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Contents

RESEARCH NOTE

Comparative Analysis of Grain Yield and its Components under Optimal and Heat Stressed Environments

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ABSTRACT

Heat is an important abiotic stress to successful wheat cultivation in South Asia, particularly when seeded later that normal seeding period. This affects sustainability of wheat production in the region. Wheat breeders in the region are continuously seeking a better understanding mechanisms leading towards developing heat tolerant wheat. A study was undertaken in four wheat growing seasons (2003–2006) to determine interrelationships among grain yield and its components as influenced by optimal and heat stress conditions. A set of 20 elite bread wheat genotypes including three checks was planted around optimum (last week of Nov.) and one month later that normal seeding period at two sites (Bhairahawa and Parwanipur) in Nepal. A wheat crop planted in the last week of December and thereafter encounters heat stress during grain filling period due to high temperatures in March and April. The value of growing degree days (GDD) per day (GDD/day) was used as the measure of heat stress during the grain-filling period for the crops planted timely and late. The values for GDD/day and mean minimum and maximum temperatures were higher during grain-filing period of the late compared to timely seeded crop. Late seeding caused reductions in days to heading (8-14 days), days to maturity (20-21 days), plant height (8-16 cm), effective tiller number (18-26 m^{-2}), kernel per spike (6-13), 1000-kernel weight (5-11 g) and grain yield (727-1969 kg ha^{-1}). The 20 genotypes showed arrays of variation for reductions in above traits. Grain yield showed significant positive correlation with 1000-kernel weight (TKW) with higher values under late (r = 0.70** to 0.85**) than timely (r = 0.44* to 0.57*) seeding. Grain yield also showed significant positive correlation with the kernel per spike only under timely seeded conditions. Reductions in grain yield due to late planting was significantly positively correlated with TKW. Results showed that TKW was most important yield component for higher wheat yield under terminal heat stress, whereas both TKW and KPS were important under normal conditions. The findings have implications for developing heat tolerant wheat in the warm wheat growing areas of South Asia and other regions with heat stress during grain-filling period.

Key words: Eastern Gangetic plains, genetic stability, wheat

INTRODUCTION

Heat stress is a major abiotic constraint to wheat production in many countries in the world. Terminal heat stress during grain-filling, caused by high temperatures in March and April, is a serious constraint causing substantial reductions in wheat (*Triticum aestivum* L.) grain yield in the Eastern Gangetic Plains (EGP) of South Asia (Rane et al 2000, Joshi et al 2007, Sharma et al 2007a). This region corresponds largely to CIMMYT wheat mega-environment 1 - late planting or high temperature (van Ginkel and Rajaram 1993). A part of this region also belongs to mega-environment 5A, which is characterized by high average temperatures in the coolest month and a high relative humidity. A short winter followed by a warm spring causes timely-planted (20 November - 10

December) wheat to mature in 110 to 120 days, but wheat is often seeded late after late-maturing rice (*Oryza sativa* L.) crops and because farmers must wait for wet soils to dry somewhat after rice harvest (Hobbs and Giri 1997). High temperatures accompanied by hot winds during grain-filling period induce premature senescence of late seeded wheat (Sharma 1992, 1993). Yields of late-seeded wheat are reduced by as much as 40 percent (Tyagi et al 2003, de Lespinay 2004, Sharma and Duveiller 2004, Duveiller et al 2005).

Despite the importance of post anthesis heat stress as a serious constraint to wheat production in many parts of the world (van Ginkle and Rajaram 1993, Black 2005, Hodson and White 2007, Sharma et al 2007a, b), not a great deal of information is available to guide efforts towards developing heat tolerant wheat. Terminal heat stress affects wheat grain yield and its three components: effective (grain bearing) tiller number per unit area (ETN) (Khanna-Chopra and Viswanathan 1999, Tahir et al 2005), kernel per spike (KPS) (Shpiler and Blum 1986, 1990, Blum and Pnuel 1990) and 1000-kernel weight (TKW) (Singha et al 2006, Tahir et al 2006). However, the results are not consistent in terms of which one of the components influence yield more than others. A few studies reported that KPS was the most important yield component for high wheat yield under heat stress (Shpiler and Blum 1986, 1990, Blum and Pnuel 1990, Kafi and Stewart 1990). Singha et al (2006) concluded that maintaining high TKW was the most important factor for higher wheat yield under heat stress caused by high temperatures during grain filling. Tahir et al (2006) reported that wheat grain yield reduction was due to lower TKW under heat stress during grain filling. Grain weight has been suggested as a potential selection criterion for improving yield under terminal heat stress condition (Munjal and Dhanda 2004, Tahir et al 2006). Tyagi et al (2003) reported that TKW was less influences by terminal heat stress compared to ETN and KPS. Different from above findings Khanna-Chopra and Viswanathan (1999) suggested that ETN was more important than other yield components in influencing wheat yield under heat stress conditions. Knott and Talukdar (1971) used grain weight as a selection criterion to improve wheat grain yield, whereas Tahir et al (2005) used more spike m^{-2} as a criteria to select for grain yield.

Since previous studies on comparative importance of grain yield components in determining gain yield under terminal heat stress is inconclusive, even contradictory at times, this study was conducted to elucidate change in expression of wheat grain yield and its component under optimal and late seeding conditions. One specific objective was to evaluate reductions in various yield components in relation to grain yield on late seeded crop that encounters terminal heat stress during grain development. Such information could guide in developing heat tolerant wheat cultivars.

MATERIALS AND METHODS

This study included 20 spring wheat genotypes well adapted the growing conditions in the plains, where this study was conducted. All genotypes were evaluated under field conditions at two sites in Nepal: Bhairahawa (27º 32' N and 83º 25' E, 105 meter above sea level) and Parwanipur (26° 43' N and 85º 58' E). These sites, situated in the lowlands of Nepal at a distance of 225 km, differ from each other. The soil type at both sites is heavy clay.

The study was conducted during the *rabi* wheat-growing season (November to April) in 2003, 2004 and 2005 in a randomized compete block design with four replicates. Individual experimental plots of 10 m^2 were seeded as 8 rows with 0.25-m row spacing. The trials were planted around optimum (25 November to 10 December) and late (one month after 1st planting) seeding time. Fertilization was done into the soil prior to seeding using 100, 50 and 25 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. The other crop management practices were consistent with good crop husbandry recommended in the region.

Days to heading was recorded when spikes of approximately 50 percent of the plants in a plot were fully emerged. At maturity, plant height in each plot was measured from ground level to the tip of the spikes. The number of spike-bearing tiller in the two middle rows of each plot was counted to determine the effective tiller number m^{-2} (ETN). Days to maturity was recorded when glumes completely lost their green color, following the procedure of Hanft and Wych (1982) and Knott and Gebeyehou (1987). The number of kernel on 10 randomly selected spikes was counted to determine kernel per spike (KPS). Plants were hand-harvested at the ground level. After threshing, grain weight was recorded. One thousand kernels taken randomly from grain harvested in each plot were weighed to obtain 1000-kernel weight (TKW).

Analysis of variance for individual site in each year was conducted to determine genotypic differences and genotype × seeding date interaction. After confirming the homogeneity of variance (Gomez and Gomez 1984), a combined analysis of variance was also conducted across two sites in each year to determine genotypic differences and genotype × environment (location and seeding date) interactions for various traits. Pair-wise correlation coefficients (*r*) were determined for various traits, first for each location in each year. Average correlations over locations were calculated using Fisher's z-transformation as outlined by Steel and Torrie (1980). Correlation coefficient was calculated between grain yield and its component under early and late seeding to examine if it changed under optimal and heat stress conditions. Correlation coefficient among reductions in grain yield and its components due to late seeding was calculated to determine the component that most affected grain yield. All above statistical analyses were conducted using the Genstat software (Genstat 2007).

Daily mean minimum and maximum data recorded in a weather station beside the research plots at Bhairahawa site were used to calculate growing degree days (GDD) using 0°C base temperature. GDD was calculated separately for vegetative and grain-filling period and for timely and late-seeded crops. Average GDD per day (GDD/day) was calculated for vegetative and grain filling period of the timely and late-seeded crop. A higher GDD/day was considered a measure of heat stress. Mean minimum (T_{min}) and maximum (T_{max}) temperatures during the two growth periods for each planting were calculated.

RESULTS

There were variations in GDD and GDD/day and minimum and maximum temperatures in the four years at Bhairahawa site (Table 1). GDD in vegetative growth period was 2, 5, 10, and 9 percent higher, respectively in 2003, 2004, 2005 and 2006 for timely than late-seeded crop. The corresponding values during grain-filling period GDD were 16, 9, 9, 6 percent higher for timely than late-seeded crop. GDD/day during vegetative growth period was somewhat higher for late than timely-seeded crop in all four years. GDD/day during grain-filing period was higher for late than timely-seeded crop in the four years.

Mean T_{min} and T_{max} as well as highest values for T_{min} and T_{max} during grain-filling period were higher for late than timely-seeded crop in each year. The general climatic observation during wheat crop season was that the year 2003 and 2006 were drier than 2004 and 2005.

There was a significant effect of location and seeding date on days to heading and maturity, plant height, ETN, KPS, TKW and grain yield in each of the four years (Table 2). In general, the location × seeding date interaction was not consistent for most of the traits in different years. The 20 wheat genotypes differed significantly for all above traits. Genotype × seeding date and genotype × location interactions were significant for all traits in each year. Genotype × seeding date × location interaction was significant for grain yield only.

Table 1. Growing degree days (GDD) and mean minimum (T_{min}) and maximum (T_{max}) temperatures during vegetative period (VGP) and grain-filing period (GFP) of timely and late-seeded wheat at Bhairahawa, Nepal, 2003-2006

Parameter	2002-2003		2003-2004		2004-2005		2005-2006	
	Timely seeded	Late seeded	Timely seeded	Late seeded	Timely seeded	Late seeded	Timely seeded	Late seeded
GDD -VGP	1095	1072	1154	1091	1207	1082	1271	1159
GDD-GFP	817	690	763	691	790	720	694	653
GDD/day-VGP	15.2	15.5	16.0	16.3	16.8	17.7	16.9	18.1
GDD/day-GFP	20.4	23.8	19.1	24.7	19.3	23.2	21.7	23.3
Mean Tmax-GFP	27.1	30.8	26.7	32.9	27.1	32.0	28.9	32.3
Mean Tmin - GFP	13.7	16.8	11.5	16.4	11.4	14.5	14.5	14.3
Maximum Tmax - GFP	31.6	35.8	32.6	37.8	33.8	34.8	34.4	37.8
Maximum Tmin - GFP	19.0	22.0	18.6	23.0	18.0	19.0	19.0	19.0

Table 2. Analysis of variance for various characters in 20 wheat genotypes evaluated under timely and late seeding in four wheat growing seasons

Source	df	Days to heading	Days to Maturity	Plant height	Effective Tiller, no	Kernel per spike	1000-Kernel wt	Grain yield
2003								
Location (L)	1	1652 **	3038 **	551 **	69325 **	12054 **	374 **	1264 **
Seeding date (SD)	1	5144 **	33008 **	5578 **	180786 **	3341 **	1563 **	1335 **
L × SD	1	3044 **	3578 **	5511 **	28	143	52 *	11
Rep (L SD)	12	26	20	141	5931	63	6	3
Genotype (G)	19	87 **	11 **	289 **	6752 **	291 **	296 **	13 **
G × L	19	36 **	11 **	45 **	3597 **	67 **	22 **	3 **
G × SD	19	31 *	8 **	76 **	3476 **	58 **	17 **	3 **
G × L × SD	19	24	4	20	1914	33	3	2 *
Error	228	17	3	14	1503	26	2	1
2004								
Location (L)	1	1437 **	15680 **	334 **	52122 **	8040 **	802 **	1199 **
Seeding date (SD)	1	3264 **	34736 **	4097 **	20995 **	2726 **	1906 **	3101 **
L × SD	1	515	1950 **	107	80645 **	115 *	170 **	12
Rep (L SD)	12	91	5	124	3450	23	27 **	4
Genotype (G)	19	250 **	31 **	426 **	6682 **	591 **	192 **	11 **
G × L	19	15 **	17 **	36 **	1196 **	113 **	62 **	4 **
G × SD	19	29 **	13 **	31 **	2007 **	111 **	67 **	4 **
G × L × SD	19	4	6	21	899	29	4	4 **
Error	228	3	5	15	603	24	3	1
2005								
Location (L)	1	145 *	1921 **	1180 **	318213 **	1531 **	1129 **	1070 **
Seeding date (SD)	1	8674 **	31008 **	8000 **	671336 **	3551 **	4407 **	3755 **
L × SD	1	67	9	3768 **	250376 **	600	56 *	11 **
Rep (L SD)	12	27	5	152	5211	132	9	4
Genotype (G)	19	176 **	33 **	534 **	4760 **	314 **	176 **	11 **
G × L	19	7 **	10 **	22 **	757 **	67 **	39 **	3 **
G × SD	19	25 **	24 **	86 **	1740 **	60 **	30 **	4 **
G × L × SD	19	5	6	13	808	39	7	4 **
Error	228	4	4	13	638	29	5	1
2006								
Location (L)	1	652 **	706 **	508 **	125504 **	1588 **	1079 **	915 **
Seeding date (SD)	1	7995 **	16606 **	10288 **	151782 **	6003 **	136 **	2212 **
L × SD	1	6	1378 **	727 *	123054 **	221	298 **	7
Rep (L SD)	4	4	3	109	4155	239	10	5
Genotype (G)	19	64 **	34 **	264 **	1049 **	121 **	119 **	7 **
G × L	19	5 **	6 **	26 **	425 *	26 **	18 **	3 **
G × SD	19	7 **	6 **	23 *	472 *	42 **	19 **	2 *
G × L × SD	19	3	3	10	319	9	6	2 *
Error	76	2	3	11	219	10	4	1

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

Late seeding caused average reductions of 6 to 14, and 20 to 21 days in the number of days to heading and maturity, respectively in different years (Table 3). Average plant height was reduced due to late seeding by 8 to 16 cm in different years. Late seeding produced significantly lower KPS, TKW and grain yield than timely seeding in all four years. On average, KPS was reduced by 6 to 13 in different years. Average reduction in TKW due to late seeding ranged from 4.1 to 11.4 g in four years. Grain yield was reduced by 34 to 55 percent due to late seeding.

Table 3. Mean values for various traits recorded on 20 wheat cultivars in three years over two sites in Nepal, 2003-2006

Year	Days to heading		Days to maturity		Plant height		Effective tiller number	
	Normal	Late	Normal	Late	Normal	Late	Normal	Late
2003	78 a†	73 b	123 a	102 b	89 a	81 b	270 a	252 a
2004	78 a	72 b	126 a	105 b	95 a	87 b	267 a	250 a
2005	75 a	70 b	119 a	99 b	93 a	83 b	273 a	247 a
2006	78 a	71 b	116 a	95 b	96 a	80 b	207 a	190 a
Year	Kernel per spike		1000-kernel weight		Grain yield			
	Normal	Late	Normal	Late	Normal	Late		
2003	40 a	34 b	35.9 a	31.5 b	2597 a	1305 b		
2004	44 a	38 b	44.0 a	32.6 b	3539 b	1570 b		
2005	47 a	40 b	39.1 a	31.7 b	3476 b	1610 b		
2006	47 a	34 b	33.7 a	29.6 b	2148 a	1421 b		

† For a given trait in the same year, means followed by different letters are significantly different at P = 0.05 based on F-test.

Grain yield showed significant positive correlation with TKW under both timely and late-seeded conditions, however, the correlations coefficients were significantly higher under late than timely-seeded conditions (Table 4). Grain yield showed significant positive correlation with KPS under timely-seeded conditions only. Kernel per spike was significantly negatively correlated with ETN under both timely and late-seeded and with TKW under late seeded conditions only.

The 20 wheat genotypes showed arrays of variation for reductions in all traits due to delayed planting in all years (Table 5). There were genotypes that showed comparatively low reductions for individual traits. In general, percent reductions were higher for grain yield than the yield component. Among yield components, KPS and TKW showed greater reductions than ETN due to delayed seeding. Reduction in grain yield due to late seeding was positively correlated with reductions in TKW in all four years, and with KPS in two of the four years (Table 6). Reduction in TKW was negatively correlated with reduction in KPS.

Table 4. Average simple correlation coefficients among various traits under normal and late seeding recorded on 20 wheat cultivars in two sites in Nepal, 2003-2006

Traits	Year	Days to heading		Days to maturity		Plant height		Effective tiller number		Kernel per spike		1000-kernel weight	
		Normal	Late	Normal	Late	Normal	Late	Normal	Late	Normal	Late	Normal	Late
Grain yield	2003	0.271	-0.180	0.218	-0.045	0.132	0.141	0.181	0.217	0.478 *	0.050	0.444 *	0.694 **
	2004	0.060	0.174	0.119	0.097	-0.099	0.254	0.235	0.229	0.510 *	0.297	0.567 **	0.775 **
	2005	0.120	0.045	0.244	0.153	0.077	0.105	0.080	0.291	0.464 *	0.272	0.560 **	0.846 **
	2006	0.048	-0.036	0.093	-0.011	0.108	0.158	0.137	0.199	0.555 *	0.285	0.456 *	0.798 **
1000-kernel weight	2003	-0.063	-0.228	-0.221	-0.200	0.271	0.223	0.124	0.165	-0.115	-0.475 *		
	2004	-0.155	-0.060	-0.393	-0.260	0.304	0.121	0.235	0.120	-0.226	-0.472 *		
	2005	-0.081	-0.184	-0.280	-0.206	0.282	0.312	0.121	0.042	-0.133	-0.464 *		
	2006	-0.151	-0.170	-0.199	-0.139	0.108	0.317	0.131	0.338	-0.178	-0.507 *		
Kernel per spike	2003	0.242	0.126	0.141	0.137	0.181	-0.156	-0.534 *	-0.487 *				
	2004	0.254	0.173	0.286	0.128	0.173	-0.123	-0.700 **	-0.456 *				
	2005	0.226	0.289	0.192	0.247	-0.088	-0.067	-0.641 **	-0.547 *				
	2006	0.038	0.121	0.199	0.026	-0.197	0.050	-0.543 *	-0.463 *				
Effective tiller number	2003	-0.203	-0.141	-0.223	-0.012	-0.007	0.178						
	2004	-0.105	-0.185	-0.181	-0.242	-0.149	0.012						
	2005	-0.101	-0.018	-0.004	-0.099	0.147	0.261						
	2006	-0.210	-0.100	-0.271	-0.056	0.097	0.164						
Plant height	2003	0.142	0.069	0.138	0.053								
	2004	0.227	0.393	0.136	0.151								
	2005	0.230	0.030	-0.030	-0.074								
	2006	0.201	0.155	0.216	0.179								
Days to maturity	2003	0.915 **	0.856 **										
	2004	0.889 **	0.823 **										
	2005	0.913 **	0.866 **										
	2006	0.893 **	0.950 **										

**, **, Correlation coefficients significantly different from zero at P = 0.05 and 0.01, respectively.*

Table 5. Range of reductions due to late seeding in different traits of wheat recorded on 20 genotypes in four wheat-growing seasons in two locations in Nepal

Year		Reduction													
		Days to heading		Days to maturity		Plant height		Effective tiller number		Kernel per spike		1000-kernel weight		Grain yield	
		days	%	days	%	cm	%	m^{-2}	%	number	%	g	%	kg ha^{-1}	%
2003	Mean	5	7	21	17	8	9	18	7	6	15	5	12	1292	50
	Range	3 – 9	4 - 15	18 - 23	14 - 19	7 - 21	8 – 11	13 - 37	5 - 11	2 -15	3 - 32	1 - 7	3 - 18	560 -1934	36 - 60
2004	Mean	6	8	21	17	8	8	17	6	6	14	11	26	1969	56
	Range	2 – 9	3 - 14	16 - 24	14 - 19	3 - 12	5 - 12	9 - 32	4 - 10	1 - 16	2 - 28	4 - 11	9 - 32	1383 - 2633	42 - 65
2005	Mean	5	7	20	17	10	11	26	10	7	15	7	19	1866	54
	Range	4 - 10	7 - 13	15- 25	13 - 21	2 - 20	4 - 17	18 -33	7 - 12	1 - 11	2 - 21	1 - 12	3 - 26	1136 - 2587	32 - 67
2006	Mean	7	9	21	18	16	17	17	8	13	28	4	12	727	34
	Range	3 - 11	4 – 14	17 - 24	15 - 20	11 - 23	10 - 23	12 - 27	5 - 12	5 - 18	14 - 36	1 - 8	2 - 18	219 - 1053	17 - 44

Table 6. Average simple correlation coefficients among reductions from normal to late seeding in grain yield and its components recorded on 20 wheat cultivars in three years over two sites in Nepal

Traits	Year	Grain yield	1000-kernel weight	Kernel per spike
Effective tiller number	2003	-0.047	0.093	-0.214
	2004	0.042	0.343	-0.222
	2005	0.107	0.208	0.017
	2006	0.121	0.190	0.235
Kernel per spike	2003	0.412	-0.450*	
	2004	0.260	-0.581**	
	2005	0.014	-0.637**	
	2006	0.385	-0.502*	
1000-kernel weight	2003	0.586**		
	2004	0.835**		
	2005	0.793**		
	2006	0.690**		

**, **, Correlation coefficients significantly different from zero at P = 0.05 and 0.01, respectively.*

DISCUSSION

Late seeding exposed wheat crop to heat stress as shown by higher mean maximum and minimum temperatures and GDD/day during grain-filling period of the late compared to timely-seeded crop. A higher GDD/day is an indicator that heat stress occurred during post-anthesis period of the late-seeded crop. This shortened grain filling duration, which in turn resulted in lower total GDD for the late-seeded crop. Late planting caused lower GDD both during vegetative and grain-filing period compared to timely seeding. Lower GDD for vegetative period is an indication that the late-seeded crop entered post-anthesis period at a lower vigor than the timely-seeded crop. Previous studies have shown that biomass accumulation in wheat is directly related to GDD. The above finding on terminal heat stress and its effect on vegetative and grain-filling period is in agreement with the previous reports (Sharma 1993).

The finding that terminal heat stress due to late seeding caused reductions in grain yield was expected and agrees with numerous previous reports from the studies conducted in South Asia (Sharma 1993, Hobbs and Giri 1997, Tyagi et al 2003, Singh et al 2006). However, the responses of yield components to late seeding and their effect on grain yield are not consistent with previous reports. Our study shows that ETN was not significantly reduced due to late seeding which is different from the previous study of Munjal and Dhanda (2004) who reported significant lower ENT due to late seeding. One reason of this difference could be difference between seeding time in the two studies. We planted timely and late trials in the last week of November and the last week of December, respectively. The equivalent seeding date of the trials of Munjal and Dhanda (2004) was the 1st week of November and the last week of December. Our finding of upto 10 percent decrease in ETN agrees with the report by Tyagi et al (2003) who found 13 percent reduction in ETN. Tyagi has planted the timely and late trials 31 days apart, similar to the interval used in our study. A lack of substantial reduction in ETN in our study could be explained by normal environmental conditions and crop health during pre-anthesis period when the spikes are already out of boot. Hence, there was no difference in ETN between timely and late seeded crops. The finding that KPS and TKW were significantly reduced due to late seeding is in agreement with the reports from previous studies in South Asia (Sharma 1993, Tyagi et al 2003, Duveiller et al 2005, Singh et al 2006). Tyagi et al (2003) reported 27 percent reduction in KPS which is in agreement with the average reductions between 14 and 28 percent found in our study. Reductions in TKW found in our study (average 12 to 32% in four years) are higher than the value (8%) reported by Tyagi et al (2003). This difference could be due to harsher growing conditions for late-seeded crop in our study causing much lower yields than that reported by Tyagi et al (2003). This was evident

through higher average grain yield reductions (34 to 56%) in our study than 21 percent reported by Tyagi et al (2003). The yield levels reported in our study is realistic by being closer to the farmers' field yield found under timely and late-seeded conditions in the region (Sharma and Duveiller 2004, 2006).

Despite high average decline in grain yield, there were individual genotypes that showed much lower reductions in individual components. The lowest reductions in ETN, KPS and TKW ranged from 4 to 7 percent, 2 to 14 percent and 2 to 9 percent, respectively. This shows that genotypic variations occur for each yield component that could be utilized in developing heat tolerant cultivars. Even though wheat breeders in South Asia select intuitively for heat tolerance by choosing genotypes that show relatively lower reductions in grain yield under late seeding, cultivars tolerant to heat stress per se are not available. The use of lower reductions in grain yield components due to heat stress as selection criteria could open additional avenue to developing heat tolerant wheat.

Correlation between grain yield and its component was not consistent for timely and late-seeded conditions suggesting that different strategies may be needed to improve grain yield through manipulation of yield components under heat-stress compared to normal conditions. Our study shows that both KPS and TKW were important in determining grain yield under normal conditions, whereas TKW strongly influenced grain yield under heat-stress conditions. This finding is partly in agreement with the report of Munjal and Dhanda (2004) who concluded that tillers per plot had direct and positive effect on grain yield under normal conditions, while TKW had the highest positive and direct effect on grain yield under heat stress conditions. Khanna-Chopra and Viswanathan (1999) reported that spike number m^{-2} was a better measurement of heat tolerance than other yield components in wheat. Singha et al (2006) concluded that maintaining high TKW was most important factor for higher wheat yield under heat stress caused by high temperatures during grain filling. Tahir et al (2006) reported that wheat grain yield reduction was due to lower kernel weight under heat stress during grain filling. Sial et al (2005) reported that TKW was sensitive to heat stress causing yield reductions. Our findings differ from that of Shpiler and Blum (1986, 1990) who found that kernel per spike was the most important yield component for wheat high yield under heat-stress conditions.

While previous studies focused on determining importance of yield components to grain yield under heat-stress conditions based on their direct correlation coefficient, our study further attempted to examine relationships among reductions in grain yield and its components to determine which trait(s) could be considered a better indirect selection criterion to develop heat tolerant wheat. The results show that reduction in TKW influenced grain yield reduction more than other components in all four years. Reductions in KPS moderately influenced grain yield in 2003 and 2005. Significant negative correlation between reductions in TKW and KPS suggests that it may be difficult to improve both traits simultaneously under terminal heat stress. Our findings are that improving kernel weight is a key to selection for high grain yield under heat-stress conditions (Collaku 1994, Sharma and Duveiller 2003).

Reductions in grain yield and its component is a confirmation of more severe heat stress faced by a late than timely-seeded wheat. The findings of this study show that optimal and heat stressed environments affect grain yield and its components differently, adding further to their complex interrelationships in terms of component compensation. Considering sensitivity of TKW to change in climatic conditions, heat in particular, and its positive correlation with grain yield make this trait more important than other yield components as a potential selection criterion to develop heat tolerant wheat in South Asia. The findings could be useful for other regions where terminal heat stress is prevalent.

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Correlation and Path Coefficients Analyses of Agronomical Traits in Tartary Buckwheat

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ABSTRACT

Association study of traits of interest with other agronomical traits is essential in understanding the magnitude and direction of changes expected during indirect selection. Correlation and path coefficients were estimated to evaluate the importance of different agromorpholgical traits in tartary buckwheat, to determine the direct and indirect effects of these components on yield, and to develop selection criteria that are useful for selecting high grain yielding varieties. A total of 192 accessions from two season's trials were used to estimate coefficients among 24 agronomical traits. The direction and magnitude of the association among the traits were found to be different. Days to flowering was positively correlated with days to maturity, number of leaves, plant height, number of cymes and cyme length. Days to maturity had a significant positive correlation with number of secondary branches, petiole length, number of leaves, leaf size, plant height, internode related traits and cyme length. The positively and significantly related traits with grain yield were number of primary branches, number of leaves, plant height, number of clusters and cymes, days to flowering, number of filled and unfilled grains, grain width and grain weight. The number of grains per plant showed the highest direct effect (0.90) in grain yield. The highest negative direct effect was expressed by the number of internodes. The indirect effects of plant height, number of clusters, days to flowering, number of leaves and number of unfilled grains via number of grains were higher. These traits-association findings can be very useful to enhance the selection procedures in tartary buckwheat improvement program.

Key words: Agronomical traits, correlation, path coefficient, tartary buckwheat

INTRODUCTION

Buckwheat is an indigenous crop that plays a major role in food security of mountainous farming community of Nepal. It is a staple food that warrants food security in some mountain regions while in other regions it is a neglected and under-privileged crop mostly grown in marginal lands. A significant number of landraces are being maintained by farmers across the country. Among the two cultivated species ie *Fagopyrum esculentum* (common buckwheat) and *F. tataricum* (tartary buckwheat) in Nepal, common buckwheat is much more preferred by farmers. But, priority is now being placed on tartary buckwheat (also called mountain buckwheat) mainly because of two reasons. First reason is that its yield is high and stable due to its self-compatibility, low seed abortion and tolerance to stresses such as frost. Second is that it has a higher nutritional and medicinal values, especially in respect to a high antioxidant activity in terms of its flavonoid content. As an example, its seed rutin content is approximately 100 times (0.8-1.7%) higher than that found in common buckwheat (0.01%) (Fabjan et al 2003). Other important aspect of buckwheat production is that the grain of buckwheat can be stored for long time without any symptoms of chemical changes. This is due to the content of several natural antioxidants including tocopherols (Keli et al 1992), phenolic acids (Durkee 1997) and flavonoids (Oomah and Mazza 1996, Watanabe et al 1997) stabilizing the grain during drying and storage. However, the flour and the groats must be used fresh since there is a

high fat content and they soon become rancid (Joshi and Rana 1995a). Additionally, majority of cultivating areas in mountainous areas in Nepal is sloppy due to which soil become more acidic. In this situation, aluminium toxicity might be a major problem limiting crop production; however, buckwheat can perform well even in acidic soil because buckwheat is highly resistant to aluminium toxicity. If high yielding varieties could be made available, it will help significantly to secure the food even in the remote and food deficit areas of Nepal. Selection, which is mainly based on phenotypic characters, is the major technique used for developing varieties.

Response to selection depends on many factors such as the interrelationship of the characters. Correlation and path coefficient analyses would assist in the choice of characters whose selection would result in the improvement of a complex character such as yield. Correlation estimates the degree of association between the variables. Path coefficient analysis can be used to obtain an indication of which variables exert an influence on other variables (Akanda and Mundt 1996). 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). Path-coefficient analysis has been useful in determining selection criteria in a number of crops, such as crested wheat grass (Dewey and Lu 1959), maize (Ivanovic and Rosic 1985) and rice (Samonte et al 1998). By determining the inter-relationships among agronomical traits, a better understanding of both the direct and indirect effects of the specific components can be attained and applied in buckwheat improvement programs.

Buckwheat breeding program was started from 1986 mainly by introduction of common buckwheat and mass selection in Nepal. Buckwheat species have been improved through mainly selection and in some extent by hybridization and using biotechnological tools (Rajbhandari and Hatley 1993, Baniya et al 1995, Baniya 2001, Biswokarma et al 2001, Joshi and Bimb 2001, Joshi and Bimb 2002). Selection, which is the most common and simple technique in the improvement of crop species, is the only method used in breeding of tartary buckwheat so far in Nepal. Whatever the methods used for improving crops, selection aids are necessary for achieving the goal effectively and efficiently. The magnitude and degree of contribution of different agromorphological traits towards yield may differ; result in the different response to selection. Therefore, this paper attempted (1) to evaluate the importance of different agromorphological traits in tartary buckwheat, (2) to determine the direct and indirect effects of these components on grain yield, and (3) to develop selection criteria for higher grain yield.

MATERIALS AND METHODS

Plant materials and field experiment

A total of 151 and 192 accessions of tartary buckwheat was characterized and evaluated in autumn seasons of 2007 and 2008, respectively in Khumaltar, Lalitpur. Khumaltar is located in 85°20' E, 27°40' N at an altitude of 1368 m above sea level. Because of limited seeds and large number of entries, augmented design (augmented random incomplete block design) was adopted with five blocks. Three checks were randomized in each block, and then the new entries (accessions of tartary buckwheat, also called test entries) were placed in the remaining plots. The plot design was two rows, one m long with a 25 cm row to row distance and 75 cm block to block. A rod row system (solid seeded or continuous row) of planting was followed. Equal amount of seeds (about 6 g) for each entry was seeded in 24 September in 2007 and 19 September in 2008. Standard cultivation practices were followed.

From this trial, a total of 192 accessions of tartary buckwheat were used for estimating correlation and path coefficients. The 24 quantitative traits (Table 1) used in this study were measured as described in IPGRI (1994) and coefficients were estimated among them. Some data were measured on plot basis, for example, days to maturity and some data were based on the individual basis, for example, plant height. In case of individual data measurement, three or five individual plants/plot or plant's parts were considered and data were averaged. For separating branch and inflorescence, presence or absence of leaf was considered and cluster was defined if there was a bract in the branch of inflorescence. Vernier caliper was used to measure the length and width of seeds. Most of these accessions were repeated in both years and therefore, data were averaged over years.

Table 1. Traits used in this study along with their abbreviation used subsequent tables and figures

SN	Abbreviation	Trait	SN	Abbreviation	Trait
1	PrimBrn	Number of primary branches	13	Cym/Pl	Number of cymes /plant
2	SecBrn	Number of secondary branches	14	Seed/cym	Number of seeds / cyme
3	PetioL	Petiole length	15	Seed/Clust	Number of seeds / cluster
4	LfNo	Number of leaves	16	FlowDays	Days to flowering
5	LfBlL	Leaf blade length	17	MatDays	Days to maturity
6	LfBlW	Leaf blade width	18	Gr/Pl	Number of grain /plant
7	PlHt	Plant height	19	GrYld/Pl	Grain yield /plant
8	IntndNo	Number of internodes	20	UnfilGr/Pl	Number of unfilled grains /plant
9	IntNdL	Internode length	21	StraYld/Pl	Straw yield /plant
10	PrimBrn/Infl	Number of primary branches/ inflorescence	22	SeedL	Seed length
11	CymL	Cyme length	23	SeedW	Seed width
12	Clust/Pl	Number of clusters /plant	24	1000-GrWt	1000-grain weight

Data analysis

Because of the augmented design, there were no replication, therefore only phenotypic correlation coefficients (r) were estimated. Yusheng (1995) explained that most of the expected genotypes could be selected according to the phenotypes. Pearson correlation (r) coefficient was estimated among these variables as suggested by Steel and Torrie (1980). Correlation coefficient was tested either significantly different from zero or not. Software provided the actual P-value; therefore, P value was reported for each coefficient. P value with zero in table 2 means less than 0.001. Path analysis was based on r-values and estimated following the procedure of Dewey and Lu (1959) and it is briefly described below. The cause and effect system is diagrammatically shown below (Figure 1). In this diagram, P is path coefficient, r is correlation coefficient, R is residual, x is a quantitative variable with n number of variables; double-arrowed lines indicate the correlation and single-arrowed indicate the direct effect on grain yield (Y).

The path coefficients were obtained using following equations and solving by simultaneous solution. These equations relate the path coefficients with correlation coefficient.

1. $r_{x1y} = P_{x1y} + r_{x1x2} P_{x2y} + r_{x1x3} P_{x3y} + r_{x1xn} P_{xny}$
2. $r_{x2y} = P_{x2y} + r_{x1x2} P_{x1y} + r_{x2x3} P_{x3y} + r_{x2xn} P_{xny}$
3. $r_{x3y} = P_{x3y} + r_{x1x3} P_{x1y} + r_{x2x3} P_{x2y} + r_{x3xn} P_{xny}$
4. $r_{xny} = P_{xny} + r_{x1xn} P_{x1y} + r_{x2xn} P_{x2y} + r_{x3xn} P_{x3y}$
5. $1 = P^2_{Ry} + P^2_{x1y} + P^2_{x2y} + P^2_{x3y} + P^2_{xny} + 2 P_{x1y} r_{x1x2} P_{x2y} + 2 P_{x1y} r_{x1x3} P_{x3y} + 2P_{x1y} r_{x1xn} P_{xny} + 2P_{x2y} r_{x2x3} P_{x3y} + 2P_{x3y} r_{x2xn} P_{xny} + 2P_{x3y} r_{x3xn} P_{xny}$

Where, r_{x1y} = Correlation coefficient between x_1 variable and grain yield (direct + indirect effects), P_{x1y} = Direct effect of variable x_1 on grain yield, r_{x1x2} P_{x2y} = Indirect effect of x_1 via x_2 variable on grain yield, r_{x1x3} P_{x3y} = Indirect effect of variable x_1 via x_3 on grain yield, r_{x1xn} P_{xny} = Indirect effect of variable x_1 via x_n on grain yield (Y).

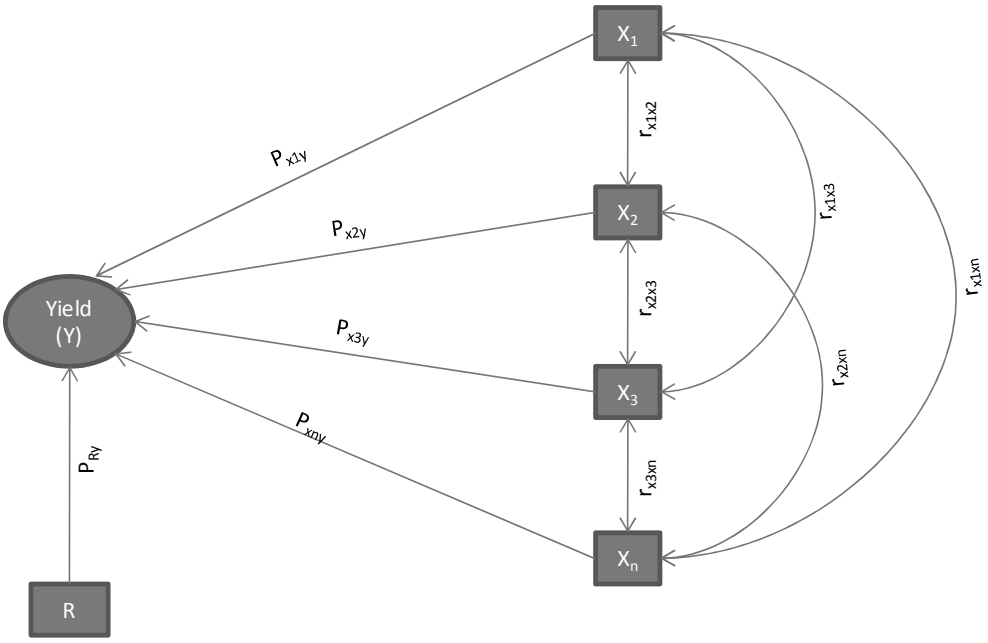

Figure 1. Path diagram showing direct effects on yield and correlation coefficients among traits.

The data were processed in MS Excel and MINITAB statistical software was used to estimate the correlation coefficients and to solve the simultaneous equations using the matrix method. These outputs of correlation and path coefficients were verified with PATHSAS outputs (Cramer et al 1999). PATHSAS is a SAS computer program for path coefficient analysis of quantitative data and available through http://cuke.hort.ncsu.edu/cucurbit/wehner/software.html.

RESULTS

The direction and magnitude of association were found to differ among 24 agronomical traits (Table 2). A negative association was found in 83 traits. Similarly 193 pairs of traits expressed a positive correlation. Days to flowering was positively and significantly correlated with number of primary branches, number of leaves, plant height, days to maturity, cyme length and number of cymes. Negatively associated traits with days to flowering were number of secondary branches, number of seeds per cluster and cyme. Days to maturity had a significant positive correlation with a number of traits for example number of branches, petiole length, number of leaves, leaf size, plant height, internode length, number of internodes, cyme length, days to flowering and number of unfilled grains. A negative association of days to maturity with number of clusters/plant and number of seeds/cyme was not significant. Days to maturity had negatively and significantly correlation with grain yield and 1000-grain weight (TGW).

Plant height was significantly and positively associated with all traits except with number of secondary branches, number of seeds/cyme, number of seeds/cluster, straw yield, seed size and grain weight. The positively and significantly related traits with plant height were number of primary branches, petiole length, leaf size, number of internodes, internode length, cyme length, days to flowering, days to maturity, number of filled and unfilled grains and grain yield. Insignificant

negative correlation of plant height was found with number of seeds/cluster, straw yield and significant negative with TGW.

The number of branches had a positive and significant correlation with number of leaves, plant height, number of internodes, number of primary branches/inflorescence, days to flowering and seed width. Most of the traits were negatively associated with TGW. A strong significant association of TGW with grain yield, seed length and seed width was observed in a positive direction. In tartary buckwheat the number of primary branches and leaves, plant height, number of internodes, number of primary branches/inflorescence, number of cymes and clusters, days to flowering, seed width, number of grains and grain weight contributed positively to an increase in yield but number of secondary branches, petiole length, leaf size and seed length had a negative contribution; however, these values were not significantly different from zero. Number of unfilled grains was positively associated with number of filled grains and grain yield.

Table 2. Correlation coefficients among different agromorphological traits in tartary buckwheat

SN	Trait	PrimBrn	2	3	4	5	6	7	8	9	10	11	12
1	SecBrn	0.01											
	P-value	0.92											
2	PetioL	0.11	-0.11										
	P-value	0.12	0.13										
3	LfNo	0.52	0.06	0.12									
	P-value	0	0.44	0.1									
4	LfBlL	0.11	0.13	0.42	0.13								
	P-value	0.12	0.08	0	0.08								
5	LfBlW	0.16	0.02	0.48	0.2	0.93							
	P-value	0.03	0.79	0	0.01	0							
6	PlHt	0.6	0.11	0.26	0.52	0.34	0.42						
	P-value	0	0.14	0	0	0	0						
7	IntndNo	0.22	0.36	0.26	0.27	0.24	0.23	0.35					
	P-value	0	0	0	0	0	0	0					
8	IntNdL	0.01	-0.19	0.48	0.06	0.3	0.29	0.21	0.02				
	P-value	0.94	0.01	0	0.44	0	0	0	0.84				
9	PrimBrn/Infl	0.4	0.29	0.15	0.2	0.09	0.11	0.23	0.52	-0.09			
	P-value	0	0	0.04	0.01	0.19	0.12	0	0	0.22			
10	CymL	0.23	0.09	0.03	0.15	0.27	0.25	0.4	0.07	-0.1	0.05		
	P-value	0	0.21	0.69	0.04	0	0	0	0.32	0.19	0.5		
11	Clust/Pl	0.48	0.03	-0.14	0.35	0.07	0.09	0.42	-0	-0.09	-0.01	0.26	
	P-value	0	0.71	0.05	0	0.31	0.23	0	0.98	0.24	0.87	0	
12	Cym/Pl	0.3	0.1	-0.18	0.26	0.02	0.03	0.25	0.12	-0.15	0.18	0.14	0.61
	P-value	0	0.16	0.02	0	0.78	0.65	0	0.09	0.04	0.02	0.05	0
13	Seed/cym	-0.17	0.03	0.22	-0.04	0.21	0.24	0.03	0.18	0.17	0.07	0.02	-0.21
	P-value	0.02	0.66	0	0.58	0	0	0.66	0.02	0.02	0.35	0.82	0
14	Seed/Clust	-0.21	-0.02	0.27	-0.08	0.22	0.25	-0.05	0.18	0.16	0.05	-0.04	-0.35
	P-value	0	0.75	0	0.3	0	0	0.51	0.01	0.02	0.45	0.63	0
15	FlowDays	0.44	-0.17	0.03	0.36	0.12	0.17	0.4	0.06	-0.05	-0.02	0.35	0.49
	P-value	0	0.02	0.71	0	0.09	0.02	0	0.43	0.54	0.82	0	0
16	MatDays	0.23	0.02	0.43	0.22	0.34	0.43	0.38	0.27	0.26	0.22	0.19	-0.06
	P-value	0	0.84	0	0	0	0	0	0	0	0	0.01	0.41
17	Gr/Pl	0.43	0.06	-0.05	0.39	0.07	0.08	0.45	0.15	0.02	0.14	0.2	0.59
	P-value	0	0.38	0.48	0	0.31	0.27	0	0.03	0.82	0.05	0.01	0
18	GrYld/Pl	0.36	-0.02	-0.07	0.32	-0.01	-0.02	0.33	-0.01	0.1	0.03	0.06	0.52
	P-value	0	0.84	0.34	0	0.85	0.82	0	0.88	0.18	0.69	0.42	0
19	UnfilGr/Pl	0.45	0.1	0.05	0.38	0.23	0.26	0.47	0.24	0.05	0.25	0.25	0.52
	P-value	0	0.16	0.47	0	0	0	0	0	0.48	0	0	0
20	StraYld/Pl	0.08	0.01	0.13	0.06	0.08	0.1	-0	0.15	0.07	0.16	0.01	-0.01
	P-value	0.26	0.84	0.07	0.44	0.26	0.17	0.98	0.04	0.37	0.03	0.87	0.86
21	SeedL	0.04	-0.06	-0.01	0.07	-0.05	-0.05	0.03	-0.1	0.11	0.09	-0.17	-0.04
	P-value	0.6	0.39	0.91	0.31	0.47	0.49	0.68	0.18	0.13	0.24	0.02	0.59
22	SeedW	0.2	-0.15	0.08	0.1	-0.02	-0.03	0.04	-0.09	0.18	-0.05	-0.19	0.19
	P-value	0.01	0.05	0.26	0.16	0.75	0.64	0.55	0.2	0.01	0.48	0.01	0.01
23	1000-GrWt	-0.05	-0.14	-0.2	-0.07	-0.29	-0.31	-0.16	-0.31	0.11	-0.23	-0.26	0.01
	P-value	0.52	0.05	0.01	0.34	0	0	0.03	0	0.15	0	0	0.91

Contd…

SN	Trait	13	14	15	16	17	18	19	20	21	22	23
13	Seed/cym	-0.17										
	P-value	0.02										
14	Seed/Clust	-0.28	0.91									
	P-value	0	0									
15	FlowDays	0.27	-0.19	-0.22								
	P-value	0	0.01	0								
16	MatDays	-0.06	-0.02	0	0.19							
	P-value	0.43	0.83	0.98	0.01							
17	Gr/Pl	0.63	0.02	-0.1	0.24	-0.06						
	P-value	0	0.79	0.17	0	0.39						
18	GrYld/Pl	0.56	-0.02	-0.13	0.15	-0.15	0.91					
	P-value	0	0.79	0.08	0.04	0.03	0					
19	UnfilGr/Pl	0.44	0.05	-0.07	0.39	0.17	0.51	0.45				
	P-value	0	0.53	0.34	0	0.02	0	0				
20	StraYld/Pl	-0.01	0.12	0.12	0.13	-0.09	0.08	0.06	0.01			
	P-value	0.86	0.1	0.09	0.07	0.23	0.27	0.43	0.84			
21	SeedL	-0.06	-0.17	-0.19	-0.02	-0.05	-0.04	0.12	0.04	0.05		
	P-value	0.39	0.02	0.01	0.74	0.5	0.6	0.09	0.54	0.53		
22	SeedW	0.25	-0.19	-0.21	0.03	0.08	0.26	0.34	0.08	-0.12	-0.13	
	P-value	0	0.01	0	0.69	0.28	0	0	0.3	0.09	0.08	
23	1000-GrWt	0.09	-0.1	-0.12	-0.16	-0.34	0.09	0.43	-0.04	0.01	0.38	0.28
	P-value	0.24	0.15	0.1	0.03	0	0.22	0	0.59	0.92	0	0

P value of 0 means less than 0.001.

The direct and indirect effects of 23 traits on yield are given in Table 3. The number of grains expressed the highest direct effect on yield followed by TGW and petiole length (Figure 2). The highest negative direct effect was expressed by number of internodes followed by cyme length. Nine other traits have also negative effects on grain yield. An indirect effect of number of cymes/plant via number of grains was the highest on yield (Figure 3). Most of the indirect effects of number of grains via a number of other traits were higher. For example, number of primary branches, days to flowering, number of clusters and cymes, plant height, number of unfilled grains and leaves, and seed width had the relatively higher indirect effect (> 0.2) via number of grains. Days to maturity via grain weight gave the highest negative indirect effect. Seven traits, namely days to maturity, leaf blade width, number of internodes, leaf blade length, cyme length, number of primary branches/inflorescence and petiole length had negative indirect effects with more than 0.059 via grain weight. The indirect effect of number of seeds/cluster via number of grains was -0.08. Among 506 values of indirect effects, 247 values were negative.

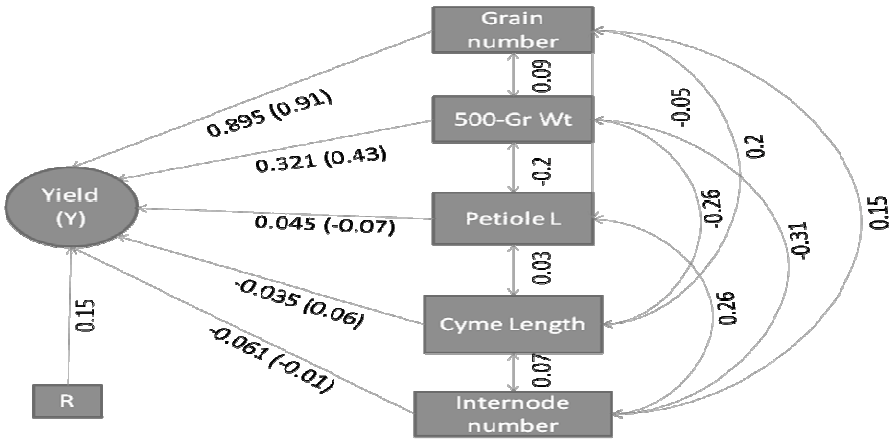

Figure 2. Direct path diagram of grain yield with other traits that had the highest positive and negative effects on yield. Correlation coefficients are also shown.

Table 3. Direct (diagonal bold) and indirect effects of 23 traits on grain yield of tartary buckwheat

SN	Trait	1	2	3	4	5	6	7	8	9	10	11	12
1	PrimBrn	0.0219	0.0001	0.0051	0.0020	0.0035	-0.0036	-0.0157	-0.0136	0.0001	-0.0032	-0.0082	0.0003
2	SecBrn	0.0002	0.0077	-0.0050	0.0002	0.0041	-0.0005	-0.0028	-0.0223	-0.0039	-0.0024	-0.0032	0.0000
3	PetioL	0.0025	-0.0009	0.0447	0.0005	0.0134	-0.0109	-0.0067	-0.0159	0.0097	-0.0012	-0.0010	-0.0001
4	LfNo	0.0115	0.0004	0.0054	0.0038	0.0040	-0.0044	-0.0136	-0.0167	0.0011	-0.0017	-0.0052	0.0002
5	LfBlL	0.0025	0.0010	0.0190	0.0005	0.0315	-0.0211	-0.0090	-0.0146	0.0060	-0.0008	-0.0094	0.0000
6	LfBlW	0.0035	0.0002	0.0214	0.0007	0.0292	-0.0228	-0.0109	-0.0143	0.0059	-0.0009	-0.0086	0.0001
7	PlHt	0.0132	0.0008	0.0114	0.0020	0.0108	-0.0095	-0.0261	-0.0211	0.0042	-0.0019	-0.0139	0.0003
8	IntndNo	0.0049	0.0028	0.0116	0.0010	0.0075	-0.0053	-0.0090	-0.0613	0.0003	-0.0043	-0.0025	0.0000
9	IntNdL	0.0001	-0.0015	0.0214	0.0002	0.0094	-0.0067	-0.0054	-0.0009	0.0203	0.0007	0.0034	-0.0001
10	PrimBrn/Infl	0.0086	0.0022	0.0066	0.0008	0.0030	-0.0026	-0.0060	-0.0320	-0.0018	-0.0082	-0.0017	0.0000
11	CymL	0.0051	0.0007	0.0013	0.0006	0.0084	-0.0056	-0.0104	-0.0044	-0.0019	-0.0004	-0.0352	0.0002
12	Clust/Pl	0.0105	0.0002	-0.0064	0.0013	0.0023	-0.0020	-0.0109	0.0001	-0.0017	0.0001	-0.0091	0.0006
13	Cym/Pl	0.0065	0.0008	-0.0079	0.0010	0.0006	-0.0008	-0.0065	-0.0075	-0.0031	-0.0014	-0.0050	0.0004
14	Seed/cym	-0.0038	0.0002	0.0098	-0.0002	0.0065	-0.0054	-0.0008	-0.0107	0.0035	-0.0006	-0.0006	-0.0001
15	Seed/Clust	-0.0047	-0.0002	0.0119	-0.0003	0.0068	-0.0058	0.0012	-0.0110	0.0033	-0.0004	0.0012	-0.0002
16	FlowDays	0.0096	-0.0013	0.0012	0.0013	0.0038	-0.0039	-0.0105	-0.0035	-0.0009	0.0001	-0.0123	0.0003
17	MatDays	0.0050	0.0001	0.0192	0.0008	0.0108	-0.0098	-0.0100	-0.0162	0.0053	-0.0018	-0.0066	0.0000
18	Gr/Pl	0.0093	0.0005	-0.0023	0.0015	0.0023	-0.0018	-0.0117	-0.0094	0.0003	-0.0011	-0.0071	0.0004
19	UnfilGr/Pl	0.0098	0.0008	0.0024	0.0014	0.0072	-0.0059	-0.0123	-0.0148	0.0011	-0.0020	-0.0087	0.0003
20	StraYld/Pl	0.0018	0.0001	0.0059	0.0002	0.0026	-0.0023	0.0001	-0.0092	0.0013	-0.0013	-0.0004	0.0000
21	SeedL	0.0008	-0.0005	-0.0004	0.0003	-0.0017	0.0011	-0.0008	0.0059	0.0022	-0.0007	0.0060	0.0000
22	SeedW	0.0044	-0.0011	0.0036	0.0004	-0.0007	0.0008	-0.0012	0.0056	0.0036	0.0004	0.0065	0.0001
23	1000-GrWt	-0.0010	-0.0011	-0.0089	-0.0003	-0.0092	0.0071	0.0042	0.0189	0.0021	0.0019	0.0090	0.0000

Contd…

SN	Trait	13	14	15	16	17	18	19	20	21	22	23
1	PrimBrn	-0.0061	0.0036	-0.0039	-0.0033	0.0021	0.3807	0.0183	-0.0014	0.0008	-0.0006	-0.0148
2	SecBrn	-0.0021	-0.0007	-0.0004	0.0013	0.0001	0.0564	0.0042	-0.0002	-0.0013	0.0005	-0.0450
3	PetioL	0.0036	-0.0046	0.0049	-0.0002	0.0039	-0.0466	0.0022	-0.0022	-0.0002	-0.0003	-0.0637
4	LfNo	-0.0052	0.0008	-0.0014	-0.0027	0.0020	0.3493	0.0155	-0.0010	0.0016	-0.0003	-0.0225
5	LfBlL	-0.0004	-0.0043	0.0040	-0.0009	0.0031	0.0654	0.0095	-0.0014	-0.0011	0.0001	-0.0936
6	LfBlW	-0.0007	-0.0049	0.0046	-0.0013	0.0039	0.0717	0.0106	-0.0017	-0.0011	0.0001	-0.1007
7	PlHt	-0.0051	-0.0007	-0.0009	-0.0030	0.0035	0.4013	0.0194	0.0000	0.0006	-0.0001	-0.0511
8	IntndNo	-0.0025	-0.0036	0.0033	-0.0004	0.0024	0.1379	0.0099	-0.0026	-0.0021	0.0003	-0.0994
9	IntNdL	0.0031	-0.0036	0.0030	0.0003	0.0024	0.0143	0.0021	-0.0011	0.0023	-0.0006	0.0338
10	PrimBrn/Infl	-0.0036	-0.0014	0.0010	0.0001	0.0020	0.1254	0.0101	-0.0027	0.0018	0.0002	-0.0727
11	CymL	-0.0029	-0.0004	-0.0006	-0.0026	0.0017	0.1809	0.0102	-0.0002	-0.0037	0.0006	-0.0823
12	Clust/Pl	-0.0125	0.0044	-0.0064	-0.0036	-0.0005	0.5258	0.0215	0.0002	-0.0008	-0.0006	0.0026
13	Cym/Pl	-0.0206	0.0035	-0.0051	-0.0020	-0.0005	0.5652	0.0179	0.0002	-0.0013	-0.0008	0.0273
14	Seed/cym	0.0035	-0.0208	0.0168	0.0014	-0.0001	0.0179	0.0019	-0.0020	-0.0035	0.0006	-0.0334
15	Seed/Clust	0.0057	-0.0190	0.0184	0.0016	0.0000	-0.0878	-0.0028	-0.0021	-0.0040	0.0007	-0.0386
16	FlowDays	-0.0055	0.0040	-0.0040	-0.0075	0.0017	0.2150	0.0161	-0.0022	-0.0005	-0.0001	-0.0498
17	MatDays	0.0012	0.0003	0.0000	-0.0014	0.0091	-0.0564	0.0069	0.0015	-0.0010	-0.0002	-0.1097
18	Gr/Pl	-0.0130	-0.0004	-0.0018	-0.0018	-0.0006	0.8958	0.0208	-0.0014	-0.0008	-0.0008	0.0283
19	UnfilGr/Pl	-0.0089	-0.0009	-0.0013	-0.0029	0.0015	0.4532	0.0411	-0.0002	0.0009	-0.0002	-0.0125
20	StraYld/Pl	0.0003	-0.0025	0.0022	-0.0010	-0.0008	0.0726	0.0006	-0.0171	0.0010	0.0004	0.0026
21	SeedL	0.0013	0.0034	-0.0034	0.0002	-0.0004	-0.0340	0.0018	-0.0008	0.0214	0.0004	0.1219
22	SeedW	-0.0051	0.0040	-0.0039	-0.0002	0.0007	0.2329	0.0031	0.0021	-0.0028	-0.0032	0.0888
23	1000-GrWt	-0.0017	0.0022	-0.0022	0.0012	-0.0031	0.0788	-0.0016	-0.0001	0.0081	-0.0009	0.3216

Residual (P_{Ry}) = 0.152.

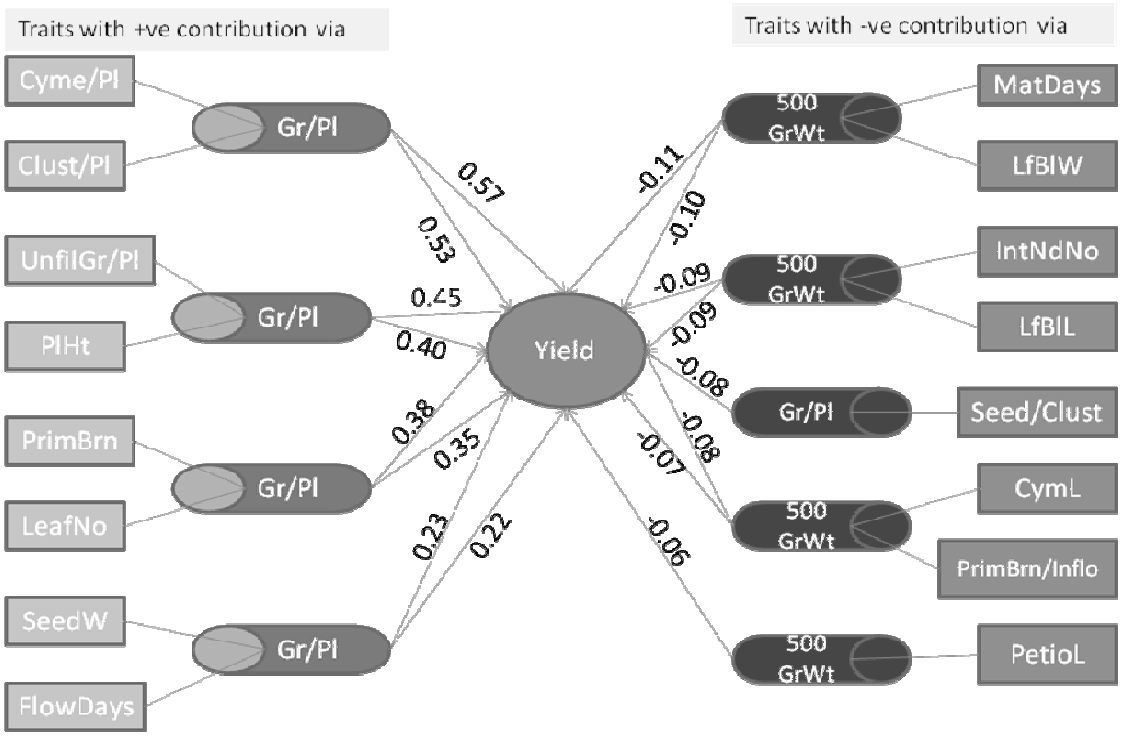

Figure 3. Indirect path diagram of grain yield with other traits that had higher positive and negative effects on yield.

DISCUSSION

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be used for improvement of traits of interest, for example, plant height, days to maturity and grain yield. The direction and magnitude of correlations have been studied by many researchers and found to be different which may be due to mainly use of different genotypes and environments.

Plant height plays important role on grain yield. Generally the taller the plant, the higher the yield in crop species. In the study of Honda et al (2003), plant height had a high positive correlation with the length of main stem, number of internodes, diameter of the main stem (Sherchand and Ujihara 1995, Hagiwara et al 1999) and number of branches. Baniya et al (1995) reported a high positive correlation of plant height with days to flowering, plant population, number of flower clusters per cyme, number of seeds per cyme and grain yield in tartary buckwheat. Positively related pairs of trait in the study of Baniya et al (1995) were days to flowering and days to maturity, plant population and days to maturity, number of flower clusters per cyme and number of seeds per cyme, number of flower clusters and grain yield, 1000-grain weight and grain yield in tartary buckwheat. The uniform elongation type was early maturing with small plant height and the mid stem elongation type was late maturing with large plant height (Hagiwara et al 1999). Zhang et al (1992) observed a high correlation between plant height and 1000-grian weight.

Correlation among assimilation area, fertility percentage, number of seeds per plant and grain yield were found highly significant and positive (Rajbhandari and Hatley 1998). The correlation between the shoot growth character and lodging degree was found to be the highest negative and significant

character for main stem length while main stem diameter produced the second highest negative and significant correlation coefficient. The number of nodes on main stem was found to be negatively correlated with lodging degree in the uniform elongation type (Hagiwara et al 1999).

In both common and tartary species number of branches, number of flower clusters and harvest index were reported to be correlated with grain yield (Sherchand and Ujihara 1995). But an insignificant correlation between the number of primary branches and yield in tartary buckwheat was also reported. Mixed results in the association of these traits demanded a further study of partitioning coefficients into phenotypic, genotypic and environment.

A correlation study helps to identify traits that are useful to response to selection. Baniya et al (1992) reported that for increased yield, plant height, number of leaves, number of clusters and seeds per cyme and grain filling period were important in common buckwheat and number of seeds per cyme and grain filling period in tartary buckwheat. Gang et al (1992) recommended selection based on chlorophyll content for improvement in biomass and grain yield in tartary. Single plant grain number was the first factor and TGW the second factor to be considered during selection in the study of Shuhua et al (1992). The importance of long growth period, TGW, number of branches and grains per plant and leaf area index during selection was highlighted by Yusheng (1995) in tartary buckwheat.

Seed yield showed a positive association with leaf length, leaf width, number of branches per plant and seed weight in the study of Joshi and Rana (1995b). They found that, leaf width had the strongest positive direct effect on yield, followed by TGW and plant height. They reported that leaf width and seed weight were the most potential traits for genetic amelioration of buckwheat.

Plant population, number of branches and flower clusters and TGW are yield components in most of the crop species. However, in buckwheat, the number of branches and flower clusters expressed negative direct effects on yield. Possibly, fertility is important factor and Choi et al (1995) reported the largest direct effect of fertility degree on grain yield. In common buckwheat, however, the fertilization rate was not correlated with the percentage of ripened grain per fertilized grain in the population of a local landrace (Inoue et al 2002). In most of the cases reported, direct effects of these traits were higher in tartary than in common buckwheat. Due to the self incompatibility in common buckwheat other factors, for example, number of visits by insect pollinators, wind movement and number of compatible pollen grains (Namai 1990) might play important roles in the setting of seeds. Direct positive effects of flowering time, stem length and number of branches and direct negative effects of emergence time, lodging degree and number of nodes on grain yield were reported by Choi et al (1995) in common buckwheat.

Variation in path coefficients indicates the availability of option to increase yield through direct as well as indirect selections. Mass selection can be used to improve grain yield through indirect selection for highly heritable traits, for example, grain filling period, which are associated with yield. The fertilization rate in a selected population was found to be significantly increased by approximately 12 percent (Inoue et al 2002). If the correlation between yield and a character is due to the direct effect of the character, it reflects a true relationship between them and selection can be practiced for such a character in order to improve yield. But if the correlation is mainly due to the indirect effect of the character through other complementary traits, the breeder has to select for the latter trait through which the indirect effect is exerted. A larger yield response can be obtained when the character for which indirect selection is practiced has a high heritability and a high correlation with yield.

A number of traits are positively correlated with grain yield, plant height and days to maturity. Indirect selection is possible to gain progress for target traits. Response to selection depends on many

factors and among them, variation and degree of correlation are the important ones. If we could identify the positively correlated traits that can be measured at early crop stage, for example, cotyledon color, size etc with yield, cost and time can be saved and selection can be exercised in multiple times. Flowering days, plant height and number of primary branches are associated with grain yield; therefore, selection can be done before maturity stage of crop.

Coefficient estimates among traits may be affected by sample size, genotypes used and environments. We used 192 sample sizes to estimate the coefficients; however, there were diverse genotypes. Coefficients estimated from the accessions from similar group would be more useful to identify the selection criteria and to apply in selection program. It will be more effective if selection is made within population developed from the same accessions that were used to estimate the coefficients. Target environments are also very important to estimate the coefficients and to make the selection. Days to maturity is generally correlated positively with grain yield, but we found negative association. It was because late maturity accessions were affected by cold climate in Khumaltar, Lalitpur in both years 2007 and 2008. Temperature was very low in December and January of these years. Due to the cold temperature, many seeds remained unfilled and leaves were also affected. Most of the seeds of early maturing accessions were filled and ready to harvest. Similarly, the number of unfilled grains was positively correlated with grain yield. This might be also due to the cold climate at later crop stage. Therefore, environments and genotypes should be considered important for exerting selection pressure based on the correlated traits and direct and indirect effects. Indirect effects of many traits were positive via number of grains on grain yield but indirect effects of many traits were negative via grain weight on grain yield. It indicates that there are many traits that can be considered for indirect selection on grain yield of tartary buckwheat. Due to non-replicated data we estimated only phenotypic correlation and path coefficients, where, non-heritable factors may have contributed largely in such type of estimates. Therefore, genotypic correlation and path coefficients would be more practically useful and reliable to identify the selection criteria.

CONCLUSION

Three traits, number of primary branches, days to flowering and number of unfilled grains were significantly and positively correlated with all three important traits ie grain yield, plant height and days to maturity. Important traits that can be considered during selection based on association study with grain yield are number of primary branches and leaves, plant height, number of clusters and cymes, days to flowering, number of filled and unfilled grains, seed width and grain weight. Path coefficient analysis showed that number of grains, TGW and petiole length were the most effective traits that can be considered during selection for developing high yielding variety. The indirect effects of number of grains via days to flowering, grain weight, number of leaves, plant height and number of clusters were also found to be considerable in magnitude. Other important traits for indirect selection were number of primary branches and leaves, plant height, number of clusters and cymes, days to flowering, number of unfilled grains and seed width. Number of grains and grain weight are the two most important traits for indirect selection of high grain yielding varieties.

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Species of *Fusarium graminearum* clade, Important Pathogens of Maize in Nepal: Pathogenic Variability and Mycotoxins

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ABSTRACT

Species of the *Fusarium graminearum* clade are important pathogens of maize in Nepal and occur predominantly on maize grown in the cool and humid environment of the high hills. These pathogens are also known to infect other cereal crops, including wheat and rice, causing important diseases. The incidence of ear rot is highest in the high hills and can cause considerable loss in crop yield. Significant virulence groups were observed among *F. graminearum* clade isolates from maize, rice and wheat during pathogenicity tests on the Arun-4 variety of maize at Khumaltar in 2001 and 2003. The incidence of ear rot by isolates from maize was 38 percent at a severity level of 1.9 in 2001, and increased in 2003. Similarly, the incidences of ear rot by isolates from rice and wheat were 30 and 26 percent, respectively at severity levels of 1.8 and 1.7 in 2001 and increased in 2003. These tests confirmed that *F. graminearum* clade isolates from all three crops are pathogenic and can cause disease on maize. Isolates from maize, wheat and rice were tested for trichothecene mycotoxin production in culture and in maize ears. The isolates were shown by liquid chromatography-mass spectroscopy to produce the trichothecenes deoxynivalenol (DON) and nivalenol (NIV) in culture and in grains from inoculated ears. The virulence of the isolates was not related to their trichothecene-production chemotype in this study, with deoxynivalenol-producing isolates and nivalenol-producing isolates both causing ear rot disease on maize.

Key words: Ear rot disease, *Fusarium graminearum* clade, maize, pathogenic variability

INTRODUCTION

Species of the *Fusarium graminearum* clade are important fungal pathogens of maize in Nepal and cause prominent *Gibberella* or red ear rot disease in the high and mid hills. Four phylogenetic species of the *F. graminearum* clade – *F. asiaticum, F. boothii, F. meridionale* and a "Nepal lineage" – have been isolated from maize in Nepal (Desjardins and Proctor 2011). Red discoloration of the kernels at the tips of the ears and of husk leaves is a recognizable symptom of red ear rot that can be seen at the time of harvest. Severely affected ears are light in weight and have tightly attached husk leaves. Numerous small black fruiting bodies of the pathogen, a *Gibberella* state, sometimes appear on husk covers or on other affected parts of the plant. The pathogen is common in areas injured by ear/kernel/silk-cut, insects or birds, and also on germinating kernels of the ears in lodged plants. Frequent rain or foggy weather prior to harvest enhances the disease and many high yielding maize varieties are susceptible to the disease in the high hills. The disease can also appear after harvest on stored ears in the high hills. Due to problems with drying maize in the high hills, local maize is more popular among the farmers in spite of its low grain yield and the small size of the ears. The pathogen can also infect seeds/seedlings/roots causing discolorations/rots/blights in the field during germination in the high hills. Stalk rots with pinkish discoloration in the internal tissues are also frequent in the mid hills. In an early survey (Manandhar and Gurung 1982), the incidence of ear rot was highest, up

to 40 percent, at locations at high hills like Kakani. Ear rot incidence was moderate, up to 20 percent, at eastern hill locations like Pakhribas and Kabre. Incidence of ear rot was in the range of 10 to15 percent in the western hills at Jumla and Lumle, and lowest below 5 percent at Khumaltar and in the Tarai at Rampur.

Species of the *F. graminearum* clade are also important for the quality of the maize since they can produce trichothecene mycotoxins deoxynivalenol (DON) and nivalenol (NIV) on moldy kernels. Trichothecene mycotoxin contamination was detected in 16 percent of 74 representative maize samples collected in Nepal in 1997 (Desjardins et al 2000) and in 75 percent of low quality maize samples collected in 2004 (Desjardins et al 2008). This pathogen is not only a major constraint in maize crop production but can also infect many other crops such as sorghum, wheat, rice and millet, and cause important diseases affecting different parts of the plant. With the objective to determine pathogenic variability among isolates of the *F. graminearum* clade from maize, rice and wheat, maize ear rot pathogenicity tests were carried out in the field at Khumaltar, NARC in collaboration with Mycotoxin Research Unit, National Center for Agricultural Utilization Research, US Department of Agriculture, Peoria, Illinois.

MATERIALS AND METHODS

Isolates of the *Fusarium graminearum* clade from maize, rice and wheat were used in the pathogenicity tests. Isolates were identified by morphology and by DNA maker analysis as previously described (Desjardins et al 2000). A total of 25 isolates of *Fusarium graminearum* clade, including 8 from rice seed, 8 from wheat seed and 8 from maize seed and one isolate from an ear rot sample for local check were included in the test on Arun-4 variety of maize at Khumaltar (Table 1). Seeds of Arun-4 were sown as main plot and isolates were inoculated in rows as sub-plots in 3 replications on 2 May 2001 and without replications in 2003. The plot size for each isolate was 5.5 m^2 to obtain 22 plants, spaced at 25 cm between plants on single row of 5.5 m at 1 m apart from row to row. Chemical fertilizer applied was 120:60:40 kg N_2, P_2O_5 and K_2O per hectare. A small piece of fungal mycelium from freshly prepared cultures of each fungal isolate was transferred into 40 milliliter of mungbean broth medium contained in a conical flask of 250 ml capacity. For spore production, these cultures were incubated on a shaker (Laboshake) for 4 days at 90 rpm. Each suspension was checked for spore production and spore concentration was adjusted to 1 x 10^5 spores per milliliter for all isolates. Spore suspensions were stored in the refrigerator. During the second and third weeks of July, each isolate was inoculated into 10 similar primary ears in the plot by injecting 1 to 2 milliliters of spore suspension within 5 to 6 days after silking by the silk channel method (Reid et al 1996). Sterile water and mungbean broth without fungal culture were also inoculated separately for the control. The incidence and severity of red ear rot disease was assessed at harvest time on 27 August in 2001 and 16 September in 2003. The severity was recorded on a 1-7 scale: 1 for ears without ear rot symptoms, that is 0 percent diseased kernels; 2 for ears with 1 to 3 percent diseased kernels; 3 for ears with 4 to 10 percent diseased kernels; 4 for ears with 11 to 25 percent area diseased; 5 for ears with 26 to 50 percent area diseased; 6 for ears with 51 to 75 percent area diseased and 7 for ears with above 76 percent area diseased (Reid et al 1996). The data were transformed into square root and arc sine values and analyzed using MSTATC (Table 2-4).

The maize samples from the 2003 field test were sent for trichothecene analysis as previously reported (Desjardins et al 2008) by LC-MS at the Mycotoxin Research Unit, National Center for Agricultural Utilization Research, US Department of Agriculture, Peoria, Illinois.

Table 1. Isolates of the *Fusarium graminearum* clade used for field tests in this study*

SN	Isolates	Variety	Location	District
	Maize			
1	GGM-46	Local Vokada	Harikharka	Dhankuta
2	GGM-15	Local	Gau shahar	Lamjung
3	Local	Local	Khumaltar	Lalitpur
4	Nep-22	Local	Gau shahar	Lamjung
5	R-9435	Manakamana-2	RARS Lumle	Kaski
6	Nep-63	Local	Gau shahar	Lamjung
7	R-9438	Khumal Yellow	Khumaltar	Lalitpur
8	GGM-70	Local	Kakani	Nuwakote
9	R-9430	Local Dadeldhura	RARS Lumle	Kaski
	Rice			
1	HKM-95	Local borlange	Chaudila	Lamjung
2	HKM-99	Local aanadi	Chaudila	Lamjung
3	HKM-86	Local chhote	Gau shahar	Lamjung
4	HKM-113	Khumal-4	Damaitar	Lalitpur
5	HKM-215	Taichung 176	Bageswari	Bhaktapur
6	HKM-40	Khumal-4	Thaiba	Lalitpur
7	HKM-136	Khumal-4	Banepa	Kavrepalanchowk
8	HKM-87, P1	Marshi	Gau shahar	Lamjung
	Wheat			
1	GGM-93	Local, small kernel	Gau shahar	Lamjung
2	GGM-193	introduced variety	Dhulikhel	Kavrepalanchowk
3	GGM-200	introduced variety	Gau shahar	Lamjung
4	GGM-87	introduced variety	Gau shahar	Lamjung
5	GGM-154	introduced variety	Gau shahar	Lamjung
6	GGM-139	introduced variety	Gau shahar	Lamjung
7	GGM-131	introduced variety	Gau shahar	Lamjung
8	GGM-211	introduced variety	Katunje	Bhaktapur

**Phylogenetic species determined by sequencing of the MAT1-1-3 gene are Fusarium asiaticum (GGM-15, Nep-22, R-9435 and GGM-70), F. meridionale (GGM-46, Nep-63, R-9438 and R-9430) and the "Nepal lineage" (HKM-87).*

RESULTS AND DISCUSSION

Significant pathogenic variability was observed among isolates of the *Fusarium graminearum* clade from maize, rice and wheat. In the 2001 field test, two different virulence groups were observed among 9 isolates from maize. Three nivalenol producing isolates, GGM-46, GGM-15 and local check from Khumaltar, were more virulent, with ear rot incidences from 62 to 69 percent and severity levels of up to 3.0. Six remaining isolates from maize were less virulent with ear rot incidences of less than 34 percent and severity level below 2.0 (Table 2). In 2001, only one of 8 rice isolates, HKM-95, a deoxynivanol producer, was highly virulent with incidence of 74 percent and severity of 3.3 (Table 3) and none of 8 isolates from wheat were highly virulent (Table 4). In the 2003 field test, average ear rot incidence (73%) and average severity (3.2) for the collection of isolates were higher than in 2001. Average incidence and severity did not differ among isolates from the three crops in the 2003 field test (Table 5).

The field pathogenicity tests in Nepal showed that isolates of the *F. graminearum* clade from maize, rice and wheat can cause high levels of maize ear rot under favourable conditions. In addition, the field tests showed that both nivalenol producing isolates and deoxynivalenol producing isolates can cause high levels of maize ear rot. Phylogenetic analysis of nine isolates of the *F. graminearum* clade

in this study has placed four isolates in phylogenetic species *F. meridionale*, four isolates in phylogenetic species *F. asiaticum* and one isolate in a new lineage designated as the "Nepal lineage" (Desjardins and Proctor 2011) (Table 1). Within this small sample size there was no correlation between phylogenetic species and ability to cause maize ear rot in the 2001 and 2003 field tests in Nepal.

Table 2. Field test of isolates of the *Fusarium graminearum* clade from maize in 2001 and 2003 and their trichothecene chemotype

Fusarium graminearum clade isolates	2001		2003		Trichothecene chemotype
	Ear rot incidence, %	Ear rot severity (1-7)	Ear rot incidence, %	Ear rot severity (1-7)	
GGM-46	69 a	3.0 a	80	3.2	NIV
GGM-15	62 a	2.8 a	100	4.8	NIV
Local check	69 a	2.7 a	80	3.7	NIV
Nep-22	22 b	1.6 b	60	2.8	DON
R-9435	34 b	1.5 b	70	3.0	DON
Nep-63	23 b	1.5 b	40	2.3	NIV
R-9438	20 b	1.4 b	70	4.0	NIV
GGM-70	23 b	1.3 b	60	2.2	DON
R-9430	21 b	1.3 b	80	2.7	NIV
CV, %	25	7.8			

Means followed by the same letter are not significantly different at 5% level using DMRT.

Table 3. Field test of isolates of the *Fusarium graminearum* clade from rice in 2001 and 2003 and their trichothecene chemotype

Fusarium graminearum clade isolates	2001		2003		Trichothecene chemotype
	Ear rot incidence, %	Ear rot severity (1-7)	Ear rot incidence, %	Ear rot severity (1-7)	
HKM-95	74 a	3.3 a	100	4.0	DON
HKM-99	53 b	2.3 b	-	-	NIV
HKM-86	24 c	1.6 c	90	4.4	DON
HKM-113	19 c	1.5 c	70	2.6	NIV
HKM-215	19 c	1.5 c	80	4.4	NIV
HKM-40	23 c	1.5 c	50	2.4	NIV
HKM-136	21 c	1.3 c	50	2.2	NIV
HKM-87	10 c	1.2 c	70	2.2	DON
CV, %	19	9.9			

Means followed by the same letter are not significantly different at 5% level using DMRT.

Table 4. Field test of isolates of the *Fusarium graminearum* clade from wheat in 2001 and 2003 and their trichothecene chemotype

Fusarium graminearum clade isolates	2001		2003		Trichothecene chemotype
	Ear rot incidence, %	Ear rot severity (1-7)	Ear rot incidence, %	Ear rot severity (1-7)	
GGM-93	47 a	2.4 a	70	2.6	NIV
GGM-193	38 ab	2.0 ab	90	4.5	DON
GGM-200	37 ab	1.7 ab	33	1.3	DON
GGM-87	37 abc	1.7 ab	80	4.6	NIV
GGM-154	27 abcd	1.8 ab	100	4.1	DON
GGM-139	10 bcd	1.3 b	80	2.9	NIV
GGM-131	7 d	1.2 b	60	1.9	DON
GGM-211	7 cd	1.1 b	90	3.9	NIV
CV, %	40	17			

Means followed by the same letter are not significantly different at 5% level using DMRT.

Table 5. Field test of isolates of the *Fusarium graminearum* clade from maize, rice and wheat in 2001 and 2003 and their trichothecene chemotype

Crop	Number of isolates	2001		2003		Number of isolates producing	
		Ear rot incidence %	Ear rot severity	Ear rot incidence %	Ear rot severity	NIV	DON
Maize	9	38	1.9	71	3.2	6	3
Rice	8	30	1.8	73	3.2	5	3
Wheat	8	26	1.7	75	3.3	4	4
Mean of crops		31	1.8	73	3.2		
Control (water)		17	1.3	20	1.3		
Control (mung bean)		11	1.1	-	-		

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Ethnoveterinary Practices in Western Morang, Nepal

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ABSTRACT

The ethnomedicinal practices appear to be a part of traditional system of treatment for cattle in remote areas of Nepal. The knowledge of local healers with the utilization of biological resources in various ailments is still in practice and is communicated verbally to limited family members. Now-a-days, documentation of traditional knowledge is receiving much attention. The study, carried out in seven village development committees of Morang district, documents the traditional uses of crude drugs obtained form 37 plant species belonging to 24 families which are used for the treatment of 21 common ailments of cattle. The botanical name, family, local name, plant parts used, method of preparation and method of application are presented.

Key words: Crude drugs, documentation, domestic cattle, local healers

INTRODUCTION

Since ancient times, people have used plants to heal their as well as animals' ailments. Indigenous knowledge of local healers associating with the use of the plants plays a key role in primary health care. This indigenous knowledge have been transmitted from generation to generation in the form of inherited culture and such practices have been handed down verbally and only few of information were documented in books and in many other religious scripts (Raut 2010). The knowledge of the people may be at the edge of extinction due to lack of proper record and investigations. Therefore, now-a-days, the documentation of indigenous knowledge is receiving much attention. The Medicinal and Aromatic Plants Database of Nepal (MAPDON) encompasses over 1624 species of medicinal plants including 1515 species of angiosperms, 18 species of gymnosperm, 58 species of pteridophytes, 6 species of lichens and 9 species of fungi (Shrestha et al 2000). An inventory on general ethnobotanical practices and ethnomedicines to treat various human disorders are available (Raut 2010, Dangol and Gurung 1999, Dahal and Das 1999, Yadav 1999, Shakya 2000, Manandhar 1991, 1995). However, very little efforts have been made to explore the ethnoveterinary uses of various medicinal plants in different parts of country. The literatures show that a very few documentation of the herbal veterinary practices in Nepal have been made (Manandhar 2001, Acharya and Acharya 2010). Thus, an effort was made to gather the existing knowledge on the use of different plants to treat various common ailments of cattle by different tribes of Morang.

In this context, the plants with their medicinal values for the domestic cattle used by the tribal people of Morang district were investigated along with the local name, botanical sources, families, plants parts used, method of preparation, method of application, dosage and use of additives.

MATERIALS AND METHODS

Participatory rural appraisal (PRA)

The present research was conducted in seven Village Development Committees (VDCs) of western part of Morang district. The VDCs were Katahari, Baijnathpur, Buddhanagar, Majhare, Takuwa, Rangeli and Aamgachhi. The major groups people in these VDCs were Yadav, Kebat, Rajbanshi, Bata, Muslim, Mushar, Dhanuk, Teli, Gangai, Satar, Nuniya, Jhangar, Tatma, Bramhin and Chhetri.

Participatory rural appraisal (PRA), involving both survey and inventory techniques were employed for the study. The areas were visited regularly from July 2008 to May 2009 to collect in-situ information of plants. The study was conducted with the assistance and cooperation of local healers. A semi-structured questionnaire in local language was used for interviews. Information for particular ailments was cross-checked through various means, including repeated queries. The local healers accompanied during the collection of plants and crude drugs in the field. The collected specimens were dried and subjected to prepare herbarium specimens as well as crude drugs. The samples were identified with the help of available literatures (Trease and Evans 2000, Anonymous 1997, Polinin and Stainton 1984, Shakya 2000) and deposited in Pharmacognosy laboratory of All Nepal Institute of Medical Sciences at Chabahil, Kathamandu. An inventory of the crude drugs, their local names of plants, their parts used, biological source, method of preparation and application against various ailments were prepared.

The validity level (VL), the percentage of informants claiming the use of certain plant for the same purpose, was calculated for the most frequently reported diseases or ailments as:

$$VL(\%) = \frac{Np}{N} x100$$

Where,
Np is the number of informants that claim a use of a plant species to treat a particular disease and N is the total number of informants that use the plants as medicine.

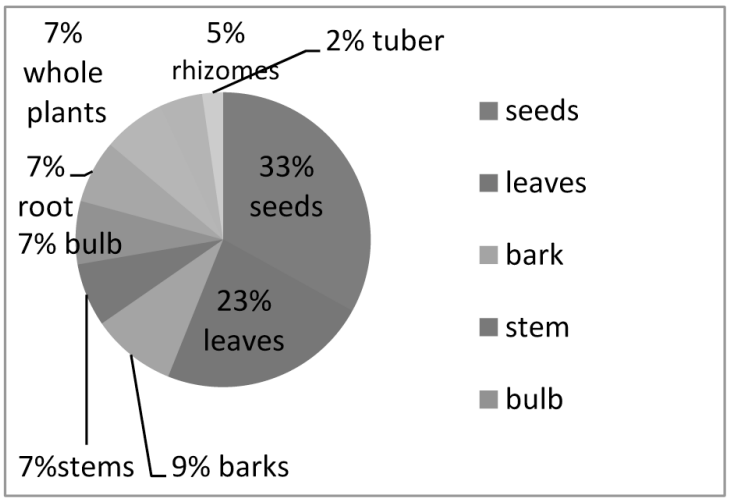
The plants were divided into following three groups according to the validity percentage:

Very high validity (VHV) – with validity score of above 40%
High validity (HV) - with validity score of 20-40%
Low validity (LV) - with validity score with less than 20%

RESULTS AND DISCUSSION

Altogether 37 plant species (both wild and cultivated) belonging to 35 genera and 24 families were found as botanical sources of crude drugs used for curing 21 common ailments of cattle. The common ailments against which the plants used, the name of the plants, plant parts used, method of preparation and method of application are given in Table 1.

The plant parts used were fruits and seeds (33%), followed by leaves (23%), bark (9.3%), stem (6.9%), bulb (6.9%), root (6.9%), whole plants (6.9%), rhizomes (4.65%) and tuber (2.3%) (Figure 1). The most common major diseases included skin disease, diarrhea, fever, blood dysentery, flatulence and chronic cough. The healers diagnose various ailments on the basis of sign and symptoms. Crude drugs used by the traditional healers were fresh or dried, mostly in the form of juice (30%), decoction (18%), roast (18%), and powder (18%) paste (15%), and oil (1.%) (Figure 2). The crude drugs were used as in the available form or mixed with other ingredients. The routes of administration were oral (66%), topical (33%) and nasal (1%) (Figure 3).



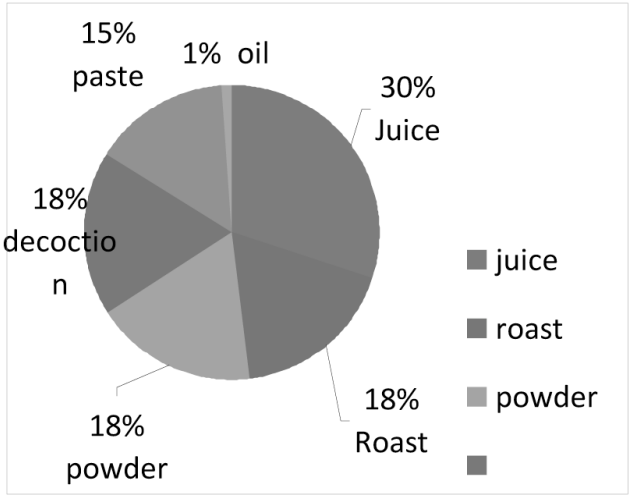


Figure 1. Plants parts used for preparation of remedies. **Figure 2.Various dosage forms.**

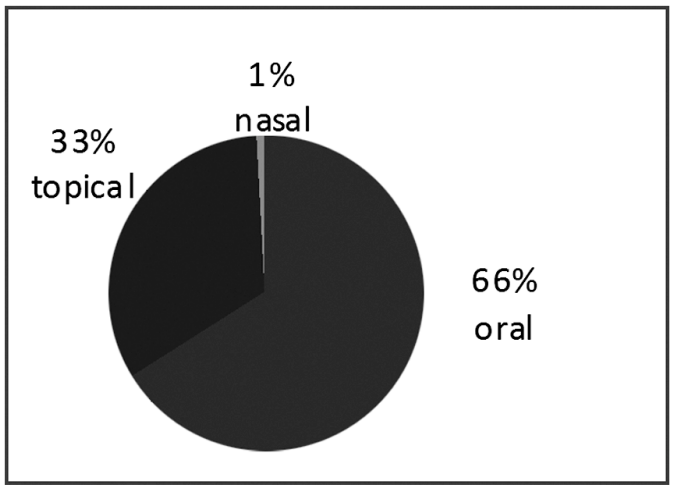


Figure 3. Routes of administration.

The traditional knowledge of the local healers of Morang district has tremendous ethnobotanical importance. They use plants and their parts for the treatment of various ailments of cattle. Generally, the local healers identify various diseases of animals by their behavior, stool, urine, hotness of ear, colour of eyes and unusual sounds produced by them. A number of crude drugs reported to have medicinal value in the present study are also supported by the findings of other researchers in Nepal (Chaudhary 1993, Manandhar 2001) and India (Gaur et al 2010, Reddy et al 2006) and some of the findings have not been reported by others. The use of *Centella asiatica* for diarrhea, *Trachyspermum ammi* and *Leucas aspera* for flatulence, *Semecarpus anacardium* and *Allium sativum* for tail cut, *Solanum tuberosum* for burn, *Melia azadirach* for intestinal worm, *Argemone maxicana* and *Oxalis corniculata* for eye complaint and *Alocasia indica* for aphrodisiac recorded in this study have not been reported by others.

The use of seeds of *Abrus precatorius* for expulsion of placenta in cattle has also practiced by the folk people of Rajasthan (Takhar and Chaudhary 2004). The ethnoveterinary importance of *Achyranthus aspera, Acorus calamus, Alstonia scholaris, Bombax ceiba, Datura metal* and *Zingiber officinalis* recorded in this study have also been reported by others for different therapeutic values (Manandhar 2001). Some plants like *Abelmoschus esculanta, Aesculus indica, Albizia chinensis, Anagalis arvensis, Buplurum candolli, Capsicum frutescen, Cassia tora, Cleome gynandra, Delphinium scabriflorum*, *Euphorbia hirta, Ficus benghalensis, Ficus neriifolia, Jatropha gossypifolia, Lyonia ovlifolia, Sida corpifolia, Lyonia ovlifolia, Sida cordata, Taxus baccata and Xanthium strumarium,* which are used in veterinary medicine (Manandhar 2001) could not be recorded in this study, because most of these plant species were not available in the study area.

Table 1. Crude drugs used by the traditional healers in the treatment of domestic cattle in Morang district

Ailments	Plants	Local names	Parts used	Method of preparation	Method of application
Diarrhea	I. *Datura metal* L. (Solanaceae)	Dhatur	Fruits	A fruit with few seeds are roasted on open fire and cooled	Fed twice a week with grasses or bamboo leaves
	II. *Cannabis sativa* L (Cannabaceae)	Ganja	Flowering tops	3-4 tops are crushed to form paste	Fed once a day for 3-4 days
	III. *Centella asiatica* (L.) Urb (Umbelliferae)	Bhatpureni	Leaves	Leaves are roasted and cooled	Fed twice a day for 3-4 days
Blood Dysentery	I. *Euphorbia royleana* Boiss (Euphorbiaceae)	Pasij	Stem	The stem is roasted and cooled	Fed twice a day with grass or bamboo leaves for 3-4 days
	II. *Dalbergia sissoo* Roxb.ex D.C. (Leguminosae)	Sissau	Leaves	Leaves are soaked in water overnight and squeezed to get juice	2-3 tea glasses juice given twice a day for 5 days
Flatulence	I. *Trachyspermum ammi* (L) Spr. (Umbelliferae)	Jamen	Fruits	About 50g fruits are grounded to fine powder and mixed with salt	Fed twice a day for 2-3days
	II. *Leucas aspera* (Willd) Link. (Labiatae)	Dulphi	Whole Plant	Crushed to get juices and half tea glass juice with one glass water	Fed twice a day for 2-3 days
Fever	I.*Urginea indica* (Roxb) Kunth (Liliaceae)	Banpiyoj	Bulbs	3-4 bulbs are crushed to make paste and mixed with hot water	Fed to the cattle twice a day for 3-4 days
	II. *Alstonia scholaris (L) R. Br.* (Apocynaceae)	Chhatim	Bark	A decoction is made	Given to the cattle at the time of fever
	III. a. *Zingiber officinale* Rosc. (Zingiberaceae)	Aadi	Rhizome	Equal amount of a and b is crushed and mixed with few fruits of c	Fed to cattle twice a day for 3-4 days with warm water
	b. *Acorus calamus* L. (Araceae)	Acheni	Rhizome		
	c. *Piper nigrum* L. (Piperaceae)	Marich	Fruit		
Milk Production	I. *Asparagus racemosus* Willd. (Liliaceae)	Sitawari	Root	About 250g root are decocted in 2lit. water	Fed to cattle twice a day for 15 days
	II. *Amaranthus viridis* L. (Amaranthaceae)	Genhari Sag	Leaves	A decoction is made with a little amount of salt	Fed to cattle twice a day for 15 days
Placental Retention with Quicker Parturition	1.*Bambusa arundinacea* (Ritz).Willd (Graminae)	Bans	Leaves	Fresh leaves are cut into small pieces	Fed to cattle at that time
	II. *Achyranthes aspera* L. (Graminae)	Chirchiri	Root	Root cut into small pieces and tied with a string to form a bead.	Bead tied to the neck at that time
	III. *Abrus precatorius* L. (Leguminosae)	Karjaini	Seeds	Seed are separated from the fruits	Fed to cattle with grass at that time
Shoulder Wound	I. *Solanum melongena* L. (Solanaceae)	Begun	Fruits	Fruits are roasted and made into paste with warm mustard oil	Applied once a day as paste to shoulder wound till cured
	II. *Datura metal* L. (Solanaceae)	Dhatur	Leaves	Leaves squeezed to get juice	Applied locally once a day till cured
Tail Cut	1.a.*Semecarpus anacardium* L. (Anacardiaceae)	Bhela	Fruits	4-5 each(a and b) mixed and warmed in mustard oil	The cut end is dipped in warmed oil and applied till cured
	b. *Allium sativum* L. (Liliaceae)	Lasun	Bulbs		
Burn	I. *Solanum tuberosum* L. (Solanaceae)	Alu	Tuber	Crushed and made into a paste	Applied to burnt wound once a day till cured
	II. *Streblus asper* Lour (Moraceae)	Sahor	Leaves	Crushed and made into a paste	Applied to the burnt wound once a day
Intestinal Worm	I. *Azadirachta indica* A. Juss. (Meliaceae)	Neem	Leaves	The leaves are cut into small pieces	Fed to the cattle with bamboo leaves for 3-4 days
	II. *Melia azadirach* L. (Meliaceae)	Bakena	Leaves	Crushed and made into decoction.	Fed to the cattle with bamboo leaves for 3-4 days
	III. *Clerodendrum viscosum* Vent (Verbenaceae)	Bhait	Leaves	Crushed to obtain juice	Fed one tea glass juice twice a day for two days
Constipation	I. *Allium cepa* L. (Liliaceae)	Piyoj	Bulbs	4-5 bulbs crushed to obtain juice	Fed to cattle once a day for four days
	II.*Trachyspermum ammi* (L).Sprengel (Umbelliferae)	Jamen	Fruits	About 50g fruits grounded to fine powder and mixed with salt	Fed twice a day for 2-3 days

Contd…

Ailments	Plants	Local names	Parts used	Method of preparation	Method of application
Diuretic	I. *Moringa oleifera* Lam. (Moringaceae)	Sohijan	Bark	Crushed and made into decoction	Fed 2-3 tea glass juice thrice a day for 1 day
	II. *Musa paradisiaca* L. (Musaceae)	Kera	Root/Stem	Crushed to obtain juice	Fed 2-3 tea glass juice thrice a day for 1 day
Joint Swelling	I. *Vitex negundo* L. (Verbenaceae)	Sinwair	Leaves	Leaves are plucked and made into decoction	Massage twice a day for 3-4 days to swelling
	II. *Datura metal* L. (Solanaceae)	Dhatur	Leaves	Many leaves tied around a stick, warmed near the open fire, dipped into kerosene oil	Press the stick thrice a day for 3-4 days on swelling
Eye Complaint	I. *Argemone mexicana* L. (Papaveraceae)	Katar	Seeds	Oil is prepared by pressing of seeds	2-4 ml oil put into eyes once a day for 4-5 days
	II.*Oxalis corniculata* (Oxalidaceae)	Amlola	Whole Plant	Crushed to get juice	2-4 ml juice given to eyes once a day for 4-5 days
Aphrodisiac	I. *Alocasia indica* (Roxb). Schott (Araceae)	Maan	Young stem	Stem is roasted and mixed with salt	Fed single stem once a day for three days
Blood in Urine	I. a. *Ficus religiosa* L. (Moraceae)	Pipar	Bark	About 50 g bark grounded and mixed with powder of 10 fruits (b) and sufficient amount of fruits (c)	Fed to the cattle twice a day for 2-3 days
	b. *Elettaria cardamomum* (L) Manton (Zingiberaceae)	Alaichi	Fruits		
	c. *Cucumis sativus* L. (Cucurbitaceae)	Khira	Fruits		
Chronic Cough	I. *Brassica napus* L. (Cruciferae)	Tori	Seeds	Oil produced is warmed	Fed to the cattle and applied to horns and ear
	II. *Piper nigrum* L. (Piperaceae)	Marich	Fruits	Grounded to fine powder and about 3 g mixed with 250 ml mustard oil	Administered through nose twice a day for 4-5 days
Appetite Loss	I. *Tinospora cordifolia* Wild (Menispermaceae)	Gurujlati	Stem	Crushed to obtain juice	Fed 2-3 tea glasses juice once a day for 10-15 days
Food and Mouth	I. *Ficus religiosa* L. (Moraceae)	Pipar	Bark	About 50g bark boiled in water to make its half concentrate	Applied locally to the wound, twice a day till fully cured
Cut	I. *Semecarpus anacardium* L. (Anacardiaceae)	Bhela	Fruits	Some fruits are warmed in mustard oil	Applied locally twice a day till fully cured
Inflammation	I. *Datura metal* L. (Solanaceae)	Dhatur	Fruits	Some fruits are crushed to get juice	Massage twice a day for 3-4 days on the site

CONCLUSION

The use of the medicinal plants in the treatment of human and cattle ailments has been practiced since time immemorial. The medicinal plants are more popular in the rural areas due to the beliefs owing to their effectiveness, easy access, low cost and no or less side effects. The knowledge of traditional healers is very secret, usually kept within themselves and it is often not easy to share with others. Therefore, the knowledge of traditional healers is on the verge of extinction. The plant species reported in this study deserve antimicrobial, phytochemical and pharmacological screening in order to identify natural active compounds for their potential uses. Thus, attempts should continue to document the knowledge and practice of traditional healers and the healers should be duly recognized as the pioneer of ethnomedicine. The traditional medical practices would be an income generating source for the traditional healers if they are supported by scientific training and backup.

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Sustainability of Community-based Seed Production Enterprises in Nepal: Institutional Issues

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ABSTRACT

Sustainability of community-based seed production (CBSP) enterprises is a concern in the recent literature. This paper reviews and analyzes the sustainability issues of these enterprises with reference to Nepal, focusing on institutional aspects. Findings indicate that lack of appropriate mechanisms to access business skills, financial services, quality control, and source seed from service providers, and benefit sharing process among the members/shareholders are the important institutional issues for the sustainability of these enterprises. Amendment of seed policy with the provision of business start-up funds at nominal interest rates, and business plan trainings to CBSP enterprises and private entrepreneurs to set up source seed production centers and seed laboratories would contribute to resolve these issues. Another issue to be considered in the revised seed policy is redefining the concept of District Seed Self Sufficiency Program (DISSPRO) making proper linkage with CBSP enterprises and traders such as agrovets. Similarly, the amendment of cooperative policy with respect of member participation and benefit sharing would also contribute in the sustainability of these enterprises.

Key words: Agriculture, business skills, cereal and legume, food crops

INTRODUCTION

Community-based seed production (CBSP) enterprises are the rural organizations owned and operated by farmers at a local level for the production and marketing of seeds (Witcombe et al 2010, Srinivas et al 2010). The objective of these organizations is to generate profit by producing and marketing quality seeds of different crop varieties as per the farmers' needs (Bishaw and van Gastel 2008, Almekinders and Louwaars 1999). Farmers involved in CBSP enterprises are benefitted in two ways: first, seed production is more remunerative than grain production; and secondly, profit from seed marketing also goes to the seed growers/shareholders. Being operated locally by farmers, these enterprises offer potential to provide varietal choice cheaply due to low overheads and transportation costs. The role of CBSP enterprises has been realized very crucial for the delivery of cereal and legume seeds in marginal areas where private companies have little economic incentive to expand their business (Tripp 2001, David 2004, Joshi 2006). Acknowledging the importance of seed, the Second World Seed Conference held in 2009 in Rome, Italy, concluded with the statement that "Urgent government measures and increased public and private investment in the seed sector are required for the long term if agriculture is to meet the challenge of food security in the context of population growth and climate change" (FAO 2009).

SEED SUPPLY SITUATION IN NEPAL

In case of Nepal more than 93 percent of the total seed requirement is supplied by informal system ie farmer to farmer exchange and remaining (7%) by formal system (Table 1). The formal seed system consists Nepal Agriculture Research Council (NARC) that supplies mainly breeder and foundation seed whereas the major role to supply foundation and other categories of seed (certified and

improved) is of National Seed Company (NSC) – the government-owned seed company of Nepal. In addition to these, non-government organizations and private institutions are also involved in seed production and marketing. These private entities are in the form of groups, cooperatives, companies, agrovets, suppliers and so on; however, the former two are mainly engaged in production.

Table 1. Seed supply and requirement situation of major cereals in Nepal

Crops	Area (ha)	Seed rate (kg/ha)	Total seed requirement (t)	Total seed supplied (t)	SRR (%)
Rice	1549262	50	30985	5017	6.5
Maize	870166	20	438508	1040	5.98
Wheat	706481	120	5887	7007	8.27

Source: SQCC 2008.

There is no documented information available on the total number of CBSP enterprises and their seed production and sales volume in Nepal, though one case has shown that 5 CBSP enterprises in the Chitwan district sold 2622 tons of seeds of 8 crop varieties worth 1.3 million USD in 2010 (Table 2). This figure is bigger than that of the NSC in case of cereals and legumes (DSCC 2009), the food crops of Nepal that contribute over 50 percent to the food production and 74 percent to the calorie consumption in the country (Shrestha and Ednar 2007).

Table 2. Seeds of different crop varieties sold by CBSP enterprises of Chiwan district, Nepal

Crops	2008		2010	
	Volume sold (t)	Value (000 USD)	Volume sold amount (t)	Value (000 USD)
Rice	1242.5	426.0	1450	625.0
Maize	449.0	166.8	520	260.0
Wheat	413.5	159.5	550	314.3
Rapeseed	13.8	11.8	13	16.7
Lentil	23.2	19.9	30	47.1
Phaseolus bean	54.3	42.7	35	50.0
Cowpea	8.3	7.1	20	37.1
Soybean	3.0	2.1	4	2.9
Total	2207.6	835.9	2622	1353.1

Source: *DSCC 2010.*

In spite of the great potential of CBSP enterprises in supplying seeds of improved crop varieties in rural farm communities, in recent literature, sustainability of these enterprises has been a debatable issue. However, very limited information is available how they could be sustainable. This article briefly outlines the evolution of the CBSP enterprises concept, and analyzes the sustainability issues of these enterprises focusing on institutional aspects.

EVOLUTIONARY HISTORY OF CBSP ENTERPRISES

After the Green Revolution of the 1960s, governments and donor agencies recognized the importance of high quality (genetically and physically) seeds and their support went to the establishment of a highly subsidized formal seed sector, often seed parastatals (Cromwell and Wiggins 1993, Almekinders et al 1994, Mywish et al 1999, Lyon and Danquash 1998). These institutions promoted a limited range of crop varieties, generally focusing on large farmers in favorable environments. As a result, most small farmers could not realize the benefits of the green revolution (Bishaw 2004). In Africa during the 1980s, there was a policy shift towards disbanding the parastatals and encouraging private sector development. Being a profit-driven undertaking, the commercial seed companies focused their business on hybrid seeds of maize and vegetables, targeting high potential areas. Therefore, seeds of open-pollinated food crops such as cereal and legumes were rarely supplied by

these companies unless they were purchased in bulk by development and/or relief operations (Almekinders et al 1994).

In search of appropriate delivery mechanisms, from 1990 onwards government and non-government agencies in Asian and African countries promoted various modalities. These modalities include community seed banks and farmer-managed small seed enterprises. However, the latter became more popular in these countries mainly due to its "business component" (David 2004, Witcombe et al 2010, Srinivas et al 2010).

In Nepal, different initiatives to support CBSP started from the 1990s. The National Seed Act and National Seed Policy formed in 1998 and 2000, respectively. However, the latter paved the way to involve private agencies in the seed sub-sector. The District Seed Self Sufficiency Program (DISSPRO) was introduced in 1998 (Poudel et al 2003). This program envisaged creating source seed centers in 15 districts (two in the Terai, the plain area and one in the mid-hill) of each development region. The selected districts were to produce certified first generation (C1) seed from foundation seed (FS) supplied by research stations. Later, the area covered by DISSPRO increased to 63 districts (Chand and Karki 2005).

In addition to the government's led initiatives, several donor-supported projects were also implemented with the objective to help establish the local seed supply system in the country. Some of the projects to enumerate are: Seed Production and Inputs Storage Project (SPISP), Private Producers Sellers Programme (PPSP), Mechi Hill Development Programme, Koshi Hill Seed and Vegetable Development Project, Rural Save Grain Project, Seed Sector Support Project, Hill Seed Programme, Action Aid Rural Development Programme for Seed Production and PAC (Pakhribas Agriculture Center), (Lumle Agriculture Center) supported seed programme and so on. These projects were focused mainly in the hills, and focused mainly on vegetable seed. However, the Special Program in Nepal (SPIN) project, funded by Food and Agriculture Organization (FAO) and implemented from 1995 to 1997 in six terai districts, was focused on cereal seed. Later, the Department for International Development (DFID) funded projects focusing on participatory crop improvement in cereals and legumes were implemented in terai districts from 1997 to 2006. Currently, two projects have been focused on strengthening CBSP enterprises in cereal-based system. In case of maize, Hill Maize Research Project (HMRP) which is funded by SDC (Swiss Development Corporation) and administered by International Center for Maize and Wheat Research (CIMMYT) is implemented in hilly districts. Similarly, two DFID-funded projects entitled "Participatory Crop Improvement in South Asia" led by two National Non-government Organizations (NGOs) of Nepal – the Forum for Rural Welfare and Agricultural Reform for Development (FORWARD Nepal) and the Local Initiative for Biodiversity Research and Development (LIBIRD) have been implemented from 2008 to 2012 emphasizing capacity building of CBSP enterprises (FORWARD 2010).

THE CONCEPT OF SUSTAINABILITY AND INSTITUTIONS

Sustainability is a concept that has arisen from the debate on sustainable development. "Sustainable development is the development which meets the needs of present without compromising the ability of future generation to meet their own needs" (WECD 1987). The role of local enterprises or organizations to achieve the sustainable development goal has been recognized. It means to achieve the sustainability of agriculture system, the enterprises which supply seeds to the farming communities need to be sustainable or they need to be continue their services in the long run (DFID 2000). The most important motivating factor to continue their seed business by farmers is the profitability from the seed business. This profit is largely determined by norms or rules of CBSP enterprises and their service providers. These rules, which are also called institutions, affect the whole process of seed production and marketing. Good governance, which is measured by participation, etc,

is an important issue in CBSP enterprises' sustainability. Similarly, policies of government agencies and private actors to deliver their services in seed enterprises and other related sub-sectors affect the CBSP enterprises' performance (Arthur 1992).

INSTITUTIONAL ISSUES ASSOCIATED WITH CBSP ENTERPRISES

Poor institutional governance

CBSP enterprises organize business in the form of groups or cooperative structures in Nepal, and the latter structure is considered more formal (Witcombe et al 2010). Good governance is one of the success indicators of these enterprises and is measured by democracy, participation and empowerment (Gray and Kraenzle 1998). Policies, norms and organizational structures guide the enterprises to achieve these indicators. No study has been done about the effect of institutional structure on governance and profitability in case of Nepalese CBSP enterprises.

However, an analysis of cooperative policies from 24 developing countries, including Nepal, has identified the problems of benefit sharing and corporate governance (Cook 1995). For example, if the one-member-one vote principle is applied in decision making process, farmers who supply a large volume of produce have no more say than minor suppliers, which results in inadequate investments from members. As recommended by Acharya (2009), other issues to be incorporated in the cooperative policy include: the minimum quorum should not be less than all absolute majority when making decisions and the primary cooperative societies should have members only from a limited geographical area.

Limited business skill

Most of the CBSP enterprises of Nepal are the products of different rural development programs and not all those programs had business development components (Poudel et al 2003, Crissman and Uquillas 1992, Tripp et al 1998). So, many CBSP enterprises without business skills became involved in seed production activity as per the guidance of the project activities. A number of studies have proven the positive role of business skills for the success of seed enterprises, as people having these skills can develop and implement business plan successfully (Bishaw 2004, David 2004, Witcombe et al 2010). This skill is developed through training, exposure and previous business experience. The main reason behind the failure of the SPIN project to set up viable CBSP enterprises in Nepal was lack of enterprise and marketing skills interventions (Chand and Karki 2005).

Poor linkage with agriculture innovation system

Institutional innovation is an important success factor of any enterprise. This innovation is generated through the interaction of CBSP enterprises with other service providers of the agriculture innovation system. These service providers include Nepal Agricultural Research Council (NARC), which provides source seed and associated technologies; extension agencies such as District Agriculture Development Offices (DADOs), seed testing laboratories and NGOs; policy bodies mainly Ministry of Agriculture and Cooperative and National Seed Board; and others like micro finance institutions and traders such as agrovets.

In spite of the great role of institutional innovation, there is no functional mechanism to link the CBSP enterprises with the above-mentioned service providers. As practiced in some African countries (David 2004) and Chitawan district of Nepal (Witcombe et al 2010) formation of District Seed Coordination Committee (DSCC) would solve this problem.

Inefficient seed quality control mechanism

Nepal has already amended seed legislation in line with developed countries, but there are still challenges for its implementation, one being an ineffective seed quality control mechanism. Truthful labeling, a method of seed quality control system in which producers themselves assure their seed

quality, is the most efficient and economical method of seed quality management. This system is recommended for private seed entrepreneurs including CBSP enterprises considering its positive role in business profitability (David 2004, Trip 2001). Though the truthful-labeling system is provisioned in the seed law of Nepal, the formal sector still focuses on traditional certification scheme for CBSP enterprises (Lal et al 2009). Under the traditional certification scheme, government seed inspectors put tag on the basis of 2-3 times field verification and laboratory report though it varies from crop to crop. Looking at the limited capacity of DADOs and seed testing laboratories (five, one in each development region), it is almost impossible for CBSP enterprises to go through this complex certification scheme. Promotion of truthful labeling concept and seed testing laboratories at the private level would minimize the problems of quality control (David 2004).

Multinational companies are marketing hybrid seeds in Nepal through agrovets, though seed law strictly demands that only released/registered varieties be marketed in the country. Poor implementation of seed law and an open border system with India makes it difficult for CBSP enterprises in estimating the effective seed demand, and designing as well as implementing marketing strategies (Chand and Karki 2005).

Lack of nationally agreed protocol on CBSP enterprises strengthening

Both government agencies and NGOs have been strengthening CBSP enterprises in Nepal but there is a lack of nationally agreed protocol how these enterprises should be empowered and institutionalized. Institutionalization of the enterprises is necessary to receive follow-up supports from government agencies. Previous studies have recommended that government agencies provide technical and business skills for a few years even in NGO-facilitated CBSP enterprises (David 2004). In the absence of CBSP enterprises implementation modality accredited by the government, DADOs are compelled to use DISSPRO modality where nothing is mentioned about institutional development and business approach. The solution in this context would be to develop a clear CBSP enterprises implementation modality and to revise the concept of DISSPRO in the form of DSCC.

Limited access to financial services

Access to finance is a key to successful operation of any business and CBSP enterprises are no exception. Since the time for planting and harvesting of crops is seasonal in nature, CBSP enterprises need to collect the seed from growers and store it up to seven months before selling in the market. This requires prompt payment at the time of seed collection, especially to small farmers due to economic reasons. If CBSP enterprises fail to do so, seed might be sold as grains or growers could sell their seed to other traders, and this affects seed transaction volume and profitability. Accessibility of loan to CBSP enterprises depends on availability of micro-finance institutions and policies of these institutions and government (Pradhan 2009, Witcombe et al 2010).

In Nepal, rural finance includes agricultural finance, microfinance, cooperatives and other informal sources such as village merchants, friends and relatives. The service of formal financial institution is concentrated in city areas and these institutions hesitate to lend money to seed enterprises run by farmers. CBSP enterprises have to pay exorbitant interest rates demonstrating collaterals such as land certificates, even if financial institutions agree to provide loans (Pradhan 2009).

The case of Africa has shown that CBSP enterprises need soft loans in minimum interest rates to start their business and to procure necessary equipment (David 2004). There is no government policy to provide above mentioned services to rural institutions including CBSP enterprises in Nepal though few CBSP enterprises received grant from DADOs though in nominal amount (Witcombe et al 2010).

Limited access to source seed

One of the main reasons why farmers buy seeds is to obtain good quality seeds of the existing varieties or new varieties (Almekinders et al 1994). Demand for seed is generally higher once the variety becomes popularized than in the initial stage. It is therefore important for CBSP enterprises to

prepare an appropriate mix of popular and new varieties by analyzing market demands. In Nepal, the amount of source seeds CBSP enterprises need does not only depend on expected demand but largely on the quantity of source seeds of concerned varieties available at NARC's centers (Shrestha and Ednar 2007). Like large private companies, CBSP enterprises cannot invest on developing new varieties. Rather, they should depend on varieties developed from national agriculture research system (Joshi et al 1997, Joshi 2001). In the formal sector, the foundation seed (source seed) production is still limited at the NARC stations and the volume of seed production is very low as compared to requirements (Table 3). Though some private firms already have got license to produce this category of seed, none of them has started supplying foundation seeds of cereals and legumes crops (Khadka et al 2007). Harmonization of seed policy with the provision of crop/enterprise insurance system would motivate private sector to be involved in source seed production enterprises (Witcombe and Virk 1997, Almekinders et al 1994).

Table 3. Foundation seed supply situation of major food crops in Nepal

Crop	Area	Annual	Quantities of seed certified (t)					
	(000 ha)	requirement (t)	2004	2005	2006	2007	2008	2009
Rice	1549	19362	229.1	193.9	232.2	244.5	327.3	253.0
Maize	870	6090	17.7	12.9	17.1	6.7	10.6	124.8
Wheat	706	21180	118.4	70.6	92.7	88.9	180.1	43.6
Lentil	265	1988	0.96	NA	0.2	2.5	1.02	NA

Source: *MoAC 2009.*

Another issue associated with source seed is that the very narrow range of crop varieties developed from public research organizations is not sufficient to meet farmers' diverse demands. However, to address the niche specificity/heterogeneity, CBSP enterprises should offer a range of crop varieties. The solution would be integrating participatory crop improvement approaches, such as client-oriented breeding and participatory variety selection, in national agriculture research and development programs (Witcombe and Virk 1997). These approaches facilitate the incorporation of farmers' criteria in the variety development process, which could lead to the wider adoption of crop varieties. Some rice and legume varieties have been developed and released in Nepal employing above-mentioned approaches in partnership with government, NGOs and international research institution (Khanal et al 2006). This indicates that period for variety development and institutionalization can be reduced substantially using these approaches (Witcombe et al 2010).

CONCLUSION

CBSP enterprises have been promoted in developing countries, including Nepal, to disseminate improved crop varieties. Government and NGOs are promoting these enterprises to achieve the goal of food security, especially in the marginal areas. Poor institutional governance, limited business skills, difficulty in accessing financial services and source seed, lack of common CBSP enterprises strengthening protocol and inefficient seed quality control mechanisms are important institutional issues associated with sustainability of these enterprises. These issues could be addressed by the amendment of seed policy at the national level. The agendas for seed policy amendment are provision of business start-up funds and business plan training both for CBSP enterprises and other private agencies interested in setting up source seed production centers, seed lab, etc. Revising the concept of DISSPRO in the form of DSCC and is another policy recommendation. Similarly, amendment of cooperative policy addressing the issue of participation and benefit sharing would solve the problem of corporate governance. There is limited information about how institutional structures affect the profitability of CBSP enterprises in Nepal, so more understanding is needed in this area. This study analyzes the institutional issues but sustainability of these enterprises is governed not only by institutional factors but also by economic, social and environmental factors. Further study is required in this area, integrating all four components of sustainability.

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Effect of Fodder Trees on Growth and Yield of Maize and Finger Millet Under Agrisilviculture in the Eastern Hills of Nepal

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ABSTRACT

Maize (*Zea mays* L.) and finger millet (*Eleusine coracana* L.) were experimented to examine the suitability and quantify the effect of fodder trees: *Bauhinia purpurea* (Tanki) and *Albizia jullibrissin* (Rato Siris) in the mid hills of eastern Nepal in 1998 and 1999. Matured trees affected the growth and yield of the crops depending upon distance from the tree. There was marked negative effect on most agronomic parameters in zone A (up to 4 m) for maize and millet (up to 3 m). Most growth and yield attributes increased slightly with increased distance in zone B (5-8 m), and tended to decrease slightly in zone C (8-12 m) or closer to the terrace edge. Finger millet was less affected by the trees compared to maize. Similarly, Rato Siris caused less negative effect on growth and yield parameters compared to Tanki. The average yield of maize found low (1693 kg/ha) in zone A, whereas the yield increased by 1.4 times (2397 kg/ha) in zones B and C. Millet yield was the lowest (1484 kg/ha) in zone C and found the highest in zone B (2039 kg/ha). In general, trees caused severe negative effect up to 4 m. The middle part of the terrace (zone B) found more suitable for these crops.

Key words: Agroforestry, *Albizia jullibrissin*, *Bauhinia purpurea,* effect, finger millet, maize

INTRODUCTION

Fodder trees form an integral part of the hill agriculture system under traditional agroforestry practices in Nepal. The trees provide fodder and bedding for animals, wood for cooking, heating, and for other household purposes to meet the daily need of the rural communities. The traditional farming system, agroforestry, fulfills the growing demand of fodder, fuel-wood and farm yard manure and ultimately contributes to the welfare of people. It helps sustain the hill farming system, prevent land degradation, improve environment and reduce women's drudgery. However, over exploitation of forests has led to farmers becoming increasingly dependent on trees from private land. Carter and Gilmour (1989) reported that farmers responded to the declining forest situation by growing more trees on farmland, however, adverse effect of trees on crops is a constraint (Joshi and Thapa 1993). Extensive use of tree fodder is a common practice and there is high scope of agroforestry for the hill farming communities (Amatya 1999, Karki 1992, Thapa 1987).

Literatures suggest that effect of trees on crop growth and yield varies with tree species, tree size, distance from tree and crop species. Shading, water dripping, root disturbance, competition for nutrient and moisture are the negative impact of tree-crop interface, which have been experienced by the local people (Carter 1991, Thapa 1994, Joshi 1997). It is believed that leguminous trees such as *Leucaena* spp., *Albizia* spp., *Acacia* spp. and *Bauhinia* spp. have a positive influence on adjacent crop. Farmers in the eastern hills classify trees grown in cropping land into 'Rukho' (unfertile) for negatively affecting species and 'Malilo' (fertile) for positively affecting species on the succeeding crop. They also categorize nutritious fodder as 'Posilo'.

In Dhankuta, farmers were interested to plant fodder trees as in other districts. Fodder producing, nitrogen fixing, and soil conserving species are given priority. Both Tanki and Siris are used for fodder, however, the former is more common. Barakoti et al (1999) found positive effect on wheat

and negative effect on maize in alley cropping of mixed tree species (*Artocarpus lakoocha* (Badahar), *Bauhinia purpurea* (Tanki), *Eucalyptus camaldulensis* (Masala), *Leucaena leucocephala* (Ipil-ipil) and *Madhuca latifolia* (Mahuwa) in the terai conditions where intercropping was encouraging in the on-farm conditions (Barakoti 1990). Puri and Bangarwa (1992) reported that in Haryana, India trees limited wheat yield up to a distance of 3 m from the tree, while beyond 7 m there was no impact. *Acacia nilotica* affected wheat yield and prolonged maturity, while *Dalbergia sissoo* (Sisau) had less effect. In Pakistan, *Albizia procera* (Seto Siris), *Eucalyptus camaldulensis*, *Leucaena leucocephala, Morus alba* (Kimbu) had no effect on wheat yield beyond 2 m (Akbar et al 1990).

Most researches on tree-crop interface are concentrated on flat land, while little information is available for the hills. Neupane (2004) concluded that farmers in the hills normally do not consider environmental benefits, such as soil conservation, landslide prevention, fertility improvement, nutrient recycling and pumping nutrients from deeper soil layer, they look more for tangible benefits. However, they include numbers of multipurpose tree species in their farmland. The research was aimed to quantify the effect of selected fodder tree species on growth and yield traits of the main food crops (maize and finger millet) of the hills at different distances from the tree.

MATERIALS AND METHODS

On-farm researches were conducted on two fodder tree species: Tanki (*Bauhinia purpurea*) and Rato Siris (*Albizia jullibrissin*) and two cereal crops: maize (*Zea mays* L.) and finger millet (*Eleusine coracana* L.) in 1998 and 1999 in Dhankuta (1200 masl) and Terhathum (1400 masl) districts of Nepal. The experiments were designed according to Akbar et al (1990) and Puri and Bangarwa (1992). Modification made by Joshi and Devkota (1996) was also incorporated. Experiments were conducted under eight fully matured selected trees (15-18 years old) of Tanki in Syaule village (Dhankuta) and Rato Siris in Fakchamara (Terhathum). Measurements of the trees (height, diameter) and terraces (width, riser height) were taken.

Trial plots for observation of crops were selected and laid-out marking transects towards four directions (aspects) of each tree (Figure 1). For maize sampling, three zones were marked: the area directly under the tree crown (up to 4 m), as zone 'A', the area from 4 to 8 m distance as zone 'B' and the area from 8 to 12 m as zone 'C'. A quadrate of 1.5 m x 1.5 m (sample area of 2.25 m²) was marked in each zone and transect. Thus, there were 12 sample plots around each tree for maize assessment. For millet sampling, 2 plots of 1 m² in each zone were marked and mean data were presented.

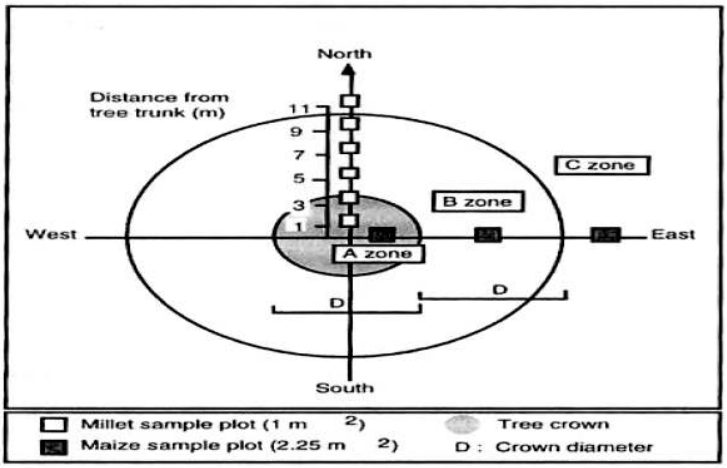

Figure 1: Trial layout and sampling design.

The crop variety Manakamana 1 of maize and Okahle 1 of finger millet were grown using farmers' local practice. Data on various parameters such as plant population, plant height, yields and others were monitored mainly at harvesting time. Crop parameters under each tree species were recorded, and statistical analysis was performed employing standard method ANOVA in MSTAT.

Soil samples were collected from all three zones (A, B, C) around each tree before trial planting. Composite samples from 4 aspects in each zone were collected and mixed. NPK, organic matter, pH, texture were analyzed at the soil laboratory of Agricultural Research Station, Pakhribas.

RESULTS AND DISCUSSION

Tree and terrace measurements

Characteristics of the experimental fodder trees and terraces are presented in Table 1a (Tanki) and Table 1b (Rato Siris). The measurement of trees showed that average trunk diameter at breast height (DBH) of Tanki was 31 cm with a crown radius of 2.6 m. The DBH of Rato Siris trees was slightly higher (38 cm) with varied height. The terrace riser was higher (2.4 m) in Fakchamara than in Syaule (1.6 m), and the terraces were also wider (7-8 m) than in Syaule (by 5 m). Fakchamara locates at a higher elevation than Syaule by 300 m.

Table 1a. Characteristics of Tanki (*Bauhinia purpurea*) tree in Syaule, Dhankuta

Tree No	Tree height, m	DBH, cm	Crown diameter, m	Terrace height, m	Terrace width, m		Altitude, m
					Upper	Lower	
1	7.5	30	6.0	1.8	4.7	8.0	1360
2	11.5	33	5.2	1.4	6.0	3.0	1360
3	7.5	32	5.6	1.1	6.4	6.7	1360
4	8.5	32	5.6	1.4	6.1	6.8	1360
5	6.5	28	4.0	2.0	5.5	4.5	1200
6	10.5	37	5.0	1.6	3.5	5.5	1200
7	6.5	26	4.3	1.6	3.5	4.5	1200
8	9.5	30	6.0	2.0	4.5	3.5	1200
Mean	8.5	31.0	5.2	1.6	5.0	5.3	1280

Table 1b. Characteristics of Rato Siris (*Albizia julibrissin*) in Fakchamara, Terhathum

Tree No	Tree height, m	DBH, cm	Crown diameter, m	Terrace height, m	Terrace width, m		Altitude, m
					Upper	Lower	
1	10.5	35	6.0	2.0	11.5	9.8	1540
2	6.2	26	5.0	2.3	4.5	5.1	1550
3	8.5	33	5.0	2.5	10.2	4.5	1550
4	7.5	42	6.0	2.1	5.3	4.3	1600
5	6.5	37	5.0	3.4	7.9	14.4	1600
6	12.0	43	6.5	3.5	7.8	8.1	1580
7	10.5	44	5.5	2.5	8.4	13.5	1600
8	10.0	43	5.0	1.0	3.4	7.9	1630
Mean	9.0	37.8	5.5	2.4	7.4	8.4	1580

Soil characteristics

The mean results of soil samples of the research sites are presented in Table 2. The soils were normally sandy loam in Syaule and sandy clay loam in Fakchamara. The soil was acidic in reaction, pH varied from 4.6 to 5.7 and found higher in 1998 than in 1999. P^H did not vary based on zones or distances from the tree. Organic matter content of Fakchamara soil was higher than Syaule soil. The grand mean showed that it was higher (2.52%) in zone A nearer to the tree as compared to zone C (2.35%). No definite trend in the content of NPK was observed, however, phosphorus found higher in zone B both at Syaule (19.2 ppm) and Fakchamara (12.9 ppm). Syaule soil contained higher amount

of nitrogen (0.44-0.47%) and Fakchamara soil contained higher concentration of potassium (244-251 ppm) but had low phosphorus content (10.6-12.9 ppm). The general status of the soil of both sites is presented in Figure 2.

Table 2. Soil characteristics at different zones of experimental sites

Zone	N	P	K	OM	pH	Soil type
Soil test result of Syaule, Dhankuta, mean of 2 years						
A	0.450	16.84	170	2.17	5.09	
B	0.437	19.18	167	2.01	5.17	Sandy loam
C	0.474	17.13	162	1.99	5.16	
Soil test result of Fakchamara, Terhathum, mean of 2 years						
A	0.122	10.56	252	2.86	5.16	
B	0.121	12.88	244	2.71	5.23	Sandy clay loam
C	0.116	16.19	251	270	5.20	

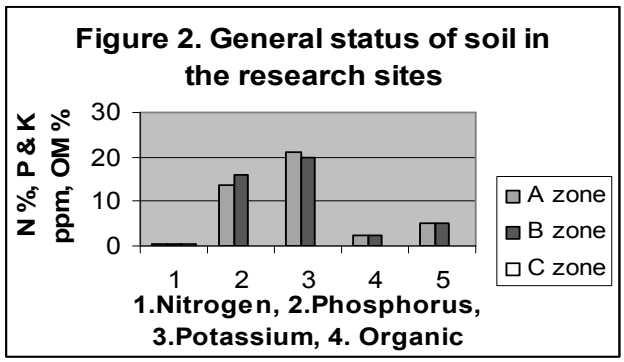

Figure 2. Soil parameters of the research sites (mean of 2 years).

Performance of maize under fodder trees

The traits of maize recorded in the experimental plots are presented in Table 3 and the results of ANOVA in Table 3a.

Table 3. Growth and yield components of maize under fodder trees (mean of two years)

Zone	Plant ht, cm	Ear ht, cm	Maturity %	Plant stand/ ha	Cob wt, g	1000 grain wt., g	Gr. yield kg/ha	Stover yield, t/ha
Maize parameters under Tanki tree								
A	167	72	96	34565	129	343	1693	7.69
B	176	78	99	39176	159	376	2398	8.84
C	175	80	98	39704	164	362	2396	9.57
Maize parameters under Rato Siris tree								
A	178	82	97	44090	147	361	2514	8.29
B	183	81	99	44107	157	369	2518	8.64
C	184	82	99	44424	155	357	2524	8.52

Table 3a. Analysis of variance (ANOVA) results

Indicator	Factor	Plant ht	Ear ht	Maturity	Pl stand	Cob wt	Seed wt	Grn. yld	Stv.yld
	Mean	177.0	79.2	98.0	41160.9	151.8	361.2	2342.3	8.59
F-test	A	**	**	ns	**	ns	ns	**	ns
	B	**	ns	**	ns	**	*	**	**
Interaction	A × B	ns	ns	ns	ns	**	ns	**	**
LSD	A	na	na	-	na	-	-	na	-
	B	5.346	-	1.32	-	8.33	13.52	215.8	0.54
Interaction	A × B	-	-	-	-	11.7	-	305.2	0.76
CV, %		2.83	4.98	1.27	6.2	5.09	3.51	8.65	5.86

Plant population: Overall plant population or stand of maize under Tanki tree was the lowest (34565) in zone A compared to zones B and C (over 39,000), outside the tree canopy. The data showed highly significant difference between the fodder trees. The means within zones and interaction were not significant. The year-wise stands ranged 31333-45333/ha, which is the average of farmers' practice but is lower than recommended one (53333/ha). The stands were less than grand mean (41161) under Tanki by 2-7 thousand and were higher under Rato Siris trees by 3 thousand. It revealed the severe effect of Tanki on germination and survival of maize. The stands varied based on year; it was higher in 1999 than in 1998, particularly in zones B and C. The population under Rato Siris trees was higher than Tanki and ranged from 34921 to 50158/ha based on year. No definite trend was followed under Siris trees (around 44,000nd). The coefficient of variation (CV) was 6.2 percent for the stand.

Plant and ear height: Both the plant and ear height of maize was highly significant ($P < 0.01$) but interaction between trees and zones was not significant (ANOVA table). Average plant height of maize under Tanki was the shortest in zone A (167 cm) and increased in zones B and C (176-184 cm). More stunted plants were formed in zone A under Tanki than Rato Siris trees. The means showed less height in 1999 than in 1998 by 10 to 53 cm, taller height was mainly due to higher precipitation in 1998. Maize plants under Rato Siris were taller (178-184 cm) than Tanki (167-176 cm) that indicated more favourable conditions under Rato Siris. It might be as reported by Thapa (1994) that water drip falling down from small compound leaved trees such as Siris is smaller in size than that falling from broad leaved species. Ear height found followed same trend as plant height under Tanki but Rato Siris tree affected differently without depending upon zones. The average ear height was more than two times (65-83 cm under Tanki and 71-93 cm under Rato Siris) less than plant height.

Thousand grain weight: The thousand grain weight was also influenced by the trees and zones. The data gave significant ($P < 0.05$) results among the distances from the trees. The grain weight showed a trend for the three zones of which middle part of the terrace found more suitable to form heavier grain (336-384 g in general and 343-376 g as mean) under both tree species.

Cob weight: Cob weight of maize found highly significant among zones and under zone and fodder species interaction following similar trend as grain weight but there was less difference between the zones B and C. Heavier cobs were weighed in zones B and C (362-376 g).

Maturity: The fodder trees slightly affected maturation of maize crop. Slightly earlier maturity was in zones B and C than zone A under both tree species. There was highly significant effect of zones (LSD = 1.32). Fodder trees and their interactions gave no significant results.

Grain yield: The maize grain yield was highly significant ($P < 0.01$). It was lowest in zone A and increased in zone B by 354 kg/ha. Then the quantity either slightly increased or decreased based on zone and aspect/direction. Hence, the yield sharply varied (1292-3228 kg/ha in the plots), from the grand mean (2342 kg/ha). The least significant differences for zones was 216 and for interaction was 305 (ANOVA table).

Stover yield: The stover yield varied following similar trend as grain yield. The data revealed that stover yields were higher in zone B and C than in zone A ranging from 7.69 to 9.57 t/ha (Table 3). The data varied based on years.

Performance of finger millet under fodder trees

The traits of finger millet recorded in the experimental plots are presented in Table 4 and the results of ANOVA in Table 4a.

Table 4. Growth and yield components of finger millet under fodder trees (mean of two years)

Zone	Plant ht, cm	Plant stand/ ha	Maturity, %	Head no	Head wt, g	1000 grain wt, g	Grain yield kg/ha	Straw yield, t/ha
Finger millet parameters under Tanki tree								
A	78.8	999.3	79.9	858.3	46.5	2.93	1761	14.05
B	77.7	1035.3	87.6	931.0	47.5	2.89	2038	15.33
C	79.5	1045.3	88.3	917.0	46.0	2.83	2017	15.45
Finger millet parameters under Rato Siris tree								
A	72.2	1222.0	85.3	1053.8	27.9	2.92	1730	12.50
B	70.4	1267.3	92.6	1138.3	27.1	2.82	1810	11.88
C	69.6	1250.8	92.7	1139.3	28.1	2.92	1878	12.00

Table 4a. Analysis of variance (ANOVA) results

Indicator	Factor	Plant ht	Plant stand	Maturity	Head No	Head wt	1000 Seed wt	Grain yield	Straw yield
	Mean	74.7	1136.7	87.7	1006.3	37.2	2.9	1873	13.53
F Test	A	**	**	**	**	**	ns	*	**
	B	ns	*	**	**	ns	ns	*	ns
Interaction	A × B	ns	ns	ns	ns	ns	ns	ns	ns
LSD	A	na	na	na	na	na	-	na	na
	B	-	33.96	2.606	46.78	-	-	170.1	-
Interaction	A × B	-	-	-	-	-	-	-	-
CV, %		3.92	2.8	2.79	4.36	6.64	4.13	8.53	7.33

Plant population: Finger millet plant population increased gradually with an increase in distance from tree. The plant stand ranged 0.914-1.171 million/ha under Tanki and 1.137-1.390 million/ha under Rato Siris trees that were highly significant ($P < 0.01$) between fodder trees and significant ($P < 0.05$) between the zones. There was increasing trend of plant stand with distance from tree, from zone A to zone B and C under both Tanki and Rato Siris. Slight difference between zone B and C might be due to similar conditions of soil, nutrient and moisture. Most plants were thin under zone A.

Plant height: The height of millet plants varied from 70-79 cm (Table 4). The overall means of zones indicated no definite trend of plant height as affected by fodder trees. The data revealed more positive effect of Tanki than Rato Siris on the finger millet growth and gave highly significant difference between them. The height among zones and interaction was not significant.

Maturity: Millet crop matured late in zone A than zones B and C by 7 days. The means gave highly significant differences between fodder species and zones from the trees. Zones B and C equally favoured to harvest the crop earlier under both Tanki and Rato Siris trees. LSD was 2.6 days.

Head number: The number of heads/ha was highly significant ($P < 0.01$) for both fodder species and zones from the trees. The millet heads were least in zone A (0.86-1.05 million/ha) compared to zones B and C (0.92-1.14 million/ha) under both Tanki and Rato Siris trees. The average head number was nearly 0.1-0.2 million/ha less than plant stands. The head number being higher under Rato Siris than Tanki might be due to better microclimate.

Head weight: There was significant ($P < 0.05$) difference between fodder species only. The head weight under Rato Siris was lower than Tanki, however, there was no definite trend as head number. Heavier heads were formed in the Tanki block by more than 1.5 times.

1000 seed grain weight: The seed weight of millet found not much varied between the treatments (2.82-2.93). The means showed insignificant result.

Straw yield: The total biomass including the head varied highly significantly based on fodder species, where it was low (11.6-15.8 t/ha) in zone A and high (12.8-18.0 t/ha) in zone C based on years, the grand mean was 13.53 t/ha. The trend was not definite under Rato Siris. Straw yield produced 4-5 t/ha more in 1998 compared to 1999 due to more rainfall in 1998. The plants were thin in zone A compared to zones B and C.

Grain yield: The grain yield of finger millet varied significantly ($P<0.05$) based on fodders and zones or distances from the trees. Lower yield (around 17 hundred kg) in zone A and higher and equal yields (18 to 20 hundred kgs) in zones B and C were the main characteristic. Thus, zones B and C favored to produce the highest grain yields. There was narrow variation among zones in 1999 (1855-1929 kg/ha). This phenomenon was not followed under Rato Siris. The highest grain yield was obtained in zone C in 1998 and in zone A in 1999. However, the grand mean (1873 kg) showed increasing trend of grain yield from zone A to zone B and C.

Lodging: The result is not presented but there was some lodging of maize and millet under both Rato Siris and Tanki in zone A.

CONCLUSION

Matured Tanki (*Bauhinia purpurea*) and Rato Siris (*Albizia jullibrissin*) affect maize and millet crops grown around the trees in the hill terraces. However, the effect on different parameters is different depending on the distance from the tree. The overall crop data, particularly of maize, appear to increase up to zone B (5-8 m) and they tend to decrease beyond that, normally in all aspects. The data suggest that the effect of zones or distances from the trees involving tree canopy, shade, rain water drip, aspect/direction are detrimental for crop data variation, effect on growth and yield parameters fluctuation. It is concluded that closer the crops grown to the trees, severe the effect on the growth and yield traits of the crops. South and east aspects are relatively favorable to maize, and north and west aspects to finger millet.

RECOMMENDATIONS

Based on the two years' results the following recommendations and suggestions could be drawn:

- Both maize and finger millet could be grown under 15-20 years old bauhinia (Tanki) and *Albizia jullibrissin* (Rato Siris) trees.
- The existing tree-crop farming practice adopted by the hills farmers could be replicated under similar hill conditions of other regions in Nepal, India, and Bhutan etc.
- The highly affected part, zone A, by the fodder trees should be avoided to grow: maize up to 3 m and millet up to 2 m from Tanki tree as far as possible. The distance of Rato Siris could be reduced to 1 m for millet and 2 m for maize crop.
- In future more number of multipurpose fodder trees should be included in such study to give choice to the farmers.
- It is suggested to quantify the effect of different aged trees having narrow and wide crowns as well as leaves.

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Evaluation of Different Genotypes of Gladiolus for Corm and Cormel Production

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ABSTRACT

Twenty-one genotypes were evaluated under field conditions for parameters of corm and cormel production at Indian Institute of Horticultural Research, Bangalore during August 2006 - June 2008. All parameters such as number of corms per bed, number of corms per corm, weight of corm (g), corm diameter (cm), number of cormels per bed, number of cormels per corm, weight of cormel (g) and cormel diameter (cm) were highly significant. Genotype 'Hybrid selection 84-4-9' produced the highest number of corms per corm (3.16) and cormels per corm (134.25). Genotype 'Hybrid selection 87-1-1' recorded the maximum corm weight (124.50 g) and corm diameter (8.00 cm). Genotype '*Psittacinus* hybrid' produced the maximum weight of cormel (3.41 g) and cormel diameter (1.92 cm). Based on the results genotypes: '*Psittacinus* hybrid', 'Hybrid selection 84-4-9' and '*Gladiolus callianthus'* can be utilized in varietal improvement program for corm production while genotypes: 'Hybrid selection 84-4-9', 'Shobha', and 'Sapna' can be utilized in varietal improvement program for cormel production.

Key words: Corm, cormel, gladiolus, varietal improvement

INTRODUCTION

Gladiolus is one of the most important commercial cut flowers in the world. It belongs to family Iridaceae and native to South Africa.. It is very rich in its varietal wealth and every year there is an addition of two hundred new varieties (Desh Raj and Misra 1998). Recently, gladiolus has occupied prime position in the floriculture industry. Corms and cormels as the common propagule of gladiolus have high commercial value. Yield of corm and cormel is affected depending upon genotype and agro-climate (Sharma and Sharga 1996). At present, large numbers of exotic as well as Indian cultivars are under cultivation, and there is limited information regarding their performance of producing corms and cormels. Particularly the parameters such as weight of mother corm, weight of daughter corm, number of cormels per corm and dormancy period of corm have high heritability and genetic advance. Thus, genotypes potential for higher yield of corms and cormels need to be identified for further crop improvement (Patil et al 2004).

MATERIALS AND METHODS

The experiment was conducted under field conditions having red loam soil in block VII of Indian Institute of Horticultural Research, Hessaraghatta, Bangalore during August 2006 - June 2008. A total of 21 gladiolus genotypes, ie 10 cultivars, 9 hybrid selections (HS) and 2 species, were evaluated for corm and cormel production. Recommended amount of farm yard manure and NPK was applied.

Uniform sprouted corms (about 5 cm diameter) were treated with 0.2 percent aqueous suspension of Bavistin (carbendazim) for 20 min prior to planting. The corms were planted on ridge beds sized 1.6- × 1.5-m, in 5 cm depth in inter-row and intra-row spacing of 30 cm and 20 cm, respectively. The experiment was laid out in randomized complete block design with three replications. The cultivation practices such as inter-culture, irrigation and plant protection were followed as per recommended. Corms and cormels were harvested at 45 days after flowering, when leaves turned yellowing and 25 percent cormels turned brown. The corms and cormels were kept in plastic tray, and dried in airy room for five days. Observations on number of corms per bed, number of corms per corm, corm weight (g), corm diameter (cm), number of cormels per bed, number of cormels per corm, cormel weight (g) and cormel diameter (cm) were made.

RESULTS

The gladiolus genotypes significantly differed for total number of corms produced per bed, number of corms produced per corm, weight of corm (g), corm diameter (cm), number of cormels produced per bed, number of cormels produced per corm, weight of cormel (g) and cormel diameter (cm) among 21 different genotypes evaluated (Table 1).

Table 1. Performance of different genotypes of gladiolus for corm and cormel production

SN	Genotypes	Total number of corms per bed (2.4 m^2)	Number of corms per corm	Corm weight (g)	Corm diameter (cm)	Total number of cormels per bed (2.4 m^2)	Number of cormels per corm	Cormel weight (g)	Cormel diameter (cm)
1	Aarti	54.17	1.95	58.87	6.04	620.00	22.14	1.69	1.59
2	Arka Kesar	21.33	0.99	66.72	6.97	733.00	23.93	0.34	1.18
3	Darshan	52.67	2.29	53.21	6.11	624.67	23.87	1.48	1.45
4	Dhiraj	49.83	1.79	77.86	7.03	476.50	17.07	1.45	1.73
5	Kum Kum	58.67	2.43	47.89	5.63	504.67	18.45	0.87	1.33
6	Pink Friendship	22.33	1.04	63.12	6.55	1263.67	44.84	0.30	1.05
7	Poonam	35.33	1.32	78.99	6.91	729.50	26.05	0.45	1.20
8	Sapna	33.00	1.27	84.42	7.68	2026.33	72.37	0.23	0.92
9	Shobha	51.83	1.85	95.41	7.59	2107.67	75.27	0.21	1.09
10	Tilak	45.83	1.93	75.04	6.67	713.00	26.33	1.41	1.61
11	H.S. 82-11-27	67.33	2.41	74.06	6.48	787.67	29.29	0.90	1.35
12	H.S. 84-4-9	86.83	3.16	46.19	5.89	3737.17	134.25	0.59	1.06
13	H.S. 84-6-13	21.33	0.99	63.42	6.16	239.33	8.55	0.15	1.10
14	H.S. 84-7-11	53.33	1.94	87.14	7.09	560.83	20.03	0.49	1.41
15	H.S. 86-32-11	40.83	1.48	103.20	7.66	391.50	13.98	0.37	1.07
16	H.S. 87-1-1	45.83	1.64	124.50	8.00	610.83	21.82	0.71	1.55
17	H.S. 87-22-1	64.67	2.35	97.44	7.82	1013.00	36.18	0.49	1.28
18	H.S. 88-4-8	50.17	1.80	66.59	6.87	557.83	19.92	1.23	1.45
19	H.S. 88-10-22	54.00	1.93	73.76	6.40	1206.67	43.10	0.71	1.41
20	*Gladiolus callianthus*	73.50	3.00	23.44	4.90	1112.17	39.72	0.23	0.98
21	*Psittacinus* hybrid	95.17	3.09	61.26	5.67	389.83	13.92	3.41	1.92
	Mean	51.33	1.94	72.50	6.67	974.09	34.81	0.84	1.32
	F-test	**	**	**	**	**	**	**	**
	C.D. @ 5%	12.852	0.560	18.862	0.622	453.117	16.185	0.324	0.220

***, Highly significant. H.S., Hybrid selection.*

Total number of corms per bed (2.4 m^2)

Total number of corms per bed in different genotypes varied from 21.33 (8.9 per m^2) to 95.17 (39.7 per m^2) with a mean value of 51.33 corms per bed (21.4 per m^2). The genotype '*Psittacinus* hybrid' produced the highest number of corms (95.17) per bed (39.7 per m^2) followed by 'Hybrid selection 84-4-9' with 86.83 (36.2 per m^2) and '*Gladiolus callianthus'* with 73.50 (30.6 per m^2). However, genotypes viz., '*Psittacinus* hybrid' and 'Hybrid selection 84-4-9' were statistically at par. Whereas, genotype viz. 'Arka Kesar' and 'Hybrid selection 84-6-13' produced the lowest number of corms (21.33) per bed (8.9 per m^2) followed by 'Pink Friendship' with 22.33 (9.3 per m^2) and 'Sapna' with

33 (13.7 per m^2). But four genotypes viz., 'Arka Kesar', 'Hybrid selection 84-6-13', 'Pink Friendship' and 'Sapna' were statistically at par.

Number of corms per corm

Number of corms per corm varied from 0.99 to 3.16 with a mean value of 1.94. Genotype 'Hybrid selection 84-4-9' produced the maximum corms (3.16 per corm) followed by '*Psittacinus* hybrid*'* (3.09 per corm) and '*Gladiolus callianthus'* (3.00 per corm); however, genotypes viz., 'Hybrid selection 84-4-9', '*Psittacinus* hybrid*'* and '*Gladiolus callianthus'* were found statistically inconsequential. On the contrary, 'Arka Kesar' and 'Hybrid selection 84-6-13' produced the minimum number of corms (0.99 per corm) followed by 'Pink Friendship' (1.04 per corm) and 'Sapna' (1.27 per corm). The variations for this character in genotypes viz., 'Arka Kesar', 'Hybrid selection 84-6-13', 'Pink Friendship', 'Poonam', and 'Hybrid selection 86-32-11' were statistically inconsequential.

Weight of corm

Weight of corm varied from 23.44 g to 124.50 g with a mean value of 72.50 g. Genotype 'Hybrid selection 87-1-1' recorded the maximum corm weight (124.50 g) followed by 'Hybrid selection 86-32-11' (103.20 g) and 'Shobha' (95.41 g). '*Gladiolus callianthus'* recorded significantly the lowest corm weight (23.44 g) followed by 'Hybrid selection 84-4-9' (46.19 g) and 'Kum Kum' (47.89 g), while 'Hybrid selection 84-4-9' (46.19 g) and 'Kum Kum' (47.89 g) were statistically at par.

Corm diameter

Corm diameter ranged from 4.90 cm to 8.00 cm with a mean value of 6.67 cm. Genotype 'Hybrid selection 87-1-1' had the maximum corm diameter (8.00 cm) followed by 'Hybrid selection 87-22-1' (7.82 cm) and 'Sapna' (7.68 cm). 'Hybrid selection 87-1-1', 'Hybrid selection 87-22-1', 'Sapna', 'Hybrid selection 86-32-11' and 'Shobha' were statistically at par. Genotype *'Gladiolus callianthus'* had the minimum corm diameter (4.90 cm) followed by 'Kum Kum' (5.63 cm) and '*Psittacinus* hybrid*'* (5.67 cm). The genotype *'Gladiolus callianthus'* differed significantly from those of 'Kum Kum' and '*Psittacinus* hybrid'.

Total number of cormels per bed (2.4 m^2)

Number of cormels varied from 239.33 to 3737.17 with a mean value of 974.09 cormels per bed. Genotype 'Hybrid selection 84-4-9' produced the highest number of cormels (3737.17 per bed) followed by 'Shobha' (2107.67 per bed) and 'Sapna' 2026.33 per bed). In contrast, 'Hybrid selection 84-6-13' produced the fewest number of cormels (239.33 per bed) followed by 'Hybrid selection 86-32-11' (391.50 per bed) and 'Dhiraj' (476.50 per bed). Cormels produced per bed among the genotypes, viz. 'Hybrid selection 84-6-13', 'Hybrid selection 86-32-11', 'Dhiraj', 'Kum Kum', 'Hybrid selection 88-4-8', 'Hybrid selection 84-7-11', 'Hybrid selection 87-1-1', 'Aarti' and 'Darshan' did not differ statistically.

Number of cormels per corm

Number of cormels varied from 8.55 to 134.25 with a mean value of 34.81 cormels per corm. Genotype 'Hybrid selection 84-4-9' recorded remarkably the highest number of cormels (134.25per corm) followed by 'Shobha' (75.27 per corm) and 'Sapna' (72.37 per corm), while 'Shobha' and 'Sapna' were statistically inconsequential. Although, genotype 'Hybrid selection 84-6-13' recorded the lowest number of cormels (8.55 per corm), the variations in two genotypes viz., *'Psittacinus* hybrid' (13.92) and 'Hybrid selection 86-32-11' (13.98) were at par.

Weight of cormel

Weight of cormel varied from 0.15 g to 3.41 g with a mean value of 0.84 g. Genotype '*Psittacinus* hybrid' produced the maximum weight of cormel (3.41 g) followed significantly by 'Aarti' (1.69 g)

and 'Darshan' (1.48 g). While genotypes viz., 'Hybrid selection 84-6-13' produced the minimum cormel weight (0.15 g) followed by 'Shobha' (0.21 g) and 'Sapna' as well as *Gladiolus callianthus'* (0.23 g). The cormel weight of 'Hybrid selection 84-6-13', 'Shobha', 'Sapna', *'Gladiolus callianthus'*, 'Pink Friendship', 'Arka Kesar', 'Hybrid selection 86-32-11' and 'Poonam' were not significant.

Cormel diameter

Cormel diameter varied from 0.92 cm to 1.92 cm with a mean value of 1.32 cm. Genotype *'Psittacinus* hybrid' recorded the maximum cormel diameter (1.92 cm) followed by 'Dhiraj' (1.73 cm) and 'Tilak' (1.61 cm). In the genotypes viz. *'Psittacinus* hybrid' and 'Dhiraj' cormel diameter was statistically at par whereas the minimum cormel diameter (0.92 cm) was recorded in 'Sapna' followed by *'Gladiolus callianthus'* (0.98 cm) and 'Pink Friendship' (1.05 cm). The variations in cormel diameter among the genotypes viz. 'Sapna', *'Gladiolus callianthus',* 'Pink Friendship', 'Hybrid selection 84-4-9', 'Hybrid selection 86-32-11' and 'Shobha' were not significant.

DISCUSSION

Regarding corm and cormel production, genotype '*Psittacinus* hybrid' performed better for number of corms per bed, corms per corm, weight of cormel and cormel diameter. In contrast, 'Arka Kesar' and 'Hybrid selection 84-6-13' performed poor for number of corms per bed and corms per corm. Furthermore, 'Hybrid selection 84-6-13' gave the fewest number of cormels per bed, cormels per corm and cormel weight. 'Hybrid selection 87-1-1' was superior over other genotypes for corm weight and the corm diameter. Moreover, 'Hybrid selection 87-1-1' possessed higher weight of corm and diameter of corm in comparison to those of outstanding exotic genotypes viz., 'American Beauty' and 'Summer Pearl' under transitional tract of Karnataka (Pasanavar 1994, Hedge 1994). Similarly, Kishan et al (2005) recorded the maximum weight of corm in 'Gold Dust' (124.66 g) and 'Dhanvantari' (120.00 g) under Delhi conditions. The aforementioned genotypes were relatively superior ones. In the present study, genotype 'Hybrid selection 84-4-9' possessed the highest number of cormels, which was significantly different from 'Shobha' and 'Sapna'. Pandey et al (2006) noted high number of cormels per corm in genotypes viz., 'Plumtart' and 'White Prosperity'. On the other hand, Dwivedi and Singh (2000) found the maximum number of cormels per corm in 'White prosperity', 'Eurovision' as well as in 'Novelty'. The finding of the present study suggested that 'Hybrid selection 84-4-9' is almost similar to 'Plumtart' but better than 'White Prosperity', 'Eurovision' and 'Novelty' with respect to number of cormels per corm. 'Hybrid selection 84-4-9' is contemplated as the best one to produce the largest number of cormels per corm as this genotype could have an inherent trait for producing higher number of cormels. In respect of corm production, the present study showed that *'Psittacinus* hybrid', 'Hybrid selection 84-4-9' and '*Gladiolus callianthus'* were promising. In terms of cormel production, 'Hybrid selection 84-4-9', 'Shobha', and 'Sapna' were promising genotypes. Also, the aforementioned genotypes were noticed superior genotypes to 'Meera', 'Nazarana' and 'Poonam' even though these three genotypes were recorded as superior ones in respect of corm and cormel production in earlier study (Negi et al 1982).

CONCLUSION

Evaluation of different genotypes of gladiolus for corm and cormel production is indispensable to select desirable parents to utilize for hybridization programme. Genotypes, which possess desirable characters viz. more corms per com and cormels per corm can be selected for developing new cultivars. On the basis of desirable characters recorded in the present study, the promising genotypes viz. 'Shobha', 'Hybrid Selection 87-1-1', 'Hybrid Selection 86-32-11', 'Hybrid Selection 84-4-9, and Sapna' can be utilized to develop new hybrids through intervarietal and interspecific hybridization.

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Economics of Dairy Farming : A Case Study of Phulbari Village in Chitwan District of Nepal

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ABSTRACT

The present case study on economics of dairy farming in Phulbari village of Chitwan district in 2005 showed that the average daily milk production of buffalo and cow was highest among large farm size category followed by small and medium ones. The highest average daily milk yield in large category was due to large number of improved breed and milch cows. Lower milk price was found in large category due to its low fat and SNF content in comparison to other categories. Thus, the cost of milk production was negatively related with farm size. The cost of milk production of small farm size category was 25 percent higher than large farm size category. The sum of the two elasticity coefficients of labor and capital was found 1.483 suggesting that perhaps the milk production in different farm categories was characterized by increasing returns to scale. Benefit-cost ratio of large category was highest (1.42) followed by medium (1.33) and small (1.23) farm size categories. The significant difference in gross margins among the farm categories notwithstanding the dairy business has been a profitable and contributed significantly in the household economy.

Key words: Commercialization, cost, farm category, milk, profit, returns to scale

INTRODUCTION

Agriculture contributes 33 percent to the gross domestic product (GDP) and supports 65.7 percent of the population (MoAC 2010). The livestock sector contributes about one third to agricultural GDP and 4 percent to national exports. The dairy sector contributes about two third in livestock sub-sector. The growth of national milk production over the past decade was about 2.6 percent per annum (TLDP 2002).

The Dairy Development Corporation (DDC) is basically concerned with marketing aspect. The actual volume of milk production and its supply depends upon the production capability of the farmers. In the past, the cost of milk production per litre was found to be higher and uneconomical in terms of the milk prices and production level (Pokhrel 1991). The milk producers have been getting NRs 13 per litre of milk from rural area of Hetauda. So it is argued that the dairy farmers are not getting reasonable price relative to the cost of production (Anonymous 2004). Cost of production of milk in Nepal is generally 10 to 20 percent higher as compared to India (Shakya and Shrestha 2004).

The DFAMS (1990) observed that the percent of livestock contribution in terms of milk, manure, calf and drought power to the household economy was 36 percent in Dhading and 14 percent in Chitwan district. It also contributed in channeling a large amount of urban money to the rural areas for improving the living standard of the rural poor (NDDB/DSP 2001). With an establishment of dairy processing plant in Chitwan, the dairy business has been declared as commercial farming in the district. A total of one lakh and 50 thousand litres of milk is being produced daily. Among them, 40 thousand litres of milk is collected by the DDC and other private dairy (Ghimire 2004). The Phulbari VDC covers 1,388 hectares of land including 679 households comprising 3,018 populations (DADO

2004/2005). It is identified as the pocket area for milk production and it has one milk chilling vat and two collection centers for milk (DLSO 2004). However, it is not known accurately how much cost is incurred by farmers to produce the milk and whether or not price being paid by the buyers are reasonable to farmers. Therefore, it is necessary to find out the actual cost of milk production.

In this context, this study was designed to assess the economics of milk production and its contribution to household economy as a broad objective. The specific objectives were to: assess the benefit and cost of dairy farming business in Phulbari VDC of Chitwan; assess the inputs and output relationship in milk production; and assess the contribution of milk production in household economy. Moreover, the null hypothesis that labor and capital together do not have any impact on milk production was designed during this study.

METHODOLOGY

Study area, population and sampling design

The Phulbari VDC in Chitwan district was selected purposely due to the potentiality of milk production, accessibility of researcher, and budget and time constraints. Total population of the study area was taken as study population whereas the milk producers of selected VDC were regarded as the targeted sampling population. A list of milk producers, number of milch animals and land size were prepared using the reconnaissance survey, group discussion and key informant survey techniques. The milk producers were grouped into three strata according to the number of milch animals and land size. Altogether 80 sample households comprised of 26, 38 and 16 from the small, medium and large category respectively, were taken by using stratified proportionate random sampling technique. The details regarding the farm size categorization is presented in Table 1.

Table 1. Determination of sample size by farm categories

SN	Number of milch animals	Land holding sizes, Bigha	Farm size category	Household, number	Sample size, number
1	1	Up to 0.5	Small	109 (32.83)	26 (24.00)
2	Up to 2	> 0.5 to 1.5	Medium	160 (48.19)	38 (24.00)
3	2 or more	> 1.5	Large	63 (18.97)	16 (25.00)
4	Total			332 (100)	80 (24.09)

Figures in parentheses indicate the percentage.

Sources and techniques of data collection

Both the primary and secondary data was collected and analyzed. Milk producers were the major sources of primary data. Besides the information obtained through observation and group discussion, the study used key informant surveys. The secondary data were collected through related publications on milk production from different organizations such as Marketing Development Directorate, Ministry of Agriculture and Cooperatives, Central Bureau of Statistics, Agro Enterprise Center, District Livestock Service Office, Nepal Dairy Development Board, National Dairy Cooperatives etc. Techniques such as interview, group discussion, informal interaction were also used to collect and verify the data.

Approaches to estimate different costs and revenues

The use of particular method of valuation depends upon the purpose of valuation and nature of assets (Johl and Kapur 2000). Prasad (1992) calculated the depreciation of animal by subtracting the estimated value after productive life from the purchase cost of animal divided by number of year of productive life. Depreciation of shed and equipment was calculated by subtracting the junk value from purchase price of assets divided by expected life of assets. Different methods used in the estimation of the cost and revenue items were discussed below.

Depreciation of animal, shed and equipment value: Depreciation of animal was calculated by subtracting the auctioned value from purchase value divided by the number of economic lactation. Whereas the depreciation of shed and equipment were calculated by subtracting the salvage value from construction and purchase prices of shed and equipment, respectively, divided by the expected life of shed and equipment as reported by farmers.
Cost of maintenance and interest on capital: Cost of maintenance and interest on capital was calculated based on reported price and prevailing interest rate of Agricultural Development Bank.

Valuation of purchasable inputs: Purchased inputs like feed, rice straw, medicine, salt, firewood, rope, electricity etc. were valued at the reported prices.

Valuation of family labor and green grass: The hours of involvement was asked for the determination of number of hours involved in milk production activities. The labor has been valued at the prevailing market wages whereas the cost of green grass was valued based on willingness to pay (WTP) technique. WTP is defined as the maximum amount of money that may be contributed by an individual to equalize a utility change. This technique is based on the principle that the maximum amount of money an individual is willing to pay for a commodity is an indicator of the value to him/her of that commodity (Naing 2003).

Valuation of calf and manure: Calf and manure value were determined based on the reported prices.

Tools and techniques of data analysis
The primary and secondary information collected from the field survey and other methods was coded, tabulated and analyzed by using Statistical Package of Social Science (SPSS) and Micro-Soft Excel.

Gross margin analysis
The accounting identities used to measure the gross margin, net profits, benefit-cost analysis are as follows.

Gross margin = Gross return – Total variable cost

Where,
Gross return = Sum of gross return from milk, manure and calf
Total variable cost = Sum of cost of all variable items

The net profit: The net profit is the difference between total revenue and the total cost incurred. Mathematically, it can be presented as:

$$\prod = TR - TC$$
$$\prod = TR - (TFC + TVC)$$
$$\prod = \sum P_y \times Y - \sum P_{xi} \times X_i - K$$

Where,
$\prod$ = Net profit, TR = Total revenue, TC= Total cost, TFC = Total fixed cost, TVC = Total variable cost, Y = Quantity of output, X_i = Quantity of i^{th} input, P_y = Price of output, P_{xi} = Price of i^{th} input, K = Fixed factors.

Benefit-Cost analysis: The benefit-cost analysis was carried out by using following formula:

B/C ratio = Gross return/Total cost

Empirical model

The empirical model used in this study was the Cobb-Douglas production function. This model was selected because among the production function, the power function is a new linear production function which is also known as Cobb-Douglas production function after the name of the persons who first applied it in empirical works (Debertin 1986, Sankhayan 1988). This function has been widely used in agricultural studies because of its simplicity. Furthermore, this function allows constant, increasing or decreasing returns to scale, or not all the three and even any two at the same time. Returns to scale in Cobb-Douglas function is determined by the sum of the power coefficients ie.

$b_1 + b_2 + ... + b_n = 1$

If only two inputs are used then;

If $b_1 + b_2 = 1$, we have constant return to scale

If $b_1 + b_2 < 1$, we have decreasing return to scale

If $b_1 + b_2 > 1$, we have increasing return to scale

The model specified was:

$$Y = AX_1^{b1} X_2^{b2} \mu$$

Where,

Y = Production of Milk (Litre/lactation), A = Intercept, X_1 = Labor inputs (person days/lactation), X_2 = Capital inputs (NRs/lactation), b_1 to b_2 = Elasticity coefficients, μ = Error term. When Cobb-Douglas production function was transferred into log-linear form, it was expressed as:

$$\ln Y = \ln A + b_1 \ln X_1 + b_2 \ln X_2 + \mu$$

The values of the input coefficient imply their contribution to the production of milk or the coefficients are the level of determination to milk production.

Analysis of contribution of milk to household economy

The household income is the sum of different sources of income such as the farm income (income from crops), off-farm income (income from services, remittance, business, pension, daily wages etc) and income from dairy farming (income from milk, manure and calf).

RESULTS AND DISCUSSION

Population distribution

The household family members were categorized into four age groups namely less than 5 years, 5-14 years, 15-59 years and more than 59 years. Economically active population was considered 15-59 years of age. In totality, about 67 percent of total population was recorded as economically active populations and this percentage was the highest (70.29%) in medium category followed by large (67.82%) and small (59.84%) categories. Male constituted 51.22 percent of total population and 48.78 percent were female. Proportion of male was found to be higher in small and medium categories, whereas female in large category. Average family size of the respondent was 5.61, which is more or less similar to the national average of 5.45 (CBS 2004). The detail of characteristics of sample households in terms of age, gender and family size are presented in Table 2.

Educational attainment

The proportion of secondary level of education was found the highest in both small and medium categories and of intermediate level was found the highest in large farm category (Table 3). This might be due to more awareness about education and more household income in large category as compared to other categories of households.

Table 2. Characteristics of sampled household by farm categories

Characteristics	Farm categories			Total
	Small	Medium	Large	
< 5 years age	4 (3.04)	9 (4.45)	6 (5.21)	19 (4.23)
5 - 14 years age	33 (25)	33 (16.34)	16 (13.92)	82 (18.26)
15 - 59 years age	79 (59.84)	142 (70.29)	78 (67.82)	299 (66.60)
> 59 years age	16 (12.12)	18 (8.92)	15 (13.05)	49 (10.91)
Male	74 (56.06)	103 (50.99)	53 (46.08)	230 (51.22)
Female	58 (43.94)	99 (49.01)	62 (53.92)	219 (48.78)
Family size	5.03	5.31	7.18	5.61
Total	132 (100)	202 (100)	115 (100)	449 (100)

Figures in parentheses indicate percentage.

Table 3. Educational status of the sampled household by farm categories

Education	Farm categories			Total
	Small	Medium	Large	
Illiterate	11 (8.73)	18 (9.27)	14 (12.85)	63 (10.02)
Literate	27 (21.43)	27 (13.93)	15 (13.76)	69 (16.09)
Primary	29 (23.02)	29 (14.95)	17 (15.60)	75 (17.48)
Secondary	41 (32.53)	67 (34.54)	14 (12.84)	122 (28.44)
Intermediate	13 (10.32)	33 (17.01)	29 (26.61)	75 (17.48)
Bachelor and above	5 (3.97)	20 (10.30)	20 (18.34)	45 (10.49)
Total	126 (100)	194 (100)	109 (100)	429 (100)

Figures in parentheses indicate percentage.

Breeds by farm categories

The average number of local buffaloes was the highest in small category followed by large and medium category. Improved breed of cattle and buffaloes increased as farm size category increased. Large category farmers can investment more capital on purchasing improved breeds than other categories . The details about breeds by farm size category is presented in Table 4.

Table 4. Breeds by farm categories

Farm categories	Buffalo				Cattle			
	Local		Improved		Local		Improved	
	Number	Mean	Number	Mean	Number	Mean	Number	Mean
Small	40	1.53	20	0.76	14	0.53	6	0.24
Medium	37	0.97	41	1.07	30	0.78	40	1.06
Large	19	1.18	42	2.62	14	0.88	80	5
Total	96	1.20	103	1.28	58	0.73	126	1.57

Milk yield and lactation period

The daily milk production of buffalo and cattle was the highest in large category followed by small and medium farm category. The lactation period of buffalo and cattle was the highest in medium categories. In total, the lactation period of buffalo and cattle was 8.86 and 9.37 months, respectively (Table 5). A large number of improved breed and lower lactation period could be the reason for higher milk yield in large categories (Table 4 and 5).

Price distribution of milk by farm categories

The overall average milk price was NRs 16.80 per litre in the village but the price distribution was not uniform among the farm categories. Milk price increased with decrease in farm categories (Table 6). The lower milk price in large category might be due to the fact that the milk produced from improved cow breeds contains low fat and SNF as compared to buffaloes.

Table 5. Daily milk yield and lactation period of animals by farm categories

Farm category	Milk yield, litre/day		Lactation period, months	
	Cow	Buffalo	Cow	Buffalo
Small	7.35	4.09	9	8.65
Medium	7.29	3.97	9.73	9.14
Large	10.43	4.92	9.16	8.55
Average	7.93	4.19	9.37	8.86

Table 6. Price distribution of milk by farm categories

Farm categories	Milk prices, NRs*/litre
Small	17.35
Medium	17.24
Large	15.73
Average	16.80

**, Buying rate of 1 US $ = 72.03 NRs (Nepalese Rupees) as of the fiscal year 2005/06.*

Milk production and its cost

The average cost of milk per litre was found to be the highest in small category followed by medium and large categories. The average cost of milk production without deducting the value of calf and manure was NRs 14.36 per litre and if deduct the value of calf and manure, the cost of milk was NRs 11.94 per litre. The cost of milk production by small category was around 25 percent higher than large category farmers (Table 7). But still it is lower than the milk price received by the farmers. The average cost of milk is estimated little bit higher than cost calculated by NDDB/DSP in 2001. It might be due to the lower milk yield of animals per day, inflation in various inputs, including some extra variables like green grass, fuel cost etc.

Table 7. Production and cost of milk by farm categories

Farm categories	Total milk yield, litre			Average milk production cost, NRs/litre	
		C*, NRs.	C**, NRs.	C*	C**
Small	1522.92	24872.52	20680.43	16.33	13.57
Medium	2356.21	35495.15	28861.20	15.06	12.24
Large	5630.30	72113.50	57520.23	12.80	10.21
Total	2740.20	39366.46	32744.32	14.36	11.94

C, Cost without deducting the value of calf and manure. C**, Cost with deducting the value of calf and manure. Buying rate of 1 US $ = 72.03 NRs (Nepalese Rupees) as of the fiscal year 2005/06.*

Determination of inputs and output relationship

The Cobb-Douglas Production Function was used to determine the inputs and output relationship in the study. The results indicated that the elasticities of coefficient 0.67 measures the elasticity of output with respect to the labor input. Specifically, this number states that, holding the capital input constant, if the labor input increase by 1 percent, on the average the output goes up by about 0.67 percent. Similarly, holding the labor input constant, if the capital input increase by 1 percent, on the average output goes up by about 0.80 percent. If we add the elasticity coefficient, we obtain an economically important parameter, called the returns to scale parameter, which gives the response of output to a proportional change in inputs. If the sum of the two elasticity coefficients is 1, we have constant returns to scale; if it is greater than 1, we have increasing returns to scale; if it is less than 1, we have decreasing returns to scale (Gujrati 1999). From this study, the sum of two elasticity coefficients was found 1.483, suggesting that perhaps the milk production in different farm categories was characterized by increasing returns to scale. Returning to the estimated coefficients, we saw that both labor and capital were individually statistically significant although the impact of capital seems to be more important than that of labor.

The estimated F-value is so highly significant (because the p-value is almost zero) that we can strongly reject the null hypothesis that the labor and capital together do not have any impact on output. The R^2 value of 0.75 means that about 75 percent of the variation in the (log) of output is explained by the (logs) of labor and capital. The details are presented in Table 8.

Table 8. Inputs and output relationship in milk production

Variables	Elasticity coefficients	Standard error	P-value
Constant	1.48	0.243	0.172
Labor including family labor, person days	0.676**	0.139	0.000
Capital, NRs	0.807**	0.75	0.000
F-ratio	128.5**		0.000
Multiple R = 0.807, R^2 = 0.752 and Adjusted R^2 = 0.747			

***, Significant at 1 percent level of significance.*

Benefit-cost analysis of milk production

The net profit from milk increases with the increase in farm categories. The average net profit per milch animal was NRs 8,031.75 in one lactation period. The benefit-cost ratio of large category was the highest (1.42) followed by medium (1.33) and small (1.23) category. The overall benefit-cost ratio was 1.33 (Table 9). This indicates the good profitability from the dairy enterprises of all farm categories.

Table 9. Benefit-cost analysis of milk production by farm categories (per milch animal)

Farm categories	Total, NRs		Net profit, NRs	B/C Ratio
	Revenue	Cost		
Small	30767.04	24872.52	5894.52	1.23
Medium	32752.15	24479.41	8272.74	1.33
Large	34896.20	24528.40	10367.80	1.42
Average	31784.13	23752.38	8031.75	1.33

Buying rate of 1 US$= 72.03 NRs (Nepalese Rupees) as of the fiscal year 2005/06.

Gross margin analysis

The gross margin from milk production is presented in Table 10. The average gross margin was NRs 12,964.64 per milch animal. The highest gross margin (NRs 15,811.52) per milch animal was recorded in large category followed by medium (NRs 12,863.66) and small (NRs 9,987.40) category.

Table 10. Gross margin of milk production by farm categories

Farm categories	Total, NRs./milch animal		Gross margin, NRs./milch animal
	Revenue	Variable cost	
Small	30,767.04	20,779.64	9,987.40
Medium	32,752.15	19,888.49	12,863.66
Large	34,896.20	19,084.68	15,811.52
Average	31,784.13	18,819.49	12,964.64

Significant at 5 percent level of significance, F-ratio = 6.062, P-value = 0.005. Buying rate of 1 US $ = 72.03 NRs (Nepalese Rupees) as of the fiscal year 2005/06.*

The one-way ANOVA test was used to compare gross margin among the farm categories. The output showed that there was significant difference in gross margin among the farm categories.

Contribution of different income sources to household economy

In summary, it has been found that the contribution of milk is more than that of farm-income in the total income, but the combined contribution of both the milk and other farm income has been barely one-half of the off-farm income even among the "farm households in the rural area" of the Phulbari VDC in Chitwan district. This might be due to the fact that more income was provided by remittance, civil services, and business activities in the off-farm income. The details are presented in Figure 1.

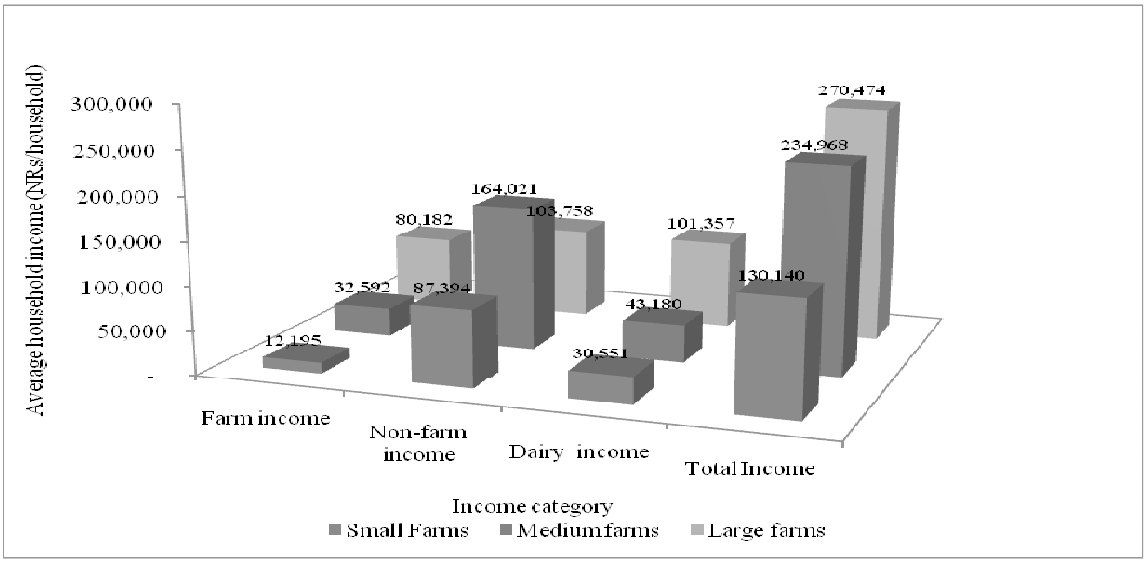

Figure 1. Details of contribution of different income sources to household income.

SUMMARY AND CONCLUSION

- The dairy business is one of the potential agri-businesses in Chitwan district. With the establishment of dairy processing plant, the dairy business has been declared as commercial farming in the district. Consequently, the trend of total milk production in the district is increasing.
- The average milk production of buffalo and cow per day was the highest in the large category followed by small and medium categories. The higher average daily milk yield in large category was due to the greater number of improved breed and milch cows.
- The milk price in large category farms is lower due to low fat and SNF contents as compared to other farm size categories.
- The production of milk has increased with increment in the farm size categories. On the other hand, the cost of milk production by small category was 25 percent higher than large category.
- The unit cost of milk production was little bit higher than the cost calculated by NDDB/DSP in 2001. This could be due to lower milk yield of animals per day, inflation in various inputs, and inclusion of extra variables such as green grass, fuel cost etc.
- The sum of two elasticity coefficients of labor and capital was found 1.483, suggesting that perhaps the milk production in different farm categories was characterized by increasing returns to scale. Returning to the estimated coefficients, we saw that both labor and capital were individually statistically significant although the impact of capital seems to be more important than that of labor.
- Overall, the net profit per milch animal was NRs 8,031.75 in one lactation period. The benefit-cost ratio of large category was the highest (1.42) followed by medium (1.33) and small (1.23) categories. This indicated that the dairy enterprise is in good conditions.
- The gross margin from milk production varied among the farm size categories. The highest gross margin (NRs 15,811.52) per milch animal was recorded in large category followed by medium (NRs 12863.66) and small (NRs 9987.40) categories. There was significant difference in gross margin among the farm categories.

- The above findings indicated that, dairy can be one of the major components for addressing the poverty alleviation in the country because the entreprise of milk production provides the direct cash income to the farmers. In this regard, the development angencies need to motivate the farmers for the commercialization of dairy farming with suitable production and marketing adjustments.

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Evaluating the Effect of Lime Application on Soil pH, Wheat Productivity and Profitability in Chitwan Valley, Nepal

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ABSTRACT

Data from one crop growing season were used to determine the effect of lime application on a strongly acid soil and to analyze changes in soil pH and subsequent effects on wheat yield and profitability in pot and field trials. Eighteen treatment combinations with six lime rates (0, 1.5, 3.0, 4.5, 6.0 and 7.5 Mg ha^{-1}) as the sub-plot factor and three application time (30, 20 and 10 days before planting) as the main-plot factor were imposed on a split plot design. Results showed that lime application increased soil pH significantly ($P < 0.05$). Although the highest grain yield (4.47 Mg ha^{-1}) was recorded for 4.5 Mg ha^{-1} of lime application corresponding to 20 percent yield increase relative to no liming in the field trial, the lowest lime rate (1.5 Mg ha^{-1}) resulted to the highest net return. Liming was very effective in reducing crop lodging (12.4% for 7.5 Mg ha^{-1} of liming against 48.7% for the control) and increased lodging was negatively correlated with wheat yield ($r = 0.72$, $P < 0.01$). It is concluded that potentials exist to increase profit from relatively lower rates of liming that are within the reach of resource poor small farmers in this area.

Keywords: Crop lodging, economics of liming, Nepal, soil acidity, wheat yield

INTRODUCTION

After decades of continuous corn and mustard mono-cropping, soil pH in Chitwan valley of Nepal declined to levels limiting profitable crop production. A survey by Fujimoto (1998) indicated that 60 percent cropland in Nepal needs soil amendment because soil is acidic, organic matter (OM) and nitrogen (N) contents are low in most areas. Wheat (*Triticum aestivum* L.), one of the three major crops in Nepal, occupies 22 percent of total cultivated farm land and it contributes approximately 16 percent to total cereal production in the country (Joshi et al 1994). Most lands grown for wheat in Nepal have soil pH below the optimum (5.5 to 6.5). Mahler and McDole (1987) evaluated wheat grain yield response to pH in artificially acidified soil in northern Idaho, USA. They determined that pH levels below 5.19 to 5.37 restricted the grain yield. Westerman (1987) found similar conclusions from study conducted in Oklahoma, USA. Both used agricultural limestone to treat acid soils. Although average productivity of wheat in Nepal has steadily increased from 1.4 to 2.0 Mg ha^{-1} over the last decade (NARC 2001), it is still far below the average productivity compared with those in neighboring countries in South Asia. Hence, with proper liming, there exists tremendous potential to increase wheat yield in Nepal.

Previous studies encouraged farmers to apply liming materials to soil in order to improve crop production (Porter and Cox 1994, Sharma and Gupta 1994a, Adhikari 1995, Whalen et al 2000, Selvi et al 2005). However, their reports missed the key points which the growers deem prioritize when a

liming technology is introduced into the farming system. The greater cause of concern in this study was, therefore, the concept of multiple benefits, wheat growers in this region might reap out of a judicious liming program. In subsistence farming system such as this, besides wheat grain, wheat-straw has many utilities in making a mat, thatched roof, mulching soils in kitchen garden, seedbeds and so on. But crop damage due to heavy rain and gusty wind during wheat season are common. Therefore, in addition to grain yields, crop resistance to lodging and economic returns from liming practices are equally important measures of probability of acceptance of liming technology in this region. Therefore, adoption of such bulky amendment must be justified economically. However, a plenty of lime is available in today's market at a much lower price relative to the prices of chemical fertilizers implying that even the poor and small farmers have an easy access to lime for land application.

Research shows that the effectiveness of lime on soil and crop may vary with the soil (mainly pH, texture and OM), crop variety, management practices, weather conditions, time of lime application and the properties lime itself (type, rate, quality and grade) (McLay and Porter 1994, Whalen et al 2000, Tripathi 2001, Kaitibie et al 2002). Heavy application of liming may also be detrimental to nutrient availability. It may, for instances, induce deficiencies of iron, manganese, copper and zinc; reduce the availability of phosphate which in turn may restrict the uptake of boron. However, the danger of over-liming is not very common on fine-textured soils with high buffering capacities, but it can occur easily on coarse-textured soils that are low in OM (Brady and Weil 2008). Although higher levels of liming are theoretically objectionable in coarse-textured soils for the reasons mentioned above, relatively few field-scale research studies have been conducted on such soils.

The objectives of this study were to evaluate the effects of rate and time of liming on (i) changes in soil pH including Ca, available P and CEC (ii) wheat productivity and tendency to lodging, and (iii) economic returns from liming coarse-textured soil of Chitwan valley in Nepal.

MATERIALS AND METHODS

Experimental site and soil characteristics

Field experiment

The experiment was conducted on farmer's field in the suburb of Bharatpur municipality in Chitwan district in the southern central inner Tarai region of Nepal. Located at 27° 31" N and 84° 25" E, the study area has a mean elevation of 256 m above sea level and is characterized by hot and humid climate (Almance Characterization Tool Nepal 1999).

Until 2000, maize and mustard were the predominant crops grown in annual rotation for many years and spring was fallowed on this field (Table 1). A few years before the experiment, new crops such as sesame, buckwheat and wheat partially replaced previous long-term maize and mustard mono-cropping system. However, maize and mustard were still grown intermittently. It is expected that these cropping systems returned at least a fair amount of plant nutrients to the soil because much of the biomass produced was left in the soil after crop harvest.

Table 1. Previous annual cropping systems in the experimental site, Prembasti, Chitwan

Cropping years	Rainy season	Winter season	Spring season
1999/2000	Maize	Mustard	Fallow
2000/2001	Sesame	Buckwheat	Fallow
2001/2002	Sesame	Wheat	Fallow
2002/2003	Maize	Experiment season	

After analysis of surface to 15 cm depth soil samples before planting, the results showed that soil was sandy loam (670, 160 and 170 g kg^{-1} of sand, silt and clay fraction, respectively), relatively dense (bulk density 1.46 Mg m^{-3}) and strongly acidic (pH 4.6, 1:1 soil water ratio). According to Soil Testing and Service Section (2002), soil was medium level in OM content (37 g kg^{-1}), total N (1.2 g kg^{-1}) and available K_2O (65 mg kg^{-1}) and high in available P_20_5 (78 mg kg^{-1}). Cation exchange capacity (CEC) of soil was 20 $cmol_c$ kg^{-1}.

Weather data collected from Rampur Meteorological Station, nine kilometers away from the experimental site, showed that growing season rainfall had unusual pattern in the study year (Table 2). While the first-half part of the growing season was a little dry, later-half part received high rainfall compared with previous 12 years' monthly average which affected the frequency and amounts of irrigation application to this test crop.

Table 2. Twelve years monthly normal, average and deviation from normal weather to the actual weather for growing season, October 2002 to March 2003 in the study area

Month	Maximum T °C			Minimum T °C			Rainfall (mm)			RH (%)		
	N[1]	A[2]	D[3]	N[1]	A[2]	D[3]	N[1]	A[2]	D[3]	N[1]	A[2]	D[3]
Oct	31.1	32.5	0.38	20.6	21.7	1.14	118	5.80	-112	85.5	85.8	0.3
Nov	28.9	29.6	0.70	16.6	15.9	-0.77	3.17	44.6	41.4	92.7	75.1	-17.6
Dec	25.1	24.7	-0.35	9.52	11.5	1.96	6.26	6.1	-0.2	96.6	97.1	0.52
Jan	22.5	20.2	-2.28	8.53	8.90	0.37	10.5	47.4	36.9	97.9	97.0	-0.96
Feb	25.8	24.9	-0.92	9.68	11.3	1.63	14.8	83.9	69.1	92.1	98.4	6.28
Mar	31.4	29.7	-1.63	13.8	16.9	3.18	21.9	67.2	45.3	73.3	85.0	11.7

T °C, Temperature in degree Celsius. [1]Normal (12 years average). [2]Actual during the cropping year.
[3]Deviation from normal.
***Source:** Meteorological Station at National Maize Research Program, Rampur, Chitwan, 2003.*

Experimental design

Measured gross experimental field area (533 m^2) was disk harrowed on 19 October 2002. Treatments included six rates of applying agricultural lime ($CaCO_3$) (0, 1.5, 3.0, 4.5, 6.0 and 7.5 Mg ha^{-1}) as sub-plot factor applied at three intervals of time as main-plot factor (30, 20 and 10 days) before planting of wheat. All the treatments were three replicate. Eighteen treatment combinations resulted in a total of 54 observational units. Each unit was 3 m long and 2 m wide where 8 rows of 3 m length were arranged at 25 cm apart. The space between replications was 2.5 m and that of split was 1 m. Treatments were assigned to these units (3 × 2-m) using a random number table. On a soil with similar pH and texture, Soil Testing and Service Section (2002) generally recommends 2.3 Mg ha^{-1} for agricultural lime application in this plain region.

Recommendation doses of 100 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} were applied (source: urea, di-ammonium phosphate and muriate of potash) on November 20, 2003 whereas 20 kg N ha^{-1} was top-dressed at 41 days after planting. The control treatment also received these fertilizer inputs so that the differences of soil and crop performances between control and limed plots could be assumed to be due to the differences in the rate and time of lime application. This lime material is called *Krishi Chun* in Nepal. The *Krishi Chun* applied in this study is hereafter simply called 'lime' in this article. Calculated amount of commercial grade of lime (finely ground, 99% purity), the most common and least expensive, available for use by farmers in the region, was broadcast on designated plots and immediately incorporated with a spade. Three dates of lime applied were 22 October, 1 November and 11 November of 2002 that corresponded to 30, 20 and 10 days before planting of wheat, respectively.

Growing of wheat and soil analysis

BL-1473, an improved variety of wheat, and medium in height with early maturity was planted with seed rate of 120 kg ha^{-1} on 12 November 2002. Nine-gram seeds per row were sown in the 3 m long

furrows maintaining 25 cm row-to-row distance and continuous seeding in rows. The sowing depth was maintained 4 cm below soil surface. The first irrigation was applied manually using a water-can after mulching and before planting of wheat to facilitate seed germination. Due to ample rain during the 2nd half part of the growing season, fields were irrigated only during the early season (ie 13 December 2002) coinciding with critical growth stage of wheat (crown root initiation stage, CRI stage) requiring water.

After 120 days of planting, above-ground part of crop was harvested manually on 21 March and threshed on 26 March 2003. Central 4-row (3 m^2) was harvested excluding 2 rows in each boarder side. Harvested crop was initially dried under sun in the field and then threshed using a mechanical thresher.

After wheat harvesting, composite soil samples (0 to 15-cm) were taken from each observational unit, air dried at room temperature, ground and passed through 2 mm sieve for pH, P, K, Ca and CEC. Soil pH was determined by 1:1 soil water ratio, available P by Watanabe and Olsen (1965), Ca and CEC by 1N NH_4OAc extraction method. These soil samples were analyzed in Regional Soil Testing Laboratory of Khairenitar, Tanahun, Nepal.

Crop parameters and economic analyses

Major yield and yield-attributing characteristics of wheat such as grain and straw/biomass yields, plant height, number of effective tillers, days to heading, and tendency to lodging were measured. Plant heights were recorded selecting five random plant samples from net plot area before harvesting. Days to heading was indicated by number of days when the plants of each plot were at 50 percent heading stage. It was calculated from date of planting to the date of heading. Crop lodging is one of the major indicators for farmers' adaptation of new technology in this region. They consider plants 'lodged' if plant leaning ranged from 30 to 40 degree with respect to upright position at harvest. Using this criterion, the lodged plants were counted from the net plot area prior to harvesting. Economic analysis for marginal benefit from liming was also determined for which net return, total cost and benefit/cost ratio were computed for each treatment to develop an understanding of how these parameters were interrelated to profit-making out of the liming program.

Operational definitions for these economic analyses used are: (1) Net return = Gross return minus cost of cultivation; (2) Total cost = Sum of cost (fixed and variable) for different inputs such as land preparation, labor, machine, fertilizer, lime, irrigation, pesticides; and (3) Benefit/cost ratio = Net return / cost of cultivation. Cost of cultivation and net return are given in US dollar (detail calculation not shown). Percent moisture in grain was recorded using a moisture meter at the time of weighing the fresh yield. The grain yield was adjusted at 12 percent moisture level by using the following formula:

$$\text{Grain yield (Mg ha}^{-1}) = \frac{(100\text{-MC}) \cdot \text{net plot yield (kg)} \cdot 10{,}000\ m^2}{(100\text{-}12) \cdot \text{net plot area} \cdot 10{,}000}$$

Where,
MC = %age moisture content in the grain

Pot experiment

In order to understand the potential effect of liming on soil pH and wheat yield, crop was also grown in pots of 6 kg capacity at one corner of the field. Soil samples from furrow slices were collected from the respective field plots and applied the pot-soil with the same treatments as in the field trial. Ten seeds were sown in each pot. Upon seed emergence, seedlings were thinned to five per pot. Utmost plant protection measures were taken against soil dryness, rain, wind-storms, and pest attack. Crop

was harvested at physiological maturity. Changes in soil pH, and crop parameters such as plant heights, effective tillers, harvest index, grain and straw yields were measured and analyzed statistically.

Statistics analysis

MSTATC was used for the analysis of variance (ANOVA) to test the significance of treatment effect on measured variables. Duncan's multiple range test (DMRT) was used to compare the values of significant treatment means at 5 and 1 percent level of significance. Simple correlation analysis was done to analyze the relation among different agronomic and soil traits. Regression analysis was done to find out the optimum level of lime for wheat crop in this soil.

RESULTS AND DISCUSSION

Effect of lime application on wheat productivity

Results showed that despite significantly taller plants and earlier heading on limed plots (Table 3), grain and straw yields were not significant relative to those on control plots. Nevertheless, the highest grain yield (4.47 Mg ha^{-1}) was from 4.5 Mg ha^{-1} of lime application which was appreciably higher (20%) compared with the control plot (3.73 Mg ha^{-1}).

Table 3. Effect of lime application rate on the performance of wheat crop in the field trial

Level of lime (Mg ha^{-1})	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Days to heading	Plant height (cm)	Effective tillers (no)
0 (control)	3.73	6.26	64.2 a[†]	91.3 b	312
1.5	4.25 (14)[§]	6.74 (7.7)[§]	63.6 ab	98.2 a	359
3.0	4.34 (16)	7.38 (18)	63.2 abc	97.2 a	363
4.5	4.47 (20)	6.96 (11)	62.7 bc	98.6 a	350
6.0	4.25 (14)	6.31 (1.0)	62.8 bc	98.7 a	353
7.5	4.30 (15)	6.56 (4.8)	62.2 c	97.9 a	369
CV, %	14	15	1.8	2.5	12
LSD	ns	ns	1.1	2.36	ns
SEm	1.91	4.32	0.38	0.81	13.9

[†] Means followed by the same letter in a column are not significantly different (DMRT, P = 0.05). [§] Values in parenthesis indicate % increase in grain and straw yields in excess of the control. CV, Coefficient of variation. LSD, Least significant difference. ns, Not significant. SEm, Standard error. Value in a cell for a given rate of lime application is the average of 9 observations (3 time intervals time 3 replications of lime rate).

Similar findings were also reported by Ritchie and Porter (1994) and Sharma and Gupta (1994b) that the effect of lime was not significant on yields, though the response was positive. Straw yield also was not significantly affected by liming. However, limed plots showed higher straw biomass (up to 18%) compared with those of the control plots (Table 3). A significant linear relationship ($r = 0.49$, $P < 0.05$) between rate of lime application and wheat yield indicated that lime could be an important factor contributing to increased wheat yield on this soil. Lime rates above 4.5 Mg ha^{-1} reduced wheat yields but difference was not significant compared with the lower rates. However, the yield still kept 14 percent or higher in excess of the control which would be acceptable for farmers provided increased yield due to liming is economically profitable.

In order to examine the potential effect of lime on crop yields, wheat was also grown in the pot. Analysis of variance showed that unlike in the field trial, application of lime in the pot-soil significantly affected the grain and straw yields of wheat ($P < 0.05$) (Table 4). Number of effective tillers was observed to be the key factor to contribute the significant yield increases in the pot experiment. However, a trend of declining grain yield was observed with lime rates beyond 4.5 Mg

ha^{-1} (data not shown) similar to the case of field trial. These results clearly indicated that potential exists for increased yield and straw biomass of wheat significantly from low level of liming on this soil given the favorable environment and management practices, even under the field conditions relative to no liming. Effect of time and interaction of time with different rates of lime were not significant on many of the selected crop parameters both in the pot and field trials, indicating that rate of liming did not affect these parameters responses to the factor of time interval of lime application. It was probably due to rapid change in soil pH in the presence of adequate moisture removing the effect of time of liming before planting of wheat.

Table 4. Analysis of variance and mean squares for yield components of wheat in the pot experiment

Source of variance	df	Effective tillers/pot	No of grain/ear	Grain yield/pot	Straw yield/pot	HI %	Plant height (cm)
Replication	2	0.06	7.06	3.6	3.2	0.002	27
Time of liming (A)	2	3.56	25.1	0.09	0.2	0.001	5.6
Error (A)	4	1.78	7.14	3.1	0.9	0.001	5.3
Rate of liming (B)	5	5.56**	51.8	14.4**	13.3*	0.002*	20
Error (B)	30	1.45	25.5	2.4	4.3	0.001	14
A × B	10	1.38	12.4	1.9	4.5	0.001	6.4

**, **, Significant at P = 0.05 and 0.01 probability levels respectively. df, Degree of freedom. Effective tillers/pot, The average number of panicle bearing tillers at maturity by five plants per pot. HI = Harvest index (%), [Economic yield (grain yield) / Biological yield (biomass yield)] × 100. A, Time of liming (six rates of lime corresponding to zero to 7.5 Mg ha^{-1} applied 30, 20 and 10 days intervals before wheat planning). B, Rate of liming (0, 1.5, 3, 4.5, 6 and 7.5 Mg ha^{-1} of calcitic lime applied).*

Effect of lime application on soil pH

Liming had significant effects on soil pH both in pot and field trials that subsequently increased levels of Ca, available P and CEC in the soil (Table 5). Exchangeable Ca (31.9 to 88 mg kg^{-1}) increased linearly with increasing lime application rates. The relationship agreed well with the findings of Prasad (1992). Exchangeable Ca was strongly correlated with soil pH ($r = 0.98$, $P < 0.001$). Similarly, liming increased available P from 156 to as high as 212 Mg ha^{-1}. Prasad (1992) also reported higher P for limed plots than that of un-limed plots. It also correlated significantly with soil pH ($r = 0.72$, $P < 0.001$). But for reasons unknown, lime application beyond 3 Mg ha^{-1} did not increase the available P and CEC significantly in soil, which indicated that factors other than lime materials will influence P and CEC. Adetunji and Bamiro (1994) observed increased CEC due to liming within the first three weeks of incubation.

Table 5. Effect of lime application rate on Ca, CEC, available P and pH of soil in the field trial

Rate of lime (Mg ha^{-1})	Calcium (mg kg^{-1})	CEC ($cmol_c$ kg^{-1})	Available P (kg ha^{-1})	Soil pH	
				Before planting	After harvest
0 (control)	31.9 f[§]	20.6 c[§]	185 b[§]	4.6 e (5.1 f)[¶]	4.7 c (4.8 d)[¶]
1.5	41.2 e	21.9 abc	200 ab	4.9 d (6.0 e)	4.9 b (5.6 c)
3.0	47.3 d	21.0 bc	212 a	5.2 c (6.5 d)	5.0 b (6.1 b)
4.5	60.2 c	21.9 abc	189 b	5.2 c (6.7 c)	5.1 b (6.6 a)
6.0	68.7 b	22.8 a	181 b	5.5 b (6.9 b)	5.4 a (6.8 a)
7.5	88.0 a	22.1 ab	198 ab	5.7 a (7.0 a)	5.5 a (6.7 a)
CV, %	9.6	6.50	10.7	3.64 (1.37)	3.9 (4.9)
LSD	5.2	1.36	19.9	0.18 (0.08)	0.2 (0.3)
SEm	1.8	0.47	6.90	0.06 (0.03)	0.06 (0.09)

[§] Means followed by the same letter in a column are not significantly different (DMRT, P = 0.05). [¶] Soil pH values in parenthesis are the data from the pot experiment, not from the field trial. Value in a cell for a given rate of lime application is the average of 9 observations (3 time intervals × 3 replications of lime rate).

Within a crop season, liming (7 Mg ha^{-1}) increased soil pH from initial 5.1 to 7.0 before planting and from 4.8 to 6.7 after harvesting in the pot experiment (Table 5), almost increase pH by 2 units than that occurred under field trial (4.6 to 5.7). Results closely agree with those obtained by Maier et al (2002) where calcitic lime (10 Mg ha^{-1}) raised soil pH by 2.3 units (4.5 to 7) in glasshouse experiment using light textured Entisol over the single potato season. They also observed relatively small rise in soil pH in their field trial than the glasshouse pH values. Increases in soil pH by liming acid soils are also reported by many other studies (Bishnoi et al 1988, Adhikari 1995, Kaitibie et al 2002).

In this study, the same lime treatment produced dissimilar outcomes between pot and field trials, needing for further investigation. For the field trail, where soil pH could not exceed 5.7, it is likely that sufficient exchangeable aluminum was dominant factor to affect the plant growth, and the percentage base saturation (BS%) was low (Kamprath 1967). However, for the pot-soil with pH 5.8 to 6.5 or 7.0, literature indicated that BS percent should be increased tremendously (70 to 90%), and the effect of H ion was insignificant to affect the acidity-sensitive crops only (Buol et al 1997). In addition, greater availability of Ca at higher pH (5.5 to 6.5) might have enhanced nitrification through increased activities of most of the microorganisms responsible for the conversion of ammonium-N to nitrate-N (Tisdale et al 1993). Hue et al (1987) studied physiological process of Macadamia seedlings by exposing them to different soil pH and found that aluminum (Al) was detrimental factor to plant process when soil solution Al exceeded 1.2 mg L^{-1} and it also reduced Mn uptake by the plant at low pH range. Relating these reviews to the results of this study, it suggested that improved yield of wheat due to liming particularly in the pot experiment could be explained by the increased availability of N, P, Ca, Mg and Mn by reducing Fe and Al activities in soil solution when pH was raised from very strongly to slightly acidic soil.

In the pot experiment, regression analysis of soil pH and liming before wheat planting was described by the following regression equation:

Soil pH = 5.48 + 0.24 Lime (R^2= 0.86)

Similarly, for the pH after harvest of the crop was:

Soil pH = 5.13 + 0.26 Lime (R^2= 0.87)

Thus, 86 and 87 percent of the pH variations before wheat planting and after harvest, respectively, can be accounted by a linear function of lime alone.

In the field trial, regression analysis between soil pH and liming before wheat planting was described by the following regression equation:

Soil pH = 4.67 + 0.14 Lime (R^2= 0.97)

Similarly, for the pH after harvest of the crop was:

Soil pH = 4.70 + 0.11 Lime (R^2= 0.97)

Thus, 97 percent of the total pH variations before wheat planting and after harvest of the crop can be accounted for by a linear function of lime alone.

As discussed earlier, it would not be surprising that increase in soil pH in the field trial was only about one-half of that observed in the pot experiment. Relatively small rise in pH in the field trial might be attributed to (1) the soil surface loss of applied lime with rainwater toward the later half-part of the growing season (Table 2), (2) likelihood of incomplete mixing of lime while incorporating into the soil manually and (3) soil moisture variations in the field due to undulating soil surfaces. All these factors seem to be adversely affecting the effectiveness of liming to change soil pH.

In the pH range observed for the field trial, it would therefore be expected that exchangeable Al affected plant growth adversely while BS percent was still low. Therefore, persistence of low pH as a major growth limiting factor explains why increase in wheat yield was not significant in the field trial relative to the un-limed plots. While lower rates of lime showed potentials to raise soil pH to a desirable level and increased crop yields significantly in the pot experiment, proper land care and soil management practices seem to be of greater concern to make liming program a success under field conditions and avoid over liming in this coarse soil.

Did the liming insure crop against adverse weather conditions and lodging?

Under unusual growing season, weather conditions have potentials to muddle research results. The weather conditions for this study period (Table 2) showed that minimum monthly temperature, rainfall and relative humidity were all mostly higher relative to 12 years monthly average implying exposure of the wheat crop to a relatively stressful condition. Despite those adversities, taller erected plants with higher yields on the limed plots clearly revealed that lime increased plants capacity to endure dry weather during early season and to withstand high rainfall towards maturity as shown by reduced crop lodging. These results provided a strong basis in support of liming practices to help ensure grain and straw production on sustained basis. None of the relevant past research works that were reviewed documented the tendency of wheat crop to lodging upon liming. It may, therefore, be an encouraging finding of the work for this particular soil-crop-lime management scenario in Nepal. Based on a long-term study of liming (3.8 Mg ha^{-1} of $CaCO_3$) effects on the fine-root standing crop of *Picea abies* and *Pinus sylvestris*, Clemensson-Lindell and Persson (1993) indicated that plant roots on limed plots showed a tendency to increase the specific root length (SRL = fine root-length/fine root dry-weight, mg/g) where SRL correlated well with steam volume growth.

With some variations in crop lodging among main plot treatments of time (ie lime application 30, 20 and 10 days before planting, DBP), mean values for three DBP clearly indicated that crop lodging decreased consistently with increasing rate of lime application (Figure 1).

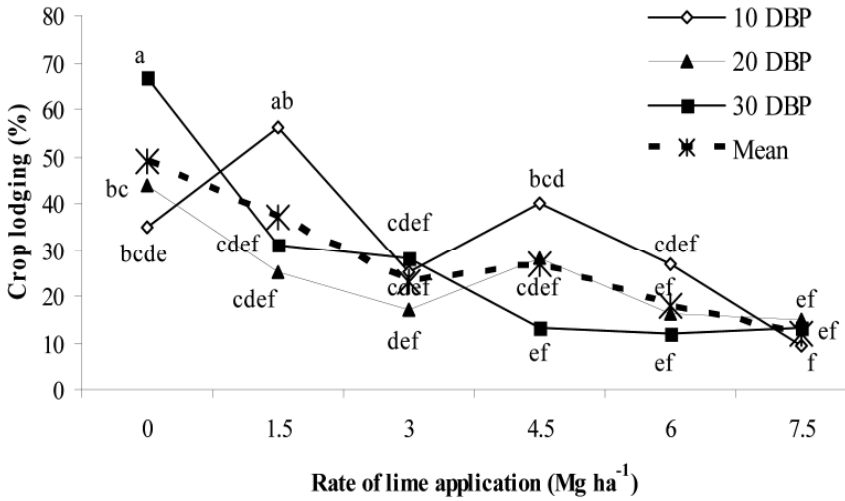

Figure 1. Effects of rice and interval of liming before planting (DBP) on crop lodging in the field trial. Means followed by the same letter for all DBP and lime application rates are not significantly different at 5% probability level by DMRT. Letters for data points on dashed bold line (ie mean values after averaging 10, 20 and 30 DBP) are not shown.

A strong linear relationship ($r = 0.74$, $P < 0.01$) was observed between these variables. Plots, which received lime at the rate of 3 Mg ha^{-1} or higher, significantly ($P < 0.05$) lowered the percentages of lodging (12.4 to 23.2%) than plots without liming (48.7%). The rate and time of lime application had

significant ($P < 0.05$) interaction effect on crop lodging (Table 6) indicating that rate of liming affected lodging response to interval of time of lime application. Percentage lodging was inversely related to the yield of wheat ($r = 0.72$, $P < 0.01$) (data not shown), which implied that rate of liming increased wheat yields by proving resistance to lodging. The question then, is to know whether increased yield of wheat would be economically justifiable.

Table 6. Analysis of variance showing mean squares for pre-harvest crop parameters in the field trial

Source of variance	df	Effective tillers/m^2	Days to heading	Lodging (%)	Root length (cm)	Plant height (cm)
Replication	2	1310	0.17	1553	19.9	30.8
Time of liming (A)	2	1144	0.39	282	1.30	0.66
Error (A)	4	3387	0.22	590	5.60	28.2
Rate of liming (B)	5	3710	4.58	1576**	3.60	72.5**
Error (B)	30	1740	1.29	155	3.40	6.00
A × B	10	1092	1.17	439*	5.80	2.20

**, **, Significant at 0.05 and 0.01 probability levels respectively. df, Degree of freedom. A, Time of liming (six rates of lime corresponding to zero to 7.5 Mg ha^{-1} applied 30, 20 and 10 days intervals before wheat planning). B, Rate of liming (0, 1.5, 3, 4.5, 6 and 7.5 Mg ha^{-1} of calcitic lime applied).*

Did the liming benefit the farmers?

A potential reason for why liming is not well adapted as part of land-improvement practices in this region appears to be due to the economics tied to the liming program in agriculture. How would the farmers realize tangible benefits from a liming program? Is liming material within an easy access to the farmers at times and prices they can afford to buy it? These are some of the fundamental questions to be addressed besides the science involved with lime, and soil and crop interactions. From the field trial, a simple calculation of the ratio of benefit to cost (B:C ratio) scenario was derived and briefly summarized the findings and shown in Figure 2.

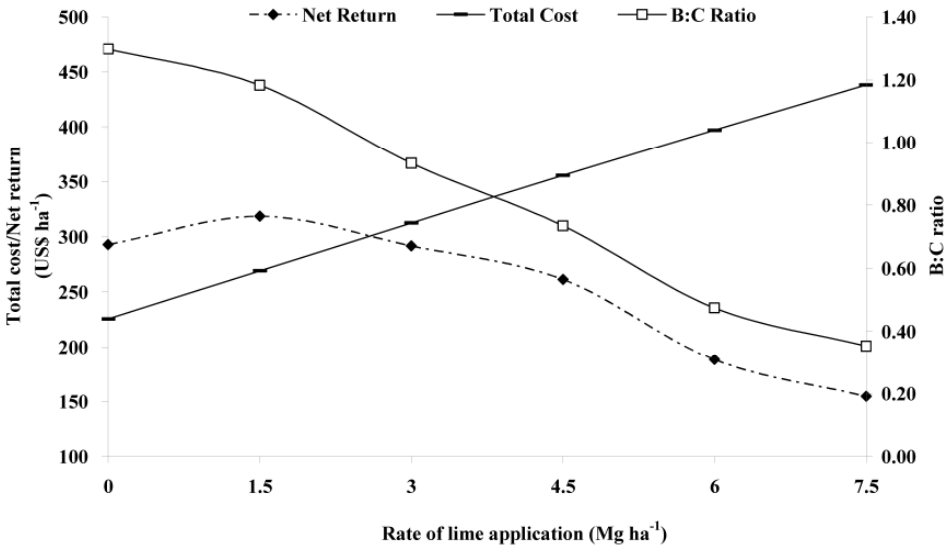

Figure 2. The relationship of total cost, net return and benefit/cost ratio (B:C ratio) with increasing rate of lime application (0 to 7.5 Mg ha^{-1}) in the field trial. The calculation of total cost/net return in US$ is based on exchange rate of US$ 1:00 equivalent to Nepali Rupees (NRs) 78.00 for 15 March 2003 as per Central Bank of Nepal. Total cost of production per ha shown in US$ may appear very small which was due to lower rates of input and labor costs in Nepal in comparison with the rates of similar inputs in developed countries.

Figure 2 illustrated that the highest B:C ratio was obtained from the un-limed control plot because the cost of cultivation on un-limed plots was the lowest due to no liming and had narrow yield gap compared with the limed-plots. However, the net return increased steadily up to the liming rate of 1.5 Mg ha^{-1} where B:C ratio was still high, thereafter net return and B:C ratio dropped sharply, but the total cost continued to rise. Therefore, liming rate of 1.5 Mg ha^{-1} was identified to be the most preferred level the small-holder farmers would likely to afford because the net return exceeded the production cost. Conversely, lime rates of 3 Mg ha^{-1} or higher, suggested that income from increased grain and straw yields might not compensate the cost of liming, thus not justifiable in economic terms. But from the perspectives of raising soils pH, and lowering crop lodging, liming up to 3 to 4.5 Mg ha^{-1} seemed justifiable. From these observations it appears that lower rates of liming would still be advantageous for augmenting economic incentives of wheat growers. Lime recommendation (2.3 Mg ha^{-1}) made by Soil Testing and Service Section (2002) for similar soil in this region was aimed at raising soil pH and crop productivity, but probably did not consider the economics of liming and crop lodging.

CONCLUSIONS

Liming reduced soil acidity which ameliorated soil chemical environment as shown by increased exchangeable Ca, available P and CEC. Although wheat yields were not statistically significant ($P > 0.05$) in the field trial, yet the low rate of lime application (1.5 Mg ha^{-1}) produced economically justifiable net return. Conversely, pot experiment showed potentials of lime rate as low as 3.0 Mg ha^{-1} for raising soil pH to the neutral range favorable to higher nutrient availability. At 3.0 Mg ha^{-1} of lime application, crop lodging reduced sharply relative to the control and lodging was not different from higher rates of liming. Crop tolerance to lodging against adverse growing weather conditions was seen as an encouraging result of liming on this soil. Insignificant effect of time of liming on most soil and crop properties indicated that farmers need not apply lime long before planting in this hot and humid environment.

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Effects of Season on Rapid Multiplication of Virus-free Plantlets under *In Vitro* and on Production of Pre-basic Seeds of Potato (*Solanum tuberosum* L.) under *In Vivo* Conditions

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ABSTRACT

Experiments were conducted to investigate the effects of multiplication season on infection, regeneration and plant height of virus-free plantlets under *in vitro* conditions and the effect of planting seasons and conditions on plant mortality, plant height and production of pre-basic seeds (PBS) of potato under *in vivo* (glasshouse and screenhouse) conditions. *In vitro* results showed that contamination of sub-cultures was higher (9.2%) during the autumn season than in the spring season (6.2%) multiplication. However, regeneration rate was higher (95.4%) during the autumn season than in the spring multiplication (89.2%). The autumn multiplication produced taller plants (7.3 cm) than the spring multiplication (7.0 cm). *In vivo* results revealed that mortality rate of transplanted *in vitro* plantlets was higher in spring plantation (8.7% in glasshouse and 9.4% in screenhouse) than in the autumn plantation (7.0% in glasshouse and 6.2% in screenhouse). In the case of PBS production, spring plantation produced significantly higher numbers of PBS (4.3/per plant) than autumn plantation, and autumn plantation produced higher rate (59.3%) of medium to bigger size PBS than spring plantation (38.8%) and similar trend was observed in all evaluated cultivars. However, cultivars were not significantly different in number and size of PBS. In another study, screenhouse produced significantly higher number of PBS per plant than glasshouse, but the glasshouse produced higher rate of bigger size PBS than the screenhouse.

Key words: Autumn season, glasshouse, number of PBS, screenhouse, size of pre-basic seed, spring season

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most important food crop after rice, maize and wheat in Nepal. Potato serves as a major vegetable in the terai and mid-hills, and staple food in the high hills, and it plays a vital role in food security in the country. Area under potato is about 1,83,000 ha and total production is about 24,59,000 tons with the national average yield 13.437 tons/ha (NPDP 2010). Of the total area under potato, 16.6 percent is in the high hills and mountains, 43.5 percent in the mid-hills and 39.9 percent in the terai region of Nepal (ABPSD 2008). Technically, the high hill areas of Nepal are highly suitable for quality seed production of potato due to low virus infection. Annual total seed requirement is about 300,000 tons and quality seed supply through farmer to farmer is about 20 percent in the country. The potato productivity has been increasing slowly every year due to increased supply of quality seed at the farmers level (NPRP 2010). However, the present productivity is still low when compared with neighboring countries, India (17.3 t/ha) and China (16.5 t/ha) (faostat.org). In asexually propagating crop like potato, production of disease-free planting materials from tissue culture is common and also reliable technique for the production of clean seed stock. The tissue culture technology has also made possible for mass production of pathogen-free planting materials in a short period of time (Ahloowalia 1999, Struik and Lommen 1990). Micro-propagation, dealing with the propagation of plantlets under *in vitro*, has many advantages over conventional vegetative propagation, and its application in horticulture, agriculture and forestry is increasing. However,

commercial use of micro-propagation is still limited because of its higher production cost (Ahloowalia 1999).

In order to produce high quality disease-free pre-basic seed (PBS) of potato, National Potato Research Program (NPRP) of Nepal Agricultural Research Council (NARC) established a tissue culture laboratory and glasshouse facilities in 1989, and since then NPRP has been producing PBSs each year during autumn and spring seasons. For the production of virus-free PBS, disease-free *in vitro* plantlets are produced in the tissue culture laboratory and transplanted under aphid-proof glasshouse or screenhouse under sterile conditions. The size and number of PBS destined for field plantings has a strong effect on the success of seed potato production program. The NPRP has been providing the PBS to the farmers at subsidized price so as to make it affordable to farmers. To sustain such a high cost PBS production program, there is no alternative other than reducing the cost of production by increasing the efficiency of *in vitro* multiplication and production of higher number and bigger size of PBS. The objectives of this study were to evaluate the incubation season for rapid multiplication of plantlets under *in vitro* conditions, and planting seasons, and conditions for the production of higher number of bigger sized PBS.

MATERIALS AND METHODS

Production of virus-free *in vitro* plantlets for mother stock

Six potato viruses ie potato leaf roll (PLRV), potato virus A (PVA), potato virus M (PVM), potato virus S (PVS), potato virus X (PVX) and potato virus Y (PVY) eliminated through meristem tip culture *in vitro* plantlets of potato cvs. Cardinal, Desiree, Janak Dev, Khumal Seto-1 and Kufri Jyoti were multiplied through single nodal cuttings on MS (Murashige and Skoog 1962) solid medium containing 3 percent sucrose in glass jar (400 ml capacity) for mother stock. The cultures were maintained at 22 ± 2°C with 16 h photoperiod (2000 lux) for five weeks under tissue culture laboratory of National Potato Research Program (NPRP), Khumaltar, Lalitpur.

Rapid propagation

For mass production of *in vitro* plantlets, single nodal segments were harvested from five-week old cultures and sub-cultured on MS solid medium containing 3 percent sucrose in glass jar under laminar flow cabinet and incubated as described earlier. This process was continued until sufficient plantlets were produced for transplanting for autumn and spring seasons under glasshouse and screenhouse conditions for PBS production.

Planting conditions and soil preparation

Plantings were done under two conditions, glasshouse and screenhouse. In the glasshouse, glasses were fixed in all sides and sensor was installed for opening and closing of the buckets (ventilation) (two in sides and two in roof) and insect proof screen was also fixed in the buckets. Most of the glasshouse construction materials were imported from Switzerland. The screenhouse was made from local materials and screen was fixed in all four sides and glasses were fixed only on roof and without any artificial cooling system. Both the glasshouse and screenhouse had similar arrangements ie bench size, bench height and soil. Benches in the glasshouse and the screenhouse were filled with virgin sub-soil as a media for planting the *in vitro* plantlets. The soil was drenched with water uniformly in each season one month before transplanting and drained. Next day, the soil surface was gently raked and formaldehyde solution (1%) was drenched thoroughly to treat the soil. Each bench was covered with polythene sheets immediately after the application of formaldehyde. Polythene sheets were removed one week after the treatment and soil was turned over several times with the help of clean spades to get rid of the volatile chemical residues, which otherwise are phyto-toxic to plantlets (NPRP 2008).

Fertilization
Chemical fertilizer was applied at the rate of 200:200:120 kg of nitrogen, phosphorus and potash per hectare basis. All phosphorus and potash and half of the nitrogen were applied at the time of transplanting. The remaining half of nitrogen was applied in two split doses, first at 30-35 days after transplanting (DAT) and the second at 45-45 days after transplanting in both seasons and conditions (NPRP 2008).

Transplanting
Four-week old acclimatized *in vitro* plantlets were transplanted on the sterile soil with 20 cm apart from row to row and 10 cm apart from plant to plant. On the same day after transplanting, 0.1 percent Bavistin (carbendazim) was sprayed over the plantlets to protect from the various soil-borne pathogens. The *in vitro* plantlets were planted on the last week of August for autumn planting and on the first week of February for spring planting in subsequent year. Cultural operations such as earthing-up, irrigation, application of pesticides and haulm pulling etc. were done as per the schedule in both seasons and conditions.

Production of virus-free pre-basic seed (PBS)
PBS was produced during two seasons; the autumn plantation was harvested at December and the spring plantation was harvested at May in each year. Autumn planting is the main season for potato cultivation especially in the Kathmandu Valley and similar agro-ecological conditions. For PBS production program, spring season was also utilized. This study was designed to evaluate the performance of autumn and spring planting seasons and glasshouse and screenhouse conditions for the production of bigger sized PBS.

Grading and storage
After harvesting, PBSs were graded into four categories on the basis of size (> 5.0 g, > 1.0-5.0 g, 0.5 - 1.0 g, < 0.5 g) and respective numbers were recorded (NPRP 2008). PBSs were packed in nylon net bags with proper leveling and then stored at 4˚C at separate chambers. PBS harvested in autumn season was stored for about ten months (January to October), targeting distribution for terai plantation, whereas those harvested in spring season was stored for about six months (May to November) and targeting distribution for hill plantation.

Data analysis
Experiments were conducted in completely randomized design. Rate of infection, regeneration and plant height under *in vitro* conditions, and mortality rate, plant height and number and size of PBS under *in vivo* conditions were recorded in each year. Under *in vitro* conditions, a minimum of 50 bottles were used in each year (2005/06 to 2009/10) and mean data are presented. Under *in vivo* conditions (glasshouse/screenhouse), single bench of each cultivar in each year was used, and the mean data are presented (NPRP 2006, 2007, 2008, 2009, 2010). In the case of PBS production and size distribution, analysis of variance (ANOVA) was employed and means separation was done by Duncan Multiplication Range Test (DMRT) at 0.05 level using MSTATC package (MSTATC 1986).

RESULTS AND DISCUSSION

Response of multiplication season on contamination of sub-cultures, regeneration and plant height of plantlets under laboratory conditions
In general, contamination of sub-cultures was higher during the autumn season (9.2%) than in the spring season (6.2%) multiplication. In contrast, regeneration rate was higher during the autumn season (95.4%) than in the spring multiplication (89.2%). Also, the autumn multiplication produced taller plants (7.3 cm) than the spring multiplication (7.0 cm) (Table 1). During the autumn season, the outside environment had high humidity and high temperature which was more favorable for

development of microorganisms and that ultimately resulted in higher contamination of the sub-cultures, but the conditions favored development of plants. In contrast, humidity and temperature was low during the spring season, limiting the growth and activity of microorganisms, and also of the plants.

Response of planting season and condition on mortality rate and plant height under *in vivo* conditions

The mean mortality rate of transplanted *in vitro* plantlets was higher in spring plantation (8.7% in glasshouse and 9.4% in screenhouse) than in the autumn plantation (7.0% in glasshouse and 6.2% in screenhouse) (Table 2). The results also showed that mortality was less in glasshouse in spring plantation and the mortality was less in screenhouse in autumn plantation. This may be due to low temperature (below 10°C) in screenhouse at the early period of planting time (January/February) during the spring season. The cultivar, 'Khumal Seto-1' had higher rate of mortality compared with other cultivars. In general, spring plantation produced higher plant height than the autumn plantation and the plant height was higher in glasshouse than in screenhouse for all tested potato cultivars. This could be due to less light period during the spring season and also less light intensity in the glasshouse.

Table 1. Contamination, regeneration and plant height of five major potato cultivars multiplied at two different multiplication seasons under laboratory condition (2008/9 and 2009/10)

Potato cultivar	Autumn season			Spring season		
	Contamination, %	Regeneration rate, %	Plant height, cm	Contamination, %	Regeneration rate, %	Plant height, cm
Cardinal	10.0 ± 0.94	97.4 ± 3.56	8.2 ± 1.21	6.0 ± 0.51	89.5 ± 4.23	7.5 ± 0.85
Desiree	9.0 ± 0.76	98.2 ± 3.21	7.8 ± 0.73	6.0 ± 0.63	92.2 ± 4.32	8.0 ± 0.91
Janak Dev	8.0 ± 1.02	96.1 ± 4.89	6.9 ± 1.01	5.0 ± 0.82	90.7 ± 6.10	6.6 ± 0.65
Khumal Seto-1	8.0 ± 1.22	90.4 ± 5.06	6.8 ± 0.95	7.0 ± 0.85	85.3 ± 6.03	6.3 ± 0.70
Kufri Jyoti	11.0 ± 0.89	95.0 ± 3.91	6.8 ± 1.20	7.0 ± 1.02	88.2 ± 3.98	6.6 ± 0.51
Mean	9.2	95.4	7.3	6.2	89.2	7.0

Fifty bottles of each cultivar were used in each year and 10 single nodal cuttings were sub-cultured in each bottle. Data is presented as mean ± standard error.

In all the tested potato cultivars, a slightly higher plant height was observed in the glasshouse than the screenhouse conditions in both the seasons. There was slightly low temperature and more aeration observed inside the screenhouse than in the semi-control glasshouse conditions (data not shown). Potato cv. 'Janak Dev' produced the highest plant height followed by 'Khumal Seto-1' and the lowest plant height was in 'Desiree' in both of the conditions and seasons throughout the study periods (Table 2). This is obvious because of the genetic background of the individual potato cultivar.

Table 2. Mortality rate and plant height of *in vitro* plantlets grown under glasshouse and screenhouse conditions in two different planting seasons (2005/6-2009/10)

Potato cultivar	Autumn season				Spring season			
	Glasshouse		Screenhouse		Glasshouse		Screenhouse	
	Mortality, %	Plant height, cm	Mortality, %	Plant height, cm	Mortality, %	Plant height, cm	Mortality, %	Plant height, cm
Cardinal	5.5 ± 0.66	59.5 ± 3.15	5.0 ± 0.25	55.6 ± 3.58	8.0 ± 0.58	61.2 ± 5.69	9.5 ± 0.61	60.1 ± 5.60
Desiree	5.4 ± 0.51	19.5 ± 2.51	5.9 ± 0.62	18.5 ± 4.25	7.4 ± 0.65	21.5 ± 3.21	7.5 ± 0..52	20.5 ± 2.98
Janak Dev	6.5 ± 0.65	90.6 ± 6.40	6.5 ± 0.29	85.5 ± 5.89	7.8 ± 0.45	91.5 ± 9.20	8.0 ± 0.36	90.5 ± 8.01
Khumal Seto-1	10.2 ± 0.72	62.0 ± 4.92	8.6 ± 0.65	59.5 ± 8.21	11.2 ± 1.02	63.5 ± 6.50	12.0 ± 0.98	60.8 ± 5.90
Kufri Jyoti	7.0 ± 0.56	51.2 ± 3.40	5.2 ± 0.30	50.1 ± 5.69	9.2 ± 0.54	55.3 ± 6.40	10.0 ± 0.88	54.5 ± 6.07
Mean	7.0	56.6	6.2	54.0	8.7	58.6	9.4	57.3

Data is presented as mean ± standard error.

Response of planting seasons on PBS production and its size distribution

Spring plantation produced significantly higher number of PBS (4.7 per plant) than autumn plantation (3.1). Autumn plantation produced significantly higher percentage (59.3%) of bigger sized (> 1 g)

PBS number and spring plantation produced significantly higher percentage (63.7%) of smaller sized (1 g and less) PBS number (Table 3). Among the cultivars, 'Janak Dev' produced the highest number of PBS (4.5/plant) and 'Khumal Seto-1' produced the lowest numbers of PBS (3.2/plant). 'Kufri Jyoti' produced the highest percentage (54.2%) of bigger sized (> 1 g) PBS and 'Desiree' produced the lowest percentage (42%) of bigger sized PBS. Number of PBS production was not significantly different between the long day (Kufri Jyoti) and short day (Khumal Seto-1) potato cultivars. This could be due to the fact that the potatoes were grown under closed conditions (glasshouse/screenhouse). For the production of higher number of bigger sized PBS, plant density could be slightly increased in autumn season from the standard plant density (50 plants/m^2) and plant density could be slightly decreased in spring season. During autumn season, light intensity and night temperature goes down during the tuberization period, which is more favorable condition for better growth and development of plant as well as tuber yield of potato.

Table 3. PBS production and its size distribution (No, %) of five potato cultivars planted under autumn and spring seasons (2005/6-2009/10)

Planting season/cultivar	PBS/plant, no.	Size distribution of PBS, no (%)			
		> 5 g	> 1-5 g	0.5-1 g	< 0.5 g
Planting season (A)					
Autumn season	3.1	22.4	36.9	28.2	11.4
Spring season	4.7	8.7	28.1	35.7	28.0
F-test	**	**	**	**	**
LSD (0.05)	1.13	11.95	6.37	6.12	11.20
Cultivar (B)					
Cardinal	4.3	16.0	32.8	33.1	18.1
Kufri Jyoti	3.4	21.3	32.9	28.6	17.2
Desiree	4.1	12.2	29.8	34.3	23.9
Janak Dev	4.5	13.9	37.3	31.4	17.4
Khumal Seto-1	3.2	14.1	29.5	33.3	23.1
F-test	ns	ns	ns	ns	ns
LSD (0.05)	-	-	-	-	-
Interaction					
Autumn × Cardinal	3.2	20.0	34.4	31.2	14.4
Autumn × Kufri Jyoti	2.3	34.7	34.7	21.3	9.3
Autumn × Desiree	3.4	17.2	35.0	33.0	14.8
Autumn × Janak Dev	4.4	18.5	41.1	29.9	10.5
Autumn × Khumal Seto-1	2.3	21.6	39.5	27.9	11.0
Spring × Cardinal	5.4	12.0	31.2	34.9	21.9
Spring × Kufri Jyoti	4.5	7.9	31.2	35.8	25.1
Spring × Desiree	4.8	7.1	24.6	35.7	32.6
Spring × Janak Dev	4.6	9.3	33.4	32.8	24.5
Spring × Khumal Seto-1	4.2	6.5	19.4	38.6	35.5
F-test (A × B)	ns	*	ns	ns	*
LSD (0.05)	-	18.89	-	-	17.72

*Planting season × cultivar factorial analysis was performed. **, Highly significant. *, Significant. ns, Not significant.*

Response of planting conditions on PBS production and its size distribution

In vitro plantlets planted under the screenhouse conditions produced significantly higher numbers of PBS (4.9/plant) than under the glasshouse conditions (4.3/plant). The plant in the glasshouse produced significantly the higher percentage (47.3%) of bigger sized (> 1 g) PBS and the plants in screenhouse produced the higher percentage (27.3%) of smaller (< 0.5 g) size PBS. Among the five evaluated potato cultivars, there was no significant difference among each other, however, 'Desiree' produced

the highest (5.1/plant) and 'Khumal seto-1' produced the lowest (4.3/plant) number of PBS. Potato cv. 'Cardinal' produced significantly the highest percentage (52.6%) of bigger size (> 1 g) PBS and 'Khumal Seto' produced the lowest percentage (31.8%) of bigger size PBS. In the case of interaction analysis between planting conditions and cultivars, potato cvs. 'Cardinal' produced the highest percentage of bigger size PBS under the glasshouse conditions and 'Janak Dev' produced the highest percentage of bigger size PBS under screenhouse conditions. Similarly, 'Khumal Seto-1' produced significantly the highest percentage (45.1%) of the smallest size PBS under screenhouse conditions and 'Cardinal' produced the lowest percentage (12.4%) of smallest size PBS under glasshouse conditions.

In general, higher percentage of medium to large size PBSs were produced under glasshouse conditions and higher percentage of smaller size PBS were produced under screenhouse conditions in all evaluated potato cultivars except in 'Janak Dev' (Table 4). These results indicated that screenhouse conditions are more appropriate for the production of higher number of PBS under Kathmandu conditions. The winter temperature was slightly lower in screenhouse than in glasshouse and maximum temperature was also lower by 2-3°C in the screenhouse than in the glasshouse mainly at the time of tuberization period (March-April) (Table 5). This high temperature at glasshouse converted more stolons into the plants. On the other hand, construction cost as well as operation cost is also lower for the screenhouse than the semi-automatic glasshouse in Nepalese conditions. Considering these points, more focus should be given to the screenhouse plantation than the glasshouse plantation in the coming years to increase yield (number) of PBS.

Table 4. PBS production and its size distribution (no, %) of five potato cultivars planted under glasshouse and screenhouse conditions (2005/6 – 2009/10)

Planting condition/cultivar	PBS/plant, no	Size distribution of PBS, no. (%)			
		> 5 g	> 1-5 g	0.5-1 g	< 0.5 g
Planting condition (A)					
Glasshouse	4.3	11.9	35.4	30.7	20.3
Screenhouse	4.9	10.4	25.9	36.9	27.3
F-test	8	*	**	*	*
LSD (0.05)	0.51	1.41	7.92	4.55	5.03
Cultivar (B)					
Cardinal	4.7	15.6	37.0	34.0	13.5
Kufri Jyoti	4.4	12.8	21.8	33.9	31.6
Desiree	5.1	12.6	30.0	34.3	23.2
Janak Dev	4.7	9.5	39.8	33.9	16.9
Khumal Seto-1	4.3	6.6	25.2	33.8	34.5
F-test	Ns	*	ns	ns	*
LSD (0.05)	-	7.82	-	-	10.33
Interaction					
Glasshouse × Cardinal	4.1	17.0	36.1	34.6	12.4
Glasshouse × Kufri Jyoti	4.3	11.7	37.2	24.3	26.8
Glasshouse × Desiree	4.6	16.3	35.2	27.5	21.0
Glasshouse × Janak Dev	4.4	4.3	40.8	34.8	19.6
Glasshouse × Khumal Seto-1	4.2	8.1	33.5	34.6	23.8
Screenhouse × Cardinal	5.3	14.2	37.9	33.4	14.5
Screenhouse × Kufri Jyoti	4.5	13.8	6.3	43.6	36.3
Screenhouse × Desiree	5.6	8.8	24.8	41.1	25.3
Screenhouse × Janak Dev	4.9	14.7	38.2	33.0	14.1
Screenhouse × Khumal Seto-1	4.3	5.1	16.9	32.9	45.1
F-test (A × B)	ns	*	*	ns	*
LSD (0.05)	-	9.80	14.71	-	18.21

*Planting season × cultivar factorial analysis was performed. **, Highly significant. *, Significant. ns, Not significant.*

Table 5. Average maximum and minimum temperature of glasshouse and screenhouse during the last five years (2005/6 to 2009/10)

Month	Glasshouse		Screenhouse	
	Temperature (°C)		Temperature (°C)	
	Minimum	Maximum	Minimum	Maximum
January	5.34	26.15	4.35	21.85
February	6.25	26.21	5.52	23.45
March	7.11	30.72	8.21	26.94
April	11.05	32.05	10.25	30.20
May	14.03	33.57	14.00	32.60
June	20.12	35.60	19.50	34.11
July	21.00	34.95	20.50	33.00
August	21.25	34.15	21.81	32.09
September	21.57	32.46	20.35	31.05
October	17.78	30.05	21.55	32.05
November	12.65	26.58	10.17	29.38
December	8.18	24.43	7.46	24.18

CONCLUSION

For the rapid and efficient multiplication of plantlets under *in vitro* conditions, autumn multiplication showed slightly higher percentage of contamination. Similarly, higher percentage of regeneration with better plant growth was observed in autumn multiplication than in spring multiplication. So, autumn multiplication could be recommended unless it requires more hygienic conditions in the laboratory. For the PBS production, spring plantation produced higher number of PBSs per plant with higher percentage of smaller PBSs, so more focus should be given to the spring plantation to increase the number of bigger PBSs. Thus, autumn plantation is recommended for the production of bigger size and spring plantation is recommended for higher number of PBSs with smaller size. Among the two conditions, screenhouse plantation could be recommended for the production of higher number and glasshouse plantation for bigger size of PBSs. Finally, it is recommended that there should be slight adjustment of plant density to obtain bigger PBS with higher number in both seasons and conditions.

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RESEARCH NOTE

Chemical Management of Purple Blotch Disease of Onion

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ABSTRACT

Purple blotch caused by *Alternaria porri* is a serious disease of onion (*Allium cepa* L.) in the central terai of Nepal. Field experiments were conducted to evaluate Dithane M-45 (mancozeb), Bavistin (carbendazim), Blitox 50 (copper oxychloride) and Krinoxyl (metalaxyl+mancozeb) against the disease for two years, 2005/06 and 2007/08, at Regional Agricultural Research Station, Parwanipur, Bara. In both the years, the effect of fungicide applications on plant height, average bulb weight and bulb yield differed among the treatments, but none of the treatments had consistent effect. However, all the fungicides tested had significantly less percent disease intensity (PDI) when compared with the untreated control. Thus, two sprays of anyone of the tested fungicides after the first appearance of the disease at an interval of three weeks can be recommended for the management of the disease.

Key words: Disease management, onion, percent disease intensity, purple blotch

INTRODUCTION

Purple blotch caused by *Alternaria porri* (Ellis) Neergaard is a serious disease of onion (*Allium cepa* L.) in the central Tarai of Nepal. In Tarai, onion is grown in winter season and most farmers grow cv. Nasik Red (N-53), which is susceptible to purple blotch disease. The disease causes heavy losses in bulb yield, but the extent of losses is not known. Also, in other countries, purple blotch is the most common and destructive disease (Miller and Lacy 1996). In India, many fungicides and plant extracts had been tested to manage this disease (Rangswami 1993, Patel et al 2001, Pandya et al 2002, Vijay and Rahman 2004). Vijay and Rahman (2004) reported that four sprays of mancozeb @ 0.3% with monocrotophos @ 0.05% was the best treatment and recorded the least incidence and the highest bulb yield. Chaurasia et al (2007) found three sprays of carbendazim (Bavistin, 0.2%) the most effective in managing purple blotch of garlic in central Tarai of Nepal. This study was undertaken to find the most effective fungicide in managing the disease of onion under Parawanipur conditions.

MATERIALS AND METHODS

The experiment was carried out in randomized complete block design with three replications in 2005/2006, 2006/2007 and 2007/2008. The experimental plots of 2006/2007 could not be harvested due to some physical damage. The plot size was 3.0- × 2.4-m. Row to row spacing was 15 cm and seedling to seedling spacing was 10 cm. Fertilizer was applied at the rate of 80:40:50 kg NPK/ha. Half of the nitrogen and all phosphorus and potash were applied as basal at the time of planting and remaining half of the nitrogen was applied in two split doses (30 and 60 days after planting). In both the years, onion cv. Nasik Red was planted on 13 November 2005 and 2007 and harvested on 30 March 2006 and 25 March 2008.

Fungicides used were Dithane M-45 (mancozeb) @ 0.3%, Bavistin (carbendazim) @ 0.2%, Blitox-50 (copper oxychloride) @ 0.3% and Krinoxyl (metalaxyl + mancozeb) @ 0.15%. Treatments included two and three treatments of each fungicide. The fungicides were applied on 3 December 2005, 24 January and 8 February 2006 in the first year and 2 and 25 December 2007 and 4 January 2008 in the second year. The dates for two sprays were 3 December 2005 and 24 January 2006. The first application of the fungicides was made when the leaf tips started becoming yellow, the early symptoms of the disease under natural disease pressure. Disease was scored one month after the last spray of fungicides in a half meter quadrate on 1-5 scale, where 1 = no disease symptoms on leaves, 2 = 1-5% leaf area covered with disease lesions, 3 = 6-20% leaf area covered with disease lesions, 4 = 21-50% leaf area covered with disease lesions, and 5 = more than 50% leaf area covered with disease lesions. Twenty-five onion plants per plot were used to score purple blotch disease.

Percentage disease intensity (PDI) was calculated using following formula:
PDI = 100 x scale for each plant x number of plants / maximum grade x number of plants observed.

RESULTS AND DISCUSSION

In the first year, the effect of fungicide applications on plant height, average bulb weight and bulb yield differed among the treatments (Table 1), but none of the treatments had consistent effect. The treatments had less effect on plant height when compared with the untreated control. Average bulb yield was higher in all treatments than in the untreated control though the differences were not statistically significant. The effect of increased average bulb weight could be seen in the bulb yields though the yields were not significantly different. All the treatments had significantly less percent disease intensity (PDI) when compared with the untreated control. The highest PDI (13.4) was in the untreated control plot and the least (7.8) was in the Dithane M-45 sprayed plots. No significant difference was found between two sprays and three sprays for all fungicides tested.

Table 1. Effect of fungicides on plant height, percent disease intensity (PDI), average bulb weight and bulb yield of onion, 2005/06

Fungicide	Plant height, cm	Average bulb weight, g	Bulb yield		PDI value
			kg/plot (7.2 m^2)	kg/ha	
Dithane M-45, 0.3% two sprays	40.7 abc	196.7a	5.29 a	7347	8.1 bc
Dithane M-45, 0.3% three sprays	36.6 c	185.0 bc	4.62 ab	6436	7.8 c
Bavistin, 0.2% two sprays	48.5 a	160.0 bc	4.59 ab	6380	12.7 b
Bavistin, 0.2% three sprays	41.0 abc	193.3 a	4.35 ab	6037	11.6 b
Blitox-50, 0.3% two sprays	39.1 bc	146.7 bc	3.69 b	5125	11.3 b
Blitox-50, 0.3% three sprays	44.8 ab	163.3 bc	4.20 ab	5829	8.7 bc
Krinoxyl, 0.15% two sprays	36.9 bc	156.7 bc	4.18 ab	5801	8.1 c
Krinoxyl, 0.15% three sprays	37.3 bc	166.7 bc	4.21 ab	5847	9.7 bc
Control (no spray)	42.6 abc	116.0 c	3.41 b	4741	13.4 a

Figures marked with same letter(s) are not significantly different at 0.05% according to DMRT.

Also in the second year experiment, the trend of the effect of fungicide applications on plant height, average bulb weight and bulb yield was found similar, except for Krinoxyl (Table 2). The Krinoxyl-sprayed plots had less average bulb weight than other plots, including untreated control. Like in the first year experiment, all the fungicides had significantly less PDI than the untreated control. Fungicides and their number of sprays (2 and 3) did not differ in reducing the PDI.

Table 2. Effect of fungicides on plant height, plant disease intensity (PDI), average bulb weight and bulb yield of onion, 2006/07

Fungicide	Plant height, cm	Average bulb weight, g	Bulb yield		PDI value
			kg/plot (7.2 m^2)	kg/ha	
Dithane M-45, 0.3% two sprays	37.7 a	173.3 a	5.297 a	7356	10. 0 b
Dithane M -45, 0.3% three sprays	35.3 b	113.3 bc	3.833 a	5324	9.9 b
Bavistin, 0.2% two sprays	35.0 b	110.0 bc	4.933 a	6852	9.7 b
Bavistin, 0.2% three sprays	36.3 ab	116.7 bc	4.430 a	6159	11.2 b
Blitox-50, 0.3% two sprays	32.7 c	120.0 bc	4.367 a	6065	9.2 b
Blitox-50, 0.3% three sprays	38.3 a	130.0 bc	4.823 a	6699	10.7 b
Krinoxyl, 0.15% two sprays	35.3 b	86.7 c	4.340 a	6028	9.0 b
Krinoxyl, 0.15% three sprays	37.7 ab	93.3 c	3.923 a	5449	9.4 b
Control (no spray)	36.3 ab	143.3 ab	4.393 a	6287	24.8 a

Figures marked with same letter(s) are not significantly different at 0.05% according to DMRT.

CONCLUSION

Though the PDI of purple blotch was reduced by all fungicides their effect on yield parameters was not consistently significant among the treatments. This could be due to the fact that the disease pressure was low in both the years, which had less effect on the crop yields. Besides the disease, some other factors also might have played in yield attribution. However, the present results showed that all tested fungicides were effective in lowering PDI of purple blotch in onion when compared with untreated control. Two sprays of anyone of the commonly available fungicides (mancozeb, carbendazim, copper oxychloride, metalyxyl + mancozeb) can be recommended to manage the disease. Of them, mancozeb or copper oxychloride could be more appropriate as these fungicides are cheaper and readily available than the other two.

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RESEARCH NOTE

Flavodon flavus: An Addition to the Polyporoid Fungi from Nepal

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ABSTRACT

Flavodon flavus (KI.) Ryv., a polypore, which has been gathered from the tropical forest of Dharan area (east Nepal), is described in detail, which is recorded as new addition to the mycoflora of Nepal. The fungus is known to have medicinal value.

Key word: *Flavodon flavus* (KI.) Ryv , Nepal, polypore

INTRODUCTION

The literatures viz. Adhikari (1988, 1996, 2000, 2009, 2012), Balfour–Browne (1955, 1968), Berkeley (1854abcd), Hattori et al (2002), Hjortstam and Ryvarden (1984) and Ryvarden (1977) can be consulted for the references on the recorded species of Polypores from Nepal.

During the course of investigation, study and identification of mycological specimens the author came across the present fungus, which was gathered growing on the dead wood in tropical rain forest of Dharan (100-150 m) area. Dharan lies in north of Biratnagar, east Nepal. After study the fungus was identified as *Flavodon flavus* (KI.) Ryv. The species was not described and reported before. It is an addition to the polyporoid fungus from Nepal.

The fungus belongs to the family Steccherinaceae of Polyporales in Agaricomycetidae of Basidiomycota. Its brief morphological description, distribution in the globe and the photograph has been provided here.

Description of species

***Flavodon flavus* (KI.) Ryv.,** *Norw. Jour. Bot.* 20(1): 3 (1973); Ryvarden & Johansen (1980) 333.

Synonym: *Irpex flavus* Kl. In *Linnaea* 8:488, 1833; *Polyporus flavus* Jung. 1838; *Irpex flavus* Jungh., *Verhand. Batav. Genootsch*. 17:46, 1839; *Polystictus flavus* (Jungh.)Fr. 1851; *Irpex flavus* (Jungh.) Kal. 1881; *Xylodon flavus* (KL.) Kuntze 1898; *Polyporus crenatoporus* Rostr., *Bot. Tidsskr*. 24:360, 1902 ; *Coriolus melleoflavus* Murr., *Bull. Torr. Bot. Cl.* 35:393, 1908; *Coriolus flavus* (Jungh.) Pat. 1912; *Trametes flava* (Jungh.)Pat., 1914*; Hydnum luteomarginatum* Beeli, *Bull. Soc. Roy. Bot. Belg.* 58:210, 1926; *Hirschioporus flavus* (kl.) Teng, 1963; *Trichaptum flavum* (Jungh.) G. Cunn. 1965 (Fig. 1 and 2).

Fruit-body annual, sessile, applanate, horizontal, semicircular, effuso-reflexed to entirely resupinate. Pileus up to 3 cm in radius, villous tomentose to subtomentose, narrowly concentrically sulcate, yellow to subfulvous, pallid to grayish, margin obtuse to subacute, pale yellowish white. Hymenium yellow to fulvous cinnamon, in radial rows, developing into narrow lacerate-dentate plates, dentate

lamellae, spines up to 3 mm long, irpicoid to hydnoid, Flesh up to 2 mm thick, fibrilloso-floccose, light-weight, lurid yellow to fulvous, without crust. Hyphae dimitic. Basidia up to 22 × 5 µm, subclavate, sterigmata 4, often with granular matter between the basidia. Cystidia 20 - 46 × 3.5 - 7 µm, cylindric, subclavate, subfusiform to subventricose, mostly obtuse, with yellowish walls -1 µm thick, mostly thinly encrusted over the apex, derived from subhymenial hyphae, abundant. Spores 5.5 - 6.5 × 3 - 4 µm, white in the mass, smooth, ellipsoid, thin-walled, aguttate.

Figure 1. Basidiocarp of *Favadon flavus*

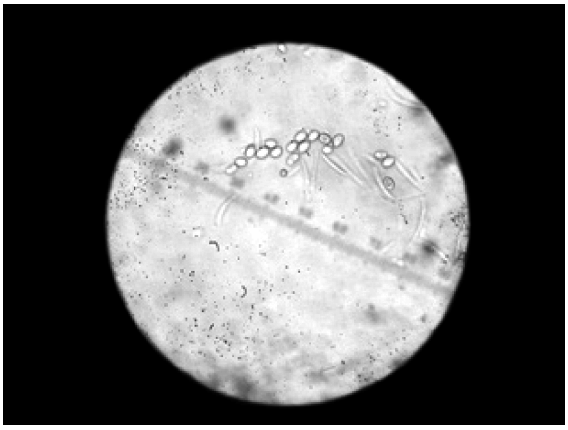

Figure 2. Basidiospores of *F. flavus*

Specimen examined: Growing on dead wood, in tropical forest composed of *Shorea – Duobanga – Dillenia,* Dharan (approx. between 100 - 150 m; North of Biratnagar, east Nepal). no. 2010103, 2067/7/ 19.

Distribution: Africa, Pakistan, India, Philippines, Malaysia, Singapore, Australia and Nepal. Wide spread in tropical areas of Asia and Africa (Old World tropics).

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