	-	3	37.5	13
Total papers	3	-	7	-	5	-	15	-	6	-	5	-	11	-	8	-	60
B. Statistical tools																	
%	2	66.7	5	71.4	4	80	2	13.3	5	83.3	5	100	10	90.9	4	50	37
A	-	-	-	-	-	-	-	-	4	66.7	-	-	-	-	-	-	4
ANOVA	-	-	-	-	1	20	-	-	-	-	-	-	4	36.4	-	-	5
Ap	-	-	-	-	-	-	-	-	4	66.7	-	-	-	-	-	-	4
χ^2	1	33.3	-	-	-	-	-	-	-	-	-	-	4	36.4	-	-	5
Cluster	-	-	5	71.4	2	40	-	-	6	100	-	-	3	27.3	-	-	16
Coding	-	-	1	14.3	-	-	-	-	-	-	-	-	-	-	-	-	1
CV	-	-	4	57.1	4	80	-	-	-	-	-	-	-	-	1	12.5	9
D	-	-	-	-	-	-	1	6.67	-	-	-	-	-	-	-	-	1
Dice coefficient	-	-	-	-	-	-	-	-	1	16.7	-	-	-	-	-	-	1
Distribution	1	33.3	3	42.9	1	20	1	6.67	-	-	-	-	1	9.09	2	25	9
Dst	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	3
fi	1	33.3	4	57.1	2	40	1	6.67	1	16.7	4	80	2	18.2	3	37.5	18
Genetic erosion	-	-	-	-	-	-	1	6.67	-	-	-	-	2	18.2	-	-	3
Goodness of fit	-	-	-	-	-	-	-	-	1	16.7	-	-	-	-	-	-	1
Gst	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	3
H'	-	-	1	14.3	-	-	1	6.67	-	-	-	-	-	-	-	-	1
H	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	4
Hs	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	3
Ht	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	3
LSD	-	-	-	-	1	20	-	-	-	-	-	-	-	-	-	-	1
Mental test	-	-	-	-	-	-	-	-	1	16.7	-	-	-	-	-	-	1
Matrix ranking	-	-	-	-	-	-	-	-	-	-	-	-	3	27.3	1	12.5	4
Maximum	-	-	-	-	-	-	-	-	-	-	-	-	3	27.3	-	-	3
Mean	2	66.7	7	100	5	100	2	13.3	6	100	-	-	8	72.7	2	25	32
Median	-	-	-	-	-	-	-	-	-	-	-	-	1	9.09	-	-	1
Minimum	-	-	-	-	-	-	-	-	-	-	-	-	3	27.3	-	-	3
Organoleptic test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	12.5	1
P	-	-	-	-	-	-	-	-	4	66.7	-	-	-	-	-	-	4
Pair-t test	-	-	-	-	-	-	-	-	-	-	-	-	2	18.2	-	-	2
PCA	-	-	4	57.1	2	40	-	-	5	83.3	-	-	-	-	-	-	11
PIC	-	-	-	-	-	-	-	-	1	16.7	-	-	-	-	-	-	1
Proportion	-	-	1	14.3	-	-	1	6.67	-	-	-	-	-	-	-	-	2
r	1	33.3	-	-	-	-	-	-	3	50	-	-	3	27.3	1	12.5	8
Range	-	-	5	71.4	4	80	-	-	3	50	-	-	1	9.09	3	37.5	16
Ranking	-	-	-	-	-	-	-	-	-	-	-	-	2	18.2	-	-	2
Rating	1	33.3	-	-	-	-	-	-	-	-	-	-	3	27.3	-	-	4
Ratio	-	-	-	-	1	20	1	6.67	-	-	-	-	2	18.2	1	12.5	5

Variables	Sectors																Total
	AE		AFP		CP		GP		IM		SS		SCE		VA		
	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi	%	fi
Richness	2	66.7	2	28.6	1	20	2	13.3	-	-	2	40	6	54.5	-	-	15
Scoring	1	33.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
SD	-	-	6	85.7	3	60	1	6.67	3	50	-	-	6	54.5	2	25	21
SE	-	-	-	-	3	60	-	-	1	16.7	-	-	-	-	1	12.5	5
Trend analysis	-	-	-	-	-	-	1	6.67	-	-	1	20	-	-	1	12.5	3
Tukey	-	-	-	-	-	-	-	-	1	16.7	-	-	-	-	-	-	1
Zymotype	-	-	-	-	-	-	-	-	3	50	-	-	-	-	-	-	3
Total papers	3	-	7	-	5	-	15	-	6	-	5	-	11	-	8	-	60
C. Crops																	
Barley	2	66.7	1	14.3	2	40	-	-	2	33.3	-	-	1	9.09	-	-	8
Buckwheat	2	66.7	-	-	2	40	-	-	2	33.3	-	-	1	9.09	1	12.5	8
Cucumber	2	66.7	-	-	1	20	-	-	-	-	-	-	3	27.3	-	-	6
Finger millet	2	66.7	1	14.3	1	20	2	13.3	-	-	1	20	3	27.3	1	12.5	11
Pigeon pea	2	66.7	1	14.3	1	20	1	6.67	-	-	-	-	1	9.09	-	-	6
Rice	2	66.7	2	28.6	3	60	4	26.7	1	16.7	3	60	8	72.7	6	75	29
Sponge gourd	2	66.7	3	42.9	-	-	-	-	-	-	-	-	2	18.2	-	-	7
Taro	3	100	2	28.6	1	20	1	6.67	1	16.7	1	20	1	9.09	1	12.5	11
Not crop specific	-	-	-	-	-	-	10	66.7	-	-	-	-	3	27.3	2	25	15
Total papers	3	-	7	-	5	-	15	-	6	-	5	-	11	-	8	-	60

AE, Agro-ecosystem. AFP, Agromorphological and farmers' perception. CP, Crop population. GP, Gender, policy and general. IM, Isozyme and molecular. SS, Seed supply and farmers' network. SCE, Social, cultural and economical. VA, Value addition. %, Percent. ANOVA, Analysis of variance, CRD, Completely randomized design, CV, Coefficient of variance, D, Simpson index, FGD, Focus group discussion, fi, Frequency, GIS, Geographic information system, Hb, Brillion index, H, Gene diversity, H', Shannon weaver index, HHS, Household survey, HH, Household, KI, Key informant, KII, Key informant interview, LRS, Literature survey, LSD, Lest significant difference, NA, Not applicable, N_e, Nei's index, PCA, Principal components analysis, PIC, Polymorphic information index, PRA, Participatory rural appraisal, r, Correlation coefficient, RCBD, Randomized complete block design, SD, Standard deviation, SE, Standard error, N, Average number of individuals sampled (mean across all loci). L,Nnumber of loci sampled. A, Mean number of alleles per locus. Ap, Mean number of alleles per polymorphic locus. P, Proportion of polymorphic loci. H, Expected heterozygosity. This value will tend to be lower than the actual value if the number of individuals sampled is low. U, Number of alleles unique to that population (=private alleles). p(1), Average frequency of private alleles, useful for obtaining indirect estimates of gene flow. Ht, Total gene diversity. Hs, Mean gene diversity within population. Dst, Mean gene diversity among populations. Gst, Coefficient of gene differentiation. Hs/Ht, Percentage mean gene diversity within population.

Agro- ecosystem

Researchers under this subject have tried to explore, characterize, evaluate and to know the distribution pattern considering categorical and numerical types of variables of crop species and households. Survey was the major tool to generate data. On farm and on station methods were also used to generate data. Among the 9 statistical tools, most common were percentage, mean and richness. Eight crop species were used. Diversity (alpha, beta, gama) and classification methods are additional appropriate tools in such type of study. Spatial and temporal study should also be considered.

Agromorphological and farmer perception

There were 7 papers under this category. Survey, on farm and on station experiments were the methods of generating data with objectives of locating and measuring diversity and characterizing variables. On farm method with observatory type was common and MINITAB was used by most of the scientists. Sample was chosen randomly with great variation in sample size. Buckwheat and cucumber were not agromorphologically studied. Categorical type of data was highest in frequency. Among statistical tools

mean was most commonly used followed by standard deviation (SD). Three papers were related to sponge gourd, which is highest in number among six crop species. Multivariate methods were also common in this subject area but their interpretation and presentation style were not well and impressive. Nature of study and set objective should be considered during choosing statistical tools. χ^2 and pattern analysis may be good methods for interpreting agromorphological and farmers' perception data.

Crop population

Objectives under this category were related to population structure, diversity and characterization. Sample was chosen randomly in most of the cases. Common experimental method was on farm with observation type, which was handled mostly by Excel software. Three variables were used in 7 crop species. Mean was the most common tools followed by percentage, coefficient of variance (CV), and range. Rice had received the highest priority for population structure study. Here principle component analysis (PCA) and cluster were not used property. Distribution at ecosystem, species and genetic levels will be core area of study in this category.

Gender, policy and general

The highest number of papers was related to gender and policy. Samples were selected purposively and data were generated mostly from survey. Perception type of data was highest in frequency followed by discrete numerical type. Percentage, mean and richness were commonly used tools. Most of the papers were not relevant to crop species. In addition to these tools, relationship, 4-square analysis and ordination methods may be used. Least number of statistical tools has been used in this subject area.

Isozyme and molecular

Only binary data were used with the objectives of evaluation, verification, diversity and genetic relationship in four crop species. This is totally lab-based research and many genetic parameters were estimated. Most of these binary data was handled by NTSys software. Use of cluster and mean were common. Unique tools eg Mental test and Cophenetic correlation etc have been used. Major issue raised here is the application of these findings. Spatial and temporal analysis along with distance measures may be other tools that can help to draw inference in such a study.

Seed supply and farmer's network

Households were the main variables studied to know the seed supply and storage system along with diversity maintenance. Most of the samples were purposively selected and all authors have generated data through survey. Categorical data type was highest in frequency. Percentage and frequency were frequently used. Study was done in only 3 crop species, finger millet, rice and taro.

Social, cultural and economical

More details information was drawn under this subject area by 11 authors in all mandated crops. There were many variables taken to characterize, evaluate, compare, relate and to assess diversity. Randomly sampled information was generated through survey in most of the cases. Data were analyzed using SPSS. Categorical and continuous numerical data dominated in this research. Percentage was frequently used and second one was mean. Rice was relatively studied many more times than other crop species. There was a use of PCA, cluster and analysis of variance (ANOVA) but their presentation and inference drawing were not impressive. Some of additional tools are 4-square analysis, ordination, classification methods, regression and trend analysis that can help to draw more valid information.

Value addition

This aspect was studied in rice, taro, buckwheat, and finger millet. Survey was the common means of data generation from purposively selected sample with an objective of adding benefit. Perception and continuous numerical data were common which were mostly described by percentage. This study was concentrated more on rice.

Summary in use of statistical tools, data types and crop species on percentage are given in Figure 1, 2. Among the 5 types of data type under these eight subject areas, categorical type was highest followed by discrete numerical (Figure l). Binary type was least in frequency. Most of the papers were related to rice followed by taro and finger millet. Cucumber and pigeon pea were studied least. Percentage was the most common tool and second most frequently used tool was mean. Genetic parameters were estimated by least number of authors (Figure 2). In addition to these tools, there are many tools. Appropriate tools should be selected based on the objective of study. In on farm research variance can't be controlled but we have to use properly during interpretation. Special design was not followed and farmer was used as a replicate. Village can be used as a block. In such cases, descriptive statistics along with χ^2, multivariate analysis and regression approaches are appropriate. Similarly SPSS and MINITAB may be good software to handle such type of data. Excel is the excellent to enter data and to process them. There are needs of improvement on interpretation, presentation of findings and drawing of conclusions. A scientific method of research ie first identify problem, set objective, formulate hypothesis and test the validity should be followed. To validate the hypothesis, data should be collected properly, analyzed and presented in a good manner and in the last findings should be generalized. For interpretation of the results, there are a number of statistical tools those can help in getting logical inference. But researcher should be able to select best one and utmost care must be exercised while collecting data.

Most of the tools used for managing and utilizing on farm data were similar to on station trails. These were used basically to answer above-mentioned four research questions. This report will be useful for developing common on farm database systems and hypothesis testing.

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Annex 1. Additional statistical tools that can be used for on farm research (Refer Table 2 for full description)

Agro-ecosystem

Classification method
- Hierarchical cluster analysis
- Non-hierarchical cluster analysis
- Modeclus cluster analysis

Ordination Method (D2)
- Polar ordination
- Principal coordinate analysis
- Reciprocal averaging
- Detrended correspondence analysis
- Canonical variate analysis
- Canonical discriminant analysis

Depended vs independed variables
- Multiple regression
- Canonical correlation
- Binary discriminant
- Multiple discriminant
- Discriminant analysis
- Relationship

GIS

Spatial and temporal analysis

4-square analysis

Agromorphological

Ranking

GIS

Univariate data analysis
- Mode
- Median
- ANOVA
- Minimum
- Maximum

Diversity Indices
- Evenness
- D
- Hb

Non parametric test

Covariate analysis

Bivariate Data analysis
- χ^2
- Similarity measures
  - Simple matching coefficient
  - Jaccord's coefficient

Multivariate data analysis
- Classification method
  - Non-hierarchical cluster analysis
- Ordination Method
  - Polar ordination
  - Principal coordinate analysis
  - Reciprocal averaging
  - Detrended correspondence analysis
  - Canonical variate analysis
- Canonical discriminant analysis
- Factor analysis of correspondence
- Pattern analysis

Distance measures
- Euclidean distance
- Mahalanobi's generalized distance
- Roger's distance
- Gower's similarity coefficient

Analysis of relationship among characters, individuals, populations, sites, sampling time, between results obtained from different sets of characters

Partitioning of variations within and between populations, sites, sampling times

4-square analysis

Crop population

Evenness

Density

Minimum viable population

Allele distributions

Out crossing rates

Gene flow

Landrace occurrence patterns
- Genotype diversity index
- D
- Net index of gene diversity
- Population size
- Variance
- Distributions
  - Common
  - Rare
  - Widespread
  - Local

Genetic structure
- Polymorphic gene
- Allelic richness
- Frequency of allelic variants
- Level of heterozygosity
- Number of multilocus genotypes
- Distinctiveness
- Degree of linkage disequilibrium
- Fixation index
- Coefficient of gene diversity

Relationship

4-square analysis

Biochemical and molecular markers
- Allelic richness
- Population subdivisions
- Effective population size
- Similarity
- Distance
- Genetic map

Spatial and temporal (time series) analysis

4-square analysis

t test

Seed system

Seed flow

Fuzzy analysis

N_e

Ranking

Rating

Sorting

Matrix ranking

Time series analysis
- Auto correlation coefficient
- Cross correlation
- Power spectral analysis

4-square analysis

RESEARCH NOTE

Occurrence of Garlic Rust in Mid Hill of Nepal

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Garlic (*Allium sativum* L.) is one of the common spice crops of Nepal. It is cultivated throughout the country, basically for bulbs as spice and young plants for vegetable. It is also used in traditional medicine. Its antimicrobial characteristics are likely due to sulphur compounds. It may also help to prevent cardiovascular diseases (Schwartz et al 1996).

Recently, a new rust disease in garlic was observed for the first time at Regional Agricultural Research Station, Lumle (ca. 1450 masl) during April 2005. The variety of garlic was Chinese lasun, which is grown as a local variety in the areas. Rust, caused by *Puccinia porri* G. Wint, in *Allium* species occurs in most of the North Temperate Zone and its severity varies among crops and localities (Hill 1996). The disease occurs most frequently under conditions of high humidity and low rainfall. Serious outbreak could reduce bulb weight from 25-60% with deterioration in quality. The disease was noticed at bulb formation stage of the crop. The leaves were severely infected that were almost entirely covered with pustules resulting yellowing and premature drying. Koike et al (2001) reported a yield loss up to 51% due to rust infection.

Early symptom consists of small circular to elongated, white flecks on leaves. As the disease progresses, those specks expand into oblong lesions. The tissue covered with the lesion ruptures and the masses of the uredospores with characteristic orange colour are released. Those uredospores are responsible for secondary disease spread. By this time, orange uredospores become visible as pustule. Teliospores develop later in the same leaf showing black pustule. The fungus overwinters as uredospores or teliospores (Hill 1996). Severely infected leaves are entirely covered with pustules, resulting in extensive yellowing, wilting and premature drying of leaves.

Infected plants were collected and examined in the laboratory of Plant Pathology Division-Nepal Agricultural Research Council, Khumaltar-Nepal. The symptoms and signs (Figure 1a and 1b) were verified and studied with the help of cited literatures (Hill 1996, Koike et al 2001) and under stereomicroscope. Characteristic single celled yellowish orange uredospores (Figure 2a and 2b) and bicelled gray teliospores with short pedicel were identified under compound microscope. According to the symptoms and laboratory examination, the causal pathogen was found to be *Puccinia porri* G.Wint (syn. *P. allii* F. Ruldophi). This is the first report of garlic rust occurrence in Nepal. However, it may spread and under congenial conditions, the outbreak may cause significant loss in garlic production in future.

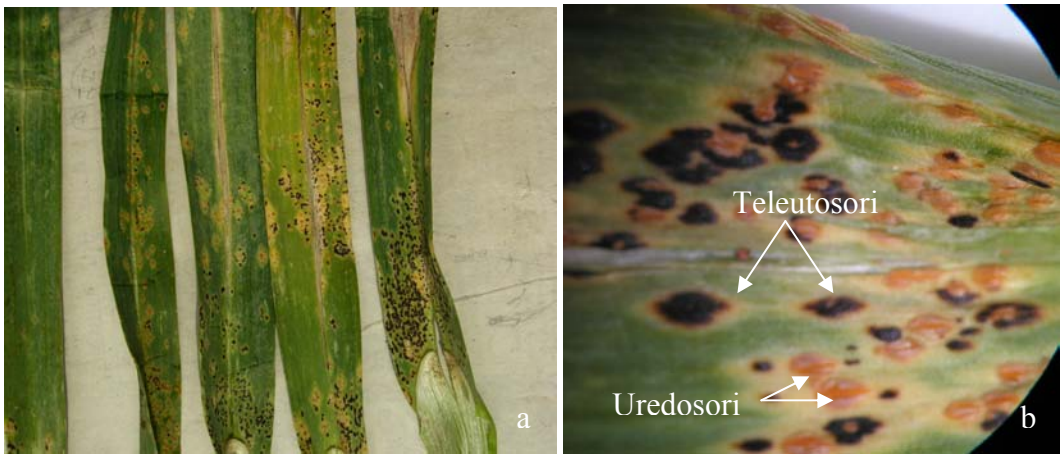

Figure 1. Garlic leaf rust caused by *Puccinia* porri, a. leaf segments showing rust pustules, b. Teleutosori and uredosori.

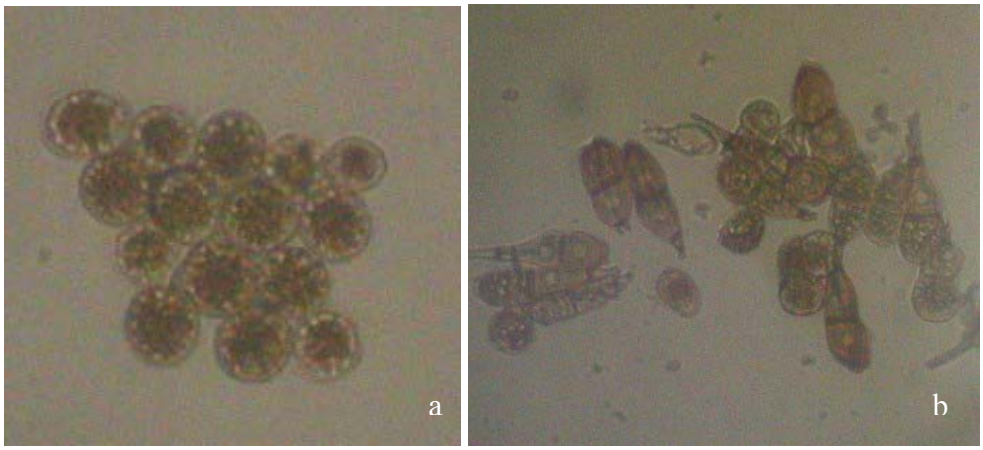

Figure 2. *Puccinia porri*, a. Uredospores, b. Teleutospores.

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REVIEW PAPER

Associative Nitrogen Fixation in Lowland Rice

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ABSTRACT

Nitrogen (N), a most limiting nutrient, is the input required in the largest quantity for lowland rice production. The concerns on N economy and efficiency and its impact on environment have renewed interest in exploring alternative or supplementary N source for sustainable agriculture. Several studies have indicated the existence of significant rice genotypic differences in N_2 fixation stimulating traits (NFS). Rice genotypes with high NFS are desirable because they add N to the soil-water-plant system without additional farm inputs and reduce dependence on fertilizer. Large genotypic differences in percent N derived from air (% Ndfa) like 1.5% in Abang Basur, medium maturing genotype, to 21% in Oking Seroni, late maturing genotype, indicates potential of isolating genotypes with high NFS for sustainable agriculture. The exogenous supply of nitrogenous fertilizer to lowland rice significantly inhibited N fixation but improved plant growth. Where as phosphorous fertilizer did not affect atom % ^{15}N excess and % Ndfa significantly but slight decrease in atom % ^{15}N excess and increase in N_2 fixation was observed. Inhibitory effect of exogenous supply of N fertilizer indicates limited potential of associative N_2 fixation to significantly benefit agriculture. Farmers would have to withhold N fertilizer from their rice crop in order to increase biological N_2-fixation associated with rice. If they do such practice the plants will be N deficient and might have a lower yield. However, the development of N fixation in response to a deficiency of available N may well be an integral part of the N cycle of natural ecosystem and low input farming system there by maintaining a N balance in the environment.

Key words: Fertilizer, fixation, nitrogen, rice

INTRODUCTION

Rice is the most important cereal crop. In the next three decades, the world will need to produce about 60% more rice than today's global production to feed the extra billion people. Nitrogen is the major nutrient limiting the high yield potential of modern rice cultivars. Development of fertilizer-responsive varieties, coupled with the realization by farmers of the importance of nitrogen, has led to high rates of N fertilizer use on rice. But unfortunately a substantial amount of the N fertilizer is lost through different mechanisms causing environmental pollution problems. Utilization of biological N fixation (BNF) technology can decrease the use of N fertilizer, reducing the environmental problems to a considerable extent. BNF technologies must be economically viable, ecologically sound, and socially acceptable to be successful (Ladha and Reddy 2003).

Current environmental protection requirements make it necessary to develop ecologically clean technique of crop production that make maximum use of natural sources of bound N. Thus, biological fixation of atmospheric N and especially non-symbiotic N_2-fixation in the soil has been subject of continuing interest in recent decades. In addition, scare and the increasing cost of nonrenewable chemical fertilizers necessitates the greater use of renewable indigenous biological N_2-fixation system as source of N for the rice.

In flooded soil, N is available to rice even in fields that have been planted for many years without fertilizer application. Sen (1928) reported the presence of heterotrophic N_2-fixing bacteria in the rice root. However, the significance of his suggestion was neglected till Yoshida and Ancajas (1971) found that some N_2-fixing activity was associated with wetland rice root. Later, evidence of N_2 fixation by wetland rice roots was confirmed by ^{15}N studies (Eskew et al 1981, Yoshida and Yoneyama 1989). Subsequently, several studies have reported the evidence and significance of associative N_2-fixation (ANF) using different methods ie N balance studies (App et al 198l), acetylene reduction assay (ARA) (Sano et al 1981, Ladha et al 1986, 1987, 1988, Tirol-Padre et al 1988), and ^{15}N studies (Buenaventura et al 1984, Watanabe et al 1987, Chalk 1991). Moderate but sustainable yield of wetland rice can be obtained without N fertilizer (Koyama and App 1979). Thus long maintenance of soil fertility has been attributed to associative and free living biological N_2-fixation (BNF) (Yoshida and Ancajas 1973, Hirota et al 1978, Watanabe 1986). It has been recognized for a long time that associative N_2-fixing biological systems in wetlands enrich the soil organic N pool and supply up to 113 kg N/ha to rice crop depending upon the ecosystem, cultural practices and rice variety grown (Watanabe et al 1977, Rao et al 1998, Ariosa et al 2004). Researchers have agreed since long time that the high fertility of lowland rice field is because of biological N fixation (Grist 1965). Yoshida and Ancajas (1971, 1973) have given convincing evidence on efficient N fixation in the rhizosphere of rice by bacteria contributing N economy of the rice soil. Flooded soil planted to rice had a significant positive N balance. The positive N balance was found to be the result of phototrophic and heterotrophic N_2-fixing agents (App et al 1980).

Nitrogen fixing bacteria make up a large percentage of the total micro-flora in the rhizosphere of lowland rice. Using acetylene reduction method, Ishizawa et al (1987) and Yoshida and Ancajas (1971) found high nitrogenase activity in roots of lowland rice. Submergence seems to provide suitable conditions for N_2-fixation on rice roots grown under lowland conditions. The estimated amounts of N fixed in the dry season were 63 kg ha^{-1} N in planted flooded soil, 28 kg ha^{-1} in unplanted flooded soil, and only negligible in upland soil (Trolldeneir 1975). Form of available N and the status of potassium nutrition influence the number of bacteria and their activity around rice root grown in solution culture (Trolldeneir 1973).

Biological N_2 fixation is gaining importance in rice ecosystem because of current concern on the environmental and soil health that are caused by the continuous use of nitrogenous fertilizers and the need for improved sustainable rice productivity. Thus, biological fixation of atmospheric N, especially non-symbiotic N_2-fixation in the soil, has been subject of continuing interest in recent decades especially for low input agriculture. Therefore, the objectives of this paper are to review prospect and contribution of ANF, free living and associative system in flooded rice soil, genotypic differences, contribution and effect of chemical fertilizer on N fixation.

PROSPECT AND CONTRIBUTION OF ASSOCIATIVE NITROGEN FIXATION

Chalk (1991) reported that ANF can potentially contribute agronomically significant amount of N (>30-40 kg N ha^{-1} yr^{-1}) to the N nutrition of plants of importance in tropical agriculture when grown in uninoculated, N-deficit soils. Nitrogen fixation by some diazotrophic bacteria like *Azotobacter*, *Clostridium*, *Azospirillum*, *Herbaspirillum* and *Burkholderia* can substitute for N fertilizer, while *Rhizobium* can promote the growth physiology or improve the root morphology of the rice plant (Choudhury and Kennedy 2004).

A number of studies have summarized the advantages of rice plant-associative N_2 fixation:

1. Part of fixed N is available to the plant immediately (Ito et al 1980, Yoshida and Yoneyama, 1980, Eskew et al 1981, Watanabe and Roger 1984).

2. Plant associated N_2 fixation is less sensitive to N fertilizer application (Watanabe et al 1981).
3. Most of the plant associated fixed N is probably not readily amenable to loss process as it is microbially bound in the rhizosphere (Ladha et al 1987).

Studies conducted in different parts of the world have shown that percent N derived from air (%Ndfa) by N_2 fixation is 0 to 35 percent in rice (Table 1). Acetylene reduction assay, ^{15}N studies and N balance studies showed that the contribution of N_2 fixation associated with rice root is about 20% of the N of rice (Watanabe et al 1979). Similarly, Boddy and Dobereiner (1984) reported that root associated BNF is one of the major sources of N for wetland rice and it is estimated at 30 kg N ha^{-1} $crop^{-1}$, on around 20% of the total plant N.

Table 1. ^{15}N dilution estimates of N_2 fixation associated with flooded rice in pot experiment (modified form Chalk 1991)

Soil	Test plant		Reference plant		% Ndfa	Reference
Treat	Cultivar	Inoculum	Cultivar	Inoculum		
U, C	R26	Pseudomona sp. Azospirillium sp.	IR 26	Nil	0	Watanabe and Lin 1984
U	-	-	-	-	20-23	Zhu et al 1986
U, C	IR 42	-	R 42	-	32-35	Buenaventura et al 1984
H, C	C5444	Klebsiella oxytoca	C5444	-	11-19	Yoo et al 1986
U, C	C5444	Klebsiella oxytoca Enterobactor cloacae	C5444 T65	K. oxytoca	0-18	Fujii et al 1987
-	IR 42	Rice covered soil	-	-	20-30	Ventura and Watanabe 1983
-	Japonica and Indica rice	Alcaligenes faecalis	-	-	20-30	You et al 1991
-	-		-	-	19-25	Yoshida and Yoneyama 1980
-	IR 42		Palawan	-	35	Wu 1993

U, Unsterilized. H, Heat sterilized. C, Covered with black code, aluminium foil or lid.

FREE LEAVING AND ASSOCIATIVE SYSTEM

Diverse N_2-fixing microorganisms (aerobic, facultative anaerobes, heterotrophs, phototrophs) are found in wetland rice ecosystem and contribute to soil N pools. The major BNF systems in the flooded rice soils include cynobacteria, photosynthetic bacteria and heterotrophic bacteria.

The contributions of cynobacteria BNF are estimated to be 10-80 kg N ha^{-1} $crop^{-1}$, averaging about 30 kg N ha^{-1} $crop^{-1}$ (Roger and Watanabe 1986). Since the discovery of the cynobacteria in N gain under flooded conditions, many inoculation experiments have been conducted using cultured cynabacteria to improve soil fertility and grain yields of rice. Roger and Watanabe (1986) calculated that cyanobacterial inoculation increase rice yields only by an average of 337 kg grain ha^{-1} $crop^{-1}$.

Heterotrophic bacterial BNF is 7 kg N ha^{-1} (App et al 1986), ranging from 11-16 kg N ha^{-1} which contributes 16-21% of total rice N requirement (Zhu et al 1984, Shrestha and Ladha 1996a).

GENOTYPIC DIFFERENCES IN NITROGEN FIXATION

Identification of rice genotypes capable of stimulating associative N_2 fixation is an important goal for rice agriculture. It is important to document the differences between different genotypes, and select genotypes that have greater ability to stimulate N_2 fixation. A genotype possessing high N_2-fixing stimulating traits (NFS) would diminish the need for fertilizer N but would have no further impact on other cultural practices.

Several studies indicate that significant genotypic differences exist in NFS for rice (Yoshida and Ancajas 1971, Lee et al 1977, Hirota et al 1978, App et al 1986, Ladha et al 1987, 1988) (Table 2). The following reasons have been suggested to explain genotypic differences in NFS: specificity of plant-bacterial associations, differences in root exudations and gaseous diffusion efficiency (Ladha et al 1986). Through the exudates of rice roots different genotypes play an important role in the effectiveness of ANF (Lin and You 1989).

Table 2. Rice genotypic variation in associative nitrogen fixation and related characteristics

Variety	N_2-fixation estimation method	Enhanced N gain level	
IR42	ARA	High (Barraquio et al 1986, Watanabe et al 1987)	Medium (App et al 1986)
	^{15}N dilution	High (Buenaventura et al 1984)	-
Hua-cho-chi-mo-mor	^{15}N	Low (Watanabe 1986)	High (App et al 1986)
IS4	ARA	Low (Ladha et al 1986) Buenaventura et al 1984	Low (App et al 1986)
	^{15}N dilution	Low (Buenaventura et al 1984)	-
BG 367-4	ARA	Low (Ladha et al 1988)	Average (Ladha et al 1988)
Dular	-	-	High (App et al 1986)
Palawan	ARA	-	Low (App et al 1986)
	^{15}N dilution	Low (Wu 1993)	-
Pokkali	^{15}N dilution	Low (Buenaventura et al 1984)	-
Ma-Wei-chan	-	-	High (App et al 1980)
Cigalon	-	-	Low (App et al 1980)
C5444	-	Low (App et al 1986)	-
Oking Seroni	^{15}N dilution	High (Buenaventura et al 1984)	High (Buenaventura et al 1984, App et al 1986)

Shrestha and Ladha (1996a) observed significantly high %Ndfa in Hsiang-Ai-Tsao 7 (20%), Yeolsulbeyo (17%), Pokkali (18%) and Biron (18%) among 22 early maturing genotypes studied in a green house experiment with 70 rice genotypes of different growth duration. These genotypes also showed the highest specific N_2 fixation of 2.08, 1.7, 1.59 and 1.56 mg g^{-1} biomass, respectively, among 70 genotypes. Oking Seroni (21%), IR2937-36-3 (16.8%), and OR-142-99 (15.3%) had the highest % Ndfa among 25 late maturing genotypes. The genotypes with low NFS were PTB 18 (2.7%), Brontok (2.7%) and Abang Busur (1.5%) among early, medium and late maturing genotypes, respectively. Shrestha and Ladha (1996a) also reported that some of the rice genotypes with high NFS also had significantly higher grain yield and N uptake: for example, Pankaj and MTU15 (medium duration) and Oking Seroni and IR29337-36-3 (late duration). But some of the genotypes superior in NFS were not superior for grain yield like Hsiang Ai Tsao 7 (early). It is therefore important to consider grain yield in addition to Ndfa for selecting rice genotypes (Vincent 1984). In another experiment, Shrestha and Ladha (1996b) again observed highest % Ndfa of about 8% in Oking Seroni followed by Murungakayan 30, Pankaj, Gogo Putih, BG380-2 and OR1420-99 as in earlier study (Shrestha and Ladha 1996a). Oking Seroni showed highest % Ndfa at all level of N applications.

EFFECT OF FERTILIZER ON NITROGEN FIXATION

Nitrogen

Since combined form of N control nitrogenase activity in the living organisms, it would be interesting to know whether exogenous supply of fertilizer N counteracts N_2-fixation in the rhizosphere. Several studies have illustrated almost complete and long lasting inhibitory effect of N fertilizers on the N_2-fixing activity of free-living cynobacteria (Roger and Kulasooriya 1980). On the other hand, a systematic study on the effect of exogenous supply of N on associative N_2 fixation is still lacking.

We know that N_2-fixation take place in the soil when there is readily available organic carbon and the concentration of mineral N is low. While in vitro experiments, long ago showed that N_2-fixation is retarded when mineral N is present, there has been little study whether it would affect N_2-fixation in the soil when the plants are present.

The rhizosphere of rice was found to be an ideal location for beneficial reduction process, the microbial reduction of molecular N to ammonia (Ishizawa et al 1970, Yoshida and Ancajas 1973). Root associated heterotrophic bacteria with N_2-fixing potential develop nitrogenase activity in response to low concentration of combined N in their environment (van Berkum and Sloger 1981, 1983).

Reduction of BNF with increasing fertilizer N has been reported long time ago (McAuliffe 1958, Boller and Heichel 1983, Henson and Heichel 1984). Evidence exists on the inhibition of N_2-fixation due to higher level of combined N in pure culture and water logged soils (Knowles and Denike 1974, Charyulu and Rao 1980). Van Berkum and Sloger (1983) reported inhibitory effect of combined N in the fixation process of bacteria associated with the root of grasses as well as N_2-fixation in root nodules on legumes. The inhibitory effect of combined N especially nitrate was observed on root hair infection, nodule initiation, nodule development (Munnus 1977), nitrogenase activity in legumes (Mengel 1994, Cherney and Duxbury 1994) and in rice (Trolldeneir 1987). The root split technique with half root dipped in a nutrient solution with 40 ppm N and other half in the solution deficient in N. Nitrogen fixation on some roots of the same plant is inhibited by high concentration of combined N and remaining other roots in an N-free medium. The N_2-fixation on these roots was lower than that of plants where entire root system was growing in a free solution. Trolldeneir (1977) in a laboratory experiment has clearly demonstrated the repression effect of N at 10 ppm combined N in the form of urea on rhizosphere N_2-fixation. On the other hand, he also reported no inhibitory effect of fertilizer N in a fertility trial with lowland rice, presumably because of rapidly decrease in N concentration of the soil solution. Ladha et al (1989) did not observe any correlation between increase or decrease in ARA per plant and the amount of N applied.

The exogenous supply of all levels of nitrogenous fertilizer to lowland rice significantly inhibited N_2-fixation but improved plant growth (Shrestha and Ladha 1996b). The inhibitory effect of combined N in Ndfa was reported in different crops like alfalfa (Lamb et al 1995), pigeonpea (Tobita et al 1978, Tsai 1993). Nelson and Knowles (1978) observed delay in the appearance of N_2-fixation when N fertilizers were applied to the soil. They found a slight lag in N_2-fixation by growing culture of *Azospirillium brasillence* when nitrate was added to medium. They found a negative correlation between the level of N application and N_2-fixation activity ($r = -0.7^*$), generally resulting a negative N balance in biological N balance (difference in N_2-fixation).

Increasing concentration of N, from 20 to 100, 200 and 400 kg N ha^{-1} reduced 85 to 75, 60 and 43 % Ndfa respectively. Thus, complete suppression effect of higher rates of N than normally applied in farming practices was not observed in N_2-fixation of fababean (Hardarson et al 1991). Kotera et al (1992) also reported significant inhibitory effect of N on N_2-fixation of gray forest soil. But in the presence of corn, which consume mineral N, the inhibitory effect of N was less pronounced. Merbach

(1995) also observed inhibitory effect of mineral N application on symbiotic N_2 fixation. Instead of fixed N, the plants took up mineral N. On the other hand he did not observed greater effect of mineral N in the species with an efficient atmospheric N_2-fixation which last till the end of the growth stage (such as *Vicia faba* and *Lupinus luteus*).

Most of the study has reported synergistic effect of low N application and suppressive effect of high N application in N_2-fixation. Balasendaram and Sen (1971) obtained increase in grain yield with Beijerinckia when inoculums and urea at the rate of 40 kg ha^{-1} was applied. The yield response was comparable to that with 80 kg N h^{-1} alone. McAuliffe (1959) observed 65% of the N fixed from atmosphere in the clover at the first cutting on the clay when 25 pounds of N per acre had been added to the soil and only 10% was fixed when the 200-pound treatment had been used. Similar decrease was also observed in Norfolk sandy loam. With time (second and third cutting) the clover fixed more N as the level in the soil declined. Increase in N_2-fixation from the first to third cuttings is apparently due to the reduction of soil N to a low level. The effect of the combined N on microbial nitrogenase varied with the concentration of the applied fertilizer N to the soil (Yoshida et al 1973, Knowles and Denire 1974, Rao 1976). High-Jensen and Schjoerring (1994) showed that application of 400 kg N ha^{-1} significantly reduced dinitrogen fixation by both enriched ^{15}N dilution and the natural ^{15}N abundance method.

Phosphorous

Some of the author (Robson 1983) have reported that phosphorus (P) increase the symbiotic N_2-fixation by stimulating host plant growth rather than exerting a direct effect of N_2-fixation per se, but some have reported P availability strongly affect traits related to N_2-fixation.

Application of P stimulates the soil N_2-ase in an alluvial soil and in a P-deficient soil under both flooded and Non-flooded conditions. The estimation of N_2-ase by P was more pronounced under non-flooded conditions. A corresponding increase in N_2-ase occurred with an increase in the P level at least up to 80 ppm level. A depression effect of P on N_2-ase occurred after 16 d under unflooded condition when the level of P was increased to 100 ppm. But under flooded conditions, the stimulation was almost continuous. Addition of P had little effect on the population of N_2-fixing microorganisms in alluvial soil. On the contrary addition of P stimulated the population of *Azospirillium* and *Azotobacter* in a P deficient soil. Data suggested that the alteration in the N_2-fixing microbial populations and the levels of available P might be responsible for changes in the N_2-ase activity in the soils. Result indicated that the level of applied P exhibited differential influence on N_2-ase and N_2-fixers in tropical paddy soil. Shrestha and Ladha (1996b) reported that phosphorous fertilizer did not affect atom % ^{15}N excess and % Ndfa significantly but slight decrease in atom % ^{15}N and increase in N_2 fixation was observed. Phosphorus fertilizer is found to increase N uptake significantly.

Sulaiman (1971) claimed that inoculation with *Azotobacter chroococcum* resulted in increased paddy yield in the presence of phosphorous fertilizer or lime. Cadisch et al (1993) reported that P limits growth and N_2-fixation to a greater extent than did potassium. Phosphorous supply increased % Ndfa by 15% at 5 kg P ha^{-1} to 259% at 75 kg P ha^{-1} at 14 weeks after sowing. App et al (1980) found significant increase in positive N balance with addition of P and iron to flooded soil planted with rice.

In leguminous crop, among the essential nutrients required by N_2-fixing symbiosis, P is a key element. It is involved in energy transfer and the supplying ATP for nitrogenase activity in nodules. Therefore, leguminous plants dependent on symbiotically fixed N for growth require more P than non N_2-fixing plants which are essentially depend on combined N. High ARA and high P content in the nodules of *Acacia mangium*, suggests that P was used preferably to enhance N_2-fixing activity even when the nodulation capacity was low. This finding supports the general hypothesis that the highly effective

nodules are strong sink for P (Robson et al 1981). Israel (1987) indicated that severe P deficiency markedly impaired both host plant growths. Symbiotic dinitrogen fixation has a higher P requirement for optimal functioning. Beck and Vadez (1994) also reported the ability of some lines of common bean to fix increased amounts of N_2 at low levels of P indicate that plant improvement to enhance N_2 fixation under P limiting conditions is possible.

Phosphorous deficiency impairs N_2 fixation in young pea plants indirectly by impairing metabolisms of the shoots, not by direct action on nodule formation (Jakobsen 1985) or functions correcting P deficiency. In soybean by supplying increasing amount of P has been found to increase nodulation, nodule mass, activity of nitrogenase (Cassman et al 1980, Ganry et al 1985, Israel 1887, Raut and Kohire 1991). Addition of 90 mg of P kg^{-1} soil significantly increased the amount of N_2 fixed by 31% at the late pod filling stage (Pongsakul and Jensen 1991).

Rice genotypes with high NFS are desirable because they add N to the soil-water-plant system without additional farm inputs and reduce dependence on fertilizer N. Some of the rice genotypes with high NFS also had significantly higher grain yield and N uptake: for example, Pankaj and MTU15 (medium duration) and Oking Seroni and IR29337-36-3 (late duration). But some of the genotypes superior in NFS were not superior for grain yield like Hsiang Ai Tsao 7 (early). It is therefore important to consider grain yield in addition to Ndfa for selecting rice genotypes.

The exogenous supply of nitrogenous fertilizer to lowland rice significantly inhibited N fixation but improved plant growth. Where as phosphorous fertilizer did not affect atom % ^{15}N excess and % Ndfa significantly but slight decrease in atom % ^{15}N excess and increase in N_2 fixation was observed. Inhibitory effect of exogenous supply of N fertilizer indicates limited potential of associative N_2 fixation to significantly benefit high input agriculture. Farmers would have to reduce N fertilizer from their rice crop in order to increase biological N fixation associated with rice. If they do, then the plants might have N deficiency and might have a lower yield.

However, the development of N fixation in response to a deficiency of available N may well be an integral part of the N cycle of natural ecosystem and low input farming system there by maintaining a N balance in the environment. Development of genetically altered bacteria for root-associated nitrogen fixation, which can fix dinitrogen in the presence of repressive levels of combined nitrogen, is essential.

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Details Guide for Writing Articles to Nepal Agric. Res. J.

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ABSTRACT: Every manuscript (article) must have a short abstract (not more than 250 words), which should be complete itself but it should be concise and clear without any cited references. Abstract should highlight rationale, objectives, materials and methods, important results and conclusion written in a manner so that it is suitable for direct reproduction in some abstracting journals. Key words (not more than 5 words) should be written below the abstract in alphabetical order. Authors and subjects index are published at volume number that are divisible by 4.

INTRODUCTION: Should give appropriate background and explain the things that are proposed. It should include short introduction to justify the research and relevant reviews and state the objectives clearly.

MATERIALS AND METHODS: Should include description of experimental materials, procedures and statistical design used as well as method/s to analyze the results. New methods should be described in detail and for methods developed by earlier researcher/s, only reference may be cited. However we prefer detail methodology. Report the location, georeferences (altitude, latitude and longitude etc) and date of experiment conducted. Write scientific name with authority, common and local name of organism. If possible mention chromosome number of organism as 2n=2x=24 for *Oryza sativa* L.

RESULTS AND DISCUSSION: Results and discussion will be either under separate or under combined headings. Results should be presented in a concise manner avoiding data that are already given in Tables. Discussion part should not repeat the results but should explain and interpret the data based on the published relevant studies. Insert graph/s and table/s wherever necessary and number them sequentially within each paper (article). The conclusion, recommendation and possible impact (if any) should be based on the supporting data. But there should not be a separate heading for conclusion and recommendation.

Units of Measurement: All units and measures should be in the metric system or in the International System Units (SI) and should be abbreviated for technical values. Currency exchange rates should be in US $ along with the local currency for the appropriate date for any prices cited.

Reporting Time and Dates: Use the 24-hr time system with four digits, the first two for hours and the last two for minutes (eg 1430 hr for 2:30 pm). Dates are reported with day of the month first, then month, followed by the year eg 7 Aug 2000).

ACKNOWLEDGMENTS: Acknowledge the person/s and/or institution/s, if necessary, who actually help to achieve the objectives of the research.

REFERENCES: Only the papers closely related to the authors' work should be referred in the text by author's family name and the year of publication and be cited in an alphabetical order. When quoting references in the text, the last names of the authors for up to two authors and last name of the first author et al for more than two authors should be given followed by the year of publication within parenthesis. When references made to more than one publication by the authors in the same year, the publication should be numbered as (a) and (b) of that year with the earliest publication the year being designated (a) and so on. Each reference should contain first author's family name followed by his/her first initial name and the middle name (initial only) and the co-author/s with initials of the first and the middle names followed by family name/s, year of publication (English calendar), title of the research article/s, name of the journal or name and place of publisher (in case of book), volume number and page number/s. If no authority is available for citation, credit the work to the publisher. Please refer following examples for reference citing.

For electronic sources follow as the same kind of material in print, starting with the author, year, title and then giving further information as for a chapter or journal article and add the on line address URL and the date of information accessed.

Journal

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 agrobiodiversity: Experiences of Nepal. **Paper presented in**: International Conference on Himalayan Biodiversity (ICHB 2003), 26-28 Feb 2003, Kathmandu.

Personal Communication and Unpublished Article

These can be mentioned directly in the text in parenthesis.

Thesis or Dissertation

If the manuscript to be published is from his/her thesis or dissertation, it should be indicated at the footnote of the first page.

Table: Each Table with a number and proper title heading should be prepared and sorted appropriately. Use the following symbols for footnotes in the order shown:, †, ‡, §, ¶, #, ††, ‡‡ etc. The single (*) and double asterisks (**) are used to indicate statistical significance and have priority in this order to show 5 and 1% levels of significance, respectively. Do not repeat information in the text presented in charts or graph. Use 10 font size and bold Table heading.

Figure: Each Figure and/or graph with a number and the proper title heading should be drawn or prepared. Figure/picture should be black and white**.** Use 10 font size and bold Figure title. Figure should be drawn without boarder. Provide figure both in Word and Excel format

So far as possible, Table and Figure should be either one-column width (making two columns in A4 size paper) or two-column width in portrait orientation.

Page Limit: The page limit for the main research article is 12 typed pages in single space including Tables, Figures and references.

Format for Review or Feature Articles

The review or feature article is much different from the main research articles in that it contains detailed description of certain topics researched or investigated earlier by concerned scientists or technicians. As in the main research article, it should contain abstract not exceeding 250 to 300 words. Each topic should have an appropriate heading and/or sub-headings with relevant tables and figures numbered separately but sequentially for each review article. At the end of each article, all discussed items should be summarized and the conclusion should be drawn. All the relevant references should be cited. Authors are requested to choose modern topics of interests to the readers. The review or feature articles should not be of more than 15 pages.

Format for Research Notes

The articles, which are not suitable to be published as main research articles but have some interesting and useful information, may be published as Research notes. In this type of paper, separate headings for introduction, materials and methods, results and discussion and references cited are not necessarily to be written but concise forms of every

part of the paper should be written in separate paragraphs. The relevant tables, figures and references may also be included but no abstract is needed. The article should be of three typed pages including tables, figures and references and other format should be as in main research article.

Statistical Methods

Report enough details of experimental design so that the results can be judged for validating and so that previous experiments may serve as a basis for the design of future experiments. A multiple comparison procedure may be useful when treatments consists of a set of unrelated materials (such as cultivars or chemicals), but may be inappropriate in other cases. When treatments are factorial their effects may be classified by partitioning into main effects and interactions. Specific relationships among treatments may be elucidated with single-degree-of-freedom contrasts (for further consult Joshi et al 2002 J. Institute Sci. Tech. 12:69-81). Regression analyses are appropriate when treatments form a progressive series of an experimental factor.

Checklist of papers submitted to Nepal Agric. Res. J.

Content

- ❑ Significance and originality of work are shown
- ❑ Reproducibility of results is illustrated
- ❑ Objectives are clearly stated in introduction
- ❑ Introduction includes a succinct evaluation of the topic, including all relevant literature citations
- ❑ Experimental design and methodology are fully explained
- ❑ Proper and sufficient analyses are conducted (review by qualified statistician before submission is encouraged)
- ❑ Discussion relates work to other published material and addresses strengths and weaknesses of research
- ❑ Major conclusions are supported by results from repeated experiments. Manuscripts are reviewed critically before submission

Format

- ❑ Double spaced and printed in one side
- ❑ Numbered Tables and Figures sequentially and located in right place
- ❑ Do not use both common and scientific names for organisms in the title
- ❑ Author names, affiliations and addresses including corresponding author name, e-mail, telephone number included
- ❑ Consistent style, format and size are used for all Figures and Tables
- ❑ Subheadings may be used, but avoid, excessive fragmentation of the text. Footnotes to the text are not permitted
- ❑ Words or phrases useful in index retrieval systems are listed in alphabetical order
- ❑ Abstract should be one paragraph
- ❑ Do not underline anywhere
- ❑ Do not make 2-column, we will do it

Writing

- ❑ Give the name of the institute where the research was conducted and not the name of the institute where you are employed at present. If there is a change of address, give the present address as a footnote
- ❑ Specify the period during which the experiment was conducted.
- ❑ Use past tense for materials and methods and results in active voice
- ❑ Results should be specific, instead of being indicative

Double spaced in triplicate

- ❑ Indicate date as 21 Jan 2005
- ❑ Spell out the standard abbreviations when first mentioned
- ❑ Do not give data in table if they are depicted graphically
- ❑ Do not repeat ideas in different forms of sentences. Check and avoid all repetitions and duplications
- ❑ Do not acknowledge for official facilities or help or for encouragement etc
- ❑ Write Mr and Dr without full stops
- ❑ Avoid period with initials of authors, acronyms etc
- ❑ Do not cite anonymous as author, instead cite the name of the institute, publisher or editor
- ❑ Give only selected, recent references (priority to Nepalese). Avoid reference from non-science literature
- ❑ Avoid comma between the surname of an author and its initial or the year of citation

Supporting material

- ❑ Cover letter supplying the named of the corresponding author with address, phone, fax number and email address.
- ❑ Cover letter provides names and addresses of potential reviewers or request with justification that certain reviewers not be used

Submission

- ❑ Pay good attention to the presentations of the article
- ❑ Always consult a recent copy of our journal
- ❑ Check all data and references from original source
- ❑ Ensure that all references in the text find a place in the references part of article and vise versa
- ❑ The spellings of names and years should correspond in the text and references part
- ❑ Do not send the article for publication until it confirms in all respects to the style of the journal and has been checked very carefully
- ❑ Before the paper is sent, check carefully all data and text for factual, grammatical or typographical errors
- ❑ Send the article in triplicate
- ❑ On revision, please answer all the referees' comments point wise, indicating the modifications made by you. If you do not agree, give reasons for your disagreement with full justification
- ❑ Return the corrected electronic and hard copies immediately along with commented paper

URL: www.narc-nepal.org
LAN (NARC, Khumal):
:\\Biotech\BKJ\SAS…

B. ABBREVIATIONS AND SYMBOLS THAT CAN BE USED WITHOUT DEFINITION AND PERIOD IN TEXT, TABLE AND FIGURE

Abbreviation/ symbol	Definition
", sec	second
$	US dollar
%	Percent
Ω	Ohm
χ^2	Chi-square
μm	Micrometer
$\bar{x}$	Arithmetic mean
*	Significant at 5% level
**	Significant at 1% level
', min	minute
£	Pound
©	Copy right
®	Registered trade mark
1^{st}	First
2,4-D	2,4-Dichlorophenoxyacetic acid
A°	Angstrom
AD	Anne Domini
ai	active ingredient
am	ante meridiem (before noon)
amt	amount
ANOVA	ANalysis Of VAriance
approx	approximately
Aug	August
avg	average
b	regression coefficient
BC	Before Christ
bp	boiling point
ca	circa, carib (about)
CBD	Convention on Biological Diversity
CBO	Community Based Organization
cf	confer (compare)
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	Centro International de Mejoramiento de maiz y Trigo (International Center for Maize and Wheat Improvement)
cm	centimeter
coef	coefficient
conc	concentration
CV	Coefficient of Variation
cv	cultivar
CVT	Coordinated Varietal Trial
d	day
Dec	December
df	degree of freedom
diam	diameter
DMRT	Duncan's Multiple Range Test
DNA	DeoxyriboNucleic Acid
DoA	Department of Agriculture
Dr	Doctor
eg	exampli gratia (for example)
ELISA	Enzyme Linked ImmunoSorbent Assay
et al	et alii (and other)
etc	et cetera (and so on)
expt	experiment
exptl	experimental
f	frequency
F	Variance ratio
F_1	Filial generation 1 (first generation)
FAO	Food and Agriculture Organization
Feb	February
FFT	Farmers' Field Trial
FYM	Farm Yard Manure
g	gram
GATT	General Agreements on Tariffs and Trade
GDP	Gross Domestic Product
GIS	Geographical Information System
GMO	Genetically Modified Organism
GO	Government Organization
h^2	heritability
ha	hectare
HMG	His Majesty of Government
hr	hour
hrs	hours
ht	height
Hz	Hertz
IAAS	Institute of Agriculture and Animal Sciences
ICIMOD	International Center for Integrated Mountain Development
ICRISAT	International Crops Research Institute for the Semi Arid Tropics
ie	id est (in other words)
IET	Initial Evaluation Trial
INGO	International Non Government Organization
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated Pest Management
IPR	Intellectual Property Right
IRRI	International Rice Research Institute
IUCN	International Union for Conservation of Nature and Natural Resources (The world conservation union)
J	Joule
Jan	January
K	Kelvin (Thermodynamic temperature)
kg	kilogram
km	kilometer
l	liter
LD	Lethal Dose
ln	logarithm (natural)
LR	LandRace
LoA	Latter of Agreement
log	logarithm (common, base 10)
LSD	Least Significant Difference
lx	lux
m	meter
M	Molar
masl	meter above sea level

max	maximum
min	minimum
mm	millimeter
MoAC	Ministry of Agriculture and Cooperatives
mol	mole
mol wt	molecular weight
MoU	Memorandum of Understanding
mp	melting point
mph	miles per hour
Mr	Mister
Ms	Miss, Misters
MSc	Master of Science
mt	metric ton
n	Number, unit
n	Sample size, unit
NARC	Nepal Agricultural Research Council
NGO	Non Government Organization
nm	nanometer
no	number
Nov	November
ns	not significant
^{o}C	Degree centigrade
Oct	October
^{o}F	Degree Fahrenheit
PCA	Principle Component Analysis
PCR	Polymerase Chain Reaction
PGR	Plant Genetic Resource
pH	The negative logarithm of the hydrogen ion concentration
PhD	Doctor of Philosophy
pm	post merideim (after noon)
PPB	Participatory Plant Breeding
ppm	part per million
PRA	Participatory Rural Appraisal
prepn	preparation
psi	pounds per square inch
PVS	Participatory Variety Selection
r	correlation coefficient
rad	radian
RAPD	Random Amplified Polymorphic DNA
RCBD	Randomized Complete Block Design
RFLP	Restricted Fragment Length Polymorphism
RH	Relative Humidity
RNA	RiboNucleic Acid
rpm	revolutions per minute
RRA	Rapid Rural Appraisal
Rs	Rupees
s	second
S^2	variance
SD	Standard Deviation
SE	Standard Error (of the mean)
SED	Standard Error of the difference
SEM	Standard Error of the Mean
Sept	September
sp	species (sing)
sp gr	specific gravity
spp	species (pl)
SSR	Simple Sequence Repeat
t	tonne, metric ton
t	Student's t
temp	temperature
TRIPS	Trade Related Intellectual Property Rights
UN	United Nations
UNDP	United Nations Development Programme
UPGMA	Unweighted Pair Group Method, Arithmetic mean
UV	Ultraviolet
V	Volt
v/v	volume/volume (conc)
var	variety
VDC	Village Development Committee
viz	videlicet (namely)
vol	volume
vs	versus
W	Watt
w/v	weight/volume (conc)
wk	week
wt	weight
WTO	World Trade Organization
yr	year
yrs	years

C. ABBREVIATED JOURNAL TITLES

We prefer full name for journals even though one can use following abbreviated names for journals in the references list. If a journal has single word name, it is not abbreviated.

Terms without abbreviation

Acta
Cell
Drug
Fauna
Fish
Flora
Food
Gene
Genes
Growth
Maydica
Plant
Planta
Sea
Soil
Weed

Abbreviated terms

Abstract, Abstracts	Abstr.	Conservation	Conserv.
Academical, Academy	Acad.	Contribuciones, Contribution	Contrib.
Advances	Adv.	Current	Curr.
African	Afr.	Department	Dep.
Agriculture, Agricultural	Agric.	Development, Developmental	Dev.
Agronomy	Agron.	Diseases	Dis.
America, American	Am.	Diversity	Diver.
Analytical	Anal.	Division	Div.
Anatomical	Anat.	Ecology	Ecol.
Animal	Anim.	Economics	Econ.
Annals	Ann.	Edition	Ed.
Annual	Annu.	Education, Educational	Educ.
Anthropological	Anthrop.	Electric	Electr.
Antibiotic	Antibiot.	Engineering	Eng.
Applied	Appl.	Entomological, Entomology	Entomol.
Aquatic	Aquat.	Environment, Environmental	Environ.
Archive, Archives	Arch.	Ethnology	Ethnol.
Association, Associates	Assoc.	Europe, European	Eur.
Atom, Atomic	At.	Evolution	Evol.
Australian	Aust.	Experimental	Exp.
Bacteriology, Bacteriologist	Bacteriol.	Federal, Federation	Fed.
Behaviour	Behav.	Fertilizer, Fertility	Fert.
Biochemie, Biochemistry, Biochemical	Biochem.	Fisheries	Fish.
		Forestry, Forest	For.
Biodiversity	Biod.	Garden	Gard.
Biological, Biologie	Biol.	Gazette	Gaz.
Biometrical, Biometry	Biometr.	General	Gen.
Biomolecular	Biomol.	Genetic, Genetics	Genet.
Biophysics	Biophys.	Geographical, Geography	Geogr.
Botanica, Botanical, Botany	Bot.	Geologica, Geological, Geology,	Geol.
British	Br.	History	Hist.
Bulletin	Bull.	Immune	Immun.
Bureau	Bur.	Immunology	Immunol.
Canada, Canadian	Can.	India	Ind.
Cardiology	Cardiol.	Information	Info.
Cellular	Cell.	Institute	Inst.
Chemical, Chemistry	Chem.	Interaction	Interact.
Chemotherapy	Chemother.	Japan, Japanese	Jap.
Commonwealth	Commw.	Journal	J.
Communications	Commun.	Laboratory	Lab.
Comparative	Comp.	London	Lond.
Computation, Computer, Computers, Computing	Comput.	Magazine	Mag.
		Management	Manage.
Conference	Conf.	Manual	Man.
Congress	Congr.	Mathematical, Mathematics	Math.

Mechanical	Mech.
Medical, Medicinal	Med.
Microbiological, Microbiology	Microbiol.
Molecular	Mol.
Monographs	Monogr.
Morphology	Morphol.
Mountain	Mount.
National	Natl.
Natural, Naturalist, Nature	Nat.
Nepal	Nep.
Netherlands	Neth.
Neurology	Neurol.
Newsletter	Newslett.
Nuclear	Nucl.
Nutrition	Nutr.
Obstetrician	Obstet.
Official	Off.
Organic	Org.
Orientalis	Orient.
Pakistan	Pak.
Pharmacology	Pharmacol.
Philippines	Philip.
Philosophical	Philos.
Physic, Physical, Physics	Phys.
Physiology	Physiol.
Planning	Plan.
Pollution	Pollut.
Practical, Practice	Prac.
Proceedings	Proc.

Psychological	Psychol.
Publication	Publ.
Quarterly	Q.
Regulation	Regul.
Report	Rep.
Research	Res.
Resources	Resour.
Review	Rev.
Scandinavian	Scand.
Science, Scientific, Scientist	Sci.
Society	Soc.
Special	Spec.
Station	Stn.
Structure	Struct.
Supplement	Suppl.
Surgery	Surg.
Survey	Surv.
Symposia, Symposium	Symp.
Systematics	Syst.
Technical	Tech.
Technology	Technol.
Therapeutics	Ther.
Topics	Top.
Transactions	Trans.
Tropical	Trop.
University	Univ.
Veterinary	Vet.
Virology	Virol.
Zoology, Zoologie	Zool.

Crop Registration

The Society of Agricultural Scientists-Nepal announces the registration of crop landraces, cultivars, wild species and parental lines by publishing crop registration manuscripts in the journal of Society. The objective of crop registration is to serve scientists by publishing information on released cultivars, landraces, wild relatives and parental lines. This will also be very useful in future. The author is responsible to make the materials available for use as source materials for research and breeding programmes. Publication provides a readily accessible name or designation process and information concerning characteristics and availability of the genotypes and facilitates utilization.

After the acceptance of Crop Registration Manuscript, the Society assigns registration number and prefixes for type of registration. The prefixes will be LR (Landrace), CV (Cultivar), WR (Wild relatives) and PL (Parental line). The registration number will be provided to author and index cumulatively in each volume of this journal.

A clear and concise manuscript with cover letter should be submitted. Manuscript should contain name or identification (any meaning of given name if applicable), experimental number or designation, names of agencies, organization and names of those officially releasing the plant materials, brief description including distinguishing characters, breeding procedures, pedigrees, information about plant introductions, region of adaptation, original sources, important traits, etc. Also include name and address of the individual or organization responsible for maintaining and distributing the materials. Consider passport descriptors and information required for Variety Release Proposal in Nepal for developing manuscript.

Follow the same style and format of other research article. For this manuscript 3 paragraph is enough, first paragraph focusing on introduction, second on description and third paragraph indicating maintenance and distribution. Submission and review process are same to other article.

Guide for Scientific Paper Writing

Bal K Joshi
Biotechnology Unit-NARC, Khumaltar

A. HOW TO WRITE A SCIENTIFIC PAPER

Style

In all sections of the paper, present tense should be used to report background that is already established. For example, The cell membrane is the barrier which separates the inside of the cell from the outside. Use future tense for work that you will do. For example, We will test the hypothesis that some anti-microbial agents can permeate the cell membrane during division to inhibit growth. Always use past tense to describe results of a specific experiment, especially your own. For example, Application of the antibiotic Chloramphenicol restricted growth of *E. coli*.

Article Title

- Your title should be specific in describing the experiment you performed.
- It should be an informative summary of the paper. Select the words in a title carefully for clarity and accuracy.
- Long titles are unappealing to readers. However, shorter titles may not be sufficiently specific, and therefore not as informative.
- All important aspects of the paper should figure in the title.
- A title should be a label, not a sentence.
- Pay attention to the association of words. Faulty word order may allow different interpretations – possibly changing your meaning – and may introduce grammatical error.
- If you use series titles, submit all series.
- Consider more than one title, and ask colleagues which one is a better description of your paper.

Authors and Addresses

- Consider following information:
    - Who did the work
    - Where they did it
    - Where they are now
    - Their relative involvement
    - To whom correspondence should be addressed
- Give full name of each author, use initials only for middle names.
- Degrees and titles are not required.
- Give the institutional address for each author following the journal style.
- If the author has moved away from where the research was carried out, give their present address as footnote.
- Include the corresponding address of the corresponding author (email compulsorily, phone, postal address).
- No one should be given authorship unless they were significantly involved in the creation of the paper (conception, design, data collection, analysis and manuscript writing). For example, do not include heads of departments simply because they are the senior member of staff.
- Every attributed author must see and approve the final draft of the paper before you submit it to a journal. However, journals may have different policy if each author should be responsible for the full content or not.
- Reviewers may discriminate against a paper with too many authors (they may not believe this number of people truly wrote the article), and may also discriminate against a paper with only one author (since the research has not been verified by a collaborator).

Abstract

- The Abstract is a summary of the study, with the primary emphasis on results and conclusions.
- Very briefly present the question(s) asked, the experimental design, a summary of observations, and list conclusions.
- Be very succinct - the abstract should be a single paragraph, no more than one page. It should stand on its own; therefore, do not refer to any other part of the report, such as a figure or table.
- Avoid long sections of introductory or explanatory material.
- As a summary of work done, it is written in past tense.
  Summarize the information given in all sections of the paper (eg introduction, materials and methods, results and discussion).

- Compose the abstract with great care. Editors frequently decide to accept or reject a paper (and readers decide to read it completely or not), after only reading the abstract.
- Confine it in a single paragraph. Include all important information but exclude unnecessary details.
- Do not cite others' work in the abstract since it is a summary of your paper and your research.
- Write in the past tense. Information from any published source can be written in the present tense.
- Information not stated in the paper should never be given in the abstract.
- Abbreviations should not be used unless they are commonly accepted terms.
- Write an abstract after you have completed and finalized the entire paper.

Introduction

- Keep the introduction brief, but do indicate the purpose of the experiments performed as well as present appropriate background.
- Make sure that the reader knows enough to appreciate the relevance of the work and why it is appropriate to ask the question that you will address with your study.
- Always state the hypothesis and/or objectives in your introduction.
- Consider following pints:
    - Nature and scope of the problem
    - Literature review
    - Rationale (reasons why the study was carried out)
    - Objective (what was done)
    - Materials and method (an outline of how the research was performed, and the reasons for selecting a particular method)
- Include only important references.
- Define specialized terms on first mention.
- If the abbreviations used are not very common, give their full form on the first mention.
- Ensure your introduction with continuous flow of information and ideas.

Materials and Methods

- Document all methods performed in your study.
- Summarize in your own words what you did.
- While it is tempting to report methods in chronological order in a narrative form, it is usually more effective to present them under headings devoted to specific procedures or groups of procedures.
- Describe in detail how the results were obtained so that a peer can repeat the procedure.
- It should be reproducible.
- Write in the past tense.
- For materials considered following three important points:
    - exact technical specifications
    - quantities
    - preparation method and source
- For industrial products, avoid trade names unless the nature or constituents of the product differ from one manufacturer to another.
- Use scientific nomenclature (genus, species and authority) for living beings. Local and national names may be given once in the paper, if it assists in understanding.
- Try to make sub-headings of this section consistent with that of result.
- Avoid using more than 3 levels of heading.
- Report date of experiment conducted and georeferences of experimental site.
- Methodology need to be described in detail. More detail is required for unusual and innovative procedures.
- Remember that this section should only describe the methodology – it should not present the results (do not mix results into this section).
- Statistical analysis must be pertinent and thorough enough to ensure the accuracy of the conclusions. Degree of freedom and level of certainty should be reported in order to facilitate evaluation of conclusions (see statistical guidelines below).

Results

- Raw data are never included in your scientific paper unless they are needed to give evidence for specific conclusions which cannot be obtained by looking at an analysis, or summation, of the data.
- Analyze your data, then present them in the form of figures (graphs), tables, and/or descriptions of observations. Data in this form are called converted data.
- Figures are preferable to tables, and tables are preferable to straight text.
- By presenting converted data, you make your point succinctly and clearly.
- The table or figure should then be presented, complete with title. The title should explain what the table or figure is showing.

- Do not draw conclusions in the results section. Reserve data interpretation for the discussion.
- Write clearly in the past tense.
- The most common mistakes in this section are the inclusion of unnecessary data and their double presentation, eg repeated in a table or a figure as well as within the text.
- Only those variables that affect results should be given in tables or graphs. If the data do not conform to a clear trend, it can be stated in a few words or a sentence.
- Write concisely – scientific papers should enable fast comprehension of the research, and not present lengthy discussions or opinions. For example do not use it is clearly shown in figure 3 that the rate of growth depends on temperature but use rate of growth depends on temperature (figure 3).
- Select only meaningful data from the collection; present them only once – in text or table or figure.

Discussion

- Interpret your data in the discussion.
- Decide if each hypothesis is supported, rejected, or if you cannot make a decision with confidence.
- Do not simply dismiss a study or part of a study as "inconclusive".
- Make what conclusions you can, then suggest how the experiment must be modified in order to properly test the hypothesis(es).
- Explain all of your observations as much as possible, focusing on mechanisms. When you refer to information, distinguish data generated by your own studies from published information or from information obtained from other students.
- Refer to work done by specific individuals (including yourself) in past tense.
- Refer to generally accepted facts and principles in present tense.
- Decide if the experimental design adequately addressed the hypothesis, and whether or not it was properly controlled.
- Finally, where do you go next? The best studies open up new avenues of research. What questions remain? Did the study lead you to any new questions? Try to think up a new hypothesis and briefly suggest new experiments to further address the main question. Be creative, and don't be afraid to speculate.
- Deal with how observed facts are related, how the present study agrees or disagrees with previous studies, and how the study might be extended in order to test or make a hypothesis.
- Present clear and valid reasoning and argument. Regardless of how important the research is, if it is not carefully considered and discussed within the article, then the overall research results are undermined.
- Analyze perfectly and draw believable conclusions – make sure this is not a fault of your paper.

Acknowledgements

- Acknowledge for
  - significant technical help received from others
  - grants, fellowships or other financial assistance
- Do not thank someone without identifying the nature of the assistance
- Do not thank peer reviewers. Do not thank someone just for inspiration.

Citation in Text

- Literature citations in the body of your paper should be in parentheses and contain only the author's last name and the date; for multiple authors include the last name of the first author, et al and the date. For example: (Joshi 2005), (Ganga et al 2004).
- If the author's name is used in the text then just the date in parentheses is sufficient. For example: Shrestha (1949), Adhikari et al (2005).
- Use the proper form for citations. Order citations in ascending by year.

References

- Include sufficient but not too many references: you need to provide a citation (reference) every time you state a fact that is not generally known, or if you are showing how your work has built on that of others.
- Review articles usually require high numbers of references. Too many references may indicate an inability to discriminate and select appropriately – you need to show good judgment in the selection, there is no right or wrong number of references to include in any article.
- The references indicate about the quality of your work: if they are all old and refer to work that is now out-of-date, then this may invalidate your findings because the ideas and facts developed in recent times may contradict the ones you cited. Including upto- date references shows that you are aware of recent research and have taken this into account with your own work.
- The minimum requirements in a reference are Author, Date, Title (readers usually decide on the basis of the title whether or not they need to consult a given reference), Inclusive pagination (this information allows the reader to distinguish between a single-page communication and a ten-page paper. It also helps them to decide whether to read the source, or even purchase a copy), Journal (publication) name (this is essential in allowing the reader locate an article or chapter)

- Three common mistakes found in references and their citations are (all waste the editor's time and increase the likelihood of rejection):
  a) Not all the citations in text are listed in the references and not all the references are cited in the text. (This usually happens when the paper is revised, so care must be taken to avoid this.)
  b) No uniformity in the presentation of references. (This indicates carelessness, and may make the editor/reviewer/author think that your research work is also carelessly done.)
  c) Incomplete information given about the references. (This may be interpreted to mean that you have not read the reference, but are including it to add support to your work.)
- To avoid missing references (or text citations) make a careful cross-check on the final draft of your paper before submission. This can be done on the computer or manually by checking the text against the references.
- All finalized references must be converted to the journal style. There are some software packages, such as EndNote.com, that can convert them to international journal styles, otherwise you need to follow the author guidelines, and also compare with articles published within the journal.
- If you are unsure as to which information to include within a reference, give all information you have available – more information is better than too little.

Tables

- Construct tables or figures only if there are large amounts of data. Few data should be given in text.
- Do not present data both in tables and figures. Where the results describe a trend a figure is more helpful than a table. Where the exact value is important, a table is of more value.
- For easy reading, put different variables of same parameter in the same column. This also makes the table compact and good-looking.
- Common abbreviations can be used without definition; others should be defined in a table footnote if they are not defined in the accompanying text. Be brief, but be clear.
- Number the figures and tables in separate sequences. All tables and figures must be cited within the text.

Illustrations

- Unless three dimensions are actually needed, avoid 3D figures.
- For the sake of legibility, the background should always be white.
- Do not use a shade of colour (or different percentage of grey) in bar diagrams. Even if the journal has a high quality multicolour print, the distinction of bars can not be represented while making normal photocopy of the article. Use easily distinguishable patterns to distinguish the separate bars.
- If the legends are in very tiny boxes, it is very difficult to distinguish the pattern or shade in them – ensure these key boxes are easily read.
- Submit the figures in final size using the font size and line weights actually desired (usually 8pt Arial or Helvetica for the text and 0.5pt for the line weights). When unnecessarily big figures are greatly reduced by the journal, the lines and letters may become too small or thin. Avoid using FULL CAPITALS or bold as they make the artwork ugly and difficult to read.
- Mention the sources for illustrations within the legend to the figure (check the journal) style.
- Distinction in line graphs can be made by using solid and dotted lines, and by using different symbols for data points in the same type of line.
- Putting lines of different thickness gives more choices, however, you should avoid it as far as possible (it may be hard to distinguish when printed). Use of the same data point in solid and open style offers more choices.
- Avoid using a pi-chart in most instances. In a scientific paper other chart types are almost always more helpful than a pi-chart which does not easily allow for comparison between data.
- Provide a descriptive legend or title to every figure; this may contain explanatory information about the illustration.
- While scanning photographs, maintain a resolution of 300ppi (or dpi) or more. But line artwork (charts, etc.) needs a higher resolution – 700ppi for example.
- If possible, use a proper drawing package to prepare your artwork, and supply to the publisher as a high resolution jpeg or eps files. Consult experts for this.
- Electronic artwork as Excel or Word pictures is acceptable, but can sometimes cause problems for the publisher. Avoid PowerPoint illustrations.

B. TIPS TO PUBLISH YOUR RESEARCH WORK

Publication is extremely important for all researchers, as it provides their work with credibility, and ensures that their results, findings and conclusions are disseminated to the research community.

Before submission – preparing your article

- Is the title accurate, informative and concise?
- Does it have an abstract that correctly summarises the actual information in the article – is it easy to read, comprehensive, yet short enough (approx 250 words is usual)?
- Are your study objectives or hypotheses clearly stated?
- Does your article say something new – does it add to the body of information in your subject area? (If it is a review article, is it sufficiently inclusive to represent all the arguments and give a fair and comprehensive review of the topic?)
- Is your article well organised? Have you used appropriate subheadings to separate the different sections of the paper for clear understanding?
- Does the methodology correctly and clearly explain how you carried out the research?
- Can it be replicated by another researcher elsewhere?
- Is the prose clearly written, is the standard of English good enough to make the article clear and easy to read?
- Are the results correctly and clearly presented? Can they be understood easily without misinterpretation?
- Have you included enough necessary details to make readers understand your write-up?
- Is the discussion clear, and does it include sufficient acknowledgement of different perspectives and interpretations?
- Does your reference list correctly match the citations given in the text?
- Have you used the referencing style specified by the journal you want to submit to?
- Are the references complete and accurate? Do they include the authors' names, article title, publication information including dates and page numbers?
- If there are any figures and tables, are they understandable without reference to the text? Are they required – do they add to the understanding? (Do not illustrate unless something cannot be easily explained in the text.) Are they clearly, completely and correctly labeled?
- Does your article contain information on principal action to be taken and recommendation for further research by other researchers?
- Have you asked colleagues to read and comment on the text? Seek opinions from friends and peers before you submit your article for publication, as they will give you suggestions for improvement.
- Have you acknowledged individuals and organisations that made substantial financial and technical contributions towards the publication of the article?

Selecting a journal for publication

- Select a journal that already publishes in the same subject area as your article.
- Select a journal that publishes material similar to yours.
- Be realistic about your choice of journal: match the quality of your research to the quality of content that the journal publishes – aim high, but do not be unrealistic.
- Publication enhances your career – but only if you choose suitable outlets – check the policy of your organisation.

Submitting your article

- Submit your article to only one journal at a time – submit to another journal only if your article has been rejected.
- Read the journal's guidelines for authors and make sure your article conforms to its requirements.
- Ensure that the focus of your article complies with the aims and scope of the journal – otherwise the editors will not be interested in it.
- Submit your article only through the recommended means specified by the journal (by email, post, etc). Make sure the format you use for the article is acceptable to the journal
- Send a short polite letter to the editor to accompany your article.
- Make sure you provide full contact details for correspondence – your name, affiliation, address, country, telephone number(s), email, etc.
- Make sure you send all necessary materials required to publish the article (do not forget the illustrations, etc).
- Keep copies of all material you send (paper and electronic files), as the journal will probably not return anything to you.

The publishing process – what you should expect after submission

- When you have submitted an article, you should expect an acknowledgement – but this may take several weeks – if you do not hear from the journal, contact the editor to make sure your article has been received by the journal.
- If the journal feels that your article is totally unsuitable, the board of editors will immediately reject it.
- Your article will be sent out to reviewers – these are subject specialists in your area who will read the article and return comments to the journal about the article's acceptability. In your letter you may suggest suitable reviewers
- Usually the reviewers will not be told your name – and you will not be told who has reviewed your article – this is to avoid undue bias.
- Once the article has been reviewed the journal will reply you, providing feedback from the reviewers – this may take several months. If you do not hear from the journal for a very long time after the acknowledgement (say six months to one year), you should write to enquire on the status of your article.

Revisions

- It is unusual for any article to be accepted by a journal without some revisions being requested.
- Revisions may be minor (eg change references order), or major (eg methodology unclear).
- Make revisions as requested by the editor – if there are any of the recommended revisions that you disagree with, contact the editor to discuss.
- The revised article needs to be returned to the journal (remember to retain a copy). Do not delay in doing this.
- It is not uncommon for some articles to undertake several revisions.
- It is possible that after revision the article is rejected – although it is unlikely unless you failed to revise the article satisfactorily.

Rejection

- Do not be disheartened to receive a rejection letter – it may not be due to the quality of the article, but because the subject is inappropriate for the journal.
- If the journal gives you reasons for rejecting the article, consider their comments seriously – other journals may have similar concerns about your article.
- If your article is rejected, you can submit it elsewhere – but remember there are reasons for rejection and you should revise your article before submitting it elsewhere (and remember to conform to the author guidelines of your newly selected journal).

Acceptance

- When your article is accepted you will receive confirmation from the journal (by email or post).
- Ask when you should expect publication.
- Check to see if the journal will provide you with printed copies of your article (offprints), or a copy of the issue in which it appears, or an electronic file of the final article (usually in PDF format).
- Ensure you are aware of your rights regarding the article – discuss with the journal if you are unsure.

The publishing process – what you should expect after acceptance

- The journal will usually publish your article in the next possible issue of the journal.
- After editing and typesetting your article, the editor will send it to you for proofreading before finally publishing it.
- At this stage you are expected to read carefully through the article and correct technical, spelling and grammatical errors. Make sure your main points have not been lost to editing.
- This is the last opportunity you have to make minor corrections on your article; therefore you must check the tables, illustrations, units of measurements, etc, to make sure they are correctly presented. You should also check that you have provided accurate data.
- Make your corrections on the article and return it to your editor promptly to meet the journal's publication deadline – if you are late you may need to wait for the next issue.
- After you have seen proofs, check whether the article has been published by contacting the editor after a short time.

Citation

- Until your article is accepted by a journal you should simply cite it as "in preparation".
- Once your article has been accepted and you have a confirmation letter from the editor of the journal, you should cite it as "in press" with the name of the journal.
- Do not give full citation (volume/issue/year/pages, etc) until the article has been published.

Copyright

- SAS-N own copyright on the article

- This will restrict your re-use of the article – e.g., you may not be able to post it on your institutional website, etc – you must check this with the journal.

After publication

- Once your article has been published you can draw other people's attention to it by citing it in your subsequent related works. You can also order copies of the article (offprints or reprints) and send to relevant organisations and individuals who will make use of it.
- If your publication is a result of funded research you should ensure that the funders receive a copy of the article.
- If possible, deposit the electronic version of the final article in an online repository – either run by your institution, or a more general archive – this will give your article more prominence (remember to include its publication citation). But you must check your copyright restrictions to ensure the journal is willing to let you do this.

C. REFERENCES AND FURTHER READING

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Zell HM. 1998. A handbook of good practice in journal publishing. 2nd Revised Edition. The International African Institute and African Books Collective, London and Oxford.

Useful websites

APA reference style – although the book is only available in print for sale, this website gives examples of references in APA style – very useful. <http://www.english.uiuc.edu/cws/wworkshop/ >

Citations – useful guide on how to cite internet (online) publications. <http://www.apastyle.org/elecsource.html>

Cordova S. How to write a scientific paper. New Mexico Junior Academy of Science http://www.nmas.org/JAhowto.html.

Smart P and J Falaiye. How to publish your research work. This resource is available on the INASP website. www.inasp.info/psi or www.inasp.info/pubs.

INASP Resources on website: www.inasp.info/psi/resources. International Network for the Availability of Scientific Publications (INASP 58 St Aldates Oxford OX1 1ST UK Email: inasp@inasp.info

Mainali KP, Editor, Himalayan Journal of Sciences, Kathmandu, Nepal, URL: www.himjsci.com

Notes on the Structure of a Scientific Paper: These guidelines were prepared with the aid of Robert Day's entertaining book How to write and publish a scientific paper (ISI Press, Philadelphia, l979). http://aerg.canberra.edu.au/pub/aerg/edupaper.htm Instructions for authors and http://www.mco.edu/lib/instr/libinstq.html Connects you to the instructions for authors of hundreds of biomedical journals.

SciDevNet. How do I write a scientific paper? http://www.scidev.net/ms/howdoi/index.cfm.

Writing styles for humanities: http://www.kyvl.org/html/ref/subwriting.shtml. This website gives a wide range of links to websites detailing how to write papers in different humanities areas.

Statistical Guidelines

Bal K Joshi
Biotechnology Unit-NARC, Khumaltar

For interpretation of the results, there are a number of statistical tools those can help for getting logical inference. Following points might be suggested to be considered during running in the road from experimentation to publications.

- Appropriate statistical procedures depending on the objectives, treatments structure and experimental design should be selected for analyzing the data.
- To correctly analyze an experiment all terms must be accounted for because most computer software packages automatically pool any unaccounted source of variation with the error term.
- For a set of data with summary statistics, useful statistics to present are the mean, the number of observations and a measure of the variation or scatter of the observations as well as the units of measurement. The range or the SE is useful measures of the variation in the data. SE is not relevant in this context, since it measure the precision
- Significance testing is not the be-all and end-all of a designed experiment. The tests, which we do, are designed to give confidence that any treatment differences, which we may have observed, are real differences and not chance ones.
- To report that treatments are significant is meaningless. It is essential to state clearly which pairs or groups of treatments are being tested against what.
- Multiple comparison tests (MCTs) may be used for unstructured qualitative treatments. Indiscriminant use of MCTs can result in loss of information and reduce efficiency when more appropriate procedures are available. It is more appropriate to form planned sets of comparisons in experiment involving qualitative treatment.
- For experiment involving factorial sets of treatments or graded levels of quantitative factors there is almost always statistical procedures which can be specified in advance and which is more appropriate than MCTs.
- Whatever the methods of presentation some appropriate measure of variance eg SE of means should be included.
- Present treatment means from results of single factor experiments and SE or SED or LSD and the other possibly significance probabilities (report actual probabilities)
- Report additional statistics (CV, SE, etc) to assess data quality
- Present relevant treatments means, a measure of their precision and significance probabilities from the result of ANOVA
- The measure of precision should be either a SE or a SED or LSD. The SED and LSD are usually suitable for balanced design. Only one of these three statistics is necessary and it is important to make it clear which is being used
- Make clear whether the number after the $\pm$ sign is a SD or a SE or a confidence interval
- For unbalanced experiments each treatment mean has a different precision. Presenting results is to include column of SEs next to each column of means and also a column containing the number of observations
- If there is no interaction then the main effect means should be presented along with SEs and significance probabilities for each variable
- If there are interactions then main effect means alone are of limited use. The individual treatment means should be presented.
- For a balanced design, there is only one SE per variable (except for split plot designs) and three rows giving F test probabilities for the two main effects and the interactions.
- For unbalanced factorial experiments additional columns for numbers of observations per group and SEs for the individual means should be added
- The key results of a linear regression analysis are usually the b, its standard error, the intercept or constant term, r and the residual standard deviation. For multiple regressions there will be a numbers of coefficients and SEs, and the coefficient of determination (R^2) will replace r.
- Line graphs or histograms portraying quantitative data usually are much more meaningful and easier to understand than are massive amounts of tabular data. It is hoped that researchers will recognize a more powerful statistical tool to be used in their research.
- If error bars are displayed on graph and charts, it must be clear whether the bars refer to SD, SE, LSD, confidence interval or range.

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SOCIETY OF AGRICULTURAL SCIENTISTS, NEPAL

Estd 1995

The Society of Agricultural Scientists, Nepal (SAS-N) is a professional organization that serves as a common forum for the agricultural scientists and researchers scattered throughout Nepal in various agricultural and related institutions. SAS-N got officially registered in District Administration Office, Lalitpur on 5 June 1995 with registration no. 490/051/52.

AIM

The SAS-N aims to bring agricultural scientists and researchers of Nepal to a common forum by way of protecting their professional integrity and improving the standard of their research works in order to contribute to a common goal of the country's economic development through the growth of agricultural sector.

OBJECTIVES

- Protect and promote the professional rights, dignity, integrity and welfare of the members of the SAS-N, whilst being fully committed to the democratic norms and fundamental human rights as laid down in the Constitution of the Kingdom of Nepal, 2047 BS (1990).
- Suggest His Majesty's Government of Nepal (HMG/N) in formulating policy and resolving the problems related to agriculture.
- Organize national and international workshops, seminars, conferences etc. on the topics relating to existing status of agricultural science and technology for increasing agricultural production and productivity, making the conclusions and recommendations for resolving various relevant problems in Nepal.
- Publish agriculture related booklets, compendia of research findings and scientific journal that are useful to farmers, extension, scientists and related persons.
- Organize various programs for the SAS-N members with an aim to share their research experiences among themselves and to coordinate their activities with national and international institutions.
- Provide consultancy services to various domestic and foreign institutions as required.
- Exchange cooperation with various organizations of agriculture and other related professional organizations and institutions, maintaining cordial relationship with them.

MEMBERSHIPS

The SAS-N has the provision of following five types of memberships.

1. General Member
2. Life Member
3. Associate Member
4. Benefactor Member
5. Honorary Member

ACHIEVEMENTS

- The SAS-N has been making significant contributions to organizational development of Nepal Agricultural Research Council (NARC) and improvement in its research management systems. The contribution made by SAS-N towards resolving the issue of conversion of HMG/N staff into NARC system was a crucial one.
- The SAS-N has been occasionally organizing seminars and talk programs to provide a scientific forum to the agricultural scientists and researchers. SAS-N has successfully organized two conventions in which significant numbers of relevant scientific papers were presented.
- The SAS-N has been representing to various policy and decision-making forums to contribute in the development of agricultural research systems in the country.
- The SAS-N has hitherto published 4 volumes of a scientific periodical in the name of Nepal Agriculture Research Journal in collaboration with NARC and one proceedings of SAS-N convention.
- The SAS-N has two editorial committees, one for a scientific journal and other for a Nepali periodical especially useful for enthusiastic farmers and entrepreneurs.

FINANCIAL RESOURCES

The SAS-N mobilizes its financial resources being earned from the membership fee, various SAS-N publications, seminars, conferences, symposia, exhibitions, commercial advertisements, consultancy received from individuals, government or non-government organizations both national and international, and other forms of income sources such as donations, grants, etc.

SAS-N EXECUTIVE COMMITTEE 2003-2006

1.	Dr Adarsh Pradhan	President
2.	Ms Shanti Bhattarai	Vice-President
3.	Dr Madhav Joshi	General Secretary
4.	Ms Gyanu Manandhar	Treasurer
5.	Mr Kamal Shah	Secretary, Administration Management
6.	Mr Binesh Man Sakha	Secretary, Coordination
7.	Mr Keshav Prasad Shrestha	Secretary, Finance Management
8.	Ms Nirmala Pandey	Member, Seminar, Conference Management
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10.	Mr Bishwa Prasad Mainali	Member, Membership Management
11.	Mr Yagya Prasad Giri	Member, Planning and Technical Services
12.	Dr Madhusudan P Upadhyay	Ex president

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