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National Maize Research Program
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Journal of Maize Research and Development (JMRD) is dedicated to publishing high-quality original research and review articles on maize breeding, genetics, agronomy, entomology, pathology, post harvest, soil science, botany, physiology, conservation agriculture and climate change effect on maize, maize economics, up-scaling research on maize and plant biotechnological approaches for maize improvement. The main objective of JMRD is to serve as a platform for the international scholars, academicians, researchers, and extensonists to share the innovative research findings in maize. The JMRD is an online open access international, peer reviewed and official journal published annually in month of December by National Maize Research Program, Rampur, Chitwan, Nepal. This Journal offers authors no publishing charges, no proofreading charges, no page charges and fast publication times. As soon as the paper is ready, it will be appeared online.

Editorial preface

Maize is oldest cultivated crops and has been a major food source of many civilizations throughout the world. There is a great and instant need to develop cost effective, location-specific, ecosystem friendly and farmer‘s preference technologies to enhance the global maize production. There is an enormous possibility to increase the maize yield so various biotic and abiotic yield limiting factors including poor crop management practices should be addressed with innovative research efforts targeted to address those constraints. The developed technologies should be farmer friendly and easily access to concerned stakeholders. The Journal of Maize Research and Development dedicated to publish all those innovative ideas, information and technologies related to maize research and development issues. We are so happy and excited to publish our second edition with 16 diverse manuscripts with latest findings from maize research and development field devoted to enhancing the maize global cultivation.

Our team always focused and gives priority on quality publications with its wider and easy global access. Keeping those things in view, recently Journal of Maize Research and Development has been listed in so many national and international indexing, abstracting and cataloguing of Google Scholar, NARC Library, JournalTOCs, DOAJ, NepJOL (INASP), ResearchGate, AGORA, J-Gate, SCOPUS Elsevier (in the process), CAB Abstracts (CABI) and TEEAL. This huge number of indexing, abstracting and electronic library catalogue demonstrates that our scientific publishing have been globally recognized. This edition is the outcome of continuous efforts, pros and guidance of many people who forever inspired and pushed us to continue our activities in publication and we would like to take this opportunity to share our deep sense of sincere gratitude and immense love to all those who made our every events successful during the period of collection, review and processing of manuscripts. We wish to express our thanks to all the editors and reviewers who contributed to review/edit articles for this issue and all authors for choosing our journal.

Last but not the least, in order to access the online version of this issue along with archived editions please visit our website http://nmrp.gov.np/journal-of-maize-research-and-development/. We encourage authors to submit their articles and readers to provide constructive comments and feedback about the journal.

Jiban Shrestha
Editor-In-Chief
20th December, 2016

Subash Subedi, Ph.D
Associate Editor-In-Chief
20th December, 2016

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Articles

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Performance evaluation of commercial maize hybrids across diverse Terai environments during the winter season in Nepal

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ABSTRACT

The hybrid maize cultivars of multinational seed companies are gradually being popular among the farmers in Nepal. This paper reports on research finding of 117 maize hybrids of 20 seed companies assessed for grain yield and other traits at three sites in winter season of 2011 and 2012. The objective of the study was to identify superior maize hybrids suitable for winter time planting in eastern, central and inner Terai of Nepal. Across site analysis of variance revealed that highly significant effect of genotype and genotype × environment interaction (GEI) on grain yield of commercial hybrids. Overall, 47 genotypes of 16 seed companies identified as high yielding and stable based on superiority measures. The statistical analysis ranked topmost three genotypes among tested hybrids as P3856 (10515 kg ha^{-1}), Bisco prince (8763 kg ha^{-1}) as well as Shaktiman (8654 kg ha^{-1}) in the first year; and 3022 (8378 kg ha^{-1}), Kirtiman manik (8323 kg ha^{-1}) as well as Top class (7996 kg ha^{-1}) in the second year. It can be concluded that stable and good performing hybrids identified as potential commercial hybrids for general cultivation on similar environments in Nepal.

Keywords: Genotype grouping, G × E interaction (GEI), grain yield, hybrid maize, superiority measure

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INTRODUCTION

Maize (*Zea mays* L.) is the key ingredient for poultry and livestock ration in addition to its position as one of the major food crop in Nepal (Dhakal et al., 2015). It has a wider range of uses as compared other cereal as food, feed, fuel, fodder, and industrial raw materials. The changing consumer habits from starch to protein rich food demanded more amounts of animal-derived foodstuff in the country. In the meantime, ever increasing trend of poultry and livestock business along with increasing population and rising income has demanded more amounts of maize grains. A current market requirement of maize grains is partly fulfilled by growing hybrids

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in winter at Terai and inner Terai (Gurung et al., 2011). Because of higher yield potentiality and assurance market of maize grains, farmers' attraction towards hybrids cultivar increased radically on these days. Yield advantage of hybrid cultivar over traditional variety is a critical component for determining the attraction towards hybrid maize (Heisey et al., 1998). In Nepal, farmers started to grow hybrid maize since 1980s by importing seeds from India due to the open border between the countries (Thapa, 2013). It has already covered approximately 80 and 10 percent of maize production respectively in Terai and mid hills (Adhikari, 2014). Hybrid maize concealed around seven to ten percent area of Nepal in 2010 (Gurung et al., 2011; Thapa, 2013) and area under hybrid maize is increasing every year. Nepal imports almost 20 percent of corn seeds every year (Adhikari, 2014) and nearly 100 percent of hybrid seed is being imported from India (Gurung et al., 2011). Hence, it can be projected that hybrid maize covered around 12-15% maize area in Nepal. Due to increasing investment of government and private sector on hybrid maize seed, it covered around 90% percent area under winter maize. However, nearly 40-45 percent of maize grains used in feed industries are being still imported from India every year (CDD, 2013). It is minimum possibility for maize area expansion in the mid hills because agricultural land has already been exhausted in Nepal (Ransom et al., 2003). However, it is still scope for increasing cropping intensity in Terai, inner Terai and foot-hills (e.g., rice-fallow systems) by growing hybrid maize in winter. The increment of winter maize area by two folds under hybrid in Terai may help to reduce current trade imbalance of the country. Unfortunately, few hybrids developed from national research system and those released are not competitive. First of all, the grain yield performance of released cultivar is low as compared to commercial hybrids and secondly, seed availability of those hybrids is almost negligible for general cultivation. Unavailability of competitive hybrid cultivars within the country and underdeveloped seed industries caused dependency over imported hybrid maize seed every year (Gurung et al., 2011). Large numbers of multinational companies' hybrids have been registered in National Seed Board in Nepal. In this context, as the hybrid maize area has been growing extensively in Terai and partly in mid-hill districts, the commercial seed companies are the major source of seed. Hybrid maize seed marketing is flourishing every year but limited commercial hybrids are suited to cultivation owing to existing diverse agro-ecological regime of the country. Therefore, the objective of this study was to identify superior maize hybrids suitable for winter time planting in eastern, central and inner Terai of Nepal.

MATERIALS AND METHODS

Commercial hybrid maize evaluation trial dataset

Hybrid maize of various commercial seed companies was being evaluated regularly in across sites coordinated trials by National Maize Research Program, Rampur since 2010/11. This experiment was conducted at three sites i.e. Rampur, Chitwan (Inner Terai), Parwanipur, Bara (Central Terai) and Tarahara, Sunsari (Eastern Terai) during winter seasons of 2010/11 and 2011/12. These are the representative sites where winter maize is extensively cultivated in winter season in Nepal. Sixty-nine hybrids of 12 seed companies and 56 hybrids of 12 seed companies were evaluated on multi-location trial in the first and second year respectively. Seven varieties from Monsanto and four seed companies were common in both the years. Therefore, altogether

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117 hybrids of 20 seed companies were evaluated in the period of two years. A detail list of the materials with respective companies is presented in table 1-2.

Table 1. List of genotypes with respect to seed company used in the multi-location trial during November 2010 to April 2011.

Seed Companies	Hybrids name
Aishwarya Seeds India Private Limited, Hyderabad, India	Aditya-929, Challenge-1, Early-2, Godavari-989, Kesherking-919, Madhur, TCS-9696
Bisco Bio-science Pvt. Ltd., Hyderabad, India	Bisco Bumper, Bisco Heera, Bisco Prince, Bisco x 81, Bisco x 92, Bisco x 97 Gold, Naya 940
Bayer Bio-science Hyderabad, India	LY-558, LY-597, Proagro-4640, Proagro-4642, Proagro-4794, Proagro-Sampanna
Charoen Pokphand Seeds Pvt. Ltd.| CP Seeds	CP-666, CP-808, CP-828, CP-838,
Delta Agri-genetics Pvt. Ltd. AP, India	10V10, 10V20, Chhabili
Dhaanya Seeds Pvt Ltd	DMH-7314, DMH-849, MM-1107, MM-1109, MM-7705
Monsanto India Ltd. Mumbai, India	900 M Gold, All-rounder, Pinnacle, Dekalb-Double, Prabal, DKC 9081, Super -900M, Hi-shell, Dekalb DK-984
Nath Bio-gene India, Ltd., Aurangabad	Big Boss, Don 1588, Samrat 1133, Samrat 1144
Nuziveedu Seed Pvt. Ltd., Hyderabad, India	NMH-1242, NMH -666 (Sandhya), NMH -777 (Sunny), NMH -731 (Srestha), NMH -909
Pioneer HI Pvt. Ltd, Hyderabad, India	30B11, 30V92, P 3404, P 3522, P 3540, P 3785, P3856
Shree Ram Bio-seed Genetics India, Pvt., Hyderabad	9220, 9681, Badshah Gold, Commando, Rajkumar, Shaktiman, Tx-369
Zuari Seed India Ltd., Hyderabad, India	C-1921, C-1945, C-1946, C-1950, C-6485

The crop planted in 2nd and 3rd week of November respectively in 2010 and 2011. The experiment was conducted in Randomized Complete Block (RCB) design with two replicates in each site on both the years. Each experimental plot had four rows of 5 m long, with 0.75 m an inter-row spacing and 0.25 m intra-row spacing.. NPK was applied as fertilizer @ 160 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in the form of urea, di-ammonium phosphate (DAP), and Murate of Potash (MoP). A total dose of phosphorus and potash applied as basal dose but urea was added on three splits; the first ½ at planting time, next ¼ and later ¼ at four weeks and six weeks after planting respectively. Furthermore, farm yard manure (10 t ha^{-1}) also incorporated in soil at the time of land preparation.

Data recording and statistical analysis

The observation recorded for grain yield (considering 0.8 standard shelling co-efficient along with 12.5 percent adjusted grain moisture before converting kg per hectare), days silking (days after planting when half of the plants extrude silks). Plant height measured before harvesting by using measuring scale. The grain yield was estimated using formula adopted by MacRobert et al. (2014).

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$$\text{Grain yield}\left(\frac{\text{kg}}{\text{ha}}\right) = \frac{\text{Fresh ear weight } \times (100 - \text{MC}) \times 0.8 \times 10{,}000}{(100 - 12.5) \times 7.5}$$

Where, MC = harvest time moisture content in grains (%), 0.8 = standard shelling co-efficient, 12.5 = standard moisture content, and 7.5 = area harvested (m^2)

All agronomic traits were analyzed using META-R software for both specific and across-site analysis (Alvarado et al., 2015). The variance due to genotype, genotype × environment interaction, and environment calculated to estimate broad sense heritability.

The per se genotypic mean grain yield ranked to assess the status of cross over GEI. Superiority index (Pi) value calculated for the rank of grain yield based on the model proposed by Lin and Binns (1988) to identify good performing and stable genotypes. The genotypes with lowest Pi value and most productive in a given set of environments were considered as superior (Lin and Binns, 1988; Ye et al., 2001).

$P_i = \sum_{j=1}^{s}(y_{ij} - y_{mj})^2 / 2v$Where, Pi= superiority index in which the smaller the value the better the genotype, yij =yield of i^{th} genotype in the j^{th} site, ymj= maximum response among the genotypes in the j^{th} site, v=numbers of genotypes.

Table 2: List of genotypes with respect to seed company used in the multi-location trial during November 2011 to April 2012.

Seed Companies	Hybrids
Advanta Seeds	PAC-740, PAC-745, PAC-746, PAC-999, Premire, Scorpio, Challenger
Bisco Bio-science Pvt. Ltd., Hyderabad, India	Bisco Jambo-65 and Bisco Moti Delux
Chand Hybrid Seeds Company Hyderabad, India.	907, C-745, Top-Sheel 957, 951 Supe, SC 719
Sichuan Deyue Technology Seed Industry Co.. Ltd. China	JM-1, JM-2, JM-3, JM-4, JM-5, JM-6, JM-7
Dhaanya Seeds Pvt Ltd	DHM-8255, MM-7529, MM-7659
Kirtiman Agro Genetics Ltd., Aurangabad, India	Kritiman Manik, Kritiman Nares, Saurav Round, Tanishk, Saurav Flat, Kirtiman Kundan
Monsanto India Ltd. Mumbai, India	900M -Gold, All-rounder, Pinnacle, Dekald-Double, Prabal, DKC-9081, Super -900M, DKC-9120,
Manisha Agri Biotech Pvt Ltd., Hyderabad. India	Manisa-6363, Manisa-7272, Manisa-9292, Manisa-8181
Pioneer HI Seeds Ltd., Hyderabad, India	P-3396
Rasi Seeds Pvt. Ltd. India	Tip-Top, Top-Class, 3022, 3033
South East Asia | Namdhari Seeds Pvt.	Bikas-666, Unnati-555 (Pragati)
Vibha Agrotech Ltd., India	Boom (VMH-2015), Elite (VMH-2009), Legend, Eden-4040, Super-High-Corn (VMH-2000), MAC (VMH-4102), X-Paid

RESULTS

Analysis of variance in maize performance

The days to silking ranged from 113-127 with mean 119 days in the first year and 108-123 days with mean 116 in next year (Table 3-4). It indicated that days to flowering differed by two weeks between the early and late genotypes so that maturity period differs by one month

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between the early and late maturing genotypes. The plant height ranged from 153-222 with mean 187 cm in 2010-11 whereas it ranges from 149-189 with mean 173 cm in 2011-12 (Table 3-4). The highest plant height observed on 30B11 followed by P3856 in the first year. Then, Top class and Kirtiman Kundan respectively observed as tall and dwarf variety in the corresponding year.

Table 3: Variation and analysis of variance for silking days, plant height and yield for top and bottom five yield performing genotypes across locations in 2010/11.

Genotypes	Silking days	Plant height (cm)	Grain yield kg ha^{-1}			
			Parwanipur	Rampur	Tarahara	Mean
Bisco-X97-Gold	123	188	7218	11704	9368	10536
P-3856	124	216	9546	11490	9541	10515
30B11	127	222	6869	9872	10345	10108
C-1946	117	184	7903	8538	11654	10096
NMH-666	116	203	6586	8016	12119	10067
CP-828	124	201	8442	6528	5622	6075
10V10	116	200	8541	3502	8494	5998
DMH-849	113	153	8623	5557	5497	5527
Dekalb-Double	118	174	8041	4190	6506	5348
Madhur	123	177	9361	3699	5332	4515
Grand Mean	119	187	8368	7464	8102	7783
Maximum	127	222	10713	9665	10134	10536
Minimum	113	153	4824	5407	6364	4515
Heritability	0.761	0.518	0.00	0.52	0.51	0.25
Genotype	8.485	107.52	0.0	1838573	1221799	425276
Gen × Loc	5.261	141.05	-	-	-	1104909
Residual	5.424	317.42	3041417	3404497	2386758	2895628
$LSD_{0.05}$	2.66	20.34	3820	3682	3083	2401
CV, %	1.96	9.53	20.84	24.72	19.07	22.00

Table 4: Variation and analysis of variance for silking days, plant height and yield for top and bottom five yield performing genotypes across locations in 2011/12.

Genotypes	Silking days	Plant height (cm)	Grain yield kg ha^{-1}			
			Parwanipur	Rampur	Tarahara	Mean
3022	119	178	9322	7370	8442	8378
Kirtiman-Manik	116	152	8100	7304	9567	8323
P-3396	112	175	9875	8120	6217	8070
Top-Class	115	189	8260	7957	7772	7996
MAC-(VMH-4102)	114	159	7717	8202	7523	7814
Pragati	108	173	5860	2862	3513	4078
SC-719	123	172	3494	5246	3093	3944
907	114	179	4394	3708	3562	3888
JM-5	111	170	5646	1305	4711	3887
Kirtiman-Kundan	119	149	3902	2916	3733	3517
Grand Mean	116	173	6552	5474	6118	6048
Maximum	123	189	9875	8202	9567	8323
Minimum	108	149	3334	1305	2043	3517
Heritability	0.70	0.650	0.846	0.760	0.460	0.560
Genotype variance	13.51	105.96	2624867	1610035	1424657	812554
Gen × Loc variance	9.75	28.31	-	-	-	1073966
Residual	15.33	291.02	954270	1019346	3286235	1753284
$LSD_{0.05}$	4.48	20	1958	2023	3632.9	1515
CV, %	3.4	9.9	14.91	18.45	29.6	21.9

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Likewise, the five top yielding genotypes produced more than 10000 kg ha^{-1} grain yields but lowest five provided 4515-6364 kg ha^{-1} with trial mean yield 7783 kg ha^{-1} in 2010-11. On the other hand, top five genotypes provided 7814-8378 kg ha^{-1} and lowest five gave 3517-4078 kg ha^{-1} with trial mean 6048 kg ha^{-1} in 2011-12. High yielding genotype produced more than 35 to 38 percent higher than average grain yield in the first year and second year respectively. It also indicated that the lowest yielding genotype has produced nearly 50 percent greater yield than the national average (2501 kg ha^{-1}) of 2012. The results from analysis of variance revealed that the effect of GEI on grain yield was highly significant with the relatively greater proportion of total variation contributed by GEI in both the years. In the meantime, a large yield variation explained by environments and GEI than genotype. It indicates that environment and GEI effect was more important for grain yield in hybrid maize.

Genotype grouping based on ranking

Four distinct groups of genotypes observed in both the years when mean rank plotted against the Francis coefficient of variation (Table 5). The mean rank 34.5 and coefficient of variation (CV) 40 percent in table 5 as well as the mean, rank 28 and Francis CV 42 percent in table 6 divided the graphs into four quadrants. It makes easy to understand the distribution pattern of genotypes in a simple and descriptive way.

Table 5. Genotype grouping based on coefficient of variation vs rank mean yield from 2010-11 data

Seed companies	Group I (11)	Group II (25)	Group III (15)	Group IV (18)
Aishwarya Seeds India (7)*	-	TCS-9696 (1)	Godavari-989 (1)	Aditya-929,Challenge-1,Early-2, Kesherking-919, Madhur (5)
Bisco Bio-science (7)	Naya-940 (1)	Bisco-Prince,Bisco-X-81, Bisco-X97-Gold (3)	Bisco-X-92 (1)	Bisco-Bumper,Bisco-Heera (2)
Bayer Bio-science (6)	-	Proagro-4642,Proagro-Sampanna (2)	LY-558,LY-597,Proagro-4640,Proagro-4794 (4)	-
CP Seeds (4)	-	-	-	CP-666,CP-808, CP-828,CP-838 (4)
Delta Agri-genetics (3)	-	10V20 (1)	-	10V10,Chhabili (2)
Dhaanya Seeds (5)	MM-1107,MM-1109,MM-7705 (3)	-	DMH-7314 (1)	DMH-849 (1)
Monsanto (9)	900-M-Gold,Dekalb-DK-984, Prabal (3)	DKC-9081,Pinnacle (2)	All-rounder,HiShell, Super-900M (3)	Dekalb-Double (1)
Nath Bio-gene (4)	-	Big-Boss (1)	Don-1588, Samrat-1144 (2)	Samrat-1133 (1)
Pioneer HI (12)	30B11,NMH-666	NMH-1242,NMH-77, P-	30V92,NMH-731,P-	NMH-909 (1)

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	(2)	3404, P-3522, P-3540,P-3856 (6)	3785 (3)	
Shree Ram Bio-seed (7)	9681, Badshah-Gold (2)	9220,Commando, Tx-369, Rajkumar, Shaktiman, (5)	-	-
Zuari Seed (5)	-	C-1921,C-1946,C-1950, -6485 (4)	-	C-1945 (1)

*Figure within bracket shows the number of hybrids

The group I comprehend the genotypes with greater mean rank value as well as higher CV percentage. The genotypes are high yielding but large variation in their performance. It indicates that the genotypes of this group perform better under favorable environment. For example, 11 hybrids of five seed companies (Table 5) and seven hybrids of four seed companies (Table 6) clustered under this group. The group II includes the genotypes having higher rank value and lower CV percentage. The genotypes of this group identified as good performing and stable. It means these genotypes are most desirable, high yielding as well as consistent over the locations. Twenty-five hybrids of nine seed companies and 22 hybrids of nine seed companies clustered under this group in respectively first and second year. In fact, the hybrids with the ability to good performance and adaptive characters might have clustered in this group.

Table 6: Genotype grouping based on coefficient of variation vs rank mean yield from 2011-12 data

Seed companies	Group I (7)	Group II (22)	Group III (10)	Group IV (17)
Advanta Seeds (7)*	-	Challenger, PAC-740,PAC-999, Premier, Scorpio (5)	PAC-745 (1)	PAC-746 (1)
Bisco Bio-Sciences (2)	-	Bisco-Jambo-65 (1)	Bisco-Moti-Delux (1)	-
Chand Hybrid (5)	-	-	907,C-745 (2)	951-Supe, SC-719, Top-Shell-957 (3)
Sichuan Deyue Technology (7)		JM-1,JM-4,JM-6 (3)	JM-3(1)	JM-2,JM-5, JM-7(3)
Dhaanya seeds (3)	DHM-8255,MM-7529 (2)	-	MM-7659 (1)	-
Kirtiman Agro Genetics (3)	-	Kirtiman-Manik, Kirtiman-Naresh (2)	-	Kirtiman Kundan (1)
Manisha Agri Biotech (4)		Manisa-8181,Manisa-9292 (2)	Manisa-7272(1)	Manisa-6363 (1)
Monsanto (8)	900M-Gold, Parbal (2)	-	-	All-rounder, Dekalb-Double , DKC-9081, DKC-9120, Pinacle, Super-900M(6)
Pioneer HI Seeds(1)	-	P-3396 (1)	-	-
Rasi Seeds (4)	-	3022, 3033,Tip-Top,Top-Class (4)	-	-
Namdhari	Bikas-666 (1)	-	Saurav-Flat, Tanishk	Pragati,Saurav-

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Seeds (5)			(2)	Round(2)
Vibha Seeds (7)	Eden-(VMH-4040), Legend (2)	Elite, MACVMH-4102, Super-Hi-corn, ×-Paid(4)	Boom -(VMH-2015) (1)	-

*Figure within bracket shows the number of hybrids

The group III comprised the genotypes having lower rank value as well as lower CV percentage. The genotypes are consistent but low yielding. Therefore, it is supposed to be the group of undesirable genotypes because of low yield performance across the environments. For example, 15 hybrids of seven seed companies in the first year and 10 hybrids of eight seed companies in the second year clustered under this group. The group IV consisted of genotypes with lower mean yield rank value but higher CV percentage. The genotypes of this group were inconsistent and low yielding. Therefore, it was the group of highly undesirable genotypes. For example, 18 genotypes of nine seed companies in the first year and seventeen hybrids of seven seed companies in the second year clustered under this group. In summary, the hybrids that clustered under group III and group IV might not be suitable to grow on eastern, central and inner Terai in Nepal.

Superiority measures based on yield

The name of potential high yielding and stable hybrids with the seed company, yield over locations and lower superiority value (Pi) presented on table 7-8.

Table 7: List of good performing and stable maize hybrids based on superiority measures across the locations in 2010-11.

Seed company	Hybrid name	Grain yield (kg ha^{-1}) Parwanipur	Rampur	Tarahara	Mean	SD	CV, %	Superiority Measure (Pi)
Shree Ram Bio-seed (5)*	Shaktiman	10157	8112	9195	8654	102	11.2	162.1
	Tx-369	8440	10284	9560	9922	929	9.9	261.8
	Commando	8094	8390	9986	9188	101	11.5	270.6
	9220	7663	7849	9639	8744	109	13	338.1
	Rajkumar	9443	6985	8476	7731	123	14.9	354.6
PHI Seeds Pvt (4)	P-3856	9546	11490	9541	1051	112	11	60.2
	P-3404	8832	7061	9903	8482	143	16.7	284.4
	P-3522	8924	8476	8391	8434	286	3.3	286.1
	P-3540	8856	7327	9019	8173	933	11.1	410.5
Zuari Seed Ltd.(4)	C-1950	9725	8668	8024	8346	859	9.8	229.9
	C-1946	7903	8537	11654	1009	200	21.4	250.8
	C-6485	8881	6758	8041	7399	106	13.5	452.5
	C-1921	9553	5913	7943	6928	182	23.4	470.6
Bisco Bio-science (3)	Bisco-X97-Gold	7218	11704	9368	1053	224	23.8	203.3
	Bisco-X-81	7976	8913	7851	8382	581	7	444.8
	Bisco-Prince	10713	8725	8801	8763	112	12	105.1
Bayer Bio-science (2)	Proagro-	8906	8770	7953	8361	516	6	313.1
	Proagro-4642	9567	8249	7679	7964	969	11.4	359.2
Monsanto Ltd. (2)	Pinnacle	9473	7501	10716	9108	162	17.6	259.9
	DKC-9081	9119	7282	8699	7991	962	11.5	416.7
Nuziveedu Seed (2)	NMH-1242	7886	9325	10709	1001	141	15.2	216
	NMH-777	8233	7919	8439	8179	262	3.2	451.9

Aishwarya Seed (1)	TCS-9696	9479	7224	10515	8869	1683	18.6	258.1
Delta Agri-genetics (1)	10V20	8218	7353	9703	8528	1189	14.1	378.1
Nath Bio-gene (1)	Big-Boss	8645	7846	8146	7996	403	4.9	422.3

*Figure within bracket shows the number of hybrids

The genotypes having lower superiority measure (Pi) value also showed higher mean yield and lower coefficient of variation. The genotypes with more than 8000 kg ha^{-1} grain yields and least standard deviation are P3522, Biscox81, Proagro Sampanna, and NMH777 in the first year and more than 7000 kg ha^{-1} grain yield and smallest standard deviation are Challenger, Top Class, MAC (VMH4102) and Super Hi-corn in the second year. Table 7-8 also include the lists of same varieties on group II in table 5 where 25 hybrids of 10 seed companies and 22 hybrids of eight seed companies produced good yield performance and stability respectively in the first and second year. In summary, P3856 of Pioneer, as well as Bisco prince of Bisco bio-science in the first year (Table 7) and 3022 of Rashi seed as well as Kritiman Manik of Kritiman agro in the second year (Table 8) was the top performing and stable hybrids. The results also showed that the same variety of Monsanto failed to produce similar yield on next season experiment in comparison to the first season. The hybrids from Dhaanya seed could not meet the criteria for both the years. Likewise, none of the varieties of CP seed, Namdhari seeds and Chand Hybrid able to show stability and good yield performance. The seed companies generating more numbers of competitive hybrids were Pioneer, Shree Ram, and Advanta followed by Bisco Bio-science, Vibha, and Zuari.

Table 8. List of good performing and stable maize hybrids based on superiority measures across locations in 2011-12.

Seed company	Hybrid name	Grain yield (kg ha^{-1})				SD	CV	Superiority Measure (Pi) based
		Parwanipur	Rampur	Tarahara	Mean		(%)	
Advanta Ltd (5)*	Scorpio	8516	6304	7829	7550	113	15	101.1
	Challenger	7679	6577	6824	7027	578	8.2	145.9
	Premier	8380	7658	5951	7330	124	17	154.5
	PAC-740	8290	6638	5372	6767	146	21.	216.5
	PAC-999	8998	5857	4895	6583	214	32.	251.0
Rashi seed (4)	3022	9322	7370	8442	8378	977	11.	20.0
	Top-Class	8260	7957	7772	7996	246	3.1	65.8
	Tip-Top	8871	7440	6625	7645	113	14.	103.2
	3033	6413	6681	7135	6743	365	5.4	205.1
Vibha Agri-tech (4)	MAC (VMH-	7717	8202	7523	7814	350	4.5	99.9
	Super-Hi-corn	7246	6498	7670	7138	593	8.3	139.1
	Elite-(VMH-	7425	5370	8396	7064	154	21.	170.0
	X-Paid	7358	4341	7389	6363	175	27.	333.2
Sichuan Deyue Tech Seeds (3)	JM-4	6330	7545	5958	6611	830	12.	257.5
	JM-6	5768	6784	6796	6450	590	9.2	282.7
	JM-1	7253	5332	6180	6255	963	15.	315.1
Kritiman Agro (2)	Kirtiman-Manik	8100	7304	9566	8323	114	13.	36.0
	Kirtiman-Nares	5936	5027	7280	6081	113	18.	352.8
Manisha Agro (2)	Manisa-9292	9207	6008	5130	6782	214	31.	219.9
	Manisa-8181	7403	6269	4841	6171	128	20.	308.3

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PHI Seeds Pvt (1)	P-3396	9875	8120	6217	8070	183	22.	112.7
Bisco Bio-science	Bisco-Jambo-65	7911	5476	7595	6994	132	18.	155.6

*Figure within bracket shows the number of hybrids

DISCUSSION

The existing heterogeneity among the evaluated hybrids and growing environment clearly reflected on days to silking, plant height, and grain yield performance of commercial hybrid maize. In general, maize experience severe cold stress during the flowering time when planted in winter. The silking period is the most sensitive period for the crop when maize planted in cold stress condition (Abendroth et al., 2011). Silking duration was quite long in winter maize because of low temperature and low solar radiation in Terai. The time required for corn to progress from vegetative to the reproductive stage is based on the amount of heat accumulated (Abendroth et al., 2011; Thomison & Nielson, 2002). Cold stress during flowering time directly affects silking time rather than anthesis, which increases the gap between anthesis and silking, obstructs fertilization, and ultimately reduce the kernel number per ear. The differences in grain yield across environments might be owing to variation in the genetic base of the hybrids, differing environmental conditions over sites, and GEI. Similar kind of observation was also reported by Sharma et al. (2008). The maize hybrids developed by different seed companies with various genetic backgrounds might be the major causes of variability in performance among genotypes. Shrestha and Kunwar (2014) from two years observation recorded that there was significant variation in eighteen maize hybrids for flowering and grain yield. The variation in climatic parameters and soil type of experimental site might be also depicted on the performance of these commercial hybrids. Growth and development of crops influenced by temperature, radiation, photoperiod and water availability (Tsimba et al., 2013). Furthermore, Parwanipur followed by Tarahara was the highest grain yield producing sites in both the years. It also showed that maize growing environment of Rampur was closer to both Parwanipur and Tarahara. A similar kind of result was also reported by Koirala et al. (2013). The effect of GEI was high on final harvest of commercial hybrids that's why the same genotype behaves differently on changed location. Four distinct groups of genotypes were observed from this distribution pattern analysis. The mean-CV method for genotype grouping was used on yield stability analysis on hybrid maize (Francis & Kannenberg, 1978). Altogether, forty-seven hybrids of twenty seed companies with higher rank value and lower CV percentage were identified as good performing and stable. In the meantime, a large yield variation explained by environments and GEI than genotype indicates that environment and GEI factors were vital than genotype in crop yield. The stable and high yielding genotypes can be suitable for general cultivation to wider regions. In addition to this, those genotypes which are performing better yield on specific location could be suitable for cultivation to a particular region. Superiority measure helps to measure the behavior of genotypes where genotype × environment interactions is significant (Lin & Binns, 1988).

CONCLUSION

The increasing numbers of new seed companies on testing of new hybrids with enough numbers of competitive varieties revealed the future potentiality of hybrid seed marketing in Nepal. Those commercial hybrids which had high yield potential and stable could be suitable for general cultivation to similar environments. However, genotypes with better yield performance

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on certain location could be suitable to grow only on that specific region. Furthermore, among the three locations, Parwanipur identified as high yielding site and Rampur as a representative site for hybrid evaluation in both years. Pioneer, Shree Ram, and Advanta followed by Bisco Bio-science, Vibha, and Zuari are recognized as the seed companies producing more numbers of competitive hybrids.

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REFERENCES

Abendroth, L. J., Elmore, R., Boyer, M., & Marlay, S. (2011). "Corn growth and development," Iowa State University, University Extension.

Adhikari, J. (2014). Seed sovereignty: Analysing the debate on hybrid seeds and GMOs and bringing about sustainability in agricultural development. *Journal of Forest and Livelihood 12*, 33-46.

Alvarado, G., Lopez, M., Vargas, M., Pacheco, A., Rodríguez, F., Burgueño, J., & Crossa, J. (2015). META-R (Multi Environment Trial Analysis with R for Windows) Version 5.0 *http://hdl.handle.net/11529/10201">hdl:11529/10201 International Maize and Wheat Improvement Center* [Distributor]V13 [Version].

CDD. (2013). Crop Division Directoriate. Impact of maize mission program. *http://cddnepal.gov.np/uploaded/Impact___Maize_Mission_Program.pdf*.

Dhakal, S. C., Regmi, P. P., Thapa, R. B., Sah, S. K., & Khatri-Chhetri, D. B. (2015). Productivity and profitability of maize-pumpkin mix cropping in Chitwan, Nepal. *Journal of Maize Research and Development* , *1*, 112-122.

Francis, T., & Kannenberg, L. (1978). Yield stability studies in short-season maize. I. A descriptive method for grouping genotypes. *Canadian Journal of Plant Science*, *58,* 1029-1034.

Gurung, D. B., Upadhyay, S. R., Pandey, B. R., Pokhrel, B. B., & Kshetri, J. B. (2011). Hybrid maize seed production: A new initiative for reliable and sustainable hybrid maize seed supply in Nepal. *Agriculture Development Journal, 8*, 1-8.

Heisey, P. W., Morris, M. L., Byerlee, D., & Lopez-Pereira, M. A. (1998). Economics of hybrid maize adoption. In Morris, M.A. (ed.). Maize seed industries in developing countries. Boulder, Colorado, Lynne Reinner.

Koirala, K. B., Gurung, D. B., Kunwar, C. B., Tripathi, M., Thakur, P., Bhandari, G., Bhandari, B., Shrestha, J., Karki, T. B., Baral, B. R., Adhikari, P., Achhami, B. B., BK, S. B., Bhurer, K. P., Chaudhary, B. N., & Chhetri, J. B. (2013). Evaluation of multinational companies' maize hybrids during winter season of 2010-2012. *Proceedings of the 27th National Summer Crops Workshop* 2.

Lin, C. S., & Binns, M. R. (1988). A superiority measure of cultivar performance for cultivar× location data. *Canadian Journal of Plant Science,* 68, 193-198.

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16210

MacRobert, J. F., Setimela, P. S., Gethi, J., & Worku, M. (2014). Maize Hybrid Seed Production Manual. Mexico,D.F.:CIMMYT.

Ransom, J. K., Paudyal, K. & Adhikari, K. (2003). Adoption of improved maize varieties in the hills of Nepal. *Agricultural Economics, 29*, 299-305.

Sharma, D., Sharma, R. C., Dhakal, R., Dhami, N. B., Gurung, D. B., Katuwal, R. B., Koirala, K. B., Prasad, R. C., Sah, S. N., Upadhyay, S. R., Tiwari, T. P., & Ortiz-Ferrara, G. (2008). Performance stability of maize genotypes across diverse hill environments in Nepal. *Euphytica, 164*, 689-698.

Shrestha, J., & Kunwar, C. B. (2014). Evaluation of original and selected maize populations for agronomic traits under mass selection. *Scrutiny International Research Journal of Agriculture, Plant Biotechnology and Bio Products, 1*, 1-11.

Thapa, M. (2013). Regulatory framework of GMOs and hybrid seeds in Nepal. *Agronomy Journal of Nepal, 3*, 128-138.

Thomison, P., & Nielson, R. (2002). Impact of delayed planting on heat unit requirements for seed maturation in maize. *Pontificia Universidad Católica de Chile. Departamento de Ciencias Vegetales. Seminario Internacional Semillas: comercialización producción y tecnología. Santiago, 15*, 140-164.

Tsimba, R., Edmeades, G. O., Millner, J. P., & Kemp, P. D. (2013). The effect of planting date on maize: Phenology, thermal time durations and growth rates in a cool temperate climate. *Field Crops Research, 150*, 145-155.

Ye, G., McNeil, D., & Hill, G. (2001). Methods for analysing multi-site plant variety trials. II. Selection for yield and stability. *Agronomy New Zealand, 31*, 25-33.

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Management of stem borer (*Chilo partellus* Swinhoe) in maize using conventional pesticides in Chitwan, Nepal

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ABSTRACT

The stem borer (*Chilo partellus* Swinhoe) is one of the most destructive pests of maize crop. Research experimentations were carried out on maize to control stem borer using conventional pesticides under field condition during summer season of two consecutive years from 2015 to 2016 at Rampur, Chitwan. All used pesticides had significant effect ($P \leq 0.05$) on percent damage and crop yield over control. In 2015, the lower percent damage (5.3%) with higher crop yield (4.52 t ha^{-1}) and lowest insect score (1.00) was observed in plot sprayed with spinosad 45% EC at 0.5 ml L^{-1} of water followed by plot treated with chloropyriphos 50% EC+cypermethrin 5%EC @1.5ml L^{-1} of water with percent damage of 6.60%, crop yield (4.23 t ha^{-1}) and insect score of 1.60. Almost similar trend of insect incidence along with damage percentage and yield data were observed in 2016. The higher percent damage control (79.06%) was observed at the plot sprayed after spinosad 45% EC at 0.5 ml L^{-1} of water with higher crop yield (4.58 t ha^{-1}) and lowest insect score (1.00) followed by the plot treated with imidacloprid 17.8% @ 0.5 ml L^{-1} of water with percent damage control of 73.10 %, crop yield (3.38 t/ha) and insect sore 1.50. The highest percent damage (20.63%) was observed in the control plot with lower yield (0.95 t ha^{-1}) and highest insect score (6.00). Over the years, spinosad 45% EC at 0.5 ml L^{-1} of water was effective bio-pesticide to control maize stem borer damage and also increase the yield.

Keywords: Maize, pesticide, stem borer

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INTRODUCTION

Maize stem borer (*Chilo partellus* Swinhoe**)** has been implicated as major insect pest to maize production throughout the country (Neupane, 1986). In severe cases, dead hearts are formed and such plants do not bear the ears. The loss caused by them has not been calculate accurately. However, some workers mentioned that the maize borer reported to cause a yield loss of 20-87% (Mathur, 1994). Sometimes yield loss has measured up to 83% (Chaterji et. al., 1969). With the introduction of new high yielding varieties/hybrids and advancement in farming technologies, the cropping pattern has changed. As a result of this, maize is grown now round the year i.e. rainy, winter and spring season. This has added new dimensions to the pestilence front. Insects hitherto have become problematic pests. Low productivity (National average 2.2 ton/ha) of maize in Nepal is attributed to many reasons. The one reason of low production is the attack of various insect pests. They attack maize plants from seeds sown in the field to maturity and feed on all parts of the plants (Gyawali, 1978; Shivakoti & KC, 1978). Maize stem borer damage decreases the yield and lower grain quality (Pingali, 2001; James, 2003). Furthermore, non judicious use of wide spectrum insecticides during last few decades have resulted various problems. Haphazard uses of chemicals are not eco-friendly in the present context. Although, maize stem borer had major impact on yield losses, however scanty works related to pest management have been carried out against this pest in Nepal. So the present experiment has been attempted on maize to control stem borer using conventional pesticides under field condition.

MATERIALS AND METHODS

The experimentation was conducted at the research farm of National Maize Research Program, Rampur, Chitwan, Nepal during summer seasons of 2015-2016. The latitude, longitude and altitude of the experimental site are 27^0 40'N, 84^0 19' E, and 228 masl respectively. Series of field experiments with 8 treatments (fipronil 0.3Gr @3-4 g per whorl, spinosad 45% EC@0.5 ml L^{-1} of water, chloropyrifos 10% EC @ 1.5 ml L^{-1} of water, Margosom @ 3 ml L^{-1} of water, chlorophyriphos 20%EC (Darshan)@1.5 ml L^{-1} of water, chloropyriphos 50%EC+cypermethrin 5%EC (Super-D) @1.5 ml L^{-1} of water, imidachloprid 17.8% (Confidor 200SL) @0.5 ml L^{-1} of water and control) were evaluated against maize stem borer. The experiments were laid in RCB design with three replications. The pipeline hybrid maize genotype RML-95/RML-96 was seeded on the first week of April (April 5, 2015) during first year of experimentation while next year, a released variety Rampur hybrid-2 was seeded on the third week of February (February 19, 2016) in a unit plot size of 6 rows of 5 m long with the spacing of 60 × 20 cm between row to row and plant to plant.

After a completion of sowing, the experiment was kept under constant supervision to an entire crop cycle. Agronomic practices were followed as recommended. Each experimental unit was fertilized with a recommended dose of 150:60:40 (N: P: K) kg ha^{-1}. Granular insecticides were applied at knee high stage in plant whorl where as liquid form of insecticides applied as foliar first at 15 days after emergence and second before tasseling stage. Insect data was recorded on the basis of 1-9 scoring scale as described by CIMMYT, Mexico (Tefera et al., 2011).

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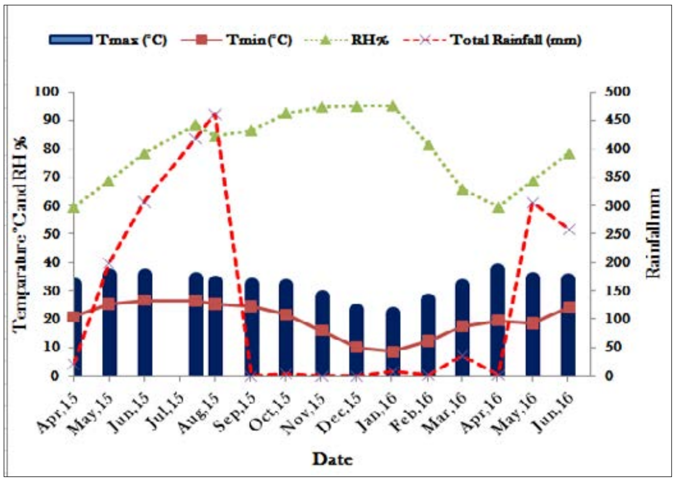

Figure 1. Meteorological data during experimental period (2015-2016) at Rampur, Chitwan Nepal.

Data on damage percentage at knee height and tasseling stage and yield (ton/hectare) were recorded. Yield increase over the control was calculated. The temperature, relative humidity and rainfall were measured during experiment period (Figure 1). All data were analyzed statistically using MSTAT-C and MS-Excel. Analysis of variance was done.

RESULTS AND DISCUSSION

Efficacy of pesticides against maize stem borer

All used conventional pesticides had significant effect (P≤0.05) on percent damage and crop yield over control. In 2015, the lower percent damage (5.30%) with higher crop yield (4.52 t/ha) and lowest insect score (1.00) was observed in plot sprayed with spinosad 45% EC at 0.5 ml L^{-1} of water followed by plot treated with chloropyriphos 50% EC+cypermethrin 5%EC @1.5 ml L^{-1} of water with percent damage of 6.60%, crop yield (4.23 t ha^{-1}) and insect score of 1.60 (Table 1).

Table 1. Effect of pesticides on damage percentage of stem borer and grain yield increase in maize at Rampur, Chitwan during 2015.

Treatments	IS (0-9 scale)	%DAS	%DC	GY (t ha^{-1})	YI (%)
1. fipronil 0.3Gr @3-4 g/whorl	†2.00	11.00	36.05	4.01	35.02
2. spinosad 45% EC@0.5ml/ l of water	1.00	5.30	69.19	4.52	52.19
3. furadon 3 Gr@3-4g/whorl	1.60	10.80	37.21	4.11	38.38

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4. Margosom @ 3 ml L^{-1} of water	2.33	11.30	34.30	3.93	32.32
5.chlorophyriphos 20%EC (Darshan)@1.5 ml L^{-1} of water	1.60	8.80	48.84	4.13	39.06
6. chloropyriphos 50%EC+cypermethrin 5%EC (Super-D) @1.5 ml L^{-1} of water	1.60	6.60	61.63	4.23	42.42
7. imidachloprid 17.8% (Confidor 200SL) @0.5 ml L^{-1} of water	2.00	7.60	55.81	4.14	39.39
8. Control (water spray)	3.50	17.20		2.97	
Grand mean	1.90	9.80		4.01	
F test	**	*		**	
LSD $_{0.05}$	0.67	5.22		0.31	
CV%	19.50	30.20		4.42	

Note: [†] Means of 3 replication. IS- Insect Score, %DAS- Percent Damage After Spray, %DC- Percent Damage Control, GY- Grain Yield, YI- Yield Increase, t/ha- ton per hectare, L- liter, EC- Emulsifiable concentration, ml- mililitre, g- gram, Gr- granule

Relationship between insect damage control and yield increase in maize

A linear positive correlation between insect damage control yield increase percentages was observed during 2015. The maize yield was found significantly highly positive correlation (r = 0.89) with the insect damage control percentage in maize stem borer management experiment through the application of conventional pesticides. The equation Y= 0.412X + 19.59 and R^2 = 0.80 gave the best fit (Figure 2). The estimated regression line indicated that the unit rise in the insect damage control percentage during experimentation period of first year (within 1-9 scale), there existed possibilities of yield increase by 0.41%.

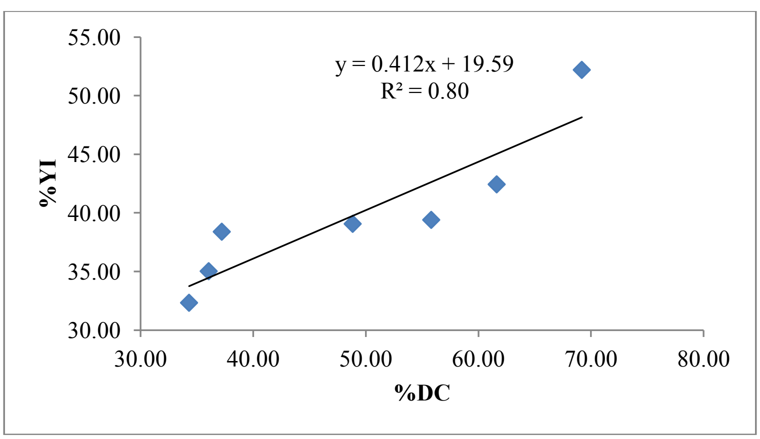

Figure 2: Relationship between percent damage control and percent yield increase in maize stem borer management experiment at Rampur, Chitwan during 2015.

Almost similar trend of insect incidence along with damage percentage and yield data were observed in 2016.

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Table 2. Effect of pesticides on stem borer damage and grain yield in maize at Rampur, Chitwan during 2016.

Treatments	IS (0-9 scale)	%DBS	%DAS	%DC	GY (t ha^{-1})	YI %
1. fipronil 0.3Gr @3-4 g/whorl	†4.67	9.85	7.10	65.58	2.08	118.95
2. spinosad 45% EC@0.5 ml L^{-1} of water	1.00	5.61	4.32	79.06	4.58	382.11
3. chloropyrifos 10% EC @ 1.5 ml L^{-1} of water	4.00	9.62	6.78	67.14	2.58	171.58
4. Margosom @ 3 ml L^{-1} of water	2.33	7.43	5.92	71.30	3.25	242.11
5.chlorophyriphos20%EC (Darshan)@1.5 ml L^{-1} of water	3.33	9.03	6.50	68.49	2.72	186.32
6.chloropyriphos50%EC+cypermethrin 5%EC (Super-D) @1.5 ml L^{-1} of water	3.17	8.56	6.22	69.85	2.95	210.53
7. imidachloprid 17.8% (Confidor 200SL) @0.5 ml L^{-1} of water	1.50	8.30	5.55	73.10	3.38	255.79
8. Control (water spray)	6.00	9.19	20.63		0.95	
Grand mean	3.25	8.45	7.88		2.81	
F test	**	**	**		**	
LSD $_{0.05}$	0.93	1.09	0.65		0.28	
CV%	16.40	7.39	4.72		5.67	

Note: † Means of 3 replication. IS- Insect score, %DBS- percent Damage Before Spray, %DAS- Percent Damage After Spray, %DC- Percent Damage Control, GY- Grain Yield, YI- Yield Increase, t/ha- ton per hectare, L- liter, EC- Emulsifiable concentration, ml- mililitre, g- gram, Gr- granule

The lower percent damage (4.32%) was observed at the plot sprayed after spinosad 45% EC at 0.5 ml L^{-1} of water with higher crop yield (4.58 t ha^{-1}) and lowest insect score (1.00) followed by the plot treated with imidacloprid 17.8% @ 0.5 ml L^{-1} of water with percent damage of 5.55%, crop yield (3.38 t ha^{-1}) and insect sore 1.50. The highest percent damage (20.63%) was observed in the control plot with lower yield (0.95 t/ha) and highest insect score (6.00) (Table 2).

Relationship between insect damage and yield

A linear negative correlation between yield and insect damage was observed during 2016. The maize yield was found significantly negative correlation ($r = -0.82$) with the insect damage percentage in maize stem borer management experiment through the application of conventional pesticides. The equation $Y= -0.164X + 4.110$ and $R^2 = 0.67$ gave the best fit (Figure 3). The estimated regression line indicated that the unit rise in the insect damage percentage during two years of experimentation (within 1-9 scale), there existed possibilities of yield reduction by 0.164 t ha^{-1}. Two year's results revealed that plot sprayed with biorational pesticide spinosad (Tracer 45% SC) @ 0.5 ml L-1 of water showed the highest efficacy against C. partellus with higher yield followed by imidacloprid @ 0.5 ml L-1 of water. This finding is supported by Ahmed et al. (2002), who found that among the biopesticides, microbial toxin spinosad (*Saccharopolyspora* spinosa) was the most effective against C. partellus where pest infestation was reduced to 3.05% after first spray.

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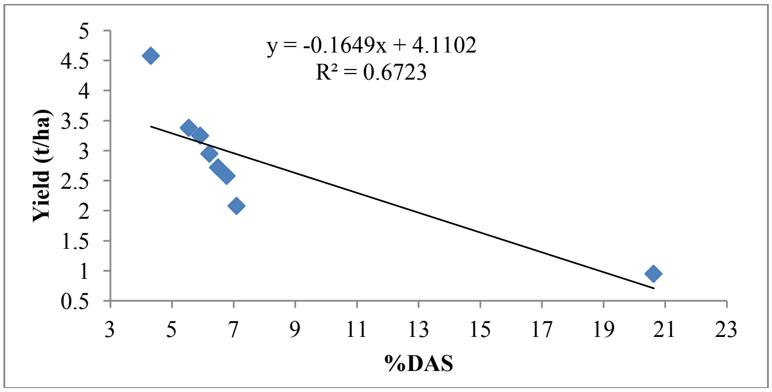

Figure 3. Relationship between insect damage % after spray and crop yield in maize stem borer management experiment at Rampur, Chitwan during 2016.

The mode of action of spinosad insecticides is may be by a neural mechanism (Orr et al., 2009). The spinosyns and spinosad have a novel mode of action, primarily targeting binding sites on nicotinic acetylcholine receptors of the insect nervous system that is distinct from those at which other insecticides have their activity. Spinosoid binding leads to disruption of acetylcholine neurotransmission (Qiao et al., 2007). Spinosad also has secondary effects as an amino-butyric acid (GABA) neurotransmitter agonist. It kills insects by hyper-excitation of the insect nervous system (Qiao et al., 2007). Spinosad so far has proven not to cause cross-resistance to any other known insecticide (Sparks et al., 2001). Among chemicals, imidacloprid provided the best control of maize stem borer with high yield from the treated plots. The present findings can also be compared with those of Mashwani et al. (2011), who reported that imidacloprid was the most effective insecticide in suppressing the *C. partellus* by 97.3%. The finding of this study is also in close agreement with the findings of Sharma and Gautam (2010) who reported that in control plots, maize yield was less by 27.9 % due to infestation of maize stem borer as compared to pesticide applied plots. Several control approaches such as biological, cultural and judicious use of chemicals are equally important against maize stem borer (Sharma & Gautam, 2010).

CONCLUSION

Over the years, the plot sprayed twice with spinosad 45% EC at 0.5 ml L^{-1} of water during foliar first at 15 days after emergence and second before tasseling stage was found effective bio-pesticide to control maize stem borer damage and also increase the yield.

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REFERENCES

Ahmad, S., Mushtaq, A., & Rauf, I. (2002). Field efficacy of some bio-insecticides against maize and jowar stem borer, *Chilo partellus* (Lepidoptera: Pyralidae). *International Journal of Agriculture & Biology, 4*(3), 332-334.

Chatterji, S.M., Young, W.R., Sharma G.C., Sayi, I.V., Chall, B.S., Khare, B.P., Rathor, Y.S., Panwar, V.P.S., & Siddiqui, K.H. (1969). Estimate of loss in maize due to insect of maize with special reference to borer. *Indian Journal of Entomology*, *31*, 109-115.

Gyawali, B.K. (1978). Studies on field biology on maize borer. The 4th National Maize Development Workshop (Jan 9-19, 1978) held at Rampur, Chitwan Nepal.

James, C. (2003). *Global Review of Commercialized Transgenic Crops: 2002 Feature: Bt Maize*. ISAAA. Brief No. 29. ISAAA: Ithaca, New York USA.

Mashwani, A.M., Ullah, F., Sattar, S., Ahmand, S., & Khan, M.A. (2011). Efficacy of different insecticides against maize stem borer, *Chilo partellus* swinhoe (*Lepidoptera: Pyralidae*) at Peshawar and Swat valleys of Khyber Pakhutunkhwa, Pakistan. *Sarhad Journal of Agriculture*, *27*(3), 459-465.

Mathur, L.M.L. (1994). Advances in insect pest management in Maize. In: G.S. Dhaliwal and Ramesh (eds.), Trends of agriculture insect pest management, Common wealth publisher, New Delhi, India, pp.113-160.

Neupane, F.P. (1986). Temperature-developmental relationship of maize borer, *Chilo partellus* (Lepidopter: Pyralidae) in Nepal. Nepalese Journal of Agricultural Science 17, 23-35.

Orr, N., Andrew, J., Shaffner, K.R., & Gary. D.C. (2009). Novel mode of action of spinosad: Receptor binding studies demonstrating lack of interaction with known insecticidal target sites. *Pesticide Biochemistry and Physiology*, *95*, 1–5.

Pingali, P.I. (2001). CIMMYT. 1999-2000. *World Maize Facts and Trends, Meeting World Maize Need: Technological Opportunities and Priorities for the Public Sector*. CIMMYT, Mexico. D.F. 57p.

Qiao, M., Daniel, E., Snyder, J.M., Alan, G.Z., Sonya, J.G., Larry, R.C., Robyn, L.S., & Davide, R.Y. (2007). Preliminary Studies on the effectiveness of the novel pulicide, spinosad, for the treatment and control of fleas on dogs. *Veterinary Parasitology*, *1*, 345–351.

Saxena, K.C., & Shrivastav, R.C. (1997). Insect pest of maize crop. In: Entomology, at a glance, New Delhi, India. 219p.

Sharma, P.N., & Gautam, P. (2010). Assessment of yield loss in maize due to attack by the maize borer, *Chilo partellus* (Swinhoe). *Nepal Journal of Science and Technology*, 11, 25-30.

Sparks, T., Gary, D.C., & Gregory, D. (2001). Natural products as insecticides: the biology, biochemistry and quantitative structure-activity relationships of spinosyns and spinosoids". *Pest Management Science*, *57*, 896-899.

Tefera T., Mugo, S., Tende, R., & Likhayo, P. (2011). *Methods of Screening Maize for Resistance to Stem Borers and Post-harvest Insect Pests.* CIMMYT. Nairobi, Kenya. pp. 1-30.

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Maize production in mid hills of Nepal: from food to feed security

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ABSTRACT

This study was undertaken in 2016 to analyze the production and utilization of maize in Nepal. Sixty maize growers from Kavre and Lamjung districts were selected using purposive, cluster and simple random sampling techniques. Similarly, six feed industries and five maize experts from Chitwan district were also interviewed. Study shows 56% of the total areas were used for maize production and 50% of the maize areas were covered by hybrid maize. There was no practice of contract maize production. The results revealed that 60%, 25% and 3% of the grain were used for animal feed, food and seed respectively in hill districts. Whereas the remaining amount of the maize (12%) was sold to the different buyers. The proportion of maize feed supply to different animals in the study area was varying. Result shows that at least 1.5 million tons of maize is required only to the feed industries affiliated with national feed industry association in Nepal. Similarly, out of total maize used in feed production, 87% of the maize was imported from India each year by feed industries. Analysis shows negative correlation between scale of feed production and use of domestic maize due to unavailability of required quantity of maize in time. The major pre-condition of feed industries for maize buying was moisture content which must be equal or less than 14%. Very little or no inert materials and physical injury, free from fungal attack and bigger size were also the criteria for maize buying. However, some of the feed industries were also thinking about protein and amino acid contents. Result shows 13% and 8.5% increasing demand of poultry feed and animal feed, respectively over the last five year in Nepal. Most likely, maize is known as a means of food security in Nepal, however, in the context of changing utilization patterns at the farm level and also tremendous increasing demand of maize at the industry level suggest to give more focus on development and dissemination of maize varieties that can contribute to the feed security issues as well.

Key words: Maize, feed security, food security, utilization pattern, food habit

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INTRODUCTION

Maize (*Zea mays* L.) is main crop after Rice in Nepal in term of area and production (MOAD, 2015). Ranum et al. (2014) reported that 98 g/person/day were the per capita maize consumption in Nepal, which was the highest in the South Asia. It is a principal food crop of the hilly farmers and source of animal feed for different feed industries in Terai region of Nepal (KC et al., 2015). In the hills of Nepal, more than 86% maize production has been used for human consumption and 80% maize production in the Terai is used for poultry and animal feed (Gurung et al., 2011). The farm level yield of maize (2.45 t/ha) is not satisfactory as compared to attainable yield (5.7 t/ha) in Nepal (MOAD, 2014; KC et al., 2015). Similarly, the seed replacement rate is also low in maize (11.3%) in Nepal (Pokharel, 2013). It is reported that the demand for maize has been growing by 5% over the last decade (Sapkota & Pokhrel, 2010). It is also reported that about 0.5 million ton feed has been produced annually in Nepal by the 114 feed industries. However, the feed demand is increasing at the rate 11 % per annum (CDD, 2011). There was about 40-45% of maize import from India every year (Bhattarai, 2011). But there is gradual decrease in import of maize in recent years. MOAD/CBS reported that the Maize import dependency ratio has decreased by 11% over the period from 2008-2014. KC et al. (2015) reported that there is shifting in demand from food to feed for livestock and poultry in Nepal. It has been observed the increasing trends of consuming more quantity of protein and micro-nutrient rich food items in Nepal in the recent days compared to last decades (MOAD/CBS, 2016). Until 2016, NARC has developed 30 varieties of maize (NMRP, 2015; NMRP, 2013; NARC, 2016). Out of 30 varieties, 5 were hybrids (Gaurab, Khumal Hybrid-2, Rampur Hybrid-2, Rampur Hybrid-4 and Rampur Hybrid-6) and 6 were de-notified (Makalu-2, Janaki, Sarlahi Seto, Hetauda Composite, Kakani Pahelo and Rampur Pahelo) (NMRP, 2015). In addition, 34 imported hybrids of maize were registered in Nepal (NMRP, 2013). In this context, we are interested to look at the production and utilization pattern of maize in hills of Nepal in changing context of food to feed security.

MATERIALS AND METHODS

Selection of Study Sites and Sample

At the first stage, Kavre and Lamjung districts were selected purposely based on potentiality of maize production to represent hills ecology in the central and western development region respectively. After consultation with officials from respective Agricultural Development offices, Kashikhanda pocket from Kavre and Ramgha pocket from Lamjung were selected. Then, 30 farmers were selected randomly from each pocket. Six feed industries were selected randomly from Chitwan district to represent major maize production districts and major hub of feed industries in the country.

Techniques used in data collection and analysis

Desk reviews were undertaken to understand maize production and their utilization patterns in Nepal. Survey was conducted with different feed industries to analyze different aspects such as the feed production, raw materials utilization, demand trend of feed for different animals etc. Expert consultation meeting was done at each proposed districts with DADO officials and other experts in the districts. In case of households and feed industries survey, face to face interview were done using semi-structured questionnaire. After collecting the data, it was compiled, reviewed and cleaned before final analysis for the accuracy of the results. This study used both descriptive statistics as well as inferential statistics. In case of inferential statistics, independent samples T-test was used to analyze the average maize yield, hybrid yield and per farm production of maize in the sample.

RESULTS AND DISCUSSION

Maize Research and production environment

Average land holding size in the study area was 0.50 ha, that is lower than national average which is 0.68 ha (MOAD, 2015). About 56% of the total area was used for maize production; this percentage was a higher in Kavre compared to Lamjung district. Twenty seven per cent farmers in the study area were using only hybrid seed. It is higher in Kavre (44%) than in Lamjung district (9%). In totality, 50% of the maize areas were covered by hybrid maize in the study area. The percentage of hybrid coverage was far higher in Kavre (70%) than in Lamjung district (13%). One third of the farmers in the study area were using both hybrid and improved seed (Table 1). CDD (2011) reported that about 71% of land is utilized for hybrid maize cultivation in Kavre by the maize mission participating farmers. Out of 25 improved varieties of maize released by NWRP, only 3 (Deuti, Rampur composite and Arun-2) were found in the field. Clear cut mandate to research and extension is required for integration/packaging of technology generated from NARC, which is utmost necessary for further up scaling of technology (Timsina et al., 2016c). Study shows none of the farmers in Lamjung were using Deuti variety; they were using Rampur composite, Arun-2 and other own saved seed which they were unable to tell the name of varieties (Figure 1). Paudyal (2001); Lamichhane et al. (2015) reported the decreasing trend of local maize varieties in mid hills of Nepal. Rampur Composite, Arun 2 and Manakamana 6 are improved varieties popular in the western hills of Nepal (Lamichhane et al., 2015).

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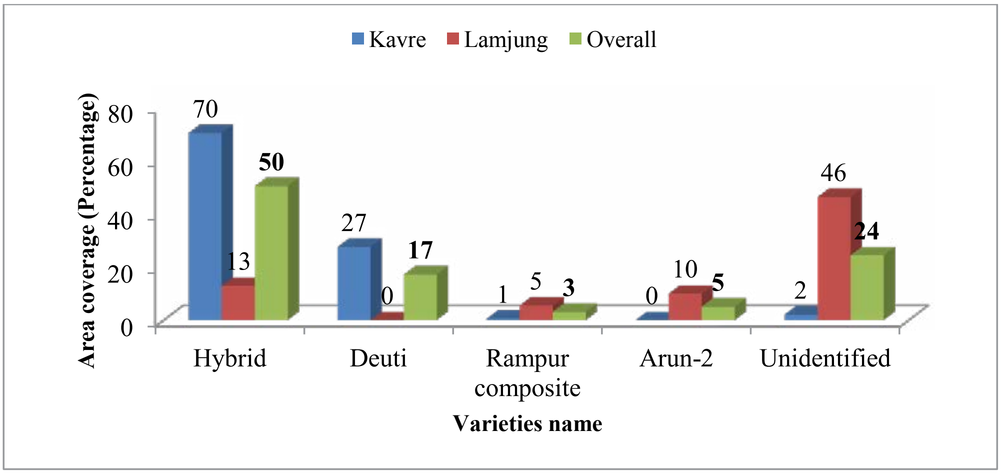

Figure 1. Coverage of different maize varieties in the study area.

Table 1: Description of maize production environment in the study area.

Description	Study area		
	Kavre (n=30)	Lamjung (n=30)	Overall (n=60)
Average land holding (ha)	0.59	0.44	0.50
Land allocated for maize production per farm (ha)	0.34	0.20	0.28
Farmers using hybrid maize only (%)	44	9	27
Farmers using improved variety only (%)	16	66	40
Farmers using both hybrid and improved varieties (%)	40	25	33
Avg. production of maize per farm (kg)+	1580	640	1146 (940)**
Yield of hybrid maize (t ha^{-1})+	5.06	3.99	4.85 (1.07)**
Avg. yield of maize (t ha^{-1})+	4.63	3.20	4.09 (1.43)**

Note: Figure in parenthesis indicates mean difference. ** Significance at 1% level of significance. + Independent t-test was used. Field survey, 2016

The average yield of maize (both hybrid and Open pollinated varieties) in the study area was 4.09 t ha^{-1}. However, Kavre has significantly higher yield (4.63 t ha^{-1}) compared to Lamjung district (3.20 t ha^{-1}). The hybrid yield in Kavre (5.06 t ha^{-1}) was found significantly higher than Lamjung (3.99 t ha^{-1}) with an average yield of hybrid (4.85 t ha^{-1}) in the study area. Paudyal (2001) reported the yields of hybrid maize in the mid-hills ranged from 3.80 to 5.06 t $ha^{-1}$with mean yield of 4.43 t ha^{-1}. Yields differs significantly across locations may be due to differences in rainfall pattern; crop establishment period; input use; plant population, quality of seed; disease and pest infestation and availability of irrigation (Paudyal, 2000; Shrestha & Timsina, 2011). Lamichhane et al. (2015) reported 63% Technology Adoption Index (TAI) of maize in the hilly areas of Nepal, which provides scope for yield improvement of the maize by adopting high yielding varieties along with recommended cultural practices. The average per farm production of maize in the study area was 1146 kg, which was also significantly higher in Kavre (1580 kg)

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compared to Lamjung district (640 kg). This may be due to higher land allocation for maize production along with higher maize productivity in Kavre compared to Lamjung district (Table 1). None of the maize growers were entered in to contract maize production; they were selling only remaining amount of maize after their use in food, feed and seed. It is common understanding in Nepal that white varieties are used for food and yellow or orange varieties are used for feed purpose but none of the farmers had planned to produce different varieties based on their utilization such as food, feed and seed purpose. However, almost all varieties grown in the study area were in yellow color except Deuti (NMRP, 2015). Yellow maize is grown and consumed worldwide commonly due to availability of provitamin A carotenoids which is not found in white maize (Babu et al., 2013). Paudyal (2001) reported several socioeconomic, environmental, and cultural factors also affect to the selection of maize varieties. Moreover, many other reasons such as productivity level, maturity, foliage quality and quantity, harvesting time and farmer belief about performance of certain varieties also affect the selection of varieties.

Utilization of Maize in the study area

Farmers were using their maize for different purposes. The utilization pattern of maize varies from place to place based on the food habits of the people (Paudyal, 2001). In totality, 60%, 25% and 3% of the maize were used for feed, food and seed purpose, respectively in the study area. Whereas the remaining amount of the maize (12%) were sold to the different buyers. In some cases, 98% of their production was used as feed. Paudyal (2001) reported about 71% of maize was used for human consumption in high hills, whereas it was 54 to 73% in mid hills. However the case was different in Terai as only 27% of maize was used in consumption, remaining maize was sold to the market (46%), used as animal feed (15%), making alcohol (9%) and kept for seed (3%). In central terai, major portion of maize (95%) went to the market and remaining quantity was used for domestic feed (Paudyal, 2001). The result shows that the current situation is completely different than that of 2001 where majority of the maize production has been used in feed rather than in food in hills of Nepal. Moreover, in case of farmers involved in maize Mission Program, 50% of their production has been sold to the feed industries and remaining 34% is used for own cattle feed and 16% as food (CDD, 2011). Study shows lower proportion of maize production in Kavre was used for food purpose compared to Lamjung district, however opposite was the case in feed and sell purpose (Figure 2). CDD reported that maize demand is increased by 300 percent in Kavre from 2006-10 and majority of the maize produced (27375 ton) in the district has been used by the feed industries. In addition to this amount, feed industries has been collected about 18250 ton of maize from other districts usually from Sarlahi and some time from India as well.

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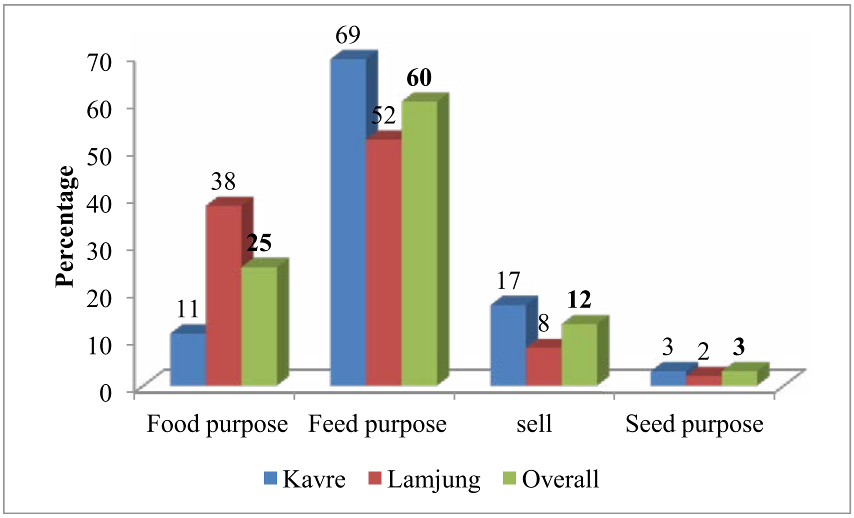

Figure 2. Distribution of maize utilization pattern in the household level (Field survey, 2016).

The proportion of maize feed supply to different animals in the study area was varying. In overall, farmers were supplying higher amount of maize feed per day to cow/s (2.59 kg), followed by buffalo/es (2.44 kg), pig/s (0.73 kg), goat/s (0.71 kg) and chicken/s (0.14 kg). In all animals, the quantity of maize feed supplied to animals was higher in Kavre compared to Lamjung district (Figure 3). This may be due to the more number of livestock animals in the Kavre district where more than 300% higher number of cattle, buffaloes, goats and pigs compared to Lamjung (MOAD, 2014). This shows that feeding supplied ratio per animal was more or less similar in the study district.

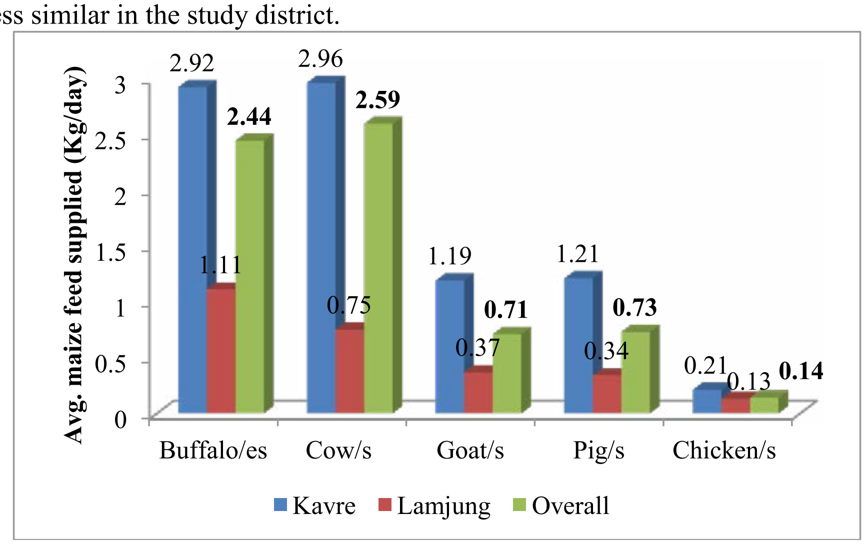

Figure 3. Details on maize utilization as a feed for different animals (Field survey, 2016)

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Maize feed production by feed industries.

The result shows that average quantity of feed produced by feed industries in the study areas was 22,200 ton per year. They were using an average 12210 ton of maize each year for producing feed. It is estimated that at least 1.5 million tons of maize is required to the existing 114 feed industries in Nepal, which is about the 70% of the total maize production (2.28 millon t) in Nepal (MoAD, 2014). Our study shows that out of total maize that was used in feed production, 87% of the maize was imported from India each year by feed industries. Analysis shows negative correlation between scale of feed production and use of domestic maize as a raw material. This is due to unavailability of required quantity of domestic maize in required time. In the domestic maize, usually feed industry has contract with different parties such as traders and farmers. Gurung et al. (2011) reported that feed industries are collecting maize grains from traders (50%), cooperatives (35%) and individual farmers (15%). Study shows that, up to 7 parties were involved for selling maize to feed industries. The major pre-condition for maize buying was moisture content which must be equal or less than 14%. Very little or no inert materials and physical injury, free from fungal attack and bigger size were also the criteria for maize buying. However, some of the feed companies were also emphasizing on protein and amino acid content. But they were not buying using such criteria. Analysis shows 13% and 8.5% increasing demand of poultry feed and animal feed, respectively over the last five year. 60% of the feed industries do not know about the quality protein maize released by NARC. They were interested to buy Nepalese maize if it would be available in required time and quantity. They suggested increasing commercial production of maize in Nepal through mechanized agriculture and encouraging cultivating maize in barren land. At the same time they also highlighted the importance of awareness creation to famers for increasing maize production adopting improved maize technologies. Establishing and improving maize seed system efficiency is also equally important (Paudyal, 2001; Ghimire, 2003). Moreover, supply of high quality farmer preferred varieties is important to increase efficiency in the seed system through achieving strategic fit in the seed supply chain (Timsina et al., 2016a, Timsina et al., 2016b & Timsina et al., 2015).

Table 2. Feed production and raw materials use in the feed industries and demand trend of feed over five years.

Particulars	Magnitude
Avg. qty. of feed produced per year (mt)	22200
Avg. qty. of maize used per year (mt)	12210
Avg. qty. of imported maize used (%)	87
Avg. qty. of domestic maize used (%)	13
Avg. demand trend of poultry feed increased over last five year (%)	13
Avg. demand trend of animal feed increased over last five year (%)	8.5

Field survey, 2016

Changing context in food habit and its effect on grain utilization pattern

About 6 kg of plant protein is required to produce 1 kg of high-quality animal protein (Pimentel and Pimentel, 2003). However, this efficiency varies widely. Worstall (2012) reported about 7

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kg, 4 kg and over 2 kg of grain required to produce 1 kg of live weight in cattle, pork and chicken, respectively. Roughly about seven times more energy is required to produce one calorie of chicken than to produce one calorie of maize for human consumption (Alter, 2010). NPC/CBS/WFP (2013) study provides some data comparing food consumption patterns in National Living Standard Survey 2 and 3 in Nepal. It is reported that the households in 2010/11 were consuming a higher quantity of micronutrient and protein rich food items as compared to 2003/04, i.e. consumption has more than doubled for meat and fish, tripled for vegetables, and fish, 40% increase in potato and over 50% for oil/ghee, eggs, fruits. In the seven year period from 2003/04, there is significant increase in the consumption of fish, meats, and poultry has been observed. For example, in rural areas in Nepal, consumption of chickens has increased by 180% since 2003/04. Timsina (2012) reported that from 1990 to 2007, there was increasing demand of more fat containing products rather than cereals in Nepal. It seems that due to changing pattern of food habit in Nepalese people, the demand of maize is growing rapidly to feed animals, as conversion ratio of plant protein to animal protein is low (Pimentel & Pimentel,2003; Worstall,2012; Economist, 2013).

CONCLUSION

The maize production in mid-hills of Nepal focusing on its utilization pattern was studied to know the current production and utilization scenarios. Study shows about 50% of the maize areas were covered by hybrid maize. There was no practice of contract maize production. Major part of the maize production has been used in farmers own animal feeding in the study area which is in increasing trend. The results revealed that 60%, 25% and 3% of the grain were used for animal feed, food and seed respectively. Whereas the remaining amount of the maize (12%) was sold to the different buyers. Similarly, feed industry has tremendous demand of maize. Out of total maize that was used in feed production, 87% of the maize was imported from India each year by feed industries. This shows a big scope to increase domestic production and supply of maize. Analysis shows negative correlation between scale of feed production and use of domestic maize. This was due to unavailability of required quantity of domestic maize in time. Result shows 13% and 8.5% per year increasing demand of poultry feed and animal feed, respectively over the last five year. Demand of meat based diet has been increasing in Nepal Moreover, it is reported that the consumers are consuming a higher quantity of micronutrient and protein rich food items compared to last decades in Nepal. In such situation, it is necessary to increase the domestic maize production focusing on feed through prioritizing hybrid maize development and its scaling up.

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REFERENCES

Alter, L. (2010). Energy Required to produce a pound of food. Retrieved from: http://www.treehugger.com/green-food/energy-required-to-produce-a-pound-of food.html

Babu, R., Palacios, N., & Prasanna, B.M. (2013). Biofortified maize – a genetic avenue for nutritional security. In: Translational Genomics for Crop Breeding: Abiotic Stress, Yield, and Quality, First Edition. (eds. RK Varshney, R Tuberosa). John Wiley & Sons, 161-176.

Bhattarai, T.C. (2011). Recent demand and supply situation of raw materials for the feed Industries in Nepal, paper presented in mission TST training in Chitwan.

CDD. (2011). Impact of maize mission program, report prepared by Crop Development Directorate, Harihar Bhawan, Lalitpur, Nepal. http://cddnepal.gov.np/downloadfile/Impact%20Study%20of%20Maize%20Mission%20Program_1465464199.pdf (accessed on 27th October, 2016).

Economist. (2013). Livestock: Meat and greens: Retrieved from: http://www.economist.com/blogs/feastandfamine/2013/12/livestock.

Ghimire, Y.N., Pokharel, T.P., & Khadka, R. (2003). Lessons Learned from the Experiences of the Scaling-up Programme of the Nepal Agricultural Research Council. In: Proceedings of workshop on "Lessons Learned from the Experiences of the Scaling-up Programme of the Nepal Agricultural Research Council", Hill Agriculture Research Project (HARP). Pp.137-144.

Gurung, D.B., KC, D. B., Ortiz Ferrara, G., Gadal, N., Pokhrel S., Bhandari, D. R., Koirala, K. B., Bhandari, B. R., & Tripathi, M. (2011). Maize Value Chians in Nepal. Paper presented in the 11th Asian Maize Confernece held at China on 7-11 November, 2011.

KC, G., Karki, T.B., Shrestha, J., & Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, *1*(1),1-9.

Lamichhane, J., Timsina, K.P., Ranabhat, D.B. & Adhikari, S. (2015). Technology adoption analysis of improved maize technology in western hills of Nepal. *Journal of Maize Research and Development*, *1*, 146-152.

MOAD. (2014). Statistical Information on Nepalese Agriculture, Ministry of Agricultural Development, 2014.

MOAD. (2015). Selected Indicators of Nepalese Agriculture and Population. Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division, Singh durbar Kathmandu, Nepal.

MOAD/CBS. (2016). Food and Nutrition Security: A Status Report. Reported by Ministry of Agricultural Development and Central Bureau of Statistics to the Food and Agricultural Organizations, Nepal.

NARC. (2016). Newly Released Crop Varieties. Published by Government of Nepal/ Nepal Agriculture Research Council, http://www.narc.gov.np/narc/varieties_released.php (accessed on 24th October, 2016).

NMRP. (2013). Registered maize Varieties in Nepal Up to 2013. Published by Government of Nepal/ Nepal Agriculture Research Council/National maize Research Program, Rampur, Chitwan.

NMRP. (2015). Characteristics of maize Varieties Developed and Released in Nepal (1966-

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16212

2015). Published by Government of Nepal/ Nepal Agriculture Research Council/National Maize Research Program, Rampur, Chitwan

NPC/CBS/WFP. (2013). Nepal Thematic Report on Food Security and Nutrition. Based on the findings of the NLSS 2010/11. NPC and CBS in collaboration with WFP, World Bank, AusAid and UNICEF. Kathmandu. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp256518.pdf (accessed on October 28, 2016).

Paudyal, K.R., Ransom, J.K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.P., & Pingali, P.L. (2001). Maize in Nepal: Production Systems, Constraints, and Priorities for Research. Kathmandu: NARC and CIMMYT.

Pimentel, D. & Pimentel, M. (2003). Sustainability of meat-based and plant-based diets and the environment. The American Journal of Clinical Nutrition, *78* (3), 6605-6635.

Pokhrel, T. (2013). Impact of Maize varieties Disseminated in Chitwan, Nepal. *Economic Journal of Nepal, 42* (6), 45-53.

Ranum, P., Pena-Rosas, J.P., & Garsia-Casal, M.N. (2014). Global maize production, utilization and consumption. *Annals of the New York Academy of Sciences*, *1*, 1312·

Sapkota, D., & Pokhrel, S. (2010). Community based maize seed production in the hills and Mountains of Nepal: A review. *Agronomy Journal of Nepal*, *1*, 107-112.

Shrestha, J., & Timsina, K.P. (2011). Agronomic Performance and Economic Analysis of Maize (*Zea mays* L.) under Different Plant Geometry and Nitrogen Rates in Chitwan, Nepal. *Nepalese Journal of Agriculture Science*, *9*, 5-13.

Timsina, K.P., Jourdain, D., & Shivakoti, G.P. (2016a). Farmer preference for seed quality: A choice experiment with tomato growers in Nepal. *International Journal of Value Chain Management*, *7* (4), 368-390.

Timsina, K.P., Bastakoti, R.C., & Shivakoti, G.P. (2016b). Achieving Strategic Fits in Onion Seed Supply Chain in Nepal. *Journal of Agribusiness in developing and emerging economies, 6* (2), 127-149.

Timsina, K.P., Ghimire, Y.N., & Pandey, S. (2016c). Existing modalities of Research and Linkage: A case of vegetable sector in Nepal. Government of Nepal, Nepal Agricultural research Council (NARC), Socioeconomics and Agricultural Policy Research Division, Lalitpur, Nepal.

Timsina, K.P. , Shivakoti, G.P., & Bradford, K.J. (2015). Supply Situation of Vegetable seeds in Nepal: An analysis from policy perspective. *Nepalese Horticulture*, *10*, 26-36.

Timsina, K.P. (2012). Analysis of Energy Requirements, Food Consumption Patterns and Food Security Situation in Nepal. Report submitted to the School of Environment, Resources and Development (SERD), Asian Institute of Technology (AIT), Thailand. Retrieved from:https://www.researchgate.net/publication/309666566_Analysis_of_Energy_Requirements_Food_Consumption_Patterns_and_Food_Security_Situation_in_Nepal.

Worstall, T. (2012). It Does Not Take 7 kg Of Grain To Make 1 kg Of Beef: Be Very Careful With Your Statistics. Retrieved from: http://www.forbes.com/sites/timworstall/2012/09/03/it-does-not-take-7-kg-of-grain-to make-1-kg-of-beef-be-very-careful-with-your- statistics/#18a40d7017b4.

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Status of maize stalk rot complex in western belts of Nepal and its integrated management

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ABSTRACT

Maize stalk rot complex is becoming a serious threat for maize growing areas of Nepal. A field monitoring for maize stalk rot complex was done during crop season (August, 2016) covering 10 farmers field each of Surkhet, Banke, Dang, Chitwan and Nawalparasi districts. Maize crop showed highly susceptible reaction to the disease at western belts of Dang and susceptible reaction was marked in Chitwan and Nawalparasi districts while the disease effect was mild at Banke and Surkhet district. Most of the plant diseases managed successfully through the application of bio-control agents, host resistance, chemicals and other different cultural control methods. The result of field experiment conducted at Dang showed that all the treatments had significant ($P \leq 0.05$) effect on percent disease index (PDI) and crop yield over farmers practice to control maize stalk rot. The higher percent disease control (52.36%) and yield increase (40.29%) were recorded from the plot sprayed with streptocyclin @ 2 g L^{-1} and insecticide (cypermethrin + chloropyrifos @ 2.5 ml L^{-1} of water during knee height and subsequent spray after 15 days interval as compared to farmers practice. Out of 30 genotypes, Rampur composit, Arun 2, Rampur 34, RamS03F08, TLBRS07F16 and Rampur 24 were found resistant against stalk rot complex with higher yield at Rampur Chitwan.

Keywords: Disease management, Stalk rot, Maize

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INTRODUCTION

Stalk rot complex of maize is now recognized as a remarkable problem in tropical and subtropical maize growing areas of Nepal. Usually post flowering maize stalk rot is prominent than pre-flowering to reduce maize yield. The pre-flowering types of stalk rot includes pythium stalk rot (*Pythium aphanidermatum*) and bacterial stalk rot (*Erwinia chrysanthemi* pv. *Zeae*), whereas others, such as *Fusarium* wilt, late wilt (*Cephalosporium maydis*), black bundle disease and charcoal rot (*Macrophomina phaseolina*), appear in the post-flowering phase (Subedi, 2015). Stalk rot is distributed throughout the country, but it is most prevalent in the hot and humid areas

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like Dang, Chitwan, Nawalparasi and Surkhet however *Pythium* stalk rot is found to be common in the mountains and the valleys in Nepal (Diwakar & Payak, 1975). From global point of view, an estimated yield loss of 9-10% have been reported due to stalk rot complex and which varied 4% in northern Europe and 14 % in South Asia and West Africa (Oerke, 2005). In Nepal bacterial stalk rot of maize (*Erwinia chrysanthemi* pv Zeae) can cause up to 80 % yield loss along with other fungal diseases in the terai area (Burlakoti & KC, 2004). Although several works have been done to cope up with other maize diseases but research activities were less in the maize stalk rot complex management in Nepal. Therefore, an instant effort is needed to manage stalk rot for tropical and subtropical maize growers. Another bitter fact is that stalk rot complex slowly becomes a serious threat in most of the terai and mid hill-low lying maize growing areas of Nepal. The complete package including development of disease resistant / tolerant variety with management practices would be effective to maize growers to tackle with the biotic constraints they faced and ultimately help to increase the maize productivity too.

MATERIALS AND METHODS

Disease monitoring

A field monitoring for stalk rot complex of maize was done during crop season (August 2016) covering about 10 farmers field each of 5 potential maize growing districts – Chitwan, Nawalparsi, Dang, Banke and Surkhet. For the surveillance, concerned officers from the respective DADOs and scientists from the NMRP, NARC research stations and CIMMYT were involved. The disease data were recorded from 10 randomly tagged plants/plot on the basis of 1-9 scoring scale (ICAR, 2012).

1 - Healthy or slight discoloration at the site of inoculation
2 - Up to 50% of the inoculated inter-node is discolored.
3 - 51-75% of the inoculated inter-node is discolored.
4 - 76-100% of the inoculated inter-node is discolored.
5 - Less than 50% discoloration of the adjacent inter-node.
6 - More than 50% discoloration of the adjacent inter-node.
7 - Discoloration of three internodes.
8 - Discoloration of four internodes.
9 - Discoloration of five or more internodes and premature death of plant

Based on the counts, disease incidence and index (severity) were recorded and suspected diseased specimens were collected for isolation and identification of pathogens under laboratory condition. Disease incidence and Percent Disease Index (PDI) (Wheeler, 1969) were calculated based on the following formula;

$$\text{Disease incidence (\%)} = \frac{\text{No. of infected plants}}{\text{Total no of plant assessed}} \times 100$$

$$\text{PDI (\%)} = \frac{\text{Sum of all numerical values}}{\text{No of plants observed}} \times \frac{100}{\text{Maximum diseases rating}}$$

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A disease monitoring form was developed to record the surveyor name, location detail, date of the survey, latitude, longitude and elevation of the survey site, crop growth stage, field area size, if disease sample collected (sample ID number) and finally any comments or observations to understand the socio economic impact of the disease. Disease maps were developed by using disease data of surveyed area.

Screening of host resistance

Thirty genotypes were tested for maize stalk rot resistance during summer season of 2016 in NMRP, Rampur. The experiment was carried out at natural epiphytotic condition following randomized complete block design with 2 replications. The plot size was 5m long with 75 cm row to row spacing and each genotype was sown in two rows. Agronomic practices were followed as recommended. The recommended fertilizers @ 120:60:40 kg ha^{-1} (N:P:K) were applied. Early plant stand, tasseling days, silking days, plant height, ear height and final plant stand were recorded. The disease severity data were recorded thrice at an interval of 10 days as described in earlier activity. The area under disease progress curve (AUDPC) was computed using midpoint rule method (Campbell & Madden, 1990). The yield data (kg ha^{-1}) and Thousand seed weight (g) were recorded.

Integrated management experiment

The experiment was conducted under natural epiphytotic condition following Randomized Complete Block design in 3 farmer's field of Pabannagar, Dang valley and considered as a hot spot for maize stalk rot severity. The unit plot size was six rows 5mmeter long with 75 cm row to row spacing i.e. 22.5 m^2 gross plot area. A maize variety Rampur Composit was sown on May 28^{th} of 2016 in all 3 fields. There were eight treatments of the experiment including cultural, agronomical, biological and chemical practices and compared with farmers practice. The treatments combinations for the experiment were designed as follows.

1. Bavistin seed treatment @ 2g kg^{-1} of seed + Saafulizer (2.5 g SAAF + 300 g Urea) during knee height and tasseling stage
2. Basal Application of high dose of phosphorous (80 kg ha^{-1}) and potassium (60 kg ha^{-1})
3. Spray streptocyclin @ 2 g L^{-1} + insecticide (cypermethrin + chloropyrifos) @ 2.5 ml/l of water during knee height and subsequent spray at15 days interval
4. Seed treatment with *Trichoderma viridae* @ (One vial of 5 ml (1×10^8 conidia/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 conidia/ml) /10 kg of FYM) per plot mixed during field preparation
5. Seed treatment with *Pseudomonas fluorescence* @ (One vial of 5 ml (1×10^8 spore/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 spore/ml) /10 kg of FYM) per plot mixed during field preparation and vegetative stage both
6. Earthing up with appropriate plant population (75×25 cm spacing) for well drainage of excess water
7. Intercropping of maize with soybean (1:2 ratio) in raised bed system + copper oxychloride @ 2 g/l of water during knee height and subsequent spray after 15 days interval
8. Farmers practice (Control).

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All treatments were replicated three times. One farmer was considered as one replication. In case of chemical, first spray was given during knee height stage and another after 15 days interval of first spray. Disease severity data was recorded before every treatment application using 1-9 scoring scale from 25 randomly tagged plants/plot as described in earlier activity. The AUDPC and PDI were calculated as described in earlier activity. Percent disease control (PDC) was calculated on the basis of the formula developed by Shivankar and Wangikar (1993). Early Plant Stand (EPS) and Final Plant Stand (FPS) were recorded as described earlier. Data was recorded on yield (kg ha^{-1}) and yield attributes after necessary sun drying. Yield increase over the farmer practice was calculated. All data were analyzed statistically using Microsoft Excel and MSTAT-C computer package program. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5% levels of significance. All percent data were subjected to arcsine transformation before statistical analysis. Disease maps were developed by using ArcGIS 10.3 software.

RESULTS AND DISCUSSIONS

Disease monitoring

The stalk rot complex symptoms were found very common and damaging in maize fields at western belts of Dang (80.86% PDI and 65.00% incidence), Chitwan (61.82% PDI and 61.00% incidence) and Nawalparasi (55.55% PDI and 52.00 % incidence) respectively (Table 1)

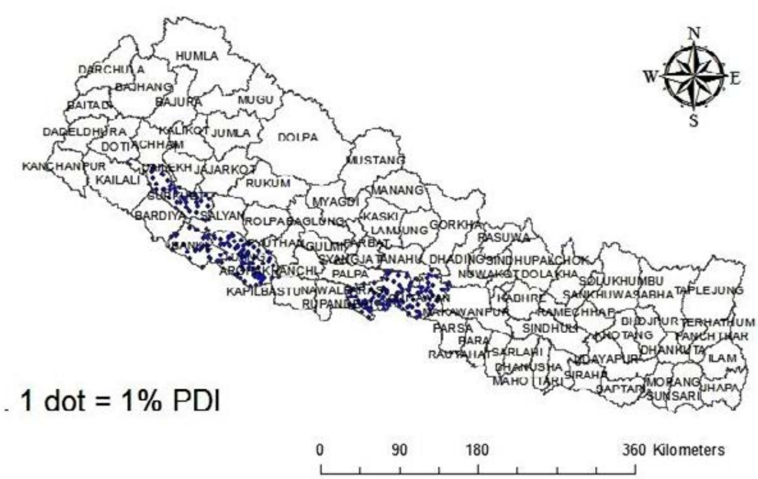

Figure 1. A disease map for disease index (Severity) of maize stalk rot complex at 5 maize growing districts of Nepal monitored during summer season (2016).

The lower disease index of 23.52 % with 14.00% incidence was recorded in Khaskusum area of Banke district followed by Surkhet having 43.57% PDI and 29.00% incidence where crop showed resistant to moderately susceptible reaction to the disease (Table 1). Disease maps for disease index or severity (Figure 1) and disease incidence (Figure 2) were developed by using the

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disease data of PDI and incidence of 5 monitored districts during August 2016 where 1 dot represents 1% PDI for Figure 1 and 1% incidence for Figure 2. Districts with higher dot densities were considered as severely infected districts for maize stalk rot complex while districts with lower dot densities were showed mild response to the disease severity and incidence.

Table 1. Disease index and incidence of maize stalk rot complex in 5 maize growing districts of Nepal during summer season of 2016

District /VDCs	Year (2016)						Disease reaction
	Disease index (PDI) (n=10)			Disease incidence (n=10)			
	Mean	SD	SE±	Mean	SD	SE±	
Banke (Khaskusum)	23.52	5.51	1.74	14.00	5.16	1.63	R
Surkhet (Dasarathpur and Mayalkuna)	43.57	5.29	1.67	29.00	7.38	2.33	MS
Dang (Aswara and Panchakule)	80.86	11.00	3.48	65.00	12.69	4.01	HS
Chitwan (Mangalpur)	61.82	8.33	2.63	61.00	8.76	2.77	S
Nawalparasi (Gaindakot and Rajahar)	55.55	10.55	3.34	52.00	12.29	3.89	S

Note : PDI- Percent Disease Index, n10 = sample size 10, SD- Standard deviation, SE- Standard error, HS- Highly susceptible, S-Susceptible, R-Resistant, MS- Moderately Susceptible

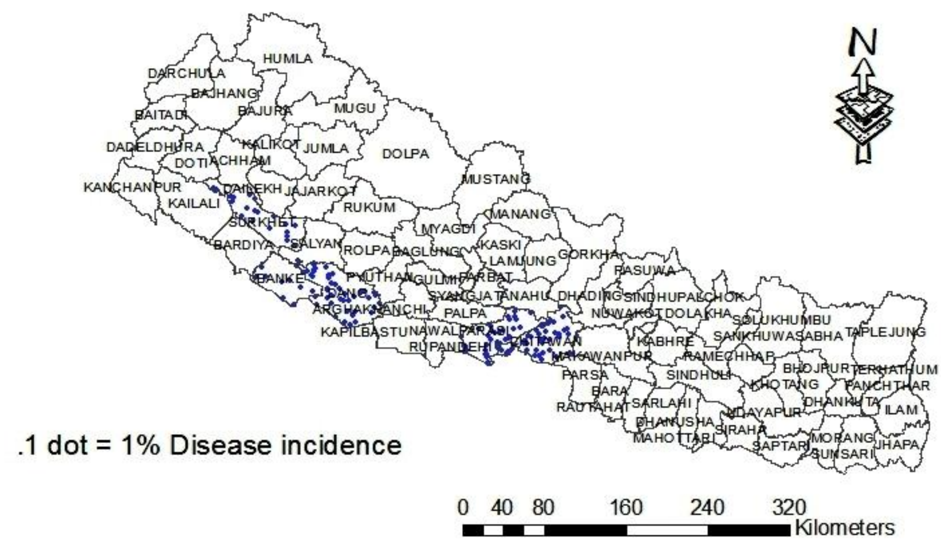

Figure 2. A disease map for disease incidence of maize stalk rot complex at 5 maize growing districts of Nepal monitored during summer season of 2016.

Screening of host resistance

The summer maize season of 2016 was affable for stalk rot complex development. The early plant stand, disease severity, final plant stand, grain yield and thousand seed weight were significantly ($P \leq 0.05$) varied among the tested maize genotypes during experiment period of 2016 at Rampur, Chitwan.

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Table 2. Screening of maize genotypes for stalk rot complex resistance at Rampur, Chitwan during 2016.

Genotypes	EPS	Disease Severity (1-9)			AUDPC	FPS	GY (kg ha^{-1})	TSWt (g)
		60 DAS	70 DAS	80 DAS				
Rampur Composit	34.50 †	1.53	2.30	4.53	53.25	29.50	2126.52	315.00
Arun 2	36.50	1.78	2.40	4.70	56.38	29.00	1987.18	347.50
Poshilo Makai 1	30.00	3.15	3.60	6.05	82.00	13.50	1343.97	282.50
S99TLYQ-B	37.00	3.15	3.58	6.05	81.75	22.00	1328.66	285.00
S99TLYQ-HG-AB	39.50	3.98	4.48	6.88	99.00	18.00	834.68	315.00
BGBYPOP	35.00	2.80	3.30	5.70	75.50	20.50	1539.79	205.00
R pop-3	33.50	3.28	3.78	6.30	85.63	16.50	1231.59	335.00
R pop-4	37.00	2.60	2.98	5.40	69.75	26.50	1643.21	267.50
Rampur Hybrid 4	35.00	2.63	2.99	5.44	70.20	20.50	1626.38	350.00
Rampur Hybrid 6	34.00	2.88	3.40	5.80	77.38	18.50	1509.41	220.00
RML 95/RML 96	39.50	4.20	4.70	7.08	103.38	18.00	864.42	275.00
RAMS03F08	33.50	2.20	2.70	4.95	62.75	26.50	1948.57	272.50
ZM 401	32.50	2.69	3.08	5.60	72.20	19.50	1669.61	342.50
ZM 627	42.00	5.08	5.30	7.40	115.38	16.50	504.51	387.50
05 SADVI	34.00	3.80	4.28	6.63	94.88	14.50	1034.42	260.00
07 SADVI	35.00	3.50	4.00	6.43	89.63	16.00	1123.63	335.00
Rampur 21	38.00	5.33	5.80	8.08	125.00	11.00	332.97	362.50
Rampur 24	34.00	3.70	4.20	6.63	93.63	15.00	1033.14	305.00
Rampur 27	36.00	2.43	2.95	5.20	67.63	25.00	1731.09	357.50
Rampur 32	27.50	2.80	3.20	5.65	74.25	12.50	1660.09	352.50
Rampur 33	33.00	3.60	4.08	6.55	91.50	14.00	1047.43	267.50
Rampur 34	32.50	1.98	2.60	4.90	60.38	24.50	1935.05	367.50
Rampur 36	37.00	3.08	3.58	6.05	81.38	20.50	1363.18	275.00
TLBRS07F16	37.50	2.40	2.90	5.08	66.38	25.50	1762.28	415.00
Across 9331 RE	35.50	3.40	3.90	6.33	87.63	19.50	1181.24	365.00
Across 9942/Ac 9944	29.50	3.73	4.30	6.68	95.00	8.00	1032.72	352.50
BLBSRS07F10	37.00	2.93	3.43	5.88	78.25	23.00	1540.43	317.50
TLBRS07F14	36.00	3.63	4.13	6.65	92.63	17.50	1075.79	357.50
Arun-4	40.00	2.84	3.28	5.73	75.58	26.00	1545.13	315.00
Farmer's Local (SC)	41.00	5.20	5.55	7.58	119.38	14.00	421.61	315.00
Grand mean	35.43	3.21	3.69	6.06	83.25	19.38	1332.62	317.33
F-test	**	**	**	**	**	**	**	**
LSD (≤0.05)	2.89	0.08	0.10	0.14	1.82	1.79	65.15	16.04
CV%	3.98	1.27	1.34	1.11	1.07	4.50	2.39	2.47

† Means of 2 replications. EPS- Early Plant Stand, AUDPC- Area under Disease Progress Curve, FPS- Final Plant Stand, GY- Grain Yield (kilogram/hectare), TSWt- Thousand Seed Weight (gram), DAS- Days after Sowing, SC- Susceptible Check, **- highly significant

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Table 3. Evaluation of agronomic traits in maize genotypes in stalk rot complex screening nursery at Rampur, Chitwan during 2016.

Genotypes	50% Tasseling	50% Silking	Plant height (cm)	Ear height (cm)
Rampur Composit	48.00†	52.00	180.00	95.50
Arun 2	46.00	49.50	180.00	88.00
Poshilo Makai 1	48.00	52.00	178.00	90.50
S99TLYQ-B	48.50	52.00	156.00	83.00
S99TLYQ-HG-AB	52.00	55.00	171.00	86.50
BGBYPOP	47.50	51.50	164.50	87.00
R pop-3	50.00	52.50	147.00	88.00
R pop-4	48.50	52.00	176.00	100.00
Rampur Hybrid 4	54.50	57.50	149.00	73.50
Rampur Hybrid 6	54.50	57.50	160.00	81.00
RML 95/RML 96	56.50	59.50	174.00	94.50
RAMS03F08	50.50	54.00	185.00	99.50
ZM 401	48.50	52.50	159.50	83.00
ZM 627	52.50	55.50	149.50	74.50
05 SADVI	54.00	57.00	150.00	69.50
07 SADVI	53.50	57.50	166.00	81.50
Rampur 21	51.50	54.50	184.00	75.00
Rampur 24	55.00	58.00	135.50	60.00
Rampur 27	56.50	59.50	160.50	79.00
Rampur 32	55.00	58.00	172.50	84.50
Rampur 33	54.00	58.50	139.50	73.00
Rampur 34	55.00	59.00	154.00	65.50
Rampur 36	55.00	58.50	163.50	73.00
TLBRS07F16	57.50	60.50	173.00	87.50
Across 9331 RE	49.50	52.50	149.50	61.50
Across 9942/Ac 9944	54.00	57.50	171.00	73.00
BLBSRS07F10	50.50	53.50	174.00	87.00
TLBRS07F14	56.50	59.50	157.00	75.00
Arun-4	47.00	50.00	143.00	70.00
Farmer's Local (SC)	57.50	60.50	172.00	83.50
Grand mean	52.25	55.58	163.15	80.77
F-test	**	**	**	**
LSD (≤0.05)	4.98	4.91	7.50	5.42
CV%	4.66	4.32	2.25	3.28

† Means of 2 replication. Cm- centimeter, SC- Susceptible Check, **- highly significant

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Out of 30 genotypes, Rampur Composite, Arun 2, RamS03F08, Rampur 34, TLBRS07F16 and Rampur 24 were resistant having area under disease progress curve (AUDPC) value of 53.25, 56.38, 60.38, 62.75, 66.38 and 67.6 respectively (Table 2). The other remaining genotypes showed moderately susceptible and susceptible reaction to the disease. The high yielding genotypes were Rampur Composite (2126.52 kg ha^{-1}), Arun-2 (1987.18 kg ha^{-1}), RAMS03F08 (1948.57 kg ha^{-1}), Rampur 34 (1935.05 kg ha^{-1}), TLBRS07F16 (1762.28 kg ha^{-1}) and Rampur 24 (1731.09 kg ha^{-1}) (Table 2). The genotypes having higher thousand seed weight were TLBRS07F16 (415 g), ZM 627 (387.5 g), Rampur 34 (367.5 g), Across 9331 RE (365 g), Rampur 21 (362.5 g) and Rampur 27 (357.5 g) (Table 2).

Relationship between grain yield (kg/ha) and AUDPC

During summer maize season (2016), among 6 (3 high yielding genotypes - Rampur Composit, Arun 2, RAMS03F08 and 3 low yielding genotypes ZM 627, Farmers local and Rampur 21), grain yield was found to had highly significant negative correlation (r = -0.99) with the AUDPCof maize stalk rot complex disease. The predicted linear regression line also displayed downward slope i.e. y = - 0.039x+136.5, with regression coefficient R^2 = 0.99, where 'y' denoted predicted crop yield of maize genotypes and 'x' stood for AUDPC of stalk rot complex of maize (Figure 3). The estimated regression line indicated that the unit rise in the AUDPC of stalk rot complex disease (within 1-9 scale), there existed possibilities of yield reduction by 0.039 kg ha^{-1}.

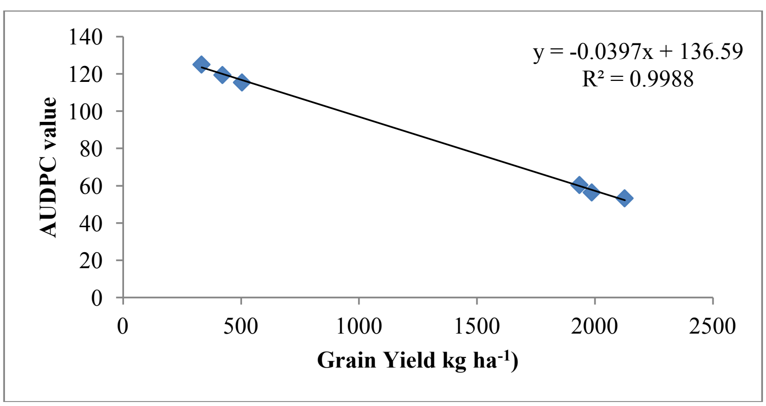

Figure 3. Relationship between crop yield (kg/ha) and AUDPC of maize stalk rot complex in screening experiment at Rampur, Chitwan during 2016

The result showed that tasseling days varied from 46 days (Arun 2) to 57.5 days (TLBRS07F16). Similarly, the silking day varied from 49.5 days (Arun 2) to 60.5 days (TLBRS07F16). The tested genotypes were highly significant for tasseling and silking days (Table 3). The plant height varied from 135.50 cm (Rampur 24) to 185.00 cm (RAMS03F08). Similarly, the ear height also varied from 60.00 cm (Rampur 24) to 100.00 cm (R pop-4). The plant height and ear height were significantly varied among the tested genotypes (Table 3).

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Integrated management

All the treatments had significant ($P \leq 0.05$) effect on percent disease index (PDI) and crop yield over farmers practice. The higher percent disease control (52.36%) and yield increase (40.29%) were recorded from the plot sprayed with streptocyclin @ 2 g/l and insecticide (cypermethrin + chloropyrifos) @ 2.5 ml/l of water during knee height and subsequent spray after 15 days interval as compared to farmers practice (Table 5). Similarly, the lower percent disease index (52.65% PDI) with higher yield (3589.00 kg ha^{-1}) was also found in the plot where maize seed were treated with Bavistin as a seed treatment @ 2g kg^{-1} of seed and soil application of Saafulizer (2.5 g SAAF + 300 g Urea) during knee height and tasseling stage as compared to farmer practice (PDI- 85.75% and yield -2760.00 kg ha^{-1}) (Table 4). The plot applied with basal application of high dose of phosphorous (80 kg ha^{-1}) and potassium (60 kg ha^{-1}) recorded significantly lower PDI (65.75%) (Table 4) with higher yield increase (19.71%) as compared to farmer practice (Table 5).

Relationship between disease control and yield increase

During the experimental period, the yield increase showed significantly highly positive correlation ($r = 0.99$) with the controlled maize stalk rot complex disease by the application of cultural, biological and chemical means. The predicted linear regression line was displayed upward slope i.e. $y = 0.799x - 0.463$, with regression coefficient $R^2 = 0.98$, where 'y' denoted predicted yield increase of maize and 'x' stood for disease control due to applied treatments (Figure 4). The estimated regression line indicated that the unit rise in the percent disease control of maize stalk rot complex (within 1-9 scale) due to applied treatments, there existed possibilities of yield increase by 0.80 percent.

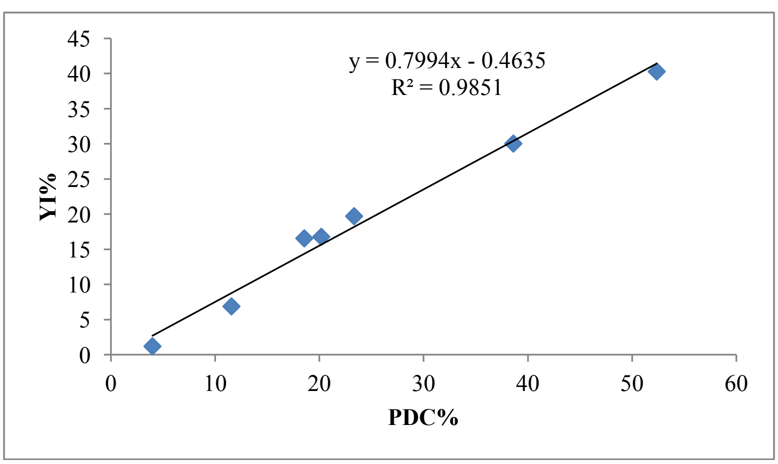

Figure 4. Relationship between disease control and yield increase in disease management experiment through cultural, biological and chemical means at Pabannagar, Dang during 2016.

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Table 4. Effect of cultural, biological and chemical practices on stalk rot complex severity and yield performance of maize at Pabannagar, Dang during 2016.

Treatments	EPS	AUDPC	PDI%	FPS	Yield ($kg\ ha^{-1}$)	TSWt (g)
1. Bavistin seed treatment @ 2g kg^{-1} of seed + Saafulizer (2.5 g SAAF + 300 g Urea) during knee height and tasseling stage	126.67[†]	49.70[g]	52.65[g]	102.30[ab]	3589.00[b]	370.70[a]
2. Basal Application of high dose of phosphorous (80 kg/ha) and potassium (60 kg ha^{-1}).	122.33	69.08[f]	65.75[f]	98.67[bc]	3304.00[c]	355.00[b]
3. Spray streptocyclin @ 2 g L^{-1}+ insecticide (cypermethrin + chloropyrifos @ 2.5 ml L^{-1} of water during knee height and subsequent spray after 15 days interval	117.67	47.08[h]	40.85[h]	106.00[a]	3872.00[a]	375.70[a]
4. Seed treatment with *Trichoderma viridae* @ (One vial of 5 ml (1×10^8 conidia/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 conidia/ml) /10 kg of FYM) per plot mixed during field preparation	127.33	71.83[e]	68.45[e]	95.67[bcd]	3223.00[d]	342.30[c]
5. Seed treatment with *Pseudomonas fluorescence* @ (One vial of 5 ml (1×10^8 spore/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 spore/ml) /10 kg of FYM) per plot mixed during field preparation and vegetative stage both	116.00	73.83[d]	69.85[d]	95.00[cd]	3217.00[d]	330.00[d]
6. Earthing up with appropriate plant population (75×25 cm spacing) for well drainage of excess water	109.67	78.42[c]	75.85[c]	93.67[cd]	2950.00[e]	316.00[e]
7. Intercropping of maize with soybean (1:2 ratio) in raised bed system + copper oxychloride @ 2 g L^{-1} of water during knee height and subsequent spray after 15 days interval	113.67	82.25[b]	82.35[b]	93.00[cd]	2793.00[f]	310.00[e]
8. Farmers practice (Control)	107.33	95.25[a]	85.75[a]	88.67[d]	2760.00[f]	307.70[e]
Grand mean	117.58	70.93	67.69	96.63	3213.65	338.42
F-test	NS	**	**	*	**	**
LSD (≤0.05)	22.99	1.15	1.13	6.68	79.28	9.12
CV%	11.17	0.93	0.95	3.95	1.41	1.54

[†] Means of 3 replication. Means in column with same superscript is not significantly different by DMRT (P<0.05). EPS-early plant stand, AUDPC- Area under disease progress curve, PDI-percent disease index, FPS-final plant stand, TSWt-thousand seed weight, Kg/ha-Kilogram per hectare, g- gram, %- percent, ml-milliliter, l-liter, cm-centimeter, NS-not significant, *-significant, **- highly significant

Stalk rot is widespread throughout the country, but most common in the hot and humid areas (Shah, 1968). The disease usually appears at the tasseling stage (Diwakar & Payak, 1975). The incidence of disease is significantly influenced by both environmental and host factors. The symptoms become evident after flowering and towards maturity, when plants show premature drying. The pathogen commonly affects the roots, crown region and lower internodes. When split open, the stalks show a pink-purple discoloration with collapse of the pith region (De Leon, 1984). Temperature and relative humidity have been found to affect both the growth of the pathogen and disease development.

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Table 5.Effect of different treatments on stalk rot disease control and yield increase percent of maize at Pabannagar, Dang during 2016

Treatments	PDC%	YI%
1. Bavistin seed treatment @ 2g kg^{-1} of seed + Saafulizer (2.5 g SAAF + 300 g Urea) during knee height and tasseling stage	38.60	30.04
2. Basal Application of high dose of phosphorous (80 kg/ha) and potassium (60 kg ha^{-1}).	23.32	19.71
3. Spray streptocyclin @ 2 g L^{-1} + insecticide (cypermethrin + chloropyrifos @ 2.5 ml L^{-1} of water during knee height and subsequent spray after 15 days interval	52.36	40.29
4. Seed treatment with *Trichoderma viridae* @ (One vial of 5 ml (1×10^8 conidia/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 conidia/ml) /10 kg of FYM) per plot mixed during field preparation	20.17	16.78
5. Seed treatment with *Pseudomonas fluorescence* @ (One vial of 5 ml (1×10^8 spore/ml) /kg of seed) + soil application @ (One vial of 5 ml (1×10^8 spore/ml) /10 kg of FYM) per plot mixed during field preparation and vegetative stage both	18.54	16.56
6. Earthing up with appropriate plant population (75×25 cm spacing) for well drainage of excess water	11.55	6.88
7. Intercropping of maize with soybean (1:2 ratio) in raised bed system + copper oxychloride @ 2 g L^{-1} of water during knee height and subsequent spray after 15 days interval	3.97	1.20
8. Farmers practice (Control)		

PDC-percent disease control, YI- yield increase, Kg/ha- Kilogram per hectare, %- percent, g- gram, %- percent, ml-milliliter, l-liter, cm-centimeter

The maximum disease development occurs within a temperature range of 30-35°C, with a relative humidity of 80-100% (Subedi, 2015). Waterlogged, low-lying or poorly drained field conditions favor a high degree of disease development. Plant age (pre-flowering growth stage) and a large plant population (≥ 60000 per ha) favor a high incidence of disease (Diwakar and Payak, 1980). Some resistant material has been identified. Resistance to stalk rot disease involves several traits including physiological, morphological and functional characters. Maize stalk strength is determined by both stalk morphology and abiotic stress factor (Singh et al, 2012). Stalk rot infectivity depends on environmental factors, the genotype and environment interaction (G×E) and host resistance of maize genotypes to the pathogens (Szoke et al, 2007). Ledencan et al (2003) marked low disease scoring of hybrids than inbreds and differed significantly in resistance and infection types. Hybrids Ganga Safed-2, Hi-starch, and composites Suwan 1 and Suwan 2, have shown resistance in India. The findings of this experiment are also supported by Thind et al. (1984) who found that spray and soil drenching of streptocycline (100 μg/ml) alone and in combination with Blitox 50 WP (2000 μg ml^{-1}) showed most effectual for the control of maize stalk rot caused by *Erwinia chrysanthemi* pv. zeae. Similarly, Burlakoti and Khatri-Chhetri (2004) also highlighted the foliar spray of streptocycline (100 ppm) was effective for the control of bacterial stalk rot of maize. An application of 75% captan per 100 l water applied as a soil drench at the base of the plant when the crop is 5-7 weeks old) can check this disease effectively (Payak & Renfro, 1974). The diseases are known to occur in Nepal, India, Indonesia, Pakistan, Philippines, Thailand and Vietnam. They are observed more commonly if there is a period of drought during or shortly after pollination (Subedi, 2015). Agronomically desirable stalk rot-resistant materials are available in Pakistan, India, Mexico and Zimbabwe, where selections against these diseases have been made. The 'stay green' character, in which plants remain green after attaining physiological maturity, has been associated with resistance to certain post-flowering stalk rots (Subedi, 2015). There is evidence of mammalian toxicity where stalks infected with these pathogens.

CONCLUSION

The result from field monitoring revealed that the maize stalk rot complex was severe in western maize growing belts of Dang while susceptible reaction was marked at Chitwan, Nawalparasi and Surkhet districts. The disease was found mild at Banke district. The higher percent disease control (52.36%) and yield increase (40.29%) were recorded from the plot sprayed with streptocyclin @ 2 g L^{-1} and insecticide (cypermethrin + chloropyrifos @ 2.5 ml L^{-1} of water during knee height and subsequent spray after 15 days interval as compared to farmers practice. Similarly, the findings from the screening experiment showed that out of 30 genotypes, Rampur Composit, Arun 2, Rampur 34, RamS03F08, TLBRS07F16 and Rampur 24 were found resistant against stalk rot complex with higher yield at Rampur Chitwan.

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REFERENCES

Burlakoti, R.R., & K.C, G.B. (2004). Bacterial diseases of crop plants in Nepal: a review. *Journal of Institute of Agriculture and Animal Science*, *25*, 1-10.

Campbell, C. L., & Madden, L.V. (1990). *Introduction to Plant Disease Epidemiology*. John Wiley & Sons, New York City.

De Leon, C. (1984). *Maize Diseases, a Guide for Field Identification,* 3rd edn. CIMMYT, EI Batan, Mexico.

Diwakar, M. C., & Payak, M.M. (1980) Influence of some environmental and host factors on Pythium stalk rot of maize. *Indian Phytopathology. 33*, 10—15

Diwakar, M.C., & Payak, M.M. (1975). Germplasm reaction to pythium stalk rot of maize. *Indian Phytopathology*, 28(4), 548-549.

ICAR. (2012). *Inoculation methods and disease rating scales for maize diseases*. Revised edn. Directorate of Maize Research. Indian Council of Agricultural Research, Pusa Campus, New Delhi-110012. India. Pp. 20-28.

Ledencan. T., Simic, D., Brkic, I., Jambrovic, A., & Zdunic, Z. (2003). Resistance of maize inbreds and, their hybrids to Fusarium stalk rot. *Czec Journal of Genetics and Plant Breeding*, 39, 15-20

Oerke, E.C. (2005). Crop losses to pests. *The journal of Agricultural Science*, *144*, 31-43.

Payak, M. M., & Renfro, B.L. (1974). A decade of research on maize diseases: impact on production and its international cooperative outreach. In: *Current Trends ill Plant Pathology* (Ed. by S. P. Rychaudhuri and J. P. Verma) pp. 160--170, Department of Botany, Lucknow University. India.

Shah, S.M. (1968). Diseases of maize in Nepal. In: Fifth Inter-Asian corn improvement workshop, Department of agriculture and Kesetsart University, Bangkok, Thailand.

Shivankar, S.K., & Wangikar, P.D. (1993). Effect of different fungicides on the control of gray mildew disease of cotton. *Indian Phytopathology*, *46* (3), 230-235.

Singh, N., Rajendran, A., Meena, S., & Mittal, G. (2012). Biochemical response and host-pathogen relation of stalk rot fungi in early stages of maize (*Zea mays* L.) *African Journal of Biotechnology*, *11*(82), 14837-14843

Subedi, S. (2015). A review on important maize diseases and their management in Nepal. *Journal of Maize Research and Development, 1*(1), 28-52.

Szoke, C.S., Árendas, T., Racz, F., Pinter, J., Nagy, E., & Marton, L.C. (2007). Correlation between maize genotypes and the stalk rot caused by maize Fusarium. *Acta Agronomy Hungarica*, *55*(4), 447-452.

Thind, B.S., Randhawa, P.S. & Soni, P.S. (1984). Chemical control of bacterial stalk rot (*Erwinia chrysanthemi* pv. Zeae) and leaf stripe (*Pseudomonas rubilineans*) of maize. *Journal of Plant Disease and Protection*, *91*(4), 424-430.

Wheeler, B.E.J. (1969). *An introduction to plant diseases*. John Wiley and Sons. Ltd. London. pp. 301.

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Assessment of soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

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ABSTRACT

Soil test-based fertility management is important for sustainable soil management. This study was carried out to determine the soil fertility status of the Agriculture Research Station, Belachapi, Dhanusha, Nepal. Using soil sampling auger 25 soil samples were collected randomly from a depth of 0-20 cm. Soil sampling points were identified using GPS device. Following standard methods adopted by Soil Science Division laboratory, Khumaltar, the collected soil samples were analyzed to find out their texture, pH, N, P_2O_5, K_2O, Ca, Mg, S, B, Fe, Zn, Cu, Mn and organic matter status. The soil fertility status maps were made using Arc-GIS 10.1 software. The observed data revealed that soil was grayish brown in colour and sub-angular blocky in structure. The sand, silt and clay content were 36.03±3.66%, 50.32±2.52% and 25.42±2.25%, respectively and categorized as eight different classes of texture. The soil was acidic in pH (5.61±0.14). The available sulphur (0.73±0.09 ppm) status was very low, whereas organic matter (1.34±0.07%), available boron (0.56±0.10 ppm), available zinc (0.54±0.22 ppm) and available copper (0.30±0.01 ppm) were low in status. The extractable potassium (95.52±13.37 ppm) and extractable calcium (1264.8±92.80ppm) exhibited medium in status. In addition, available phosphorus (33.25±6.97 ppm), available magnesium (223.20±23.65 ppm) and available manganese (20.50±2.43 ppm) were high in status. Furthermore, available iron (55.80±8.89 ppm) status was very high. To improve the potentiality of crops (maize, rice, wheat etc.) for studied area, future research strategy should be made based on its soil fertility status.

Keywords: Nutrient management, research efficacy, soil fertility maps; and soil testing

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INTRODUCTION

The sustainability of any system has become major concern now days. The evaluation of soil fertility is perhaps the most basic decision making tool in order to impose appropriate nutrient management strategies (Brady & Weil, 2004). There are various techniques for soil fertility evaluation, among them soil testing is the most widely used in the world (Havlin et al., 2010). Soil testing assess the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and to maintain the adequate fertility in soils for longer period. The texture, structure, colour etc. are important soil physical parameters. Similarly, soil reaction (pH), organic matter, macro and micronutrients etc. are also important soil chemical parameters. The physical and chemical tests provide information about the capacity of soil to supply mineral nutrients (Ganorkar & Chinchmalatpure, 2013). Spatial variation across a field become great challenge for assesses soil fertility of an area. Describing the spatial variability of soil fertility across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough & McDonnell, 1998). Nepal Agricultural Research Council (NARC) was established to strengthen agriculture sector in the country through agriculture research. Agriculture Research Station, Belachapi, Dhanusha is an important wing among the research farms of NARC, in order to generate appropriate agriculture production technologies for central terai of Nepal. The research of different field crops (rice, wheat, maize, pulses etc.) and vegetables are being carried out from longer period of time in the farm. Studies related to the soil fertility status of Agriculture Research Station, Belachapi, Dhanusha are scant. Therefore, it is important to investigate the soil fertility status and it may provide valuable information relating crop research. Considering these facts, the present study was initiated with the objective to assess the soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal.

MATERIALS AND METHODS

Study area

The study was carried out at Agriculture Research Station, Belachapi, Dhanusha, Nepal (Figure 1). The research farm is situated at the latitude 26^{o} 52’22.7”N and longitude 85^{0}56’54.5”E as well altitude 101masl.

Soil sampling

The surface soil samples (0-20 cm depth) were collected from Agriculture Research Station, Belachapi during January 2015. Altogether soil samples were collected from the research farm by using soil sampling auger (Figure 2). The exact locations of the samples were recorded using a handheld GPS receiver. The random method based on the variability of the land was used to collect soil samples.

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Laboratory analysis

The collected soil samples were analyzed at Soil Science Division laboratory, Khumaltar. The different soil parameters tested as well as methods adopted to analyze is shown on the Table 1.

Statistical analysis

Descriptive statistics (mean, range, standard deviation, standard error, coefficient of variation) of soil parameters were computed using the Minitab 17 package. Rating (very low, low, medium, high and very high) of determined values were based on Soil Science Division, Khumaltar. The coefficient of variation was ranked according to the procedure of (Aweto, 1982) where, CV < 25% = low variation, CV >25 ≤ 50% = moderate variation, CV >50% = high variation. Arc Map 10.1 with geostatistical analyst extension of Arc GIS software was used to prepare soil fertility maps while interpolation method employed was ordinary kriging with stable semi-variogram. Similarly, the nutrient index was also determined by the formula given by Ramamoorthy and Bajaj (1969).

Nutrient index (N.I.) = $(N_L \times 1 + N_M \times 2 + N_H \times 3) / N_T$

Where, N_L, N_M and N_H indicates number of samples falling in low, medium and high classes of nutrient status, respectively and N_T means total number of samples analyzed for a given area. Similarly, interpretation was done as value given by Ramamoorthy shown on the Table 2.

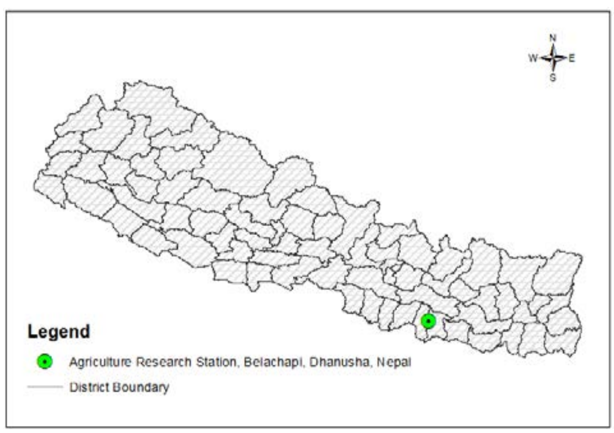

Figure 1. Location Map of Agriculture Research Station, Belachapi, Dhanusha, Nepal

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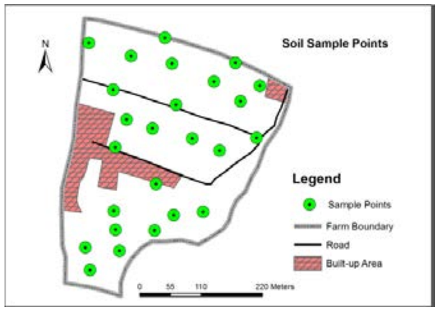

Figure 2. Distribution of soil sample points during soil sampling

Table 1. Parameters and methods adopted for the laboratory analysis at Soil Science Division, Khumaltar

S.N.	Parameters	Unit	Methods
1.	**Physical**		
	Soil texture		Hydrometer (Bouyoucos, 1927)
	Soil colour		Munshell-colour chart
	Soil structure		Field-feel
2.	**Chemical**		
	Soil pH		Potentiometric 1:2 (Jackson, 1973)
	Organic matter	%	Walkely and Black (Walkely and Black, 1934)
	Total N	%	Kjeldahl (Bremner and Mulvaney, 1982)
	Available P_2O_5	ppm	Modified Olsen's (Olsen et al., 1954)
	Extractable K_2O	ppm	Ammonium acetate (Jackson, 1967)
	Extractable Ca	ppm	EDTA Titration (El Mahi, et al.,1987)
	Extractable Mg	ppm	EDTA Titration (El Mahi, et.al.,1987)
	Available S	ppm	Turbidimetric (Verma, 1977)
	Available B	ppm	Hot water (Berger and Truog, 1939)
	Available Fe	ppm	DTPA (Lindsay and Norvell, 1978)
	Available Zn	ppm	DTPA (Lindsay and Norvell, 1978)
	Available Cu	ppm	DTPA (Lindsay and Norvell, 1978)
	Available Mn	ppm	DTPA (Lindsay and Norvell, 1978)

Table 2. Rating Chart of Nutrient index

S.N.	Nutrient Index	Value
1.	High	>2.33
2.	Low	<1.67
3.	Medium	1.67-2.33

RESULTS AND DISCUSSION

In the study area its soil fertility status with respect to texture, colour, structure, pH, organic matter, primary nutrients, secondary nutrients and micronutrients such as B, Fe, Zn, Cu, and Mn, was assessed and the results obtained are presented and discussed in the following headings.

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Soil texture

Soil texture affects the soil sustainability. The sand, silt and clay are the three components of soil texture. It affects absorption of nutrients, microbial activities, the infiltration and retention of water, soil aeration, tillage and irrigation practices (Gupta, 2004). The % sand of soil samples were ranged from 8.2 to 67.6% with the mean value of 36.03% and that of % silt were 12.8 to 68.8% with a mean of 50.32% while the range of % clay were 3.6 to 39.8% with a mean of 25.42% (Table 3). The coefficients of variation between the soil samples were 75.53%, 25.04% and 44.3% for sand, silt and clay contents, respectively.

Table 3. Soil separates status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Descriptive Statistics	Soil separates (%)		
	Sand	**Silt**	**Clay**
Mean	36.03	50.32	25.42
Standard Deviation	18.32	12.60	11.26
Standard Error	3.66	2.52	2.25
Minimum	8.2	12.8	3.6
Maximum	67.6	68.8	39.8
CV%	75.53	25.04	44.3

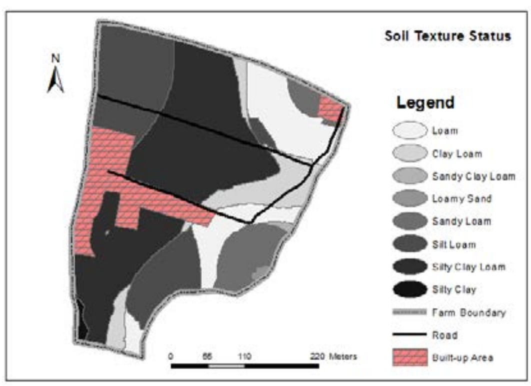

Figure 3. Soil texture status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Soil colour

Soil color reflects on the transformation and translocation occurred in the soil due to chemical, biological and physical attributes (Ponnamperuma & Deturck, 1993). It shows water drainage, aeration and organic matter content in soil. In the majority of the study area, grayish brown (10YR 6/1) colour was observed.

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Soil structure

Soil structure refers to the pattern of spatial arrangement of soil particles in a soil mass (Brady & Weil, 2004). In the majority of the area, sub angular blocky structure was observed.

Soil pH

Soil pH is important chemical parameter of soil that affects nutrient availability (Brady and Weil, 2004). The pH of soil was varied from 4.58 to 7.33 with a mean value of 5.61 (Table 4). This indicates moderately acidic soil pH (Figure 4). The availability of various nutrients for plants (rice, wheat, maize, vegetables etc.) may be reduced. Therefore, periodically agricultural lime incorporation is imperative for improvement of soil pH. The soil pH showed low variability (12.41%) among the soil samples.

Table 4. Soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Descriptive Statistics	Soil Fertility Parameters (ppm)				
	pH	OM	N	P_2O_5	K_2O
Mean	5.61	1.34	0.08	33.25	95.52
Standard Deviation	0.70	0.36	0.01	34.86	66.87
Standard Error	0.14	0.073	0.002	6.97	13.37
Minimum	4.58	0.19	0.04	0.78	21.6
Maximum	7.33	1.92	0.09	145.51	369.6
CV%	12.41	27.15	13.56	104.73	70.01

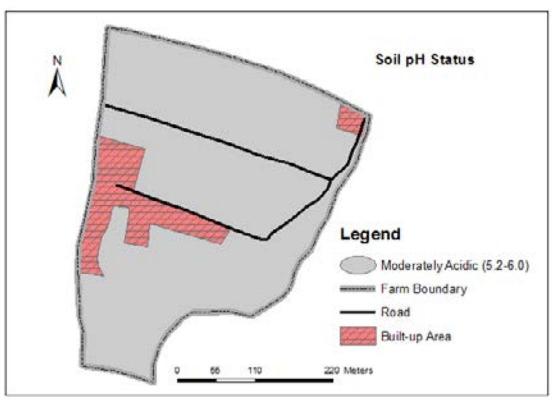

Figure 4. Soil pH status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Organic matter

Organic matter is important source of plant essential nutrients after their decomposition by microorganisms. It supplies plant nutrient, improve the soil structure, water infiltration and retention, feeds soil micro-flora and fauna, and the retention and cycling of applied fertilizer (Johnston, 2007). The organic matter content was varied from 0.19 to 1.92% with a mean value of 1.34% (Table 4). It indicates that the organic matter content was low (Figure 5; Table 7). The

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plants don't have tolerance capacity against any kinds of stressed conditions. Therefore, incorporation of organic matter adding materials is imperative for organic matter improvement of soils. Organic matter showed moderate variability (27.15%) among the soil samples.

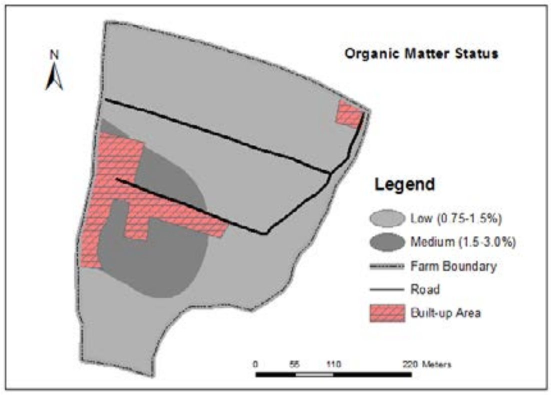

Figure 5. Organic matter status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Total nitrogen

Nitrogen is taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but in the tropics for crop production it is one of the most deficient elements (Mesfin, 1998). The total nitrogen content was ranged from 0.04 to 0.09% with a mean value of 0.08% (Table 4). This indicates medium content of total nitrogen (Figure 6; Table 7). The nitrogen content is not satisfactory. Therefore, regularly nitrogen adding organic and inorganic materials should be incorporated to make nitrogen balanced in soils. Low variability (13.56%) in total nitrogen was observed among the sampled soils.

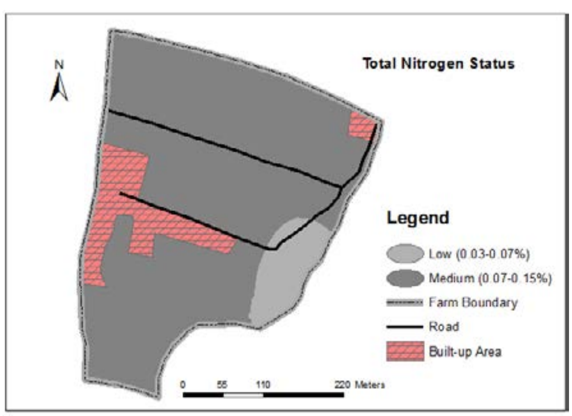

Figure 6. Total nitrogen status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

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Available phosphorus

Phosphorus is the master key to agriculture. The growth of both cultivated and uncultivated plants is limited by availability of P in the soils (Foth and Ellis, 1997). The available phosphorus (P_2O_5) was ranged from 0.78 to 145.51 ppm with a mean value of 33.25 ppm (Table 4). This showed high status of available phosphorus (Figure 7; Table 7). Available phosphorus showed high variability (104.73%) among the tested soil samples.

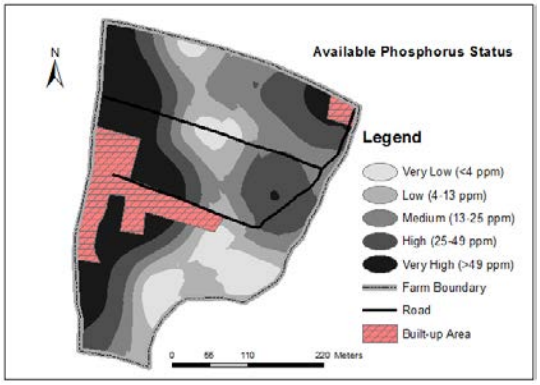

Figure 7. Available phosphorus status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Extractable potassium

Next to N and P, Potassium (K) is the third most important essential element that limit plant productivity. The extractable potassium (K_2O) content was ranged from 21.6 to 369.6 ppm with a mean value of 95.2 ppm. This suggests medium status of extractable potassium (Figure 8; Table 7). High variability (70.01%) in extractable potassium was determined among the soil samples.

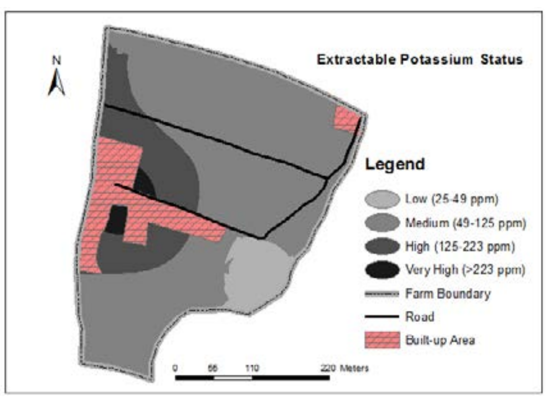

Figure 8. Extractable potassium status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

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Table 5. Soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Descriptive Statistics	Soil Fertility Parameters (ppm)			
	Ca	Mg	S	B
Mean	1264.80	223.20	0.73	0.56
Standard Deviation	463.98	118.24	0.44	0.52
Standard Error	92.80	23.65	0.088	0.10
Minimum	180	12	0.29	0.15
Maximum	2080	432	1.81	2.61
CV%	36.7	53.0	59.7	91.9

Extractable calcium

Calcium is a secondary nutrient important for cell division in plants. The calcium content was ranged from 180 to 2080 ppm with a mean value of 1264.80 ppm (Table 5). In overall, medium status of extractable calcium was observed (Figure 9; Table 7). Moderate variability (36.7%) in extractable calcium was observed among the soil samples.

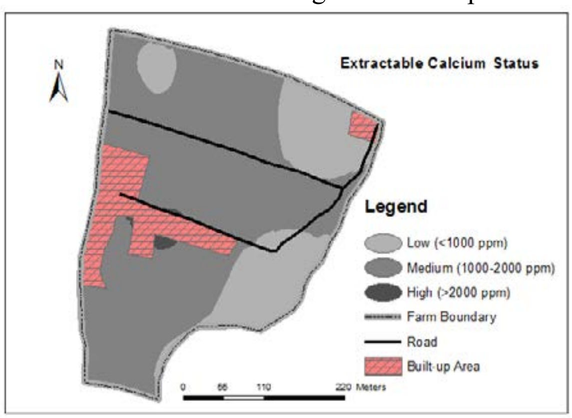

Figure 9. Extractable calcium status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Extractable magnesium

Magnesium is a water soluble cation necessary for chlorophyll pigment in green plants (Mahajan & Billore, 2014). The magnesium content was ranged from 12 to 432 ppm with a mean value of 223.20 ppm (Table 5). This revealed high content of extractable magnesium (Figure 10; Table 7). The variation (53 %) in the extractable magnesium of the observed samples is high.

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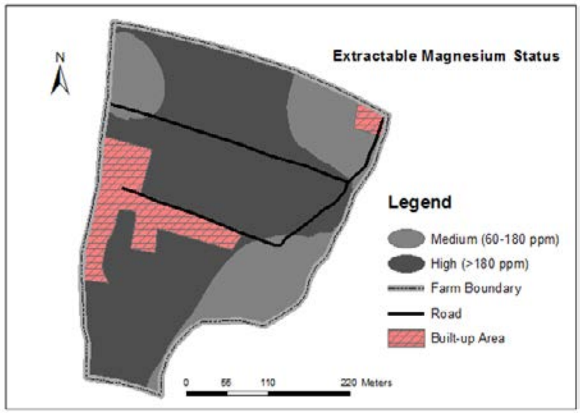

Figure 10. Extractable magnesium status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available sulphur

Sulphur is required for synthesis of S-containing amino acids cystine, methionine and cysteine, and these are essential components of protein that comprise about 90% of the total S in plants (Havlin et al., 2010). The available sulphur was varied from 0.29 to 1.81 ppm with a mean value of 0.73 ppm (Table 5). In overall, available sulphur was very low in status (Figure 11; Table 7). Therefore, regularly sulphur adding organic and inorganic materials should be incorporate to reduce sulphur mining problem in soils. Organic matter improvement is also one option for enhancing availability of available sulphur. Available sulphur showed high variability (59.7%) in the soil samples.

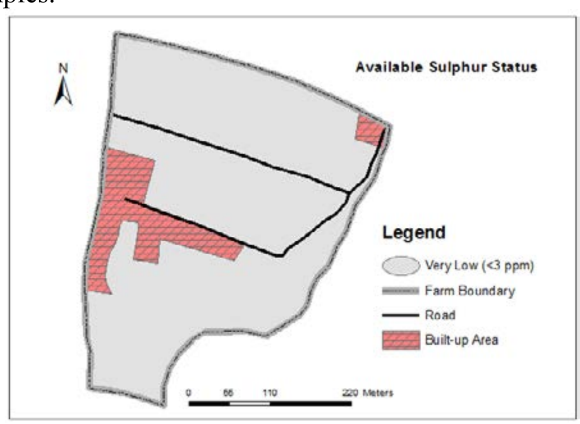

Figure 11. Available sulphur status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available boron

Boron is required by plants for their cell wall structural integrity (Havlin et al., 2010). The available boron content was ranged from 0.15 to 2.61 ppm with a mean value of 0.56 ppm (Table 5). This indicates low content of available boron (Figure 12; Table 7). Therefore, regularly boron adding organic and inorganic materials should be incorporate to maintain boron

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adequate in soils. High variability (91.9%) in available boron was observed among the soil samples.

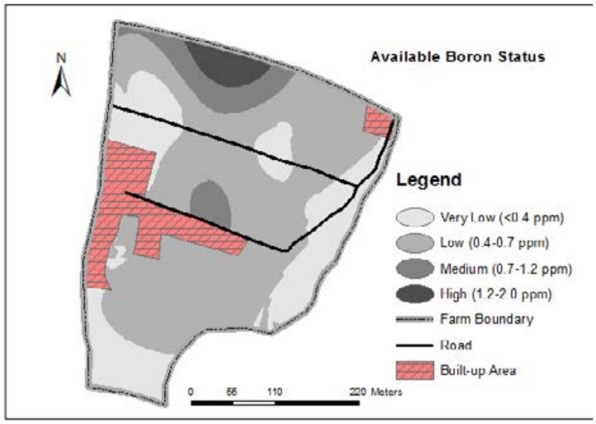

Figure 12. Available boron status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available iron

Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis (Rout & Sahoo, 2015). The available iron content was ranged from 5.56 to 160.7 ppm with a mean value of 55.80 ppm (Table 6). In overall, available iron status was high (Figure 13; Table 7). There may have high possibility for stress of iron toxicity as well deficiency of antagonistic elements in plants. Therefore, nutrients like potassium; phosphorus etc. should be applied in adequate amount for reducing iron toxicity stress in plants. Available iron showed high variability (79.7%) among the soil samples.

Table 6. Soil fertility status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Descriptive Statistics	Soil Fertility Parameters			
	Fe	**Zn**	**Cu**	**Mn**
	ppm			
Mean	55.80	0.54	0.30	20.50
Standard Deviation	44.45	1.08	0.06	12.14
Standard Error	8.89	0.22	0.01	2.43
Minimum	5.56	0.08	0.12	5.62
Maximum	160.7	5.58	0.4	47.5
CV%	79.7	199.7	21.4	59.3

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Figure 13. Available iron status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available zinc

Zinc is essential for several biochemical processes in plants, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and the maintenance of membrane integrity (Havlin et al., 2010). The available zinc content was ranged from 0.08 to 5.58 ppm with a mean value of 0.54 ppm (Table 6). This indicates low status of available zinc (Figure 14; Table 7). There may have high possibility of zinc deficiency symptoms like white bud in maize, khaira disease in rice etc. Therefore, different organic and inorganic sources of zinc should be applied in the field regularly to reduce zinc stress in plants. The available zinc showed high variability (199.7%) among the soil samples.

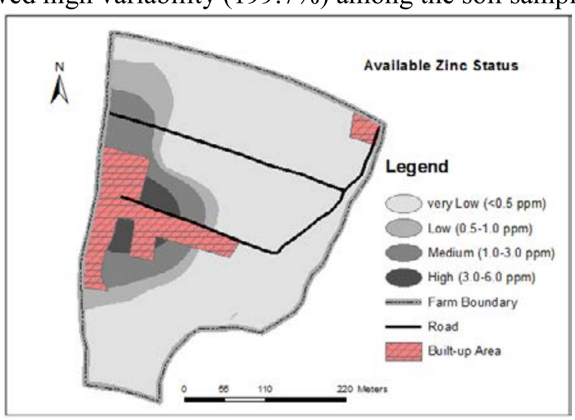

Figure 14. Available zinc status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available copper

Copper is also important micronutrient for plants, and required for lignin synthesis and acts as a constituent of ascorbic acid, oxidase, phenolase and plastocyanin (Havlin et al., 2010). The available copper content was varied from 0.12 to 0.4 ppm with the mean value of 0.30 ppm (Table 6). This indicates low status of available copper (Figure 15; Table 7). Therefore, proper

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copper management strategy should be adopted to make copper balanced in soils. Low variability (21.4%) in available copper was recorded among the soil samples.

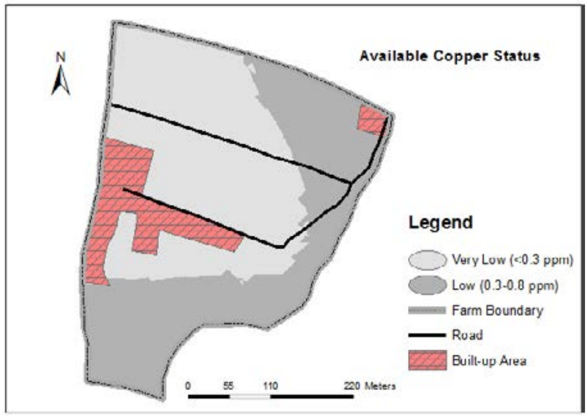

Figure 15. Available copper status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

Available manganese

Manganese plays an important role in oxidation and reduction processes in plants (Mousavi et al., 2011).The available manganese content was ranged from 5.62 to 47.5 ppm with the mean value of 20.50 ppm (Table 6). This indicates high status of available manganese (Figure 16; Table 7). The available manganese showed high variability (59.3%) among the studied soil samples.

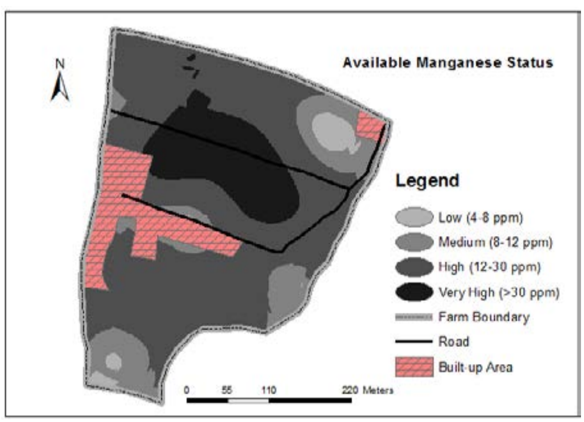

Figure 16. Available manganese status of Agriculture Research Station, Belachapi, Dhanusha, Nepal

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Table 7. Nutrient indices of studied parameters of Agriculture Research Station, Belachapi, Dhanusha, Nepal

S.N.	Parameters	% distribution of samples					Nutrient index	Remarks
		Very Low	Low	Medium	High	Very High		
1.	OM	4	64	32	-	-	1.32	Low
2.	N	-	40	60	-	-	1.6	Low
3.	P_2O_5	20	8	20	28	24	2.24	Medium
4.	K_2O	4	12	68	12	4	2.0	Medium
5.	Ca	-	32	64	4	-	1.4	Low
6.	Mg	-	8	36	56	-	2.48	High
7.	S	100	-	-	-	-	1.0	Low
8.	B	52	24	16	4	4	1.32	Low
9.	Fe	-	12	4	16	68	2.72	High
10.	Zn	84	8	4	4	-	1.12	Low
11.	Cu	36	64	-	-	-	1.0	Low
12.	Mn	-	12	20	40	28	2.56	High

CONCLUSION

Overall, the colour of soil was grayish brown and structure was sub-angular blocky. Soils were acidic in reaction and it is advisable to apply agricultural lime periodically for its amelioration. The sulphur status was very low. The organic matter, boron, zinc and copper status were low. The nitrogen, potassium and calcium status were medium. The phosphorus, magnesium and manganese status were high. The iron was very high in status. The crops (maize, rice, wheat etc.) may suffer from deficiency of low and toxicity of very high plant available nutrients. Thus, proper nutrient management strategy should be adopted especially for these nutrients. Considering the low status of soil organic matter, the practices like manure or compost incorporation, crop residue retention, green manuring etc. can be suggested for its improvement. From this study, it can be concluded that for enhancing efficacy of the agricultural research (maize, rice, wheat etc.) future research strategy should be built based on the soil fertility status of the farm.

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REFERENCES

Aweto, A.O. (1982). Variability of upper slope soils developed under sandstones in South-western Nigeria. *Geographic Journal, 25*, 27-37.

Berger, K. C, & Truog, E. (1939). Boron determination in soils and plants. *Industrial and Engineering Chemistry, 11,* 540 – 545.

Journal of Maize Research and Development (2016) 2 (1): 43-57
ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16214

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle-size analysis of soils. *Agronomy Journal*, *53*, 464 – 465.

Brady, N.C., & Weil, R.R. (2002). The nature and properties of soils (13th edition). Pearson Education, New Jersey.

Bremner, J.M., & Mulvaney, C.S. (1982). Nitrogen total. In: Page, A.L. (editor) Methods of soil analysis. Agron. No. 9, Part 2: Chemical and microbiological properties. 2nd edition. Am. Soc. Agron., Madison, WI, USA, 595- 624.

Burrough, P.A., & McDonnell, R. A. (1998). Principle of geographic information systems. Oxford: Oxford University Press.

El Mahi,Y., Ibrahim, I.S., AbdelMajid, H.M., & Eltilib, A.M. (1987). A simple method for determination of calcium and magnesium carbonate in soils. *Soil Science Society of American Journal*, *51*, 1152-1155.

Foth, H.D., & Ellis, B.G. (1997). Soil fertility (2nd edition). LLC., USA: Lewis CRC Press, 290p.

Ganorkar, R.P., & Chinchmalatpure, P.G. (2013). Physicochemical assessment of soil in Rajura Bazar in Amravati district of Maharastra (India). *International Journal of Chemical, Environmental and Pharmaceutical Research, 4*(2&3), 46-49.

Gupta, P.K. (2004): Soil, plant, water and fertilizer analysis. Shyam Printing Press, Agrobios, India, 38p.

Havlin, H.L., Beaton, J.D., Tisdale, S. L., & Nelson, W. L. (2010). Soil Fertility and Fertilizers-an introduction to nutrient management (7th edition). PHI Learning Private Limited, New Delhi.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Johnston A.E. (2007). Soil organic matter, effects on soil and crop. *Soil use and management*, *2*(3), 97-105.

Lindsay, W. L., & Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of American Journal*, *42*, 421 – 428.

Mahajan, S., & Billore, D. (2014). Assessment of physico-chemical characteristics of the soil of Nagchoon pond Khandwa, MP, India. *Research Journal of Chemical Science*, *4*(1), 26-30.

Mesfin, A. (1998). Nature and management of Ethiopian soils. Ethiopia: Alemaya University of Agriculture, 272p.

Mousavi, S.R., Shahsavari, M., & Rezaei, M. (2011). A general overview of manganese (Mn) importance for crops production. *Australian Journal of Basic and Applied Sciences*, *5*(9), 1799-1803.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *US. Department of Agriculture Circle*, *9*, 39.

Ramamurthy, B., & Bajaj, J.C. (1969). Available nitrogen, phosphorus and potassium status of Indian soils. *Fertilizer News,* 14, 25-36.

Rout, G.R. & Sahoo, S. 2015. Role of iron in plant growth and metabolism. *Review of Agriculture Science*, *3*, 1-24.

Verma, B. C. (1977). An improved Turbidimetric procedure for the determination of sulphate in plants and soils. *Talanta, 24*, 49 – 50.

Walkley, A.J., & Black, I.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science, 37*, 29-38.

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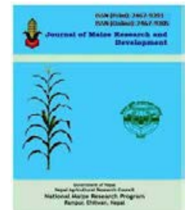
Studies on food preferences of maize weevil, *Sitophilus zeamais* Mots. to different crops in Chitwan, Nepal



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ABSTRACT

Food preference by the maize weevil, *Sitophilus zeamais* Motschulsky was studied on seven different crops and varieties including maize, wheat and rice. They were maize cultivars namely Arun-2, Manakamana-4, Deuti, buckwheat local cultivar, wheat cultivar namely Annapurna-1, polished rice-Radha 4 and unshelled rice cultivar Mansuli under storage condition at Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal from June 2013 to February 2014 . The hosts were tested using completely randomized design with three replications and were laid in free-choice and no-choice conditions. The maximum number of grain loss was recorded in wheat followed by polished rice respectively. Similarly, the highest weight loss was recorded in polished rice followed by Wheat in both conditions. F1 progeny emergence of weevil was highest in wheat followed by polished rice in free-choice and in no choice conditions, the highest progeny were emerged from polished rice followed by wheat. The lowest numbers of weevils emerged from rice in both conditions. Maximum germination losses were recorded in wheat (24.33%) and lowest in Arun-2 (9.67). The rice showed a relatively higher preference to maize weevil under storage condition.

Keywords: Food, maize, preference, weevil

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INTRODUCTION

Maize is the second most important staple food crop both in terms of area and production after rice in Nepal. It was grown in 0.87 million hectare of land with an average yield of 2.09 t/ha. Maize occupied about 28.32% of the total cultivated agricultural land and shares about 23.89 % of the total cereal production in Nepal (MoAC, 2010). In stored maize, heavy infestation of weevil cause weight losses of with ranges from 30-40% (Paneru et al., 1996). Maize weevil is one of the most serious, internal feeding pests of maize seed and grain. *S. zeamais* is found in all tropical and sub-tropical parts of the world (Dobie, 1974). Maize

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weevil can infest various stored agricultural products such as maize, sorghum, wheat, barley, rice and paddy (rough rice). There was no exact information on the quantification of post-harvest losses; however estimated loss ranged 5-40% (Manandhar et al., 2004). The damage and losses caused by these factors have been estimated 2-30% by weight basis (Entomology Division, 1999).Among these factors insect has been considered as the major part for the reduction of the quality and quantity of the maize. Paneru et al.(1996) reported storage losses due to weevil up to 31% by weight basis on maize. In Nepal, since past time, a great concern has been given to the crop growing practices for the enhancement of the production and productivity. Most of the researches had been focused on field practices like cultivation practices, insect pest management, and disease management and so on. But still, the post-harvest problems including storage insect problems, has been given less priority. In this regards, the host preference study were conducted to get the information of pest on stored products. In Nepal, farmers don't have a separate storage room for different crops and most of the farmers stored maize along with other crops like wheat, rice and buckwheat etc. Hence, weevil might get suitable environment for breeding or food in other crops. In such situation, the study will give the information that storage product should be stored separately and should prevent to contact from one host to another host to reduce its population build up.

MATERIALS AND METHODS

The experiment was conducted at Institute of Agriculture and Animal Sciences (IAAS) Rampur, Chitwan. The following grains were collected from the farmers household and research institutions. Three major maize cultivars and four other common stored grains i.e. Maize cv. Arun-2, maize cv. Manakamana-4, maize cv. Deuti, buckwheat cv. local, wheat cv. Annapurna-1, polished rice cv Radha 4 and unshelled rice cv, Mansuli were used for the experiment. Fifty grams of each treatments were kept in the free-choice and no-choice containers and were replicated thrice. The grains were kept in the Petri plates and were arranged in circular fashion in a circular plastic bucket. Similarly, weevils were confined in no-choice conditions in separate containers.

Free-choice condition

Forty newly emerged weevils were released in the center of the chamber. The whole set of experiments were covered by mosquito nets to prevent the escape of weevils. Adult weevils were removed after seven days for maximum oviposition as standard length of time (Dobie, 1974). The experiment was laid out into Complete Randomized Design (CRD) with three replications.

No- choice condition

The relative preference of different hosts by *S. zeamais* was also studied under no choice condition in Rampur, Chitwan and design was Completely Randomized Design (CRD). Treatments and the method of seed preparation were same as mentioned in free choice condition. Fifty grams of seeds were taken in a plastic jar of half kg capacity. In order to proper aeration, the mouth of the jar was covered with net with the help of rubber bands. The newly emerged ten weevil individuals were released in each container.

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Data recording and Analysis

The adults were removed after seven days and further data were recorded after 10 days of weevil removal. Subsequent data were recorded at 20 days interval and continued for the period of 2 months. The following parameters were recorded for both varietal screening and host preference.

- Germination percent before experimental setup and at end of experiment of each treatment
- Number of damaged / undamaged grains
- Weight of damaged / undamaged grains
- Moisture percentage of grains
- Number of F_1 progeny emergence
- Room temperature and R. H.

All the grains were counted and weighted for calculating the weight loss and number of grain damage in each data recording time. The percent weight loss and percent grain damage was calculated thereafter. All data were analyzed statistically using MSTAT-C and MS-Excel.

RESULTS AND DISCUSSION

Host preferences under free-choice condition

Grain damage percentage

The grain damage percentage by weevil in different possible hosts of weevil were significantly different (P<0.01) in each other over the observation period (Table 1). Wheat was the most preferred maize variety by weevil during different observation periods, whereas paddy was the least preferred host of weevil. Ranson (2000) suggested that soft types of grains are more suitable for weevil damage than hard nature of crop seeds. In 20 days of observation, polished rice was found to be statistically superior and most susceptible to weevil and loss recorded about 6 percent whereas, the least damage percentage was recorded in Deuti variety of maize (1.06 ± 0.46). The other hosts, buckwheat, Arun-2, and Manakamana-4 were not significantly different in terms of loss caused by weevil (Table 1).

Table 1. Percent grain damage by Maize weevil, *S. zeamais* under free-choice condition at Rampur, Chitwan, Nepal, 2013.

Hosts	Percent Grain Damage (No. basis) at indicated days after treatment		
	20 day	40 day	60 day
Arun-2	$1.84^{bc} \pm 0.89$	$4.17^{b} \pm 0.33$	$20.73^{b} \pm 2.75$
Manakamana-4	$1.57^{bc} \pm 1.09$	$8.14^{b} \pm 0.24$	$20.19^{b} \pm 2.89$
Deuti	$1.06^{c} \pm 0.46$	$7.41^{b} \pm 1.30$	$17.69^{b} \pm 2.65$
Buckwheat	$2.63^{bc} \pm 1.16$	$1.14^{b} \pm 1.08$	$4.61^{c} \pm 1.13$
Wheat	$2.94^{ab} \pm 0.00$	$20.60^{a} \pm 8.59$	$42.28^{a} \pm 3.01$
Policed Rice	$4.97^{a} \pm 2.00$	$8.64^{b} \pm 3.05$	$34.30^{a} \pm 6.02$
Paddy	$0.18^{c} \pm 0.00$	$0.15^{b} \pm 0.02$	$0.10^{c} \pm 0.12$
P Value	<0.01	<0.01	<0.01
CV %	22.09	10.79	11.33
$LSD_{0.05}$	1.525	8.53	10.07

Similarly, in 40 days of observation, the maximum losses were recorded in wheat

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(20.60±8.59), which was significantly different from other hosts. The rest other hosts were not statistically different. Rice was the least preferred host of weevil. Singh (2002) reported susceptibility of weevil negatively co-related with grain hardness and crude fiber content which lead to reduce the damage to paddy. In 60 days of observations, the treatments were significant among each other (P<0.01). The two host's wheat (42.28±3.01) and polished rice (34.30±6.02) based on damage percent were at par. The paddy and buckwheat were less susceptible hosts in comparison to the other hosts of weevil.

The percent grain infestation by weevil in free choice condition over the observation period were highly significant from each other's (Table 2). The increasing trends of damage percentage were recorded over the observation periods. In 20 days, the maximum grain weight loss was recorded in polished rice which was significantly higher to the other hosts (P<0.01). The other hosts were at par with each other. In 40 days of observation, the similar trend of infestation was recorded. The highest damage percentage was recorded in polished rice (7.53±0.23) followed by wheat (5.73±1.45). The highest loss was recorded in polished rice (21.33 ±0.85) followed by wheat (10.13± 1.16) whereas minimum loss was recorded in rice which was not significantly different with other hosts like Arun-2, Manakamana-4, Deuti and buckwheat. About 15% of the grains are lost in storage by the pests (Joshi, Karmacharya & Khadge, 1991) which is almost same with the result below. Among the maize verities, maximum damage was recorded in Deuti in comparison to other two maize varieties which could be associated with the starch content and size of kernel (Golob, 1984). Similarly, yellow varieties of maize are more susceptible by weevil damage than other color varieties of crops (NMRP, 2011/2012).

Table 2. Percent grain damage by Maize weevil, *S. zeamais* under free-choice condition at Rampur, Chitwan, Nepal, 2013.

Hosts	Percent Grain Damage (Wt. basis) at indicated days after treatment		
	20 day	40 day	60 day
Arun-2	$0.80^{b} \pm 0.35$	$3.33^{c} \pm 1.42$	$3.67^{c} \pm 1.20$
Manakamana-4	$0.70^{b} \pm 0.72$	$2.80^{c} \pm 0.69$	$2.00^{c} \pm 0.43$
Deuti	$1.00^{b} \pm 1.11$	$2.00^{c} \pm 1.06$	$3.33^{c} \pm 0.75$
Buckwheat	$1.53^{b} \pm 0.95$	$4.13^{c} \pm 1.17$	$3.20^{c} \pm 1.21$
Wheat	$2.06^{b} \pm 0.58$	$5.73^{b} \pm 1.45$	$10.13^{b} \pm 1.16$
Policed Rice	$9.67^{a} \pm 0.61$	$7.53^{a} \pm 0.23$	$21.33^{a} \pm 0.85$
Paddy	$2.00^{b} \pm 0.20$	$2.07^{c} \pm 0.64$	$2.60^{c} \pm 0.53$
P Value	< 0.01	<0.01	< 0.01
CV %	11.63	12.02	13.67
$LSD_{0.05}$	1.24	1.53	2.49

F1 progeny of weevil on different hosts

The level of significance among the treatments in three observations period were varied (Table 3). In 20 days interval, the weevil population among the treatments were significantly different. In 20 days, the highest weevil population was recorded in polished rice ($42.66^{b} \pm 15.43$) which was significantly different from other hosts and lowest number of weevil population was recorded in paddy ($2.66^{a} \pm 2.51$) which was not significantly different with other host than polished rice. The similar result was also reported by Throne and Eubanks (2002) and who explained that the hard surface of paddy deterred the oviposition and thus lowered the weevil population.

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In 60 days of observation, the maximum numbers of weevil population were counted in wheat (192.33 ± 8.52) and polished rice (116.33 ± 4.59) which was statistically different each other. The polished rice was the second most preferred host in terms of population buildup. Similarly, the other hosts, Arun-2 and Manakamana-4, and Deuti and Buckwheat were similar to each other. Entomology Division (2001) found that adults of *S. zeamais* developed the progeny very easily on the host with soft outer cover which absorbs the moisture easily and this result is on the same line. In general, weevil multiplication, and their damage depends on many factors such as temperature, moisture content of grains, hardness and softness of grain endosperm and quality of the grain (Entomology Division, 2011/2012) (Table 3).

Table 3. Population buildup of *S. zeamais* on different hosts under free-choice condition at Rampur, Chitwan, Nepal, 2013.

Hosts	Weevil Population (No.) at indicated days after treatment		
	20 day	40 day	60 day
Arun-2	14.33^{a}±6.56	23.67^{abc} ± 12.35	60.33^{bc} ± 15.15
Manakamana-4	14.27^{a} ± 5.47	24.00^{abc} ± 8.00	50.00^{bc}± 13.00
Deuti	7.00^{a} ± 3.10	21.33^{bc} ± 8.37	30.66^{c} ± 9.29
Buckwheat	11.00^{a} ± 0.10	23.00^{bc}± 4.30	30.66^{c} ± 9.68
Wheat	12.33^{a}± 2.08	58.33^{a}± 30.22	192.33^{a}± 8.52
Polished Rice	42.66^{b} ± 15.43	41.00^{ab} ± 34.84	116.33^{b} ± 4.59
Paddy	2.66^{a} ± 2.51	7.00^{c} ± 2.45	11.67^{c} ± 2.31
P Value	<0.05	<0.05	<0.01
CV %	23.95	10.48	24.28
$LSD_{0.05}$	12.16	47.99	40.86

Host preferences under no-choice condition

Grain damage percentage

The grain damage percentage were highly significant (P<0.01) in different days of observations (Table 4). In 20 days of observation, maximum infestation was recorded in polished rice (7.30±1.114) followed by wheat (3.28±1.14), buckwheat (1.96±0.00), Deuti (1.59±0.00), Manakamana-4 (1.18±0.83), Arun-2 (0.97±0.33) and lowest loss recorded in rice (0.053 ± 0.02). Arun-2 and Manakamana-4 were at par. Similarly, damage percentage of wheat loss was recorded highest (37.29 ± 17.53) in 40 days of observation which was statistically different from the tested hosts. Lowest damage percentage was recorded in rice (0.72±1.11). The percentage loss of some hosts like Manakamana-4 (9.42%), Deuti (8.73%), Arun-2 (5.03%), buckwheat (1.33%) and rice (0.72%) were not statistically different. Physical characteristics, i.e. seed hardness might have reduced the amount of feeding (Bernabe-Adalla, 1976) and reduce the infestations.

In 60 days of observation, the treatments were also highly significant (P<0.01). Grain loss was recorded highest in wheat (71.29±8.12), which was significantly different from other tested hosts. Polished rice was the second most susceptible hosts of weevil, with recorded upto 47.00%.The lowest percentage loss was recorded in paddy which accounts only 0.12%. The other hosts like Arun-2, Manakamana-4, Deuti were not significantly different from each other in terms of grain loss.

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Table 4. Mean percent infestation of *S. zeamais* in different food under no- choice experiment in Chitwan, condition during 2013.

Hosts	Percent Grain Damage (No. basis) at indicated days after treatment		
	20 day	40 day	60 day
Arun-2	$0.97^{cd} \pm 0.33$	$5.03^{b} \pm 0.89$	$17.44^{c} \pm 3.81$
Manakamana-4	$1.18^{cd} \pm 0.83$	$9.42^{b} \pm 4.23$	$28.09^{c} \pm 6.16$
Deuti	$1.59^{bcd} \pm 0.00$	$8.73^{b} \pm 1.38$	$23.01^{c} \pm 3.64$
Buckwheat	$1.96^{bc} \pm 0.00$	$1.33^{b} \pm 0.08$	$2.04^{d} \pm 1.83$
Wheat	$3.28^{b} \pm 1.14$	$37.29^{a} \pm 17.53$	$71.29^{a} \pm 8.12$
Policed Rice	$7.30^{a} \pm 1.14$	$27.32^{ab} \pm 4.77$	$47.31^{b} \pm 5.03$
Paddy	$0.053^{d} \pm 0.02$	$0.72^{b} \pm 1.11$	$0.12^{d} \pm 0.07$
P Value	<0.01	<0.01	<0.01
CV %	29.83	34.24	17.70
$LSD_{0.05}$	1.693	26.61	11.63

Table 5 showed that the grain damage percent in weight basis were highly significant (P <0.01). In general, polished rice and wheat were highly preferred hosts of weevil. In 20 days of treatment set up, the weight loss of polished rice was found to be maximum (10.33±0.70), which was significantly different with other tested hosts. The other tested hosts were at par in terms of infestation. In 40 days, the same results were observed as in 20 days of observations. In general, maximum loss was recorded in polished rice (9.20±0.92) followed by wheat (4.33±1.10), and lowest loss was recorded in rice (0.66±0.23). Classen et al. (1990) reported that pericarp hardness has been associated with resistance to maize weevil. Similarly, in 60 days of observation: highest loss was recorded in polished rice (11.46±0.42) and lowest in paddy (1.67±0.12).

Table 5. Mean percent infestation of *S. zeamais* in different food under no- choice experiment in Chitwan, condition during 2013.

Hosts	Percent Grain Damage (Wt. basis) at indicated days after treatment		
	20 day	40 day	60 day
Arun-2	$1.33^{b} \pm 0.42$	$2.06^{bc} \pm 0.50$	$3.33^{c} \pm 0.50$
Manakamana-4	$2.00^{b} \pm 0.72$	$3.33^{b} \pm 0.92$	$2.60^{cd} \pm 0.40$
Deuti	$1.60^{b} \pm 1.00$	$2.66^{bc} \pm 0.90$	$3.13^{c} \pm 0.58$
Buckwheat	$1.93^{b} \pm 0.64$	$2.66^{bc} \pm 1.17$	$3.00^{cd} \pm 0.53$
Wheat	$2.86^{b} \pm 0.50$	$4.33^{b} \pm 1.10$	$8.66^{b} \pm 0.90$
Policed Rice	$10.33^{a} \pm 0.70$	$9.20^{a} \pm 0.92$	$11.46^{a} \pm 0.42$
Paddy	$1.06^{b} \pm 1.15$	$0.66^{c} \pm 0.23$	$1.67^{d} \pm 0.12$
P Value	<0.01	<0.01	<0.01
CV %	25.62	24.66	11.12
$LSD_{0.05}$	1.88	2.13	1.31

Germination loss

The actual loss percent of different treatments were significantly different to each other (P<0.05). Maximum germination loss was recorded in wheat (24.33±4.04) followed by polished rice, Deuti (16.33±1.53), rice (14.00±9.54), Manakamana-4 (12.33±2.52) and lowest in Arun-2 (9.67±3.51) (Table, 6). The germination on polished rice was not recorded because of all seeds were damaged by weevil. With the increase in insect infestation, the tendency in the decrease in germination of the seeds occur (Prakash et al., 1987), which is in accordance of the given table. Similarly, Panthee (1977) reported that higher germination loss was related

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with higher weevil activities.

Table 6. Reduction in germination in different host of Maize weevil, *S. zeamais* at Rampur, Chitwan, Nepal, during 2013

Treatments	Germination (%)		
	Before treatment	After treatment	Actual germination loss
Arun-2	$86.33^{b} \pm 1.53$	$76.67^{a} \pm 2.89$	$9.67^{c} \pm 3.51$
Manakamana-4	$85.67^{b} \pm 1.15$	$73.33^{a} \pm 2.89$	$12.33^{bc} \pm 2.52$
Deuti	$96.33^{a} \pm 1.53$	$80.00^{a} \pm 0.00$	$16.33^{abc} \pm 1.53$
Buckwheat	$74.67^{c} \pm 2.52$	$60.00^{bc} \pm 5.00$	$14.67^{bc} \pm 4.62$
Wheat	$82.67^{b} \pm 2.52$	$58.33^{c} \pm 2.89$	$24.33^{a} \pm 4.04$
Paddy	$97.33^{a} \pm 2.08$	$83.33^{a} \pm 10.41$	$14.00^{bc} \pm 9.54$
P Value	<0.01	<0.01	<0.05
CV %	2.33	6.83	31.66
$LSD_{0.05}$	4.97	11.93	8.89

CONCLUSION

Wheat and polished rice were most preferred host and loss recorded up to 42.00% on number basis. Whereas, rice and buckwheat were the least preferred host of weevil. Highest numbers of weevils were emerged in wheat and polished rice whereas least number of progenies were released from rice. Maximum germination losses were recorded in wheat and lowest germination loss was recorded in Arun-2. Therefore this study suggested that rice and buckwheat are relatively less preferred to maize weevil and they can be stored for long time. In summary, the research give idea about proximity of storage for storage crops during stored inside the house. If we stored other more susceptible maize cultivars and other non-maize foods together, the weevil might get the suitable environment for population build up.

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REFERENCES

Bernabe-Adalla, C., & Bernado, E. N. (1976). Correlation between husk characters and weevil infestation of 51 varieties and lines of maize in the field. *Philippine Agricultural Science, 60*, 121-129.

Champ, B. R., & Dyte, C. E. (1977). FAO global survey of pesticide susceptibility of stored grain pests. *FAO Plant Protecion Bulletin 25*(2), 49-67.

Classen, D. Arnason, J.T., Serratos, J.A., Lambert, J.D.H., Nozzolillo, C., & Philogeneet al, B.J.R. (1990). Correlation of phenolic acid content of maize to resistance to *Sitophilus zeamais*, the maize weevil, in CIMMYT'S collections. *Journal of Chemical Ecology*. *16* (2), 301-315.

Dobie, P. (1974). The laboratory assessment of the inherent susceptibility of maize varieties to post harvest infestations by *Sitophilus zeamais* Mots. *Journal of Stored Product Research*, 10, 183-197.

Dobie, P. (1977). The contribution of the tropical stored products center to the study of the

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DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16215

insect resistance in stored maize. *Tropical Stored Products Information*, 34, 7-22.

Entomology Division. (2001). Annual Technical Report of 1999/2000. Entomology Division, Nepal Agricultural Research Council, Khumaltar, Nepal. pp.20-24.

Golob, P. (1984). Improvements in maize storage for the small holder farmer. *Tropical Stored Products Information* ,*50*, 14-19.

Gomez, K. A., & Gomez, A. A. (1986). *Statistical Procedures for Agricultural Research*. 2nd edition. John Wiley & Sons, inc. New York, USA.

Joshi, S.L., Karmacharya, B.B., & Khadge, B.R.. (1991). Trainers manual no. 14. *Plant Protection*. Manpower Development Agriculture Project, Kathmandu, November, 1991. pp.397.

Khare, B. P. (1994). *Stored grain pest and their management*. Kalyani Publishers, Ludhiyana, India. pp.314.

Manandhar, R., Sharma, P. N., & Devkota, S.R. (2004). Loss assessment of maize grains due to storage pest under different storage conditions in different Agro-ecological environments. *In:*Sherchan, D.P., Adhikari, K ,Basta, B.K.& Sharma, D. (eds.). Summer Crops Research Workshop on Maize Research and Production in Nepal. Kathmandu, Nepal, June 28-30, 2004. *Proceedings of the 24th National Summer Crops on Maize Research and Production in Nepal. NMRP, NARC*. pp. 241-243.

MoAC. (2010). Statistical information on Nepalese agriculture. Government of Nepal. Ministry of Agriculture and Cooperatives, Agri-Business Promotion and Statistics Division, Singh Darbar, Kathmandu, Nepal.

NMRP. (2011/2012). 2011/2012 Annual Report of National Maize Research Program (NMRP), Rampur Chitwan, Nepal 172p.

Paneru, R.B., Duwadi, V.R., Khanal, R., & Bhattarai, M.R. (1996). Testing of the efficacy of some local materials against weevil in stored maize. Rep. No. 139. PAC, Dhankuta.

Panthee, D. R. (1997). Identification of a suitable indigenous storage structure for Wheat seed storage. *Journal of Agriculture and Animal Science*, *17*(18),55-62.

Prakash, A., Rao, J., Pasalu, I. C., & Mathur, K. C. (1987). *Rice storage and insect pest management*. B. R. Publishing Corporation, Delhi. pp. 321.

Ransom, J. (2000). Factors affecting post harvest losses in maize. *In:*Manandhar, D. N, Ransom, J. K. Ransom & Rajbhandari, N.P. (eds.). Working Group Meeting of the Hill Maize Research Project. Khumaltar, Nepal, September 25-27, 2000. *Developing and Dissemination Technology to Reduce Post-harvest Losses in Maize Proceedings*. CIMMYT/NARC. pp. 14-18.

Singh, C. (2002). *Modern techniques of raising field crops*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India. pp.573.

Throne, J.E., & Eubanks, M.W. (2002). Resistance of Tripsacorn to *Sitophilus zeamais* and *Oryzae philussurinamensis. Journal of stored product research, 38 (2), 239-245.*

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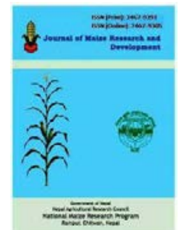
Genotype × environment interaction of quality protein maize grain yield in Nepal



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ABSTRACT

In order to determine G × E interaction of quality protein maize grain yield, six maize genotypes were evaluated under different environments of three Terai (Chitwan, Surkhet and Doti) and four mid hill (Dhankuta, Lalitpur, Dolakha and Kaski) districts of Nepal during summer seasons of 2014 and 2015. The experiments were conducted using randomized complete block design along with three replications. The genotypes namely S99TLYQ-B, S99TLYQ-HG-AB and S03TLYQ-AB-01 were identified high yielding and better adapted genotypes for Terai environments with grain yield of 4199 kg ha^{-1}, 3715 kg ha^{-1}, and 3336 kg ha^{-1} respectively and S99TLYQ-B and S03TLYQ-AB-01 for mid hill environments with grain yield of 4547 kg ha^{-1} and 4365 kg ha^{-1} respectively. Therefore, these genotypes can be suggested for cultivation in their respective environments in the country.

Keywords: Evaluation, grain yield and quality protein maize

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INTRODUCTION

The continuous evaluation and development of new varieties of maize is necessary to ensure food security in Nepal. In general, three types of hunger (calorie, protein, and micro nutrient deficiency) are facing by large portion of the people. Deployment of quality protein maize (QPM) is one of the good strategies to solve the problem of calorie and protein deficiency. In maize protein the most limiting amino acid are lycine and tryptophan (Kies et al., 1965). These amino acids are nearly double in QPM as compared to normal maize. FAO (1992) mentioned that about 80% is the

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biological value of QPM protein which is nearly double of normal maize. The QPM provides better quality feed and fodder to poultry, cattle and swine.

Maize has great diversity and is adaptive across various agro-ecological zones (Ferdu et al., 2002). Across the environments where the improved varieties are adapted would produce high and stable yields (CIMMYT, 1991). The preliminary step in varietal release is to evaluate the genotypes for yield potential and adaptation to the environments where it is cultivated. In most cases maize breeders look for a variety that has good mean performances over a large array of environments and years Gurmu et al. (2009). The continuous G × E study is necessary because with the changing environments, the performance of maize genotypes differs across the agro-ecologies. Under diverse agro ecologies in Nepal the information regarding the effect of genotype, environment and their interaction is not sufficient. Therefore, this study was done to evaluate the adaptability of six QPM maize genotypes in the Terai and Mid hill environments using AMMI model.

MATERIALS AND METHODS

Description of locations

These studies were conducted during summer seasons of 2014 and 2015 at 3 locations of terai and 4 locations of mid hill districts. The mid hill environments were Pakhribas (Dhankuta), Khumaltar (Lalitpur), Kabre (Dolakha) and Lumle (Kaski) and Terai environments were Bagyatada (Doti), Rampur (Chitwan), Madi (Chitwan) and Surkhet. The short description of these locations are given as below (Table 1).

Table 1. Description of experimental locations

Environments	Altitude, (m) (m.a.s.l)	Annual rainfall (mm)	Global Position	
			Longitude	Latitude
Hills				
Pakhribas (Dhankuta)	1315-2025	1500-1600	$87^0$17'61'E	$27^0$02'96'N
Khumaltar(Lalitpur)	1368		$85^0$20'E	$27^0$40’N
Kabre (Dolakha)	1600-1740	2466.2	$86^0$80'E	$27^0$38'N
Lumle (Kaski)	848	3172.85	$83^0$58'27.72"E	$28^0$13'6.8"N
Terai				
Bagyatada (Doti)	610	Not exceed 1000	$80^0$55'E	$29^0$15'N
Rampur (Chitwan)	228	Over 1500	$84^0$19'E	$27^0$40'N
Madi (Chitwan)	110	1500	$84^0$43’E	$27^0$40’N
Surkhet	580	1550	$81^0$47"E	$28^0$30"N

Genetic materials

Six maize genotypes were evaluated in mid hills and Terai environments of Nepal during summer seasons of 2014 and 15. The genotypes were SO3TLYQ-AB-01, SOTLYQ-AB-02, S99TLYQ-HG-AB, S99TLYQ-B, Poshilo Makai-1 and Farmer’s variety. Farmer’s variety was Rampur Composite.

Experimental design and cultural practices

The experiments were carried out using randomized complete block design along with three replications. The individual plot was 13.5 m^2 (4.5 m × 3 m) . The spacing was

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0.75 m for row to row and 0.25 m for plant to plant. Fertilizer was applied @ 120:60:40 N, P_2O_5, K_2O kg ha^{-1}. The full dose of P_2O_5 and K_2O along with half of N were used as basal dose. The half of the N was used into two times; at knee-high and pre-tasseling/silking stages. Rest of agronomic practices was done as per recommendation of National Maize Research Program, Rampur, Chitwan, Nepal.

Table 2. Description of genotypes with their characteristics

SN	Genotype	Parentage	Origin	General description
1	SO3TLYQ-AB-01	Formed using inbreds from heterotic group A and B	CIMMYT, Mexico	This is open pollinated, prerelease and yellow variety for Terai
2	SOTLYQ-AB-02	Formed using inbreds from heterotic group A and B	CIMMYT, Mexico	This is open pollinated, prerelease yellow variety for Terai
3	S99TLYQ-B	Formed using inbreds derived from heterotic group B	CIMMYT, Mexico	This genotype is open pollinated , prerelease, yellow variety for terai and mid hills
4	S99TLYQ-HG-AB	Formed using inbreds from heterotic group A and B	CIMMYT, Mexico	This is open pollinated, prerelease yellow variety for Terai
5	Poshilo Makai-1	Formed using inbreds derived from heterotic group A and B	CIMMYT, Mexico	This is open pollinated white variety released in 2008. It is recommended for Terai and mid hills
6	Rampur Composite (Farmer's Variety)	Formed from Thai composite-1 × Suwan-1	Thailand	This is open pollinated , full season yellow variety released in 1975. It is recommended for Terai and mid hills regions of Nepal

(Source: Shrestha and Tripathi, 2014)

Data recording

Grain yields were adjusted to 80% shelling recovery. Grain yield was estimated using formula adopted by Carangal et al. (1971) and Shrestha et al. (2015) by adjusting the grain moisture at 15% and converted to the grain yield kg per hectare.

Statistical analysis

The combined ANOVA for all locations was done to estimate the variations in the genotypes under study and partitioning of G × E interaction. Data were analyzed through GENSTAT packages applying 5% significance level.

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RESULTS AND DISCUSSION

The pooled analysis of genotypes over terai locations showed that the highest grain yield was given by S99TLYQ-B (4199 kg ha^{-1}) followed by S99TLYQ-HG-AB (3715 kg ha^{-1}), S03TLYQ-AB-01 (3336 kg ha^{-1}) excluding Farmer's Variety. The non-significant effects were found for genotypes, location and genotype × environment interaction (Table 3).

Table 3.Combined analysis of QPM genotypes for grain yield (kg ha^{-1}) at Doti, Rampur, Madi and Surkhet during summer seasons of 2014 and 2015

SN	Genotypes	Doti	Rampur	Madi	Surkhet	Combined
1	SO3TLYQ-AB-01	1258c	2162b	4539	5080b	3336
2	SOTLYQ-AB-02	1467c	3392ab	4781	3956ab	2937
3	S99TLYQ-B	1572bc	3241ab	5737	3383ab	4199
4	S99TLYQ-HG-AB	1664bc	2959ab	4014	4182ab	3715
5	Poshilo Makai-1	1979b	3390ab	4594	1905a	3250
6	Farmer's Variety	2563a	4167a	4053	3967ab	4490
	F-test	**	*	ns	*	0.577
	Env					0.062
	Gen × Env					0.926
	CV,%	13.2	30	20.30	30.38	31.96
	LSD0.05	421.9	1756.3	2122.2	2574.6	4996 (loc × gen)

The genotypes being close to each other produce similar response and those close to environment indicate their better adaptation to that particular environment. SO3TLYQ-AB-01 and S99TLYQ-B showed similar performance for grain yield. The genotypes Poshilo Makai-1 and Farmer's Variety were similar in their grain yield performance and they were suitable for Doti and Rampur where as SO3TLYQ-AB-01 and S99TLYQ-B were suitable for Surkhet environment (Figure 1). This finding was very similar to findings of Anley et al. (2013).

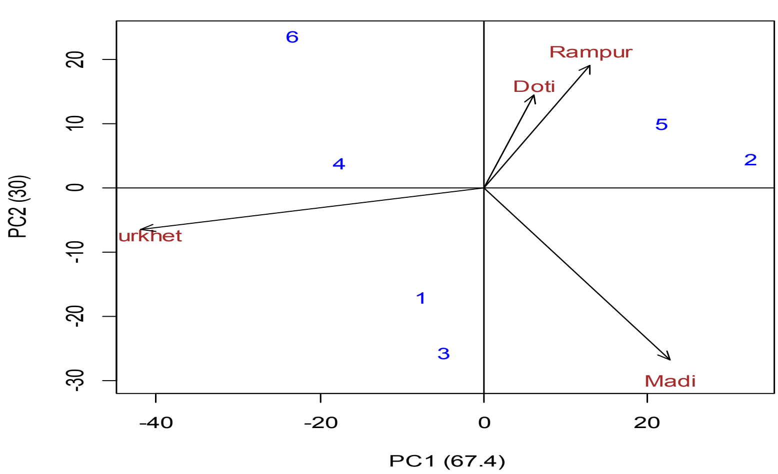

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Figure 1.Stability of QPM genotypes across the tested Terai locations (Doti, Rampur, Madi and Surkhet) during summer seasons of 2014 and 2015.

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The combined analysis of variance for grain yield (Table 4) revealed that there was non significant interaction for replication within environment. Similarly non significant effect for genotype and genotype × environment interaction and highly significant effect for environment were observed. This clearly showed that effect of environment had more influential effect on grain yield.

Table 4. Analysis of variance derived from AMMI analysis across the terai locations

Source	DF	SS	MSS	F value	Pr(>F)
ENV	3	34162654	11387551	607000	0.000943***
REP(ENV)	1	19	19	0.000	0.997749
GEN	5	8889211	1777842	0.834	0.57668
ENV:GEN	15	12576434	838429	0.393	0.926219
Error	5	10662756	2132551		

Significance Codes: '***' 0.001 '**' 0.01 '*' 0.05

Across the mid hill locations pooled analysis of genotypes (Table 5) showed that the highest grain yield was given by S99TLYQ-B (4547 kg ha^{-1}) followed by S03TLYQ-AB-01 (4365 kg ha^{-1}) excluding Posilo Makai-1 and Farmer's Variety. The genotypes were significant. There was significant effect for genotype × location for grain yield. This finding was similar to findings of Carson et al. (2002). The significantly different G × E interactions was recorded for grain yield in maize (Makumbi, 2005; Menkir & Ayodele, 2005).

Table 5. Combined analysis of QPM genotypes for grain yield (kg ha^{-1}) at Pakhribas, Khumaltar, Kabre and Lumle during summer seasons of 2014 and 2015.

SN	Genotypes	Pakhribas	Khumaltar	Kabre	Lumle	Combined
1	SO3TLYQ-AB-01	4441	2979ab	3101c	5594d	4365
2	SOTLYQ-AB-02	3866	1987b	2305c	6013cd	4026
3	S99TLYQ-B	4569	2927ab	4683c	4975ab	4547
4	S99TLYQ-HG-AB	4208	3304ab	2343b	4669abc	3847
5	Poshilo Makai-1	5454	3989a	5629ab	5482ab	5340
6	Farmers Variety	4196	3980a	6389a	3865a	4549
	F-test	ns	*	**	**	0.032
	Env					<0.001
	Gen × Env					0.011
	CV%	26.9	23.7	10.8	8.8	20.71
	$LSD_{0.05}$	2176.8	1378.5	1189.4	820.3	1950(env x gen)

The Figure 2 indicated that the performance of SO3TLYQ-AB-01 seemed better for Pakhribas. Similarly, SOTLYQ-AB-02 was better for Lumle and Poshilo Makai-1 and S99TLYQ-B for Kabre condition. In hill environments the genotype by environment interaction for grain yield was highly significant this may be due to differences among the sites in soil fertility, relative humidity and temperature, all factors which affect performance. The results showed that the genotypes responded differently to different environmental conditions. Similar findings were observed by Butron et al. (2002). Ogunbodede et al. (2001) reported that the genotypes should be partially released for locations where the performance was most favorable.

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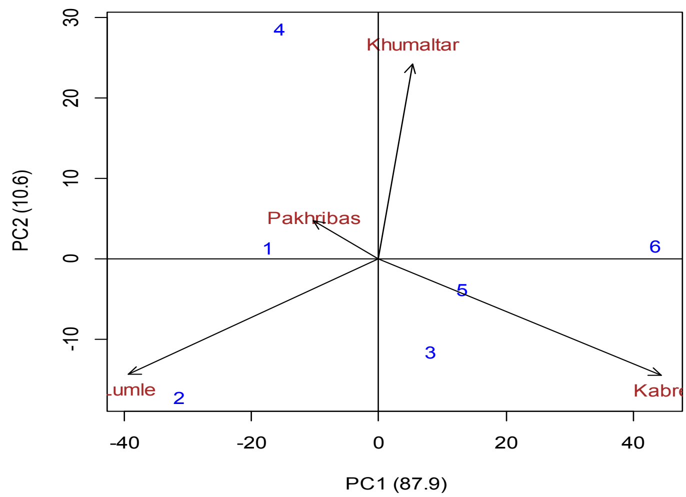

Figure 2. Stability of QPM genotypes across the hills locations. (Pakhribas, Khumaltar, Kabre and Lumle) during summer seasons of 2014 and 2015.

The combined analysis of variance for grain yield (Table 6) revealed non significant effect for replication within environment. For grain yield the effect of genotype was significant, genotype × environment effect was highly significant and environment was significant.

Table 6. Analysis of variance derived from AMMI analysis across mid hill locations

Source	DF	SS	MSS	F value	Pr(>F)
ENV	3	18749637	6249879	3.495	0.10576
REP(ENV)	5	8941208	1788242	2.5662	0.05253
GEN	5	12247819	2449564	3.5152	0.015257*
ENV:GEN	15	34329473	2288632	3.2843	0.004211**
Error	25	17421184	696847		

CONCLUSION

The better genotypes with respect to grain yield and location were Poshilo Makai-1 and Farmer's Variety for Doti and Rampur where as SO3TLYQ-AB-01 and S99TLYQ-B for Surkhet. Similarly SO3TLYQ-AB-01 was better for Pakhribas, SOTLYQ-AB-02 for Lumle and Poshilo Makai-1 and S99TLYQ-B for Kabre condition. Therefore these varieties with respect to their specific adaptation can be recommended for general cultivation.

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REFERENCES

Anley, W., Zeleke, H., & Dessalegn, Y. (2013). Genotype × Environment Interaction of Maize (*Zea mays* L.) across North Western Ethiopia. *Journal of Plant Breeding and Crop Sci*ence , *5*(9), 171-181.

Butron, A., Widstrom, N., Snook, M., & Wiseman, B. (2002). Recurrent selection for corn earworm (Lepidoptera: Noctuidae) resistance in three closely related corn southern synthetics. *Journal of Economic Entomology, 95*, 458-462.

Carson, M.L., Goodman, M.M., & Williamson, S.M. (2002). Variation in aggressiveness among isolates of Cercospora from maize as a potential cause of genotype-environment interaction in gray leaf spot trials. *Plant Disease, 86*, 1089-1093. http://dx.doi.org/10.1094/PDIS.2002.86.10.1089

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science, 11*, 658-661.

CIMMYT. (1991). High Yielding Varieties Do Not Necessary Yield Less Under Unfavorable Conditions. CIMMYT Annual Report 1990. Mexico DF.

FAO. (1992). Maize in human nutrition. *FAO Journal of Nutrition*, 110, 1070-1074.

Ferdu, A., Demissew, K., & Birhane, A. (2002). Major Insect Pests of Maize and their Management: A Review in: Nigussie M., D. Tanner and A.S. Twumasi (Eds.) Enhancing the Contribution of Maize to Food Security in Ethiopia. *Proceeding of Second National Maize Workshop*, Addis Ababa Ethiopia, 12- 16 Nov. 2001.

Gurmu, F., Mohammed, H., & Mewmaw, G. (2009).Genotype x Environment Interactions and Stability of Soybean for grain yield and Nutrition quality. *African Crop Science Journal*, *17*(2), 87 – 97.

Kies, C., Williams, E.R., & Fox, H.M. (1965). Determination of first-limiting nitrogenous factors in corn protein for nitrogen retention in human adults. *Journal of Nutrition*. *86* (65), 350-356.

Makumbi, D. (2005). Phenotypic and genotypic characterization of white maize inbreds, hybrids and synthetics under stress and non-stress environments. PhD dissertation Submitted to the Office of Graduate Studies of Texas A and M University.

Menkir, A., & Ayodele, M.A. (2005). Registration of 20 Tropical Mid-altitude Maize Line Sources with Resistance to Gray Leaf Spot. *Crop Sci*ence, 45, 803-804. http://dx.doi.org/10.2135/cropsci2005.0803

Ogunbodede, B.A., Ajibade, S.R., & Olakojo, S.A. (2001). Grain yield stability of new maize varieties in Nigeria: *African Crop Science Journal*, *9*(4), 685-691.

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development*, *1*(1),21-27. doi: http://dx.doi.org/10.3126/jmrd.v1i1.14241

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Tillage methods and mulch on water saving and yield of spring maize in Chitwan

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ABSTRACT

Tillage methods and mulch influences the productivity and water requirement of spring maize hence a field experiment was conducted at the National Maize Research Program, Rampur in spring seasons of 2011 and 2012 with the objectives to evaluate different tillage methods with and without mulch on water requirement and grain yield of spring maize. The experiment was laid out in two factors factorial randomized complete design with three replications. The treatments consisted of tillage methods (Permanent bed, Zero tillage and Conventional tillage) and mulch (with and without). Irrigation timing was fixed as knee high stage, tasseling stage and milking/dough stage. Data on number of plants, number of ears, thousand grain weight and grain yield were recorded and analysed using GenStat. Two years combined result showed that the effect of tillage methods and mulch significant influenced grain yield and water requirement of spring maize. The maize grain yield was the highest in permanent beds with mulch (4626 kg ha^{-1}) followed by zero tillage with mulch (3838 kg ha^{-1}). Whereas total water applied calculated during the crop period were the highest in conventional tillage without mulch followed by conventional tillage with mulch. The permanent bed with mulch increased the yield and reduced the water requirement of spring maize in Chitwan.

Key words: Conventional tillage, permanent beds, spring maize, water requirement, zero tillage

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INTRODUCTION

Tillage and mulch based planting methods can increase efficiencies of the applied inputs, improve soil health, reduce production cost and have exhibited a positive effects on maize yield and show great promise in meeting this challenges (Govaerts et al., 2006). One such raised bed planting is a planting system proposed for maize production in irrigated area of Chitwan, the

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largest maize growing region in Nepal. This system comprises planting maize on the top of raised beds and incorporating plant residue from the previous crop into the soil, which are chopped and left in the field (Limon- Ortega et. al., 2006). Previous studies have shown that raised-bed planting reduces seed mortality rates, increases water- and nitrogen (N)-use efficiency, and improves soil quality (Limon-Ortega et al., 2000). In addition, less labor is required for irrigation and fertilizer is better managed relative to conventional flat planting (Limon-Ortega et al., 2000, 2002). More important, raised-bed planting can reduce crop lodging (crops falling over from high winds and/or heavy rain), while increasing yield by permitting farmers to grow more and superior crops (Govaerts et al., 2006; Wang et al., 2009). Raised bed technology is a land configuration where irrigation water is applied in furrows with plants on the raised beds. The technology increases water application and distribution efficiencies and gives better crop yields. Researchers reported that increase in crop yield is because of higher fertilizer use efficiency, reduced weed infestation, improvement in root proliferation and smaller lodging of the crops. The irrigation water saving depends on size of bed-furrow system where larger bed means lesser number of furrows, less irrigation application time and finally more saving in irrigation water. However, number of beds should meet plant population per unit area and furrows to meet crop water demand and row to row distance of plants (Ahamd et al., 2011). He reviled that grain yield of maize under bed-furrow planting was 19% higher than the that obtained from traditional practices whereas water application efficiency increased from 50% to 75%, saving considerable irrigation water as compared to the traditional ridge-furrow irrigation practice. Thus the objective of the study was to determine the growth and productivity of spring maize and water saving under different tillage methods, mulch and their interactions.

MATERIALS AND METHODS

Experimental Site

A field experiment was carried out at agronomy experimental farm of National Research Programme (NMRP), Rampur, Chitwan, Nepal located at $27^{o}39^{/}$ N and $84^{o}20^{/}$ E with an altitude of 186 m above the mean sea level. The experimental farm was well facilitated with irrigation and drainage system.

Soil Type

Experimental soil was analyzed before the experiment and found as sandy loam texture. The chemical composition of the experimental soil was determined as 2.64 g kg^{-1} of organic matter content. Similarly in an average 30.20 mg kg^{-1} of available soil Nitrogen (N), 16.90 mg kg^{-1} of Phosphorous (P) and 109.36 mg kg^{-1} of Potassium (K) were found with pH value of 5.51 and Electrical Conductivity (EC) of 251.6 µs cm^{-1}.

Tillage and Seeding

The conventional tillage treatment was tilth with spring tine harrow and leveled before planting for both years after harvest rice. A flat bed of 70 cm width were constructed as a raised bed with 30 cm furrow in first year of the experiment and were used for two consecutive years.

Two rows in one bed were planted at the edges as a permanent bed planting treatment. In the no till treatment the experiment plot were kept in no till condition even for other cropping season and spring maize planted on the same condition without disturbing the soil. The crop before spring maize was harvested from the ground level without leaving any straw in the field for the treatments having no mulch whereas the previous crop (rice) was harvested leaving 30 cm straw from the ground level for the treatments having mulch. The maize variety Rampur Composite was drilled in early February in both seasons with manual maize planter at spacing of 75 cm row to row and 20 cm plant to plant. The total fertilizer applied was 120 N, 60 P_2O_5 and 40 K_2O kg ha^{-1}. The nitrogenous fertilizer was top dresses thrice after irrigation.

Crop Management

Weeding and earthing up were not done. The existing broad leaved weeds was controlled by spraying post emergence herbicide 2,4 D ethyl ester 2.5 ml/l water. Crop was harvested at the end of April. Data on number of plants, number of ears, thousand grain weight and grain yield were recorded and analyzed using GenStat.

Irrigation Water Use Efficiency

The irrigation water use efficiency is calculated from the total irrigation amount and the grain yield and is defined by the ratio of grain yield to the total irrigation amount.

$$IWUE = \left(\frac{GY}{I}\right) \times 100 \qquad (1)$$

Where, *IWUE* is the irrigation water use efficiency measured as kg m^{-3}, *GY* is the grain yield measured in ton ha^{-1} and *I* is the total irrigation amount required to produce grain yield of one hectare in mm. While calculating the IWUE the grain yield in rainfed has not considered which is being same for all the treatments. The total irrigation amount was calculated as described in equation 2.

Experimental Design

Two factorial treatments were arranged in RCB design with three replications in which three tillage methods (Conventional, Zero and Permanent Bed) were in factor A whereas mulch (with and without) in factors B. The treatment combinations were as follows:

T1 = Permanent bed planting without mulching
T2 = Permanent bed planting with mulching
T3 = Zero tillage without mulching
T4 = Zero tillage with mulching
T5 = Conventional tillage without mulching
T6 = Conventional tillage with mulching

Three irrigation timing determined for all the treatments were fixed as knee high stage, tasseling stage and milking/dough stage. Time required for irrigating different plots were recorded and total irrigation amount applied were calculated as follows.

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$$Irrigation\ Amount\ (mm) = \frac{T \times Q}{A} \quad \ldots (2)$$

Where, T is the times require irrigating each treatment plot in sec, Q is the discharge of pumps (20 liter per second = 0.02 m^3sec^{-1}) and A is the wetted area in (m^2).

RESULTS AND DISCUSSIONS

Climate and Crop Water Requirement

The experimental station falls under the subtropical humid climatic region of Nepal. The annual rainfall of the site was found 1966.7 mm and 2313.2 mm in 2011 and 2012 respectively whereas the seasonal rainfall from February to April was found to be 103 mm and 290.3 mm for respective cropping season. The temperature of the site varied from 2°C to 37.2°C in 2011 and 0°C to 39.4°C in 2012 whereas the average temperature in spring season ranges from 15.9°C to 29.4°C in 2011 and 11.7°C to 27.4°C in 2012. The rainfall and temperature of two cropping season is given in fig. 1.

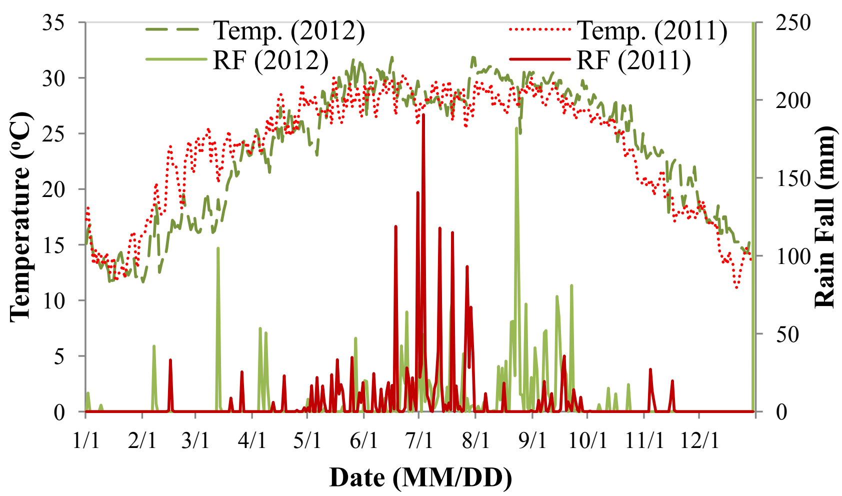

Figure 1. Rainfall and temperature monitored during 2011 and 2012

The Fig.1 shows that the rainfall was extremely low during spring season for both years this proves that the cultivation of maize in spring requires irrigation water. Bhandari (2012) and Nayava and Gurung (2010) had also reported that about 70 to 90% of the rainfall occurs during summer monsoon (June to September) and the rest of the month are almost dry. He further reported that the crop water requirement for higher maize yield is 500-600 mm depending on the climate and crop duration. Chuanyan and Zhongren (2007) had also estimated the total ET of 611.5 mm for the crop variety of similar duration of Rampur Composite in the arid region of northwest China. This results shows that there is deficit of 300-500 mm of water to grow spring maize depending on the local weather condition. This is why irrigation requirement for spring

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maize were monitored under different tillage practices to determine minimal irrigation water without reduction of grain yield.

Irrigation Amount and Irrigation Water Use Efficiency

The total irrigation amount required and the irrigation water use efficiency (IWUE) for individual treatment is presented in Table 1. The irrigation amount in 2011 cropping season is much more than in 2012 cropping season because of very less rainfall in 2011 (Fig 1). The total irrigation amount required for permanent beds with mulching and without mulch was the least (228.3 mm and 238.2 mm) respectively, followed by zero tillage with and without mulching (276.1 mm and 285.3 mm) respectively whereas the irrigation amount for the conventional tillage was found highest (357.8 mm). The analysis shows that the tillage practices with or without mulching, statistically required same level of irrigation amount. Irrigating in permanent bed and zero tillage fields significantly saved irrigation water. It was found that about 33.42 to 29.57% of less irrigation water were used in permanent bed as compare to conventional tillage with and without mulch respectively. Similarly in zero tillage treatments with and without mulching saved 20.29% and 14.79% of irrigation water compare to conventional tillage with and without mulch respectively. The permanent bed also saved 16.48% and 17.34% of irrigation amount compare to zero tillage with and without mulch respectively. The IWUE was found the highest (2.03 kg m^{-3}) for permanent bed planting with mulch condition followed by same tillage practice without mulch and were found lowest (0.62 kg m^{-3}) for conventional tillage without mulch.

Table 1. Irrigation amount (mm) of individual treatment for corresponding cropping seasons

Treatment	Irrigation Amount (mm)			IWUE (kg/m^3)
	2010-11	2011-12	Combined	
PB + No Mulch (T1)	340.3^c±22	136.1^c±9	238.2^c±16	1.54
PB + Mulch (T2)	326.1^c±29	130.4^c±12	228.3^c±21	2.03
ZT + No Mulch (T3)	407.5^b±23	163.0^b±9	285.3^b±16	1.10
ZT + Mulch (T4)	394.0^b±19	158.3^b±7	276.1^b±13	1.39
CT + No Mulch (T5)	511.2^a±13	204.5^a±5	357.8^a±9	0.62
CT + Mulch (T6)	462.6^a±31	185.6^a±12	324.1^a±22	0.88
F_{value}	**	**	**	
CV (%)	2.7	2.5	2.6	
$LSD_{0.05}$	19.82	7.52	13.7	

** represent significant level, at $\alpha = 0.01$. Same letter for mean represent non significance between the treatments at $\alpha = 0.05$

The irrigation amount saved in permanent bed has found significant with zero tillage because the irrigation water applied in the furrow irrigate two row adjacent to furrow and do not irrigate the whole bed (about 70 cm) whereas in zero tillage the irrigation water spread throughout the field even the infiltration capacity beings low compare to conventional tillage. The IWUE found satisfactory in zero tillage practice compare to permanent bed planting but the conventional tillage practices reduces IWUE drastically. The IWUE between the treatments with and without mulching didn't found significant under the same tillage practices because the

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irrigation amount required in mulching and without mulching condition under the same tillage practices were found non-significant. These findings are in agreement with the findings of Ahmad et al. (1991).

Grain Yield

Planting methods with or without mulch had significant effect on maize grain yield. Individual years and combined years results on different combinations is presented in Table 2. The treatment T2 recorded the highest grain yield (4626 kg ha^{-1}) followed by T4 (3838 kg ha^{-1}) and T1 (3672 kg ha^{-1}) treatments. The treatment T5 had significantly lowest yield (2236 kg ha^{-1}). Results of this experiment indicated that permanent bed with mulch, zero tillage with mulch and conventional tillage with mulch recorded 25.96%, 22.5% and 27.95% higher grain yields, respectively as compared to corresponding treatments without mulch. Permanent bed with mulch showed 106.86% higher grain yield as compared to conventional tillage without mulch. Similarly, T1 and T3 shows 64.22% and 40.09% higher grain yield relative to T5 treatments whereas T2 and T4 treatment increases 61.68% and 34.12% grain yield compare to T6 treatment. Karki et al. (2015) had found higher grain yield 7012.18 kg ha^{-1} in no tillage with residue compare to conventional tillage (6037.59 kg ha^{-1}). Hammad et al. (2011), had recorded grain yield of 4.67 t ha^{-1} in combination of 6 number of irrigation with 150 kg ha^{-1} fertilizer application.

Table 2. Effects of tillage methods and mulch on grain yield (kg ha^{-1}) of spring maize

Treatment	Grain Yield (kg ha^{-1})		
	2010-11	2011-12	Combined
PB + No Mulch (T1)	$3453^{c}±381$	$3892^{ab}±386$	$3672^{bc}±351$
PB + Mulch (T2)	$4769^{a}±249$	$4483^{a}±469$	$4626^{a}±285$
ZT + No Mulch (T3)	$3174^{cd}±185$	$3092^{bc}±784$	$3133^{cd}±484$
ZT + Mulch (T4)	$3959^{b}±203$	$3717^{abc}±268$	$3838^{b}±199$
CT + No Mulch (T5)	$2642^{e}±262$	$1831^{d}±829$	$2236^{e}±499$
CT + Mulch (T6)	$2827^{de}±151$	$2896^{c}±679$	$2861^{d}±409$
F_{value}	**	**	**
CV (%)	6.3	14.2	8.8
$LSD_{0.05}$	397.4	856.5	545.8

The result shows that planting spring maize on permanent bed is more beneficial than either planting on no till condition or conventional tillage. Planting with mulch enhance all the productivity significantly. The grain yield in T2 treatment has found highest because of the highest plant population and ear head per hectare along with highest 1000 grain yield as described in the following sections.

Number of Plant and Ear Head

The plant population and number of ear head per hectare were presented in Table 3 and Table 4 respectively. Both plant density and formation of ear per hectare determine the grain yield. Even the plant density has maintained by gap filling after full germination some plants

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being damaged either by some insects or pest or other environmental factors which may have created because of different tillage practices and consequently differ in irrigation amount applied. It has found that the highest plant population (50374 plant ha^{-1}) was found in T2 treatment followed by T1, T4 and T3 in order where the treatments T1, T4 and T3 show same level of plant population. The lowest plant population was found in T6 and T5 treatments. The result coincide with Adhikari et al. (2004), where he get 53,333 plants ha^{-1} under 120 kg N ha^{-1} and 44,444 plants ha^{-1} for supplied 60 kg ha^{-1} of N. Govind et al. (2015) had also recommended the similar pattern for the farmer. The tillage practice not only had affected the plant population but had also affected ear ha^{-1}. The result show that the treatments T1, T2 and T4 produce statistically same level of ears ha^{-1} with the highest no 43557 Ears in T2 followed by 40889 Ears in T1. Similarly T3 and T6 treatments give same level of ears ha^{-1} and the lowest numbers 28003 was found in T5 treatment. In this way it has been concluded that the tillage practices had greatly affected the plant population than the number of ears per hectare. The no. of plants and ear head in permanent bed was found highest because the plant receives irrigation from the furrow water which was closer to the maize plant.

Table 3. Effects of tillage methods and mulch on plant per hectare of spring maize

Treatment	Plant ha^{-1}		
	2010-11	**2011-12**	**Combined**
PB + No Mulch (T1)	41481^{bc}±4896	44444^{b}±4704	42963^{b}±4711
PB + Mulch (T2)	50673^{a}±6222	50074^{a}±5919	50374^{a}±6050
ZT + No Mulch (T3)	39407^{cd}±4008	39704^{bc}±4201	39556^{bc}±3875
ZT + Mulch (T4)	44749^{b}±5420	41481^{bc}±4201	43115^{b}±4636
CT + No Mulch (T5)	32296^{e}±7240	32593^{d}±6552	32444^{d}±6456
CT + Mulch (T6)	36741^{d}±4201	38519^{c}±4385	37630^{c}±3832
F_{value}	**	**	**
CV (%)	5.2	7.4	5.9
$LSD_{0.05}$	3864.7	5505.1	4398.3

Table 4. Effects of tillage and mulch on no of ear per hectare of spring maize

Treatment	Ear Head ha^{-1}		
	2010-11	**2011-12**	**Combined**
PB + No Mulch (T1)	39704^{b}±2566	42074^{ab}±3701	40889^{a}±3111
PB + Mulch (T2)	43854^{a}±3585	43259^{a}±3592	43557^{a}±3552
ZT + No Mulch (T3)	35852^{c}±4385	35556^{bc}±7901	35704^{b}±5557
ZT + Mulch (T4)	42073^{ab}±3702	38519^{abc}±4474	40296^{a}±3701
CT + No Mulch (T5)	28153^{e}±6788	27852^{d}±6904	28003^{c}±6842
CT + Mulch (T6)	32296^{d}±5358	33778^{cd}±7595	33037^{b}±5302
F_{value}	**	**	**
CV (%)	5.0	9.7	6.1
$LSD_{0.05}$	3362.1	6486	4099.9

Thousand Grain Weight (TGW)

The thousand grain weight (TGW) for individual treatments in both cropping season along with the combined years effects is presented in Table 5. The test weight (Thousand Grain

Weight, TGW) were highly influenced by the tillage practice in combination to mulching. The TGW significantly differ within same tillage practice planted under mulching and without mulching of previous crop. The highest TGW were found in T2 (403.8 g) treatment followed by T1 (364 g) treatment and lowest in T5 (321.9 g) treatment. The Treatments T1 and T4 had found statistically same level of TGW. Similarly, T3 and T6 treatments are also non significant for TGW. Karki et al. (2015) had also recorded highest test weight of 363.94 g in no till condition with mulching over the conventional tillage.

Table 5. Effects of tillage and mulch on thousand grain weight (g) of spring maize

Treatment	Thousand Seeds Weight (g)		
	2010-11	**2011-12**	**Combined**
PB + No Mulch (T1)	359.1^{bc}±5.4	368.9^{b}±14.1	364.0^{b}±7.4
PB + Mulch (T2)	405.7^{a}±9.4	402.0^{a}±7.4	403.8^{a}±8.0
ZT + No Mulch (T3)	351.0^{a}±cd	345.9^{cd}±7.6	348.4^{c}±1.5
ZT + Mulch (T4)	368.1^{b}±5.7	359.1^{bc}±8.6	363.6^{b}±6.9
CT + No Mulch (T5)	339.8^{e}±8.6	304.1^{e}±23.8	321.9^{d}±8.9
CT + Mulch (T6)	347.5^{de}±6.9	331.0^{d}±12.9	339.2^{c}±4.8
F_{value}	**	**	**
CV (%)	1.6	3.4	2.0
$LSD_{0.05}$	10.49	21.74	12.70

CONCLUSION

Permanent beds without or with mulch in the form of surface residue saved about 29-33% irrigation water and increases grain yield by 61% to 106% as compared conventional tillage with and without surface residue respectively. Higher yield in permanent bed and zero tillage with mulch was due to improved irrigation water use efficiency, the higher plant density with highest cob numbers per unit area and significantly higher 1000 grain weight.

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REFERENCES

Adhikari, B. H., Sherchan, D. P., & Neupane, D. D. (2004). Effects of nitrogen levels on the production of maize (*Zea mays* L.) planted at varying densities in Chitwan valley. In *Proc. of the 24th National Summer Crops Research Workshop in Maize Research and Production in Nepal*.

Ahamd, R. N., Arshad, M., & Shahid, M. A. (2011, October). Raised bed technology for crop water productivity of maize and cotton. In *Proc ICID 21 st International Congress on Irrigation and Drainage*. pp. 15-23.

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16217

Bhandari, G. (2012). Estimation of Potential evapotranspiration and crop coefficient of maize at Rupandehi district of Nepal. *International Journal of Agriculture Management Development, 2*(4), 285-293.

Chuanyan, Z. H. A. O., & Zhongren, N. A. N. (2007). Estimating water needs of maize (Zea mays L.) using the dual crop coefficient method in the arid region of northwestern China. *African Journal of Agricultural Research*, *2*(7), 325-333.

Govaerts, B., Sayre, K. D., Ceballos-Ramirez, J. M., Luna-Guido, M. L., Limon-Ortega, A., Deckers, J., & Dendooven, L. (2006). Conventionally tilled and permanent raised beds with different crop residue management: effects on soil C and N dynamics. *Plant and Soil*, *280*(1-2), 143-155.

Govind, K. C., Karki, T. B., Shrestha, J., & Achhami, B. B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, *1*(1), 1-9.

Hammad, H. M., Ahmad, A., Azhar, F., Khaliq, T., Wajid, A., Nasim, W., & Farhad, W. (2011). Optimizing water and nitrogen requirement in maize (Zea mays L.) under semiarid conditions of Pakistan. *Pakistan Journal of Bot*any, *43*(6), 2919-2923.

Karki, T. B., Govind, K. C., Shrestha, J., & Jadav, J. P. (2015). Tillage and planting density affect the performance of maize hybrids in Chitwan, Nepal. *Journal of Maize Research and Development*, *1*(1), 10-20.

Limon-Ortega, A., Sayre, K. D., & Francis, C. A. (2000). Wheat nitrogen use efficiency in a bed planting system in northwest Mexico. *Agronomy Journal*, *92*(2), 303-308.

Limon-Ortega, A., Sayre, K. D., Drijber, R. A., & Francis, C. A. (2002). Soil attributes in a furrow-irrigated bed planting system in northwest Mexico. *Soil and Tillage Research*, *63*(3), 123-132.

Limon-Ortega, A., Govaerts, B., Deckers, J., & Sayre, K. D. (2006). Soil aggregate and microbial biomass in a permanent bed wheat–maize planting system after 12 years. *Field Crops Research*, *97*(2), 302-309.

Nayava, J. L. & Gurung, D. (2010). Impact of climate change on production and productivity: A case study of maize research and development in Nepal. *Journal of Agriculture and Environment*, *11*, 59-69.

Wang, F., He, Z., Sayre, K., Li, S., Si, J., Feng, B., & Kong, L. (2009). Wheat cropping systems and technologies in China. *Field Crops Research*, *111*(3), 181-188.

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Maize response to time of nitrogen application and planting seasons

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ABSTRACT

Nitrogen (N) response by maize differs due to growing seasons, growth stages, duration and growing domain as N losses is higher due to leaching as well as volatilization. Objective of this study was to know the response of split applications of N and growing seasons on maize under Chitwan environments. Field experiments were conducted for two consecutive years at the research field of NMRP Rampur during the winter, spring, and summer seasons of 2012/013 and 2013/014. Experiments were laid out in factorial randomized complete block design with four replications for all the seasons. Early maturing maize genotype Arun-1 EV was used for the experiments. Five splits of recommended dose of N were tested. Grain yield, days to flowering, plant height, ear height, kernel rows per ear, no. of kernels per row, ear length and thousand grain weight significantly differed due to growing seasons and split applications of N. Significantly higher grain yield (3911 kg ha^{-1}) was obtained with the application of 30 kg N ha^{-1} each at 30, 45, 60, and 75 days after sowing as compared to control (2801 kg ha^{-1}). Regarding the growing seasons, highest grain yield was obtained in winter (4393 kg ha^{-1}) followed by spring (3791 kg ha^{-1}) and summer (2468 kg ha^{-1}) season, respectively. Results of these studies revealed that four splits of N viz. application of 30 kg N each at 30, 45, 60, and 75 days after sowing respectively, would be more economical to minimize N losses from the soil and efficient use of N at critical growth and development stages of maize.

Keywords: Leaching, maize, nitrogen, seasons

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INTRODUCTION

Yield is a function of genotypes, environments and crop managements. Fertilizer management is crucial for maize cultivation (Baral et al., 2015). Among the fertilizers, N is very important because this element is responsible on major activities for growth and development of maize crop (Jat et al., 2013). Maize being the heavy feeder crop, a balanced dose of organic and inorganic application of fertilizer is needed for increased productivity. Under abundant water condition, the crop growth and yield greatly depend on supply of soil N and its proper

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management (Saseendran et al., 2004). Fertilizer N applied to crop is subjected to many chances; a portion of the N will remain in the soil, some may be lost to the air, surface water, and/or ground water (Jat et al., 2013). Sherchan et al., (2007) also reported that response of N and its application time to maize differs due to genetic characters, growing season (winter, spring, and summer), maturity period (early and full season), and growing domain (mountain/hill and Terai) as losses of N takes place due to several reasons like leaching as well as volatilization from most of the soils. The result from a study about N application timing on maize conducted at NMRP research farm revealed that the N content of soil was reported to be in the range of 0.068 to 0.105 and suggested to apply 100 kg N ha^{-1}, half as basal application and the other half as top dressing at knee height stage and tasseling stage with 2 subsequent irrigations so that it could help increase crop productivity in Chitwan soil condition (Adhikary et al., 2004). The recent data published by the Ministry of Nepal showed that most of the farmers of Nepal do not apply chemical fertilizer in the maize crop as per recommendation (ABPSD, 2014). In general, they apply only urea if possible and available in the market. The farmers of outreach sites of NMRP apply around 30 kg N ha^{-1} (NMRP, 2014) once at knee high stage only. Objective of this study was to know the response of different splits and application timings of N for different growing seasons at Chitwan environments. The proper combination of nitrogen application timing and planting season are very important for higher grain yield of maize. Therefore these studies were conducted to identify that combination.

MATERIALS AND METHODS

Experimental site

The experiments were carried out at the research field of National Maize Research Program (NMRP) Rampur, Chitwan during the winter, spring, and summer seasons of 2012/013 and 013/014. The experimental site was located at $27^0$39' Northern Latitude, $84^0$21' Eastern Longitude and at an elevation of 185 meter above the sea level (NMRP, 2014). Maize can be grown throughout the year in Chitwan district and can also be grown in other similar environments (KC et al., 2015). Early maturing maize Arun-1 EV (now released in the name of Arun-3 for general cultivation) was selected for this experiment for both the years and all the seasons.

Maize variety

Early maturing maize variety (Arun-1 EV) was selected for the study. Arun-1EV was developed/selected from Arun-1 which is also the early maturing maize genotype. Arun-1 EV has yield potential up to 5,000 kg ha^{-1}. Kernel of this genotype is white and flint type. It has open leaves and shorter plant height. Stem is robust and has no lodging problem .The vigorous growth, early maturing habit, good test and good husk cover are the main traits of Arun-1 EV.

Field trial management and treatment combination

The soil of the experimental field of NMRP Rampur is sandy soil and N leaching is the major problem (Adhikary et al., 2004). Therefore, to know the effect of N losses on maize yield and yield attributing characters, following treatment combinations were tested;

T1 – 60 kg N ha^{-1} basal application and 60 kg N ha^{-1} at 45 DAS

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T2 – 40 kg N ha^{-1} basal application, 40 kg N ha^{-1} each at 45 and 60 DAS
T3 – 30 kg N ha^{-1} basal application, 30 kg N ha^{-1} each at 30, 45, and 60 DAS
T4 – 30 kg N ha^{-1} each at 30, 45, 60, and 75 DAS
T5 – Control (FYM 10 ton per hectare with no chemical fertilizers)

The factorial randomized complete block design along with four replications was used for all the seasons and years. Maize was planted in six rows of five-meter-long plot and spacing were kept 25 cm for plant to plant while 75 cm for row to row. Therefore, the plot size was 13.5 meter square for each treatment. Before maize sowing, soil samples were taken from the experimental field from the top layer (15 cm and 30 cm depth) of the soil and N content, pH, and organic matter content were analyzed at the soil laboratory of NMRP, Rampur. Recommended dose of phosphorous (60 kg ha^{-1}) and potash (40 kg ha^{-1}) were applied before maize sowing on each research plot. For farm yard manure (FYM), all amount was applied before final land preparation. Normal tillage practices were followed. Other crop management practices were similar to normal maize cultivation practices. The seed sowing dates for 2012/013 were 27 September, 19 February, and 27 May respectively. Similarly in 2013/014 plantings were done on 28 September, 21 February, and 15 June, respectively.

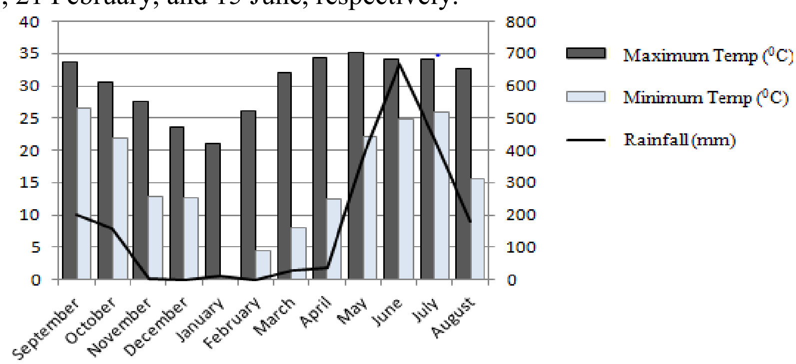

Figure 1. Weather data of the maize during its growing period at Rampur, Chitwan 2012/013.

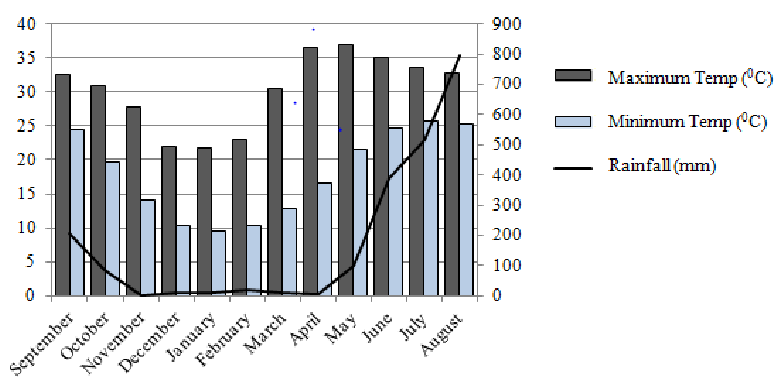

Figure 2. Weather data of the maize during its growing period at Rampur, Chitwan 2013/014.

Details of the weather data of the planting seasons of 2012/2013 and 2013/2014 is presented in the figure 1 and 2.

Grain yield was estimated using formula adopted by Carangal et al. (1971) & Shrestha et al. (2015) by adjusting the grain moisture at 15% and converted to the grain yield kg per hectare. Similarly, Data were analyzed by using CROP-STAT computer program applying 5% significance level.

RESULTS AND DISCUSSION

Soil analysis report

Soil analysis report from the samples taken before maize sowing of the two consecutive years revealed that the average organic matter (OM) content of all the plots were 2.16% (ranged from 1.99 percent to 2.5) which is considered to be good for crop growth and development. Similarly, total nitrogen content in the soil ranged from 0.099 to 0.125.In a study conducted at NMRP research farm, the N content of soil was reported to be in the range of 0.068 to 0.105 (Sherchan, 2004). The soil analysis result from both the years indicated that the research plots were quite uniform and were almost homogeneous in soil fertility.

Crop response to N

N often varies with the weather conditions during the crop growth and development, therefore the relationship between N supply, crops demand and weather conditions is important for development of successful N management strategies (Wolkowsky et al., 2015).They also recommended to provide N closer to the optimum uptake time (i.e. knee height stage through grain filling stage) in multiple applications to minimize pre-plant and seasonal N loss. Jat et al., (2013) reported that sequential applications of N just prior to planting with starter fertilizer at a rate of 30 kg N ha^{-1} and split applications at knee height stage, and at the time of flowering stage can be an effective N delivery system.

Table 1. ANOVA table for grain yield and other agronomical parameters as influenced by different N application timings and maize growing seasons under Rampur, Chitwan conditions during 2012/13 and 2013/14.

Source of Variation	Tasseling (days)	Silking (days)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Kernel rows /ear (no.)	No. of kernel /row (no.)	1000 grain weight (gram)	Grain yield (kg ha^{-1})
1. Season	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
2. Treatment (Trt)	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
3. Season × Trt	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	0.16
4. Year× Season	0.42	0.15	0.23	0.36	0.46	0.12	0.33	0.001	0.08
5. Year× Trt	0.37	0.39	0.33	0.51	0.90	0.70	0.57	0.004	0.60
6. Year× Season ×Trt	0.76	0.35	0.30	0.35	0.11	0.10	0.15	P<0.01	0.55

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Days to tasseling and silking

Significant difference (P<0.001) was observed for days to tasseling due to growing season, N application timings, and their interaction (Table 1). Same result (P<0.001) was found for days to silking as well (Table 1). Days to tasseling (49 day) and silking (54 day) was earliest in summer season planting followed by spring season (57 day tasseling and 61 day silking) and winter season planting (66 day tasseling and 73 day silking). Days to silking and tasseling was found late for winter planting compared to summer season planting. Regarding the days to tasseling and silking as influenced by N application timings, it ranged from 57 days after sowing (basal application of 60 kg N ha^{-1} and 60 kg N ha^{-1} at 45 days after sowing (DAS) to 61 DAS (Control i.e. application of 10 ton FYM ha^{-1} and no chemical fertilizers). It is obvious that the growth and development of maize is slower at cool season as compared to hot season planting and in general silking and tasseling occurs after the accumulation of approximately1135 growing degree units (GDU) (aganytime.com). The details of the tasseling and silking was presented in the Table 1, 2, and 3.

Plant height and ear height

Plant height and ear height significantly differed (P<0.001) due to growing season and N application timings (Table 1). The plant height varied in different seasons for the same variety. The interaction between growing season and N application timing was also found statistically significant (P<0.001) for both plant height and ear height. The plant height for summer (151cm) and spring season (150cm) was statistically at par however the plant and ear height significantly lower (131cm) for winter season. Similarly, for ear height significantly tallest ear height was observed in summer season (75cm), followed by spring season (71cm), and winter season (66 cm). Similarly, regarding the plant and ear height due to N application timings, it differed significantly. The tallest ear (75 cm) and plant height (153cm) was got with the application of 30 kg N ha^{-1}each at 30, 45, 60, and 75 DAS, while the lowest ear height (58 cm) and lowest plant height (119 cm) were observed. A detail is presented in table 1, 2, and 3. Several research results revealed that plant and ear height differs due to growing seasons and environments. Similar findings were reported by Sangakkara *et al.,* (2004) that plant height significantly differed due to plant population densities and growing environment. From a preliminary result conducted at NMRP, Rampur for maize, it is found that in rainy season, higher plant and ear height were found as compared to winter season (NMRP, 2015). It might be due to that plant gets lower sunlight because of cloudy days and plant goes up and up for light. Excess soil moisture would be another reason for higher plant height in rainy season as well. Similarly, the increase in plant height with more N splits would be due to supply of proper amount of N at different growth stages of maize and N promotes plant growth, increases the number and length of the internodes which resulted in progressive increase in plant height.

Yield attributing characters

Thousand grain weight, ear length, no. of kernel rows per ear, no. of kernels per row were found statistically significant (P<0.001) due to growing season and N application timings (table 1). Statistically, more bold grains, longer ear length, more no. of rows per ear, more no. of kernels per row were found in winter season plantings as compared to spring and summer season

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plantings (Figure 3, 4, 5, 6). It might be due to more accumulation of photosynthates for grain development. In summer and spring season due to higher temperature, lower rate of photosynthesis and high rate of respiration takes place resulted in lower accumulation of photosynthates as described by Hatfield and Prueger et al.(2015). In contrast, the temperature is lower in winter season that resulted in higher accumulation of photosynthate which caused for bold grains, longer ear length, more no. of ear rows, and kernels per ear as well. Similarly, almost similar results were found with more N splits as compared to lesser no. of N splits (OSU, 2016). Details of the research findings are presented in the following figures.

Table 2. Effect of different growing seasons on tasseling and silking of maize for the two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	Growing Season	Tasseling (days)		Mean	Silking (days)		Mean
		2012/013	2013/014		2012/013	2013/014	
1	Spring	57	58	58	63	68	65
2	Winter	64	68	66	65	75	70
3	Summer	50	48	49	52	56	54
	Mean	57	58	58	60	66	63
	F-test	**	**		*	**	
	$LSD_{0.05}$	1.23	1.98		2.1	1.3	
	CV%	3.4	3.8		2.9	3.5	

Table 3. Effect of growing seasons on plant height and ear height of maize for the two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	Growing	Plant height (cm)		Mean	Ear height (cm)	Mean	
	Season	2012/013	2013/014		2012/013	2013/014	
1	Winter	144	156	150	66	75	71
2	Spring	127	135	131	58	73	66
3	Summer	149	153	151	62	83	73
	Mean	140	148	144	62	77	70
	F-test	**	*		*	**	
	$LSD_{0.05}$	4.03	4.27		4.12	3.98	
	CV%	6.42	5.64		5.89	6.01	

Table 4. Effect of growing seasons on grain yield of maize for the two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	Growing Season	Grain yield (kg ha^{-1})		Mean
		2012/013	2013/014	
1	Winter	3352	4230	3791
2	Spring	4251	4535	4393
3	Summer	2689	2245	2467
	Mean	3430	3670	3550
	F-test	*	**	
	$LSD_{0.05}$	567	613	
	CV%	16.4	19.3	

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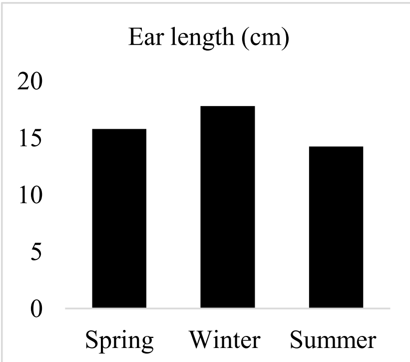


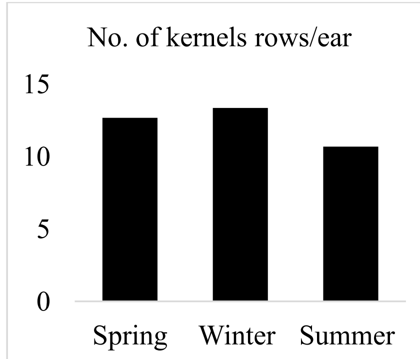
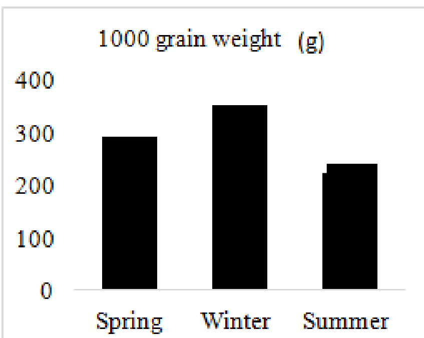


Figure 3. Combined response of growing seasons on ear length and no. of kernels rows per ear of maize for the two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal



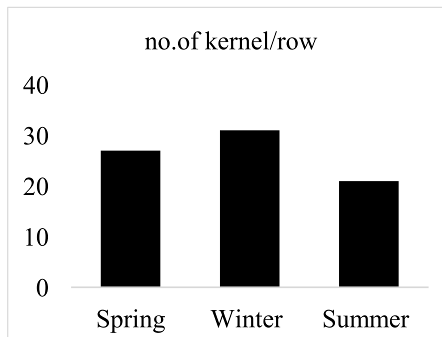


Figure 4. Combined response of growing seasons on thousand grain weight and no.of kernel per row of maize for the two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

Table 5. Effect of different nitrogen application timings on tasseling and silking of maize for two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	N application timings	Tasseling (days)		Mean	Silking (days)		Mean
		2012 /013	2013 /014		2012 /013	2013 /014	
1.	60 kg N ha^{-1} basal application and 60 kg N ha^{-1} at 45 DAS	56	58	57	60	64	62
2.	40 kg ha^{-1} basal application, 40 kg ha^{-1} each at 45 and 60 DAS.	55	59	57	60	64	62
3.	30 kg ha^{-1} basal application, 30 kg N each at 30, 45, and 60 DAS	56	57	57	61	61	61
4.	30 kg N ha^{-1} each at 30, 45, 60, and 75 DAS	55	58	57	59	65	62
5.	Control	62	60	61	68	69	69
	Mean	57	58		62	65	
	$LSD_{0.05}$	2.1	1.9		1.4	1.8	
	CV%	3.4	3.7		3.3	3.8	

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Table 6. Effect of different nitrogen application timings on plant height and ear height of maize for two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	N application timings	Plant height(cm)		Mean	Ear height(cm)		Mean
		2012/013	2013/014		2012/013	2013/014	
1	60 kg N ha^{-1} basal application and 60 kg N ha^{-1} at 45 DAS	159	134	147	76	68	72
2	40 kg ha^{-1} basal, 40 kg ha^{-1} each at 45 and 60 DAS.	152	148	150	75	73	74
3	30 kg ha^{-1} basal, 30 kg N each at 30, 45, and 60 DAS	158	145	152	77	71	74
4	30 kg N ha^{-1} each at 30, 45, 60, and 75 DAS	161	144	153	76	74	75
5	Control	112	126	119	61	54	58
	Mean	148	139		73	68	
	$LSD_{0.05}$	5.9	6.2		4.09	5.2	3.2
	CV%	7.1	6.59		7.65	7.2	

Table 7. Effect of different nitrogen application timings on grain yield of maize for two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

SN	Treatments	2012/013	2013/014	Grain yield (kg ha^{-1})
1	60 kg N ha^{-1} basal application and 60 kg N ha^{-1} at 45 DAS	3890	3737	3814
2	40 kg ha^{-1} basal, 40 kg ha^{-1} each at 45 and 60 DAS.	3466	3567	3517
3	30 kg ha^{-1} basal, 30 kg N each at 30, 45, and 60 DAS	3844	3579	3712
4	30 kg N ha^{-1} each at 30, 45, 60, and 75 DAS	3828	3993	3911
5	Control	2857	2744	2801
	Mean	3577	3524	
	$LSD_{0.05}$	544	591	
	CV%	17.3	19.2	

Figure 5. Combined response of different nitrogen application timings on ear length and no. of rows per ear of maize for two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

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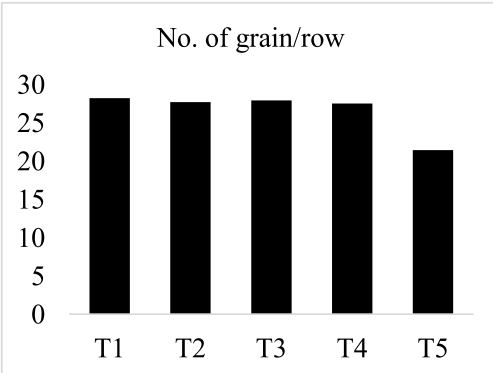

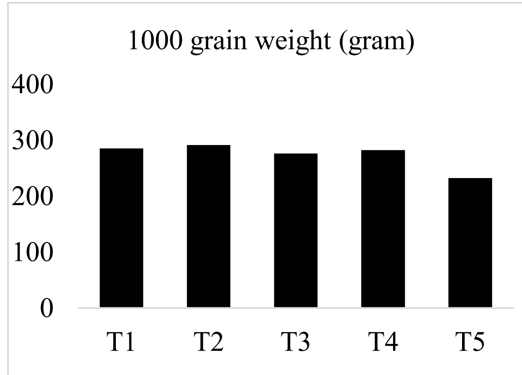

Figure 6. Combined response of different nitrogen application timings on number of grain per row and 1000-grain weight of maize for two consecutive years (2012/013 and 2013/014) at Rampur, Chitwan, Nepal

Grain yield

Grain yield significantly differed (P<0.001) due to growing seasons and fertilizer split applications. Significantly higher grain yield (3911 kg ha^{-1}) was observed with 30 kg N ha^{-1}each at 30, 45, 60, and 75 DAS. Regarding the growing season, highest grain yield was observed in winter season (4393 kg ha^{-1}) followed by spring (3791 kg ha^{-1}), and summer season (2468 kg ha^{-1}), respectively. The result behind more grain yield in the winter season might be due to accumulation of more photosynthates in the cooler season because of lower respiration rates as described by Hatfield and Prueger et al.(2015). Similarly, mortality of pollen grain would also be less in the cooler season as compared to summer and spring season planting and lesser chance of unfilled grains in the ears. The minimum temperature in the coolest season at Chitwan is around 5-7 degree Celsius and there is very little chance of pollen freezing or chilling effect in this temperature, hence more filled grains as compared to summer and spring season could be expected as explained by Hatfield and Prueger (2014). Fabunmi et al. (2009) reported that N fertilizer application has variable maize yield response and concluded that application of N with splits produced significantly higher grain yield rather than basal application only. Research results have recommended different techniques to minimize N losses from different types of soils.

CONCLUSION

Maize can be successfully grown throughout the year in Chitwan and similar terai environments, however winter season planting is more favorable for higher yield. Around 20 percent and 80 percent more grain yield could be harvested in the winter season planting as compared to spring season and summer season planting. Likewise, for good harvest of grain yield 4 splits of N viz. application of 30 kg N ha^{-1} each at 30, 45, 60, and 75 days after sowing respectively, would be more economical for achieving higher grain yield.

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REFERENCES

ABPSD. (2014). Agri-business promotion and statistical division, ministry for agriculture and cooperatives, Singhadarbar, Kathmandu, Nepal.

Adhikary, B.H., Sherchan D.P., & Neupane, D.D. (2004). Effects of nitrogen levels on the production of maize (*Zea mays* L.) planted at varying densities in the Chitwan valleys. pp 216-219. In: Sherchan, D.P., Adhikari, K., Basta, B.K., and Paudel, D. Proceedings of the 22nd national summer crops research workshop on maize research and production in Nepal, June 28-30, 2004, Nepal Agricultural Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Baral, B.R., Adhikari, P., & Shrestha, J. (2015). Growth and yield response of hybrid maize (*Zea mays* L.) to phosphorus levels in sandy loam soil of Chitwan valley, Nepal. *International Journal of Environmental Science, 4*(2),147-156.

Baral, B.R., Adhikari, P., & Shrestha, J. (2016). Productivity and Economics of Hybrid Maize (*Zea mays* L.) under different Fertilizer Doses in the Inner Terai Region of Nepal. *Journal of AgriSearch, 3*(1), 13-17

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science, 11*, 658-661.

Fabunmi, T.O. (2009). Effect of different split appliacton of NPK fertilizer on growth and yield of maize and economic returns. *Nigerian Agricultural Journal, 40,* 1-5.

Hatfield, J.L., & Prueger, J.H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes, 10*, 4–10.

Jat, M. L., Satyanarayana, T., Manundar, K., Parihar, C.M., Jat, S.L., Tetarwal, J.P., Jat, R.K., & Saharawat, Y.S. (2013). *Indian Journal of Fertilizer, 9* (4), 80-94.

K.C., G., Karki, T.B., Shrestha J., & Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of maize research and development, 1*(1), 1-9.

NMRP. (2015). Annual Report of National Maize Research Program Rampur Chitwan Nepal

OSU. (2016) Oklahoma State University. Information on world maize production. Retrieved from http://nue.okstate.edu/Crop_Information/World_Maize_Production.htm

Saseendran, S.A., Neilson, D.C., Ma L., Ahuja, L.R., & Halvorson, A.D. (2004). Modeling nitrogen management effects on winter wheat production using RZWQM and CERES-Wheat. *Agronomy Journal, 96* (3), 615-630.

Sherchan D.P., Neupane, D.D., Uprety, R., Adhikary, B.H., & Maskey, S.L. (2004). Effects of micronutrients on grain production and improving quality of maize in acidic soils of the Chitwan valley. pp 193-197. In: Sherchan, D.P., Adhikari, K., Basta, B.K., & Sherchan, D. *Proceedings of the 22nd National summer crops research workshop on maize research and production in Nepal*, held in June 28-30, (2004), at Nepal Agricultural Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

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DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16218

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development,1*(1), 21-27. doi:http://dx.doi.org/10.3126/jmrd.v1i1.14241

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Grain yield stability of early maize genotypes

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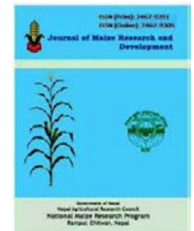

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ABSTRACT

The objective of this study was to estimate grain yield stability of early maize genotypes. Five early maize genotypes namely Pool-17, Arun1EV, Arun-4, Arun-2 and Farmer's variety were evaluated using Randomized Complete Block Design along with three replications at four different locations namely Rampur, Rajahar, Pakhribas and Kabre districts of Nepal during summer seasons of three consecutive years from 2010 to 2012 under farmer's fields. Genotype and genotype × environment (GGE) biplot was used to identify superior genotype for grain yield and stability pattern. The genotypes Arun-1 EV and Arun-4 were better adapted for Kabre and Pakhribas where as pool-17 for Rajahar environments. The overall findings showed that Arun-1EV was more stable followed by Arun-2 therefore these two varieties can be recommended to farmers for cultivation in both environments.

Key words: Early maize genotypes, grain yield, stability

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INTRODUCTION

Maize (*Zea mays* L.) is grown under diverse cropping pattern and environments in the hills and Terai. The cropping pattern exists there are maize-wheat, maize-barley, maize-potatoes, maize-fallow and farmers use shorter duration of maize varieties (80-90 days) to catch the winter and spring crops. The productivity of maize in mid and far western region is below the national average. The adoption rate of improved maize varieties is 30% lower than eastern and western mid-hills (Gurung, 1999). It might be due to longer duration of improved maize varieties which could not fit in the cropping pattern. So, there is need of improved early maize varieties which could fit in the cropping pattern and raise the productivity. The scope of early maize varieties is also in dry ecozones where monsoon is early, higher intensity and longer duration for the intensive cropping system.

The genotypes should be evaluated under different environments before recommending them to farmers. The estimates of GE (genotype-by-environment interaction) is very important to establish the breeding objectives like the choice of genitors, identification of the ideal test conditions and recommendations for regional adapted varieties (Yan *et al.,* 2000). The information on stability of early genotypes under Terai and mid-hill environments of Nepal is not sufficient. So, these studies were carried out and the objective of this study was to evaluate the stability and adaptability of five early maize genotypes in four locations using the GGE biplot.

MATERIALS AND METHODS

Four early maize genotypes namely Pool-17, Arun1EV, Arun-4, Arun-2 and Farmer's variety were evaluated at four different locations namely Rajahar, Rampur, Pakhribas and Kabre during summer seasons of three consecutive years from 2010 to 2012 under farmer's fields. The experimental designs were randomized complete block design with three replications. The plot size was six rows of 3m length. The spacing for row to row and plant to plant was 0.75 m and 0.25 m, respectively. The NPK fertilizer was used @120:60:40 kg ha^{-1}. The half of N plus full dose of P_2O_5 and K_2O were used as basal dose application. The remaining half of the N was divided into two splits and used in two times i.e. at knee-high and pre flowering stages. Rest of agronomic practices was done as per recommendation of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. Grain yield was calculated using formula adopted by Carangal et al. (1971) and Shrestha et al. (2015) by adjusting the grain moisture at 15% and converted to the grain yield per hectare. Analysis of variance for grain yield was done using statistical analysis through Genstat programme. All the genotypes were evaluated under 5% level of significance., The GGE bi-plot software was used to analyze genotype and genotype × environment (GGE) effects on genotypes across environments (Yan & Kang, 2003).

Table 1. Description of maize genotypes used in experiments

SN	Genotype	Parentage
1	Pool-17	Crosses of the early and late flint materials from mexico, the Caribean, South and Central America and Asia
2	Arun-4	Formed using local and elite germplasm
3	Arun-1 EV	Crosses of the late flint and early materials from mexico, the Caribean, South and Central America and Asia
5	Arun-2	UNCAC-242 × Philippines DMR
6	Farmers Variety	-

Table 2. Geographic description of experimental locations

Location	Longitude	Latitude	Elevation (m)
Rampur (Chitwan)	84˚19' E	27˚40' N	228
Rajahar (Nawalparasi)	84° 14' E	27° 41' N	192
Pakhribas (Dhankuta)	87°17' E	27°02' N	1720
Kabre (Dolakha)	86° 9' E	27° 38' N	1788

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RESULTS AND DISCUSSION

Analysis of variance derived from four environments for yield (Table 4) indicated the significant effects of genotype, highly significant effects for environments and their interaction on yield. The maize genotypes were significant for grain yield in different terai and mid hill environments. The Pool-17 produced the significantly highest grain yield (3624 kg ha^{-1}) in Rajhar and Arun-2 (3461 kg ha^{-1}) for Rampur condition excluding Farmer's Variety. The maize genotypes Arun-4 and Arun-2 produced significantly higher grain yield under hills condition. This findings were similar to research findings obtained by Fan et al. (2007). The diverse genetic backgrounds of parent genotypes cause the differences among locations. Obi (1991) and Akande and Lamidi (2006) reported that various agronomic characteristics are controlled by diverse genetic factors therefore genotypes perform differently in a particular location.

Table 3: Combined Grain yield of 5 early maize genotypes in Rajahar, Rampur, Pakhribas and Kabre three years of 2010, 2011 and 2012.

Genotypes	Rajahar	Rampur	Pakhribas	Kabre	Combined
Arun-1 EV	3062	3040	4115	4987	3801
Arun-4	3285	2890	4820	6126	4280
Pool-17	3624	2367	3390	4021	3351
Arun-2	2676	3461	4861	5185	4046
Farmer's variety	2754	4140	3989	4280	3791
Grand mean	3080	3180	4235	4920	3854
CV%	11.3	15.4	5.7	5.5	12.1
$LSD_{0.05}$	462.9	558.0	672.1	748.2	979.2
F-test G	*	*	*	**	*
E					**
G × E					**

According to Yan and Kang (2003), an ideal genotype gives the highest yield across tested environments and is stable in its performance. An "ideal" view is drawn (Figure 1) that showed Arun-2 was the closest to the ideal genotype, followed by Arun-1 EV. A genotype closer to the "ideal" genotype is more desirable. The genotypes would be more stable when they are close to the performance line. The biplot (Figure 2) represents a polygon indicating that the vertex genotypes were Arun-2, Arun-4, Pool-17 and Farmer's Variety.

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Table 4. ANOVA for grain yield for the five maize genotypes tested across 4 environments in Nepal (2010-2012).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	1	2151	2151	0.01	
Genotypes	4	3828763	957191	4.37	0.011
Environment	3	23344058	7781353	35.55	<.001
Genotypes × Environment	12	9459798	788316	3.6	0.006
Error	19	4158583	218873		
Total	39	40793352			

The genotypes positioned on the vertexes have the longest distance from the biplot origin, they are supposed to be the most responsive either best or the poorest at one or every environment (Yan & Rajcan, 2002). The allocation of potential mega-environments are shown by "which won where" graph (Yan et al., 2000). The lines perpendicular to the polygon separates the mega-environments. The Arun-1EV and Arun-4 were suitable for Pakhribas and Kabre environments where as Pool-17 for Rajahar and Farmer's variety for Rampur environments (Figure 2).

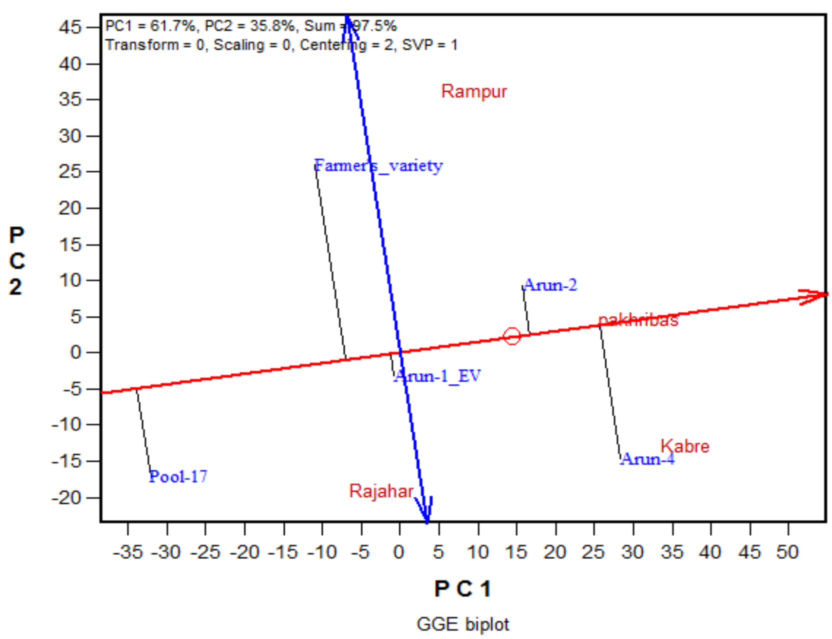

Figure 1. GGE biplot showing ranking of genotypes for mean yield and stability.

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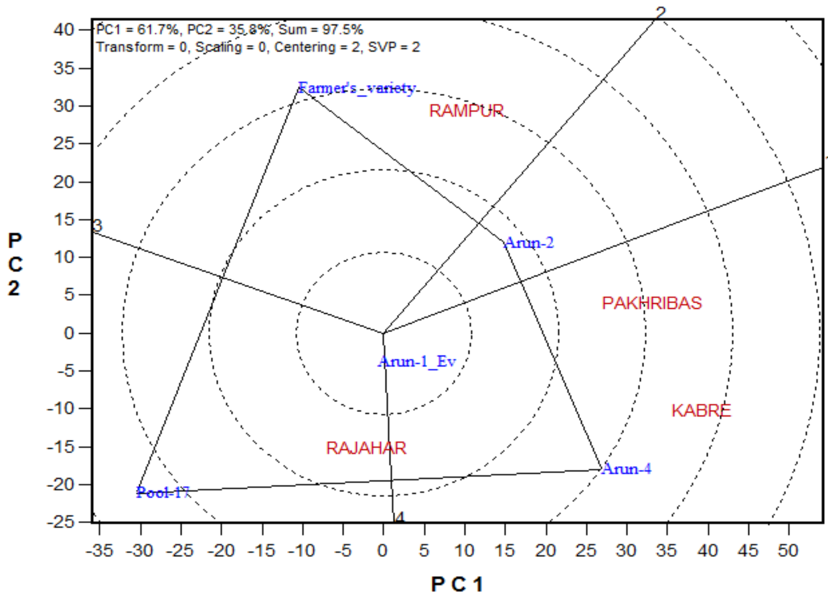

Figure 2. A genotype + genotype × environment interaction bi-plot showing early maize genotype performance in each environment

CONCLUSION

Early maize genotypes showed considerable variation in grain yield under the various terai and hill environments in Nepal. The genotypes Arun-1 EV and Arun-4 were more suitable for mid hills and pool-17 for terai. So Arun-1 EV and Arun-2 can be recommended to farmers for general cultivation.

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REFERENCES

Akande, S.R., & Lamidi, G.O. (2006). Performance of quality protein maize varieties and disease reaction in the derived savanna agro-ecology of South West Nigeria. Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. pp.1-4.

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16219

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science, 11*, 658-661.

Fan, X., Kang, M., Chen, H., Zhang, Y., Tan, J., & Xu, C. (2007). Yield stability of maize hybrids evaluated in multienvironment trials in Yunnan, China. *Agronomy Journal*, 99, 220-228

Gurung, D.B. (1999). Potentials and Contraints of the maize based cropping system in the mid and Far Western hills of Nepal. A Survey Report. HARP PP01/98. Report No. 2.

Obi, I.U. (1991). Maize: Its agronomy, diseases, pest and food values. Optimal Computer Solutions Limited. Enugu, publishers. 76 Agbani Road Enugu, Nigeria, XXVIII. Pp. 206.

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development*, *1*(1), 21-27. doi:http://dx.doi.org/10.3126/jmrd.v1i1.14241

Yan, W., & Kang, M.S. (2003) 'GGE biplot analysis: a graphical tool for breeders, geneticists, and agronomists.' (CRC Press: Boca Raton, FL)

Yan, W., & Rajcan, I. (2002). Biplot analysis of test sites and trait relations of soybean in Ontario. *Crop Science*, *42*,11–20.

Yan, W., Hunt, L.A., Sheng, Q., & Szlavnics, Z. (2000). Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Science*, *40*,597-605.

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Phosphorous as the major yield limiting nutrient for maize in the river basin areas of western Nepal

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ABSTRACT

Maize is a heavy feeder crop but not always higher quantity of chemical fertilizers leads for higher grain yield. Objective of the study was to identify the major yield limiting macro nutrient for maize in the river basis areas. Field experiments were conducted at four locations viz. Dasharathpur, Ramghat, Mehelkuna, and Gumi VDCs of Surkhet district, under research command areas of Agriculture Research Station, Surkhet. Different doses of nitrogen, phosphorous and potassium fertilizers were applied. Planting was done in the summer season of 2010 and 2011. All field experiments were laid out in randomized complete block designs with three replications at each site and year. Deuti variety of maize was used in the experiment. Days to tasseling, silking, and physiological maturity due to fertilizer application were found significant. One week earlier silking, tasseling, and physiological maturity was observed due to use of 100:100 kg ha^{-1} nitrogen and phosphorous as compared to the most late maturity with application of 100 kg nitrogen ha^{-1}. The highest grain yield (6802 kg ha^{-1}) was found with application of 100:100 kg nitrogen and phosphorous ha^{-1} and the lowest grain yield (4174 kg ha^{-1}) was found with the normal recommended fertilizer dose. Phosphorous was observed as the major yield limiting factor in this study.

Keywords: Grain yield, maize, phosphorous, river basin, western Nepal

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INTRODUCTION

Farmers are gradually shifting towards commercial cultivation and started to grow improved varieties and/or hybrids of maize in Terai as well as hilly regions of Nepal (KC et al., 2015). The cultivation of improved and hybrids in intensive cropping systems increased nutrients demand (Shrestha et al., 2015). Maize is heavy feeder crop for which locally available nutrients source mostly farmyard manures, compost and biologically fixed nitrogen are not sufficient to

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fulfill the demands of nutrient. The soil fertility decline in the hills increases due to reduction in the organic matter content where nitrogen is the major nutrient which is gradually diminishing in soils of Nepal (Tripathi & Shrestha, 2001). Chemical fertilizers play a significant role in yield increment however, increased amount of fertilizers not always contribute to increase maize yield (Amujoyegbe et al., 2007). The availability of soil moisture enhances the efficacy of these nutrients uptake (Purdue University, 2012); effect is significantly higher during rainy season maize in our context rather than winter season as we do not have assured irrigation facility. Phosphorous is required for seed formation. It enhances water use efficiency and hastens crop maturity. This nutrient play important role in photosynthesis, cell division, energy transfer, root growth, cell enlargement, root formation (Roberts, 2004). In the soil Potassium (K) is not readily available; it is involved in the structural component of soil minerals. Therefore, the amount of K supplied by soils varies, which lead to variation in the amount of K fertilizer applications across soil types (Belay et al., 2002). Potassium is one of 12 nutrients which is necessary for normal corn growth and development. Basically, K is required for the movement of water, nutrients, and carbohydrates within the plant. It enhances early growth, increases protein production, and improves the water use efficiency and resistance to diseases and insects (Brady & Weil, 2014). The optimal yield cannot be received if chemical fertilizers are not scheduled and applied at proper dose for accelerated uptake by the plants (Roberts et al., 2004). The actual amount of each nutrient needed depends on the initial soil test level, soil texture, clay minerals, and organic matter level. The objective of our study was to identify the major yield limiting nutrient in the river basin condition of research command areas of Agriculture Research Station (ARS), Surkhet.

MATERIALS AND METHODS

Testing sites

Agriculture Research Station (ARS), Surkhet is situated at $28^0 30'$ Northern latitude, $81^0 47'$ Eastern longitude, and 480 meter elevation from the sea level (NARC, 2014). The station is 26 km southeast from the district headquarter of Surkhet, Birendranagar. Field experiments were conducted at four locations of research command areas of Agriculture Research Station (ARS), situated at the river basin surroundings of the Bheri river of Surkhet district. All the research sites had a moderate climate where winter temperatures dropped to 5°C and in summer it raised up to 38°C (NARC, 2014). All the research sites have the subtropical hot humid climate. All the testing sites have similar climatic conditions to the ARS Surkhet because they are in the almost similar altitude and not far than 7 kilometers from the research station. The weather condition was as usual during the maize growing season for both the years at all the locations. Based on the soil analysis report from Soil Science Division, Khumaltar, initial nutritional status of different available major nutrients, soil organic matter, and pH of the experimental sites were N (0.11 to 0.178%), P_2O_5 (14-17 parts per million, ppm) K_2O (52-83 ppm), organic matter content (2.8-3.2%). Similarly, the soil was moderately acidic in reaction (pH: 5.32 to 5.81).

Maize variety

Deuti, a full season open pollinated variety of maize was selected for the study. Deuti was introduced in Nepal in 1999/2000 from the International Center for Wheat and Maize Improvement (CIMMYT) in the name of ZM-621. This variety was developed at Zimbabwe

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under CIMMYT regional research program for maize in the dry areas. This variety was tested for more than six years in Nepal at different growing environments under different trials and recommended for general cultivation for mid hills, Terai, and inner Terai conditions of Nepal.

Field experiment and data collection

Field experiments were laid out in four locations viz. Dasharathpur, Mehelkuna, Gumi, and Ramghat villages of Surkhet district during the rainy season of 2010 and 2011. Six different combinations of N, P, and K fertilizers were tested which is given as below;

T-1: Farmers'practice (20 kg N + 10 ton FYM ha^{-1})
T-2: 100 kg N ha^{-1}
T-3: 100:100 kg NP ha^{-1}
T-4: 100:100:100 kg NPK ha^{-1}
T-5: 100:100:100 kg NPK ha^{-1}+5-ton lime ha^{-1}
T-6: Recommended dose (120:60:40 kg NPK ha^{-1})

Randomized complete block (RCB) design with three replications at each site was followed for each year. At all the locations, each plot size was 13.5 meter square. Width of the plot was 4.5 meter i.e. six rows with 75 cm row to row distance and 25 cm plant to plant distance. The length of the plot was 3 meter. Planting was done on 12, 14, 16 and 18 June, 2010 and 11, 13, 15 and 17 June, 2011 at Dasharathpur, Ramghat, Mahelkuna and Gumi village development committee (VDC), respectively. Sources of phosphorous was single super phosphate (16 % phosphorous), source of potash was murate of potash (60 % potash), and source of nitrogen was urea (45 % nitrogen). All amount of phosphorous, potash, and one third amount of nitrogen was applied at the time of sowing. Remaining tow third of nitrogen, 50% was used at knee high stage and another 50% at tasseling/silking period, respectively. Weeding was done manually at 30 DAS and earthing up at 50 DAS. Rest of other cultural practices was done as per recommendation of National maize Research Program (NMRP), Rampur, Chitwan. Parameters like plant and ear height, flowering, physiological maturity, and grain yield were evaluated. Grain yield was estimated using formula adopted by Carangal et al. (1971) and Shrestha et al.(2015) by adjusting the grain moisture at 15% and converted to the grain yield kg per hectare. Data were analyzed by using CROP-STAT computer program applying 5% level of significance.

RESULTS AND DISCUSSION

Days to tasseling, silking, and physiological maturity

Statistically, significant difference ($P<0.001$) was observed for days to tasseling and days to silking due to applications of different doses of chemical fertilizers. The earliest tasseling (55 days) and silking (60 DAS) was found with the application of 100:100 kg N and P ha^{-1}, respectively. Likewise, the most late tasseling (61 days) and silking (68 days) was observed with the application of 100 kg N ha^{-1}. Phosphorous is the precursor for flowering and it plays a significant role for shortening the maturity period (Belay et al., 2002). Nitrogen is one of the basic structural elements and plays significant role in construction of chlorophyll (Brady & Weil,

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2014), therefore nitrogen is responsible for vegetative growth as well. Effect of nitrogen and phosphorous on vegetative growth and maturity was clearly observed in this study and consequently, phosphorous shortened the duration for flowering whereas the nitrogen delayed it. A detail of the research result is presented in Table 1.

Table1. Response of Deuti variety of maize to tasseling and silking days as influenced by different doses of N, P, and K during the summer of 2010 and 2011.

SN	Treatment	Days to 50% flowering									
		Tasseling					Silking				
		D' Pur	Ram ghat	Mahel kuna	Gumi	Av.	D' pur	Ram ghat	Mahel kuna	Gumi	Av.
1	Farmers' practice (20 kg N + 10 ton FYM ha^{-1})	58	55	59	60	58	65	60	64	64	63
2	100 kg N ha^{-1}	65	58	61	61	61	72	64	66	68	68
3	100:100 kg NP ha^{-1}	56	51	57	57	55	61	56	62	62	60
4	100:100:100 kg NPK ha^{-1}	61	55	57	58	56	65	59	61	62	62
5	100:100:100 kg NPK ha^{-1}+5-ton lime ha^{-1}	58	54	59	59	58	62	58	63	63	62
6	Recommended dose (120:60:40 kg NPK ha^{-1})	63	55	59	62	60	68	60	64	66	65
	Average	60	55	59	60	58	66	60	63	64	63
	CV%			3.28					3.30		
	P value ($_{Location}$)			<0.01					<0.01		
	P value ($_{Treatmenets}$)			<0.01					<0.01		
	$LSD_{0.05}$			2.99					2.94		

Note: P_L – P value for location, P_T – P value for different treatments, D'pur – Dasharathpur, Av. – Average

Similarly, significant difference (P<0.001) was found for physiological maturity due to application of different doses of chemical fertilizers. For days to physiological maturity too, application of 100:100 kg ha^{-1} N and P attained the earliest maturity (107 DAS). The most late (114 DAS) physiological maturity was observed with 100 kg N ha^{-1}. The difference in maturity was found 7 days between these two treatment combinations. The causes behind late in maturity would the same as in the case of days to flowering where nitrogen helped delay in maturity and phosphorous for earliness in maturity as mentioned by Baley et al.(2002). A graphical representation of the result is presented in Figure 1.

Plant and Ear height

The different levels of fertilizers application significantly affected the plant height. The tallest plant height (224 cm) was measured with 100 kg N ha^{-1}. There was no statistical significant difference for rest of the treatment combinations for plant height. Similarly, ear height was also found significantly taller (121 cm) with the application of only 100 kg N ha^{-1}. The taller ear and plant height might be due to increment in dry matter accumulation as N contributed more

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for vegetative growth as mentioned by Roberts et al. (2004). The result showed a significant effect of N on plant and ear height. A detail of research result is presented in table 2.

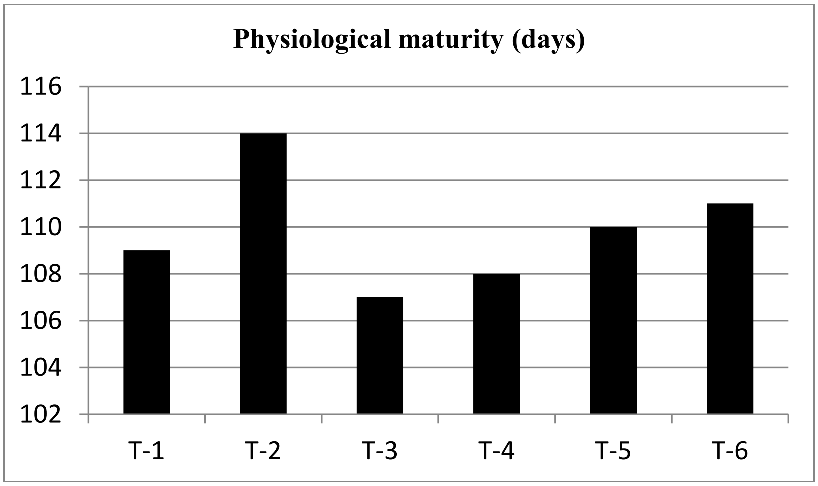

Figure 1. Physiological maturity (days) as affected by application of different fertilizer dose in the river basin areas of Surkhet district during the rainy season of 2010 and 2011

Table2. Plant and ear height of Deuti maize variety due to application of different major nutrients during the rainy season of 2010 and 2011.

SN	Treatments	Height (cm)									
		Ear height					Plant height				
		D' pur	Ram ghat	Mahel kuna	Gumi	Av.	D' pur	Ram ghat	Mahel kuna	Gulmi	Av.
1	Farmers' practice (20 kg N + 10 ton FYM ha^{-1})	95	122	124	106	112	182	221	226	208	209
2	100 kg N ha^{-1}	125	120	125	121	123	222	229	227	216	224
3	100:100 kg N:P ha^{-1}	102	104	105	117	107	196	207	198	217	205
4	100:100:100 kg NPK ha^{-1}	109	110	105	103	107	209	207	195	201	203
5	100:100:100 kg NPK ha^{-1} +5-ton lime ha^{-1}	101	103	99	98	100	201	193	199	198	198
6	Recommended dose (120:60:40 kg NPK ha^{-1})	106	113	112	108	110	212	219	210	198	210
	Average	106	112	112	109	110	204	213	209	206	208
	CV%	6.95					11.34				
	P value ($_{Location}$)	<0.01					<0.01				
	P value ($_{Treatments}$)	<0.01					<0.01				
	$LSD_{0.05}$	16.29					15.47				

D'pur – Dasharathpur, Av. – Average

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Grain Yield

Statistically, significant (P<0.001) result was found for grain yield due to application of different rates of major chemical fertilizers. The highest grain yield (6802 ha^{-1}) was produced with the application of 100:100 kg NP ha^{-1}. While, the lowest grain yield (4174 ha^{-1}) was observed with the farmers' practice i.e. application of 20 kg N ha^{-1} at knee high stage and 10 ton FYM ha^{-1} at the time of maize seed sowing. 63% more yield was found with the application of 100:100 kg NP ha^{-1} as compared to farmers' practice. Likewise, 52% more yield was found with the application of 100:100:100 kg NPK ha^{-1} followed by 50% more yield with 100:100:100 kg NPK ha^{-1} + 5 ton ha^{-1}, 49% more yield with recommended dose and 43% more yield with 100 kg N ha^{-1}, respectively. A summarized result is presented in table 3. Phosphorous was observed one of the principle plant nutrients for maize yield in this study. It is involved in many physiological processes like assimilate transport, photosynthesis, and enzyme activation that have direct consequences on crop productivity (Belay et al., 2002) that the role of phosphorous and potassium for maize growth and development was crucial. Similar result was also found by Pokharel et al., (2004) in an experiment conducted under mid hill environments of Dailekh district of Nepal. The lower yield in farmers' practice might be due to lower minerals supplement by the FYM. The compost fertilizer contains around 0.5-0.7 percent N, 0.4-0.75 percent P, and 0.2-0.55 percent K (Brady & Weil, 2014). In this study, it is found that the role of phosphorous and nitrogen was noticeable while potash did not play a significant role for higher grain yield. It may be due to the presence of medium amount of potash in the soil. The soil analysis report also showed a medium concentration of potash. Phosphorous was the major chemical fertilizer that played a significant role for higher productivity of maize in the river basin areas of the study areas. There was no significant effect of lime for grain yield in this study. Summary of research result is resented in Table 3.

Table 3. Response of Deuti maize variety for grain yield as influenced by different chemical fertilizer application during the rainy season of 2010 and 2011 under river basin areas.

SN	Treatments	Grain yield (kg ha^{-1})				Av.	YIOFP (kg ha^{-1})	YIOFP (%)
		D' pur	Ram ghat	Mahel kuna	Gumi			
1	Farmers' practice (20 kg N ha^{-1} + 10 ton FYM ha^{-1})	3125	4538	5362	3672	4174	0	0
2	100 kg N ha^{-1}	3494	6353	7725	6297	5967	1793	43.0
3	100:100 kg NP ha^{-1}	5477	7801	7129	6803	6802	2628	63.0
4	100:100:100 kg NPK ha^{-1}	5446	7624	6832	5447	6337	2163	51.8
5	100:100:100 kg NPK ha^{-1} + 5-ton lime ha^{-1}	6265	6148	7086	5504	6251	2077	49.8
6	Recommended dose (120:60:40 kg NPK ha^{-1})	5444	6358	6254	6873	6232	2058	49.3
	Average	4875	6470	6731	5766	5961	-	-
	CV%			13.17			-	-
	P value ($_{Location}$)			>0.05				
	P value ($_{Treatments}$)			<0.01				
	$LSD_{0.05}$			1926				

D'pur – Dasharathpur, Av. – Average

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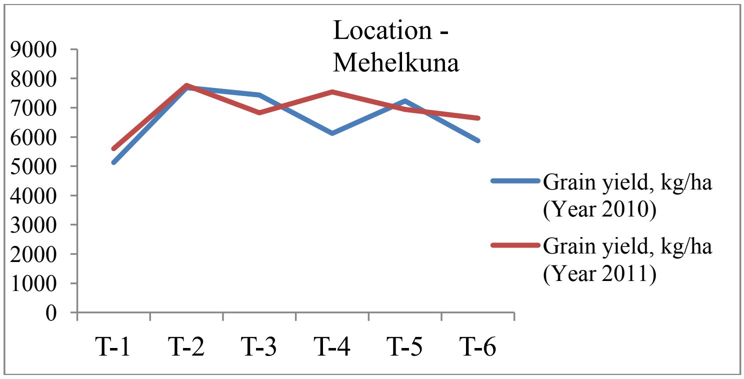

Figure 2. Grain yield (kg ha^{-1}) as influenced by different fertilizer doses of NPK at Mahelkuna of Surkhet district

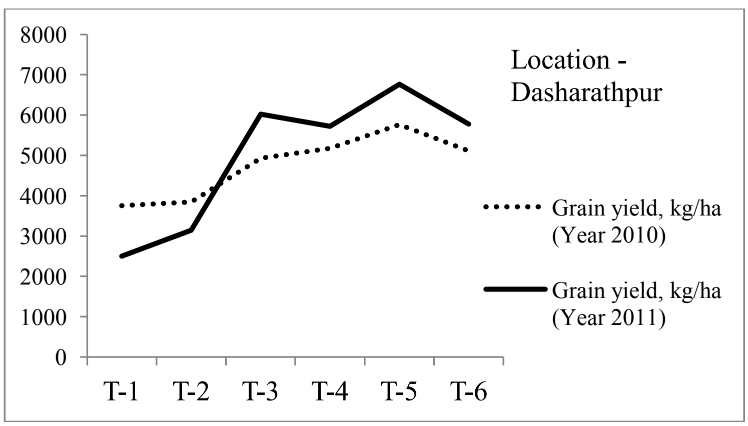

Figure 3. Response of different NPK fertilizer doses on grain yield (kg ha^{-1}) of maize for two consecutive years (2010 and 2011) at Dasharathpur, Surkhet

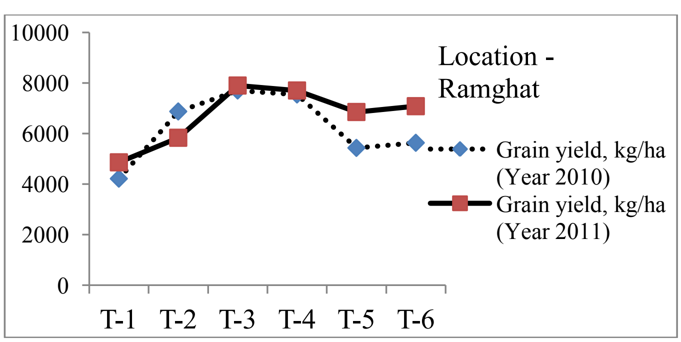

Figure 4. Response of different NPK fertilizer doses on grain yield (kg ha^{-1}) of maize for two consecutive years (2010 and 2011) at Ramghat, Surkhet

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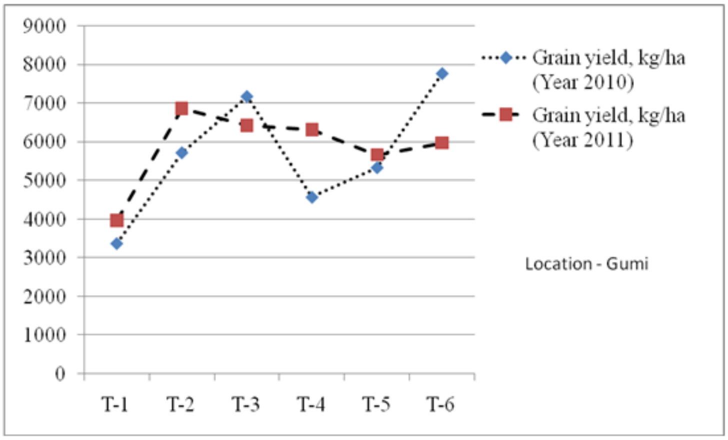

Figure 5. Response of different NPK fertilizer doses on grain yield (kg ha^{-1}) of maize for two consecutive years (2010 and 2011) at Gumi, Surkhet

CONCLUSION

Maize with 100:100 kg NP ha^{-1} attained earliest maturity. The role of phosphorous in early maturity was clearly observed in this experiment. The difference in maturity was found 7 days between these two extremes. The highest grain yield (6802 kg ha^{-1}) was found with 100:100 kg NP ha^{-1} and the lowest grain yield (4174 kg ha^{-1}) was found with farmers practice i.e. application of 20 kg N ha^{-1} at knee high stage and 10 ton FYM at sowing time. The role of potash on grain yield was found negligible in this study. Phosphorous was found as the major nutrient that limits yield in these regions. The role of lime for grain yield was also found minimal.

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REFERENCES

ABPSD. (2015). Agri-business Promotion andand Statistics Division. Statistical Information on Nepalese Agriculture. Ministry for Agriculture and Cooperatives, Singadarbar, Kathmandu, Nepal.

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16220

Amujoyegbe, B. J., Opabode J. T., & Olayinka, A. (2007). Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize (*Zea mays* L.) and sorghum (*Sorghum bicolour* (L.) Moench). *African Journal of Biotechnology, 6* (16), 1869-1873.

Belay, A., Claassens, A., & Wehner, F (2002). Effect of direct nitrogen, potassium and residual phosphorus fertilizers on soil chemical properties, microbial components and maize yield under long-term crop rotation. *Journal of biology and fertility of soils*. 35, 420-427.

Brady, N.C., & Weil, R.R., (2014). *The Nature and Properties of Soils,* (14th ed., pp. 567, 615, and 671). New Delhi, India: Pearson Education.

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science,* 11, 658-661. doi:10.1007/s00374-002-0489-x

KC, G., Karki, T.B., Shrestha, J., & Acchami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development, 1*(1):1-9.

NARC. (2014). Nepal Agricultural Research Council, Annual Report of Agriculture Research Station, Dasharathpur, Surkhet, Nepal.

Pandey, S.P. (2000). Current soil fertility management, recommendations, constraints and opportunities for maize based cropping systems in the hills of Nepal. In Tripathi, B.P., Rajbhandari, N.P., &and Ransom, J.K. (eds): Improving soil fertility management for sustainable maize productions. 16-18 August, 2000. Lumle, Kaski, Nepal.

Pokharel B.B., Adhikari, B.N., Koirala, K.B., Gurung, D.B., Poon, T.B., & Sharma, S.R. (2004). Assessment of the major maize yield limiting nutrients in mid and far western mid hill environments. pp 140-142. In: Sherchan D.P., (eds.) Proceedings of the 24th national summer crops research workshop on maize research and production in Nepal. Organized by NMRP and NARC, 28-30 June 2004, Kathmandu, Nepal.

Roberts R.K., Walters, J.T., Larson, A., English, B.C., & Howard, D.D. (2004). Effects of disease, nitrogen source, and risk on optional nitrogen fertilization timing in winter wheat production. *Agronomy Journal*, *96* (3), 792-799.

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development, 1*(1), 21-27. doi:http://dx.doi.org/10.3126/jmrd.v1i1.14241

Tripathi, B.P., & Shrestha, S. (2001). Improved soil fertility management for sustainable maize production workshop group meeting of the hill maize research project. Kathmandu: NARC and CIMMYT.

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Evaluation of maize genotypes for Turcicum leaf blight (*Exserohilum turcicum*) in Terai and inner terai of Nepal

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ABSTRACT

Thirty maize genotypes in 2014-2015 at Dumarwana, Nijgadh, Keureni and Rampur and ten genotypes in 2015-2016 at Anandpur, Shitalnagar, Dumarwana, Nijgadh and Rampur were evaluated for resistance to Turcicum leaf blight (*Exserohilum turcicum*) under farmers field conditions. The scale used for disease severity ranged from 1-5 scale based on the proportionate leaf area affected by the disease. The combined analysis over locations in 2014-2015 showed that among the 30 genotypes 25 genotypes were resistant (1.0-2.0 scale), and 5 genotypes were moderately resistant (2.1-3.0 scale). Similarly the pooled analysis over locations in 2015-2016 showed that 7 genotypes were resistant (1.0-2.0 scale) and 3 genotypes were moderately resistant (2.1-3.0 scale). The maize genotypes namely Z376-26, Z478-3, Z433-99, Z464-5, Z478-2, Z466-1, CAH1513, RML-95/RML-96, CAH1515, CAH1521, CAH1515, CAH151, CAH153, ZH114228 , Z376-9, Z466-3, Z376-5, RML-32/RML-17, RML-86/RML-96 and 900MGold were resistant with disease severity scale of 1.5 and with higher grain yield in both the years. Thus above genotypes were identified as promising sources of resistance against *E. turcicum* and they can be used to develop disease resistant and high yielding varieties to enhance maize productivity in terai and inner terai of Nepal.

Key words: resistant, susceptible, genotypes, severity

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INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop in Nepal in terms of both area and production after rice. It is the principle food crop in the hills of Nepal. Both abiotic and biotic stresses contribute to lower maize yields in Nepal. The most devastating diseases of

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maize in the context of Nepal are leaf blights (northern and southern), ear rot, stalk rot, rust, downy mildews, etc. (Khadka & Shah, 1967; Shah, 1968; Thapa, 1977; Manandhar, 1983; Batsa et al., 1989; Paudel et al., 1989). Among the major global issues, food and nutrition security, especially in developing and under developed countries are the biggest challenges of the present agricultural scenario (Ulrich, 2011). For the livestock maize serves as important fodder crop, for human staple food crop and for many agro-allied industries as source of raw materials in the world (Bello et al., 2010; Randjelovic et al., 2011). Turcicum Leaf blight (TLB) of maize caused by *Exserohilum turcicum* (Pass.) K.J. Leonard and E.G. Suggs (teleomorph *Setosphaeria turcica* Luttrell) was first observed by Passerini on corn in Italy in 1876, and has been reported from all maize growing areas of the world wherever maize is cultivated (Atac. 1984; Leonard et al., 1985). The pathogen was formerly known as *Helminthosporium turcicum* (Khedekar et al., 2010; Muiru et al., 2007). Khadka and Shah (1967) reported this disease for the first time in Nepal. TLB, also known as Northern corn leaf blight (NCLB), is more prevalent in the hills during summer and winter to early spring in Terai and Inner terai. The disease occurs in maize from the seedling to maturity stages. The epidemic of the disease is increasing every year in all maize growing areas because of intensive maize cultivation where three maize crops are harvested each year from the same land. TLB reported in 1966 for the first time in Nepal (DAER, 1966) and was not considered as the major disease of maize crop 1985. Temperatures between 20 and 25 ^{0}C, relative humidity from 90 to 100%, and low luminosity favor the disease development (Bentolila et al., 1991). In mid-altitude regions where there is high humidity, low temperature and cloudy weather TLB can be severe during the maize growing season (Singh et al., 2004; Harlapur, 2005). Although many maize genotypes have been released from breeding programmes, their reactions to the turcicum leaf blight are largely unknown. This experiment was carried out in order to identify the reaction of maize genotypes to turcicum leaf blight pathogen under field conditions.

MATERIALS AND METHODS

Experimental site

The followings locations were selected for the experiments. The geographical details of these sites are as below;

Table 1. Geographic description of experimental locations

Location	Longitude	Latitude	Elevation (m)
Dumarwana (Bara)	85° 1' 8.5"E	27° 7' 55.7"N	124
Nijgadh (Bara)	85° 10' 32.5"E	27° 12' 11.8"N	169
Keureni (Nawalparasi)	84°12'31.44" E	27°40'22.77" N	178
Shitalnagar (Nawalparasi)	84° 23' 21.1"E	27° 41' 42.5"N	193
Anandpur (Chitwan)	84° 23' 13.7"E	27° 40' 12.1" N	194
Rampur (Chitwan)	84° 20' 20.9"E	27° 39' 0.3"N	182

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Field experiments

All field experiments were conducted during winter seasons in 2014-2015 and 2015-2016 using randomized complete block design (RCBD) with 2 replications at 6 locations of 3 districts namely; Bara (Dumarwana and Nijgadh), Chitwan (Rampur and Anandpur) and Nawalparasi (Keureni and Shitalnagar). The row to row and plant to plant spacing were 60 cm and 25 cm respectively. The plot area was 24 m^2 in 2014-2015 and 30 m^2 in 2015-2016. The fertilizer used was 200:60:40 kg NPK ha^{-1} for all experiments. The recommended package of practices was followed during crop growth according to recommendations given by National Maize Research Program (NMRP), Rampur, Chitwan. Disease severity was measured using scale of 1–5 rating as per CIMMYT protocol (CIMMYT, 1985; Singh et al. 2004).

Data collection and analysis

Each maize genotype was screened using standard 1-5 scale. According to Payak and Sharma, (1982), 1 scale for complete resistant and 5 for the complete susceptible. Based on this rating scale, the maize lines were categorized into four groups namely, resistant (R) genotypes with a score < 2.0; moderately resistant (MR) 2.1-3.0; moderately susceptible (MS) 3.1-3.5 and highly susceptible (S) > 3.5. Grain yields were adjusted to 80% shelling recovery. Grain yield was estimated using formula adopted by Carangal et al. (1971) and Shrestha et al. (2015) by adjusting the grain moisture at 15% and converted to the grain yield kg per hectare. Data were analyzed through GENSTAT packages applying 5% significance level.

RESULTS AND DISCUSSION

Results from individual locations (Table 2) in 2014-2015 showed that at Dumarwana genotypes Z376-9, Z466-3, Z376-5 were resistant with disease severity scale of 1.5 and with grain yield of >10.5 t ha^{-1}. Similarly at Nijgadh RML-32/RML-17, Z376-26 and Z478-3 were resistant with 1.5 disease severity scale and >9 t ha^{-1}grain yield. Likewise at Kuereni Z433-99 and Z464-5 showed resistant reaction having disease severity scale of 1.5 and with grain yield >11 t ha^{-1}. At Rampur genotypes Z478-2, Z466-1 and 900MGold were resistant (with 1.5 disease severity scale) and grain yield of >8.5 t ha^{-1}.

Table 2. Response of maize genotypes for turcicum leaf blight and grain yield (t ha^{-1}) in 2014-2015 winter

SN	Genotypes	Dumarwana		Nijgadh		Keureni		Rampur		Combined	
		TLB. (1-5)	GY	TLB. (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY
1	Z478-2	1.5	10.65	1.5	8.98	1.5	8.02	1.5	9	1.5	9.2
2	Z478-3	1.5	9.49	1.5	9.38	1.5	10.06	1.5	8.64	1.5	9.4
3	Z478-5	1.5	9.99	1.5	8.74	1.5	8.87	1.5	8.12	1.5	8.9
4	Z478-4	2	9.57	2	9.86	1.5	10.09	2	7.74	1.9	9.3
5	Z478-8	1.5	9.92	3	6.65	1.5	8.01	2	5.95	2	7.6
6	Z480-1	2	11.37	3	7.41	2.5	4.09	2.5	5.71	2.5	7.1
7	Z478-9	2.5	6	3.5	10.59	2.5	5.13	1.5	5.17	2.5	6.7
8	Z480-2	1.5	6.81	4.5	6.47	2	6.91	2.5	5.32	2.6	6.4

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9	Z478-10	2.5	7.13	4.5	6.32	1.5	8.41	2	5.51	2.6	6.8
10	Z433-11	1.5	10.44	1.5	6.76	1	12.29	1.5	2.89	1.4	8.1
11	Z433-99	1.5	10.27	2.5	5.77	1.5	11.42	1.5	6.27	1.8	8.4
12	Z464-5	1.5	8.81	2	6.07	1.5	11.27	1.5	6.24	1.6	8.1
13	Z376-30	1.5	8.41	2	3.67	1.5	9.68	1.5	5.38	1.6	6.8
14	Z466-4	1.5	7.95	3	7.64	1.5	6.24	1.5	6.34	1.9	7
15	Z466-3	1.5	11.21	2	6.83	1.5	9.03	1.5	7.11	1.6	8.5
16	Z466-1	1.5	10.61	3.5	7.39	1.5	7.73	1.5	8.91	2	8.7
17	Z376-2	1.5	9.86	2.5	6.36	1.5	9.38	1.5	7.97	1.8	8.4
18	Z376-5	1.5	10.62	2.5	7.84	1.5	5.41	1.5	7.25	1.8	7.8
19	Z376-6	1.5	10.07	1.5	7.96	2	7.63	1.5	8.56	1.6	8.6
20	Z376-8	1.5	10.16	1.5	7.33	1.5	9.04	1.5	7.55	1.5	8.5
21	Z376-9	1.5	11.38	1.5	7.9	1.5	8.79	2	7.92	1.6	9
22	Z376-26	1	10.11	1.5	9.47	1.5	8.5	1.5	8.54	1.4	9.2
23	Z376-34	1.5	8.45	2.5	9.67	1.5	7.1	1.5	8.45	1.8	8.4
24	Z376-51	1.5	8.25	1.5	8.72	1.5	10.47	1.5	7.05	1.5	8.6
25	900M Gold	1.5	9.35	2	7.69	1.5	7.71	1.5	8.79	1.6	8.4
26	30V92	2.5	8.57	2	10.42	3	9.09	4.5	4.95	3	8.3
27	RML-32/RML-17	2	10.64	1.5	11.37	2	7.65	2.5	8.27	2	9.5
28	RML-95/RML-96	1.5	11.15	2	11.04	1.5	9.04	2	7.46	1.8	9.7
29	RML-86/RML-96	1.5	9.74	2.5	7.63	1.5	10.94	2	7.43	1.9	8.9
30	Rampur Hybrid-2	1.5	10.71	1.5	8.74	2	9.17	2.5	6.32	1.9	8.7
	Mean	1.6	9.59	2.3	8.02	1.7	8.57	1.8	7.03	1.9	8.3
	F-test									**	ns
	CV%									27	18.9
	$LSD_{0.05}$									0.7	2.2

GY: Grain yield

In 2015-2016 (Table 3) at Nijgadh genotypes CAH1513 and CAH1515 were resistant with disease severity scale of 1.5 and with grain yield of >7 t ha^{-1}. Similarly at Dumarwana RML-95/RML-96, CAH1515 and CAH1521 were resistant with 1.5 disease severity scale and >7 t ha^{-1}grain yield. Likewise at Shitalnagar CAH1521, CAH1515, CAH151 and CAH153 showed resistant reaction having disease severity scale of 1.5 and with grain yield >11 t ha^{-1}. At Rampur genotypes ZH114228 and CAH153 were resistant (with 1.5 disease severity scale) and grain yield of >5 t $ha^{-1}$and at Anandapur genotypes CAH1515, ZH114228 and RML-86/RML-96 were resistant with grain yield of > 8 t ha^{-1}.

The maize germplasm with resistance to *E. turcicum* was previously reported (Muriithi and Mutinda, 2001; Pandurangegowda *et al*., 2002; Dharanendraswamy, 2003; Harlapur, 2005). Maize susceptibility, cropping practices, and weather conditions strongly influence disease development. The quantitative and qualitative mechanisms control maize resistance to TLB (Hooker, 1981; Ogliari *et a*l., 2007). Quantitative resistance is described by low lesion number, small lesion area having typical necrotic lesion types, along with reduced severity and area under disease progress curve (AUDPC) values; whereas the qualitative resistance is characterized by small lesions surrounded by chlorotic halo also referred to as Ht (*Helminthosporium turcicum*)-lesions type. The results of these experiments showed that resistance reactions for TLB varied with locations and these findings were similar to findings obtained by Welz and Geiger (2000) who reported differential expression of resistance by some varieties when tested at different

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places. The variation in reactions with different climatic conditions was due to environmental factors such as temperature and light that can modify resistance based on Ht genes and also disease pressure varies in different areas.

Table 3. Response of maize genotypes for turcicum leaf blight and grain yield (t ha^{-1}) during winter season of 2015-2016.

SN	Genotypes	Nijgadh		Dumarwana		Shitalnagar		Rampur		Anandapur		Combined	
		TLB (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY	TLB (1-5)	GY
1	CAH158	1	4.6	1.5	6.5	2	11.7	2.5	4.8	2	7.6	1.8	7.03
2	CAH1521	2	2.9	1.5	7.1	1.5	12.3	2	4.3	1.5	11	1.7	7.51
3	CAH1513	1.5	8.4	2	7.5	2	11.3	3.5	2	2	9.5	2.2	7.74
4	CAH1515	1.5	7	1.5	7.5	1.5	12.8	2	3.5	1.5	9.4	1.6	8.02
5	CAH151	2	6.8	2	7.1	1.5	11.1	1	3.9	1	8	1.5	7.39
6	CAH153	2.5	7.7	2	8.1	1.5	11.9	1.5	6.4	1.5	7	1.8	8.22
7	ZH114228	3	8.5	1.5	6.2	2	13.4	1.5	5.6	1.5	9	1.9	8.56
8	CAH1511	2.5	8	2	8.1	2.5	12.1	2	5.1	1.5	6.8	2.1	8.02
9	RML-95/RML-96	3	5.1	1.5	7.7	2	9.5	2	3.5	2	8.7	2.1	6.88
10	RML-86/RML-96	2.5	5.5	2	7.4	1.5	9.1	1.5	3.5	1.5	9.7	1.8	7.04
	Mean	2.15	6.45	1.75	7.32	1.8	11.52	1.95	4.26	1.6	8.67	1.9	7.64
	F-test											*	*
	CV%											26.3	17.9
	$LSD_{0.05}$											0.6	1.76

GY: Grain yield

Table 4. Pooled reaction (over locations) to TLB of maize genotypes in 2014-2015 and 2015-2016

2014/15				2015/16	
Genotypes	Reaction	Genotypes	Reaction	Genotypes	Reaction
Z478-2	R	Z466-1	R	CAH158	R
Z478-3	R	Z376-2	R	CAH1521	R
Z478-5	R	Z376-5	R	CAH1513	MR
Z478-4	R	Z376-6	R	CAH1515	R
Z478-8	R	Z376-8	R	CAH151	R
Z480-1	MR	Z376-9	R	CAH153	R
Z478-9	MR	Z376-26	R	ZH114228	R
Z480-2	MR	Z376-34	R	CAH1511	MR
Z478-10	MR	Z376-51	R	RML-95/RML-96	MR
Z433-11	R	900M Gold	R	RML-86/RML-96	R
Z433-99	R	30V92	MR		
Z464-5	R	RML-32/RML-17	R		
Z376-30	R	RML-95/RML-96	R		

Z466-4	R	RML-86/RML-96	R
Z466-3	R	Rampur Hybrid-2	R

The combined analysis over locations in 2014/15 showed that among the 30 genotypes 25 genotypes were resistant (1-2.0 scale), and 5 genotypes were moderately resistant (2.1-3.0 scale). Similarly the pooled analysis over locations in 2015/16 showed that 7 genotypes were resistant (1-2.0 scale) and 3 genotype was moderately resistant (2.1-3.0 scale) (Table 4).

CONCLUSION

The maize genotypes namely Z376-26, Z478-3, Z433-99, Z464-5, Z478-2, Z466-1, CAH1513, RML-95/RML-96, CAH1515, CAH1521, CAH1515, CAH151, CAH153, ZH114228 , Z376-9, Z466-3, Z376-5, RML-32/RML-17, RML-86/RML-96 and 900MGold were resistant with higher grain yield. Therefore they can be used in breeding program as potential sources of resistance and can be grown to enhance maize productivity in terai and inner terai of Nepal.

REFERENCES

Atac, A. (1984). Survey of fungus diseases of second crop maize in the Mediterranean region. *Bitkikoruma Bulletin*, *24*, 137-143**.**

Batsa B. K., Paudel, D. C., & Chaudhary, B. (1989). Review of maize disease investigation in Nepal. Proceeding of the fifteenth summer crops workshop. pp. 114.

Bello, O. B., Abdumaliq, S.Y., Afolabi, M.S., & Ige, S. A. (2010). Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F1 hybrids in a diallel cross. *African Journal of Biotech*nology, *9*(18), 2633-2639.

Bentolila, S., Guitton, C., Bouvet, N., Sailad, A., Nykaza, S., & Freyssinet, G. (1991). Identification of RFLP marker tightly linked to the Ht1 gene in maize. *Theoretical Applied Genetics*, *82*, 393-398.

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science*, *11*, 658-661.

CIMMYT (1985). Managing trials and reporting data for CIMMYT's International maize testing program. CIMMYT, El Batan, Mexico.

DAER (1966). First Annual report. Department of Agricultural Education and Research. p. 35. Shree Mahal, Pulchowk, Lalitpur, Nepal.

Dharanendraswamy, S. (2003). Studies on turcicum leaf blight of maize caused by *Exserohilum turcicum*. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Harlapur, S. I. (2005). Epidemiology and management of turcicum Leaf blight of maize caused by Exserohilum turcicium (pass.) Leonard and suggs. Ph.D. (Plant Pathology). Thesis, University of Agricultural Sciences, Dharwad

Journal of Maize Research and Development (2016) 2 (1): 109-116
ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16221

Harlapur, S. I. (2005). Epidemiology and management of turcicum leaf blight of maize caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs. Ph.D. Thesis, University Agriculture Science, Dharwad, India.

Hooker, A.L. (1981). Resistance to Helminthosporium turcicum from Tripsacum floridanum incorporated into corn. *Maize Genetics Cooperative Newsletter*,55, 87-88.

Khadka, B. B., & Shah, S. M. (1967). Preliminary list of plant disease records in Nepal. *Nepal Journal of Agric*ulture, *2,* 47-76.

Khedekar, S. A., Harlapur, S. I., Kulkarni, S., Benagi, V. I., & Deshpande, V. K. (2010). Integrated management of turcicum leaf blight of maize caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs. *Karnataka Journal of Agricultural Science*, *23*(2), 372-373.

Leonard, K. J., Levy, Y., & Smith, D. R. (1989). Proposed nomenclature for pathogenic races of *Exserohilum turcicum* on corn. *Plant Dis*ease, *73,* 776-777.

Manandhar, K. L. (1983). The investigation of maize disease in Nepal: Identification and Prevalence. *Journal of Institute Agriculture and Animal Sci*ence, 4, 45-56.

Muiru, W. M., Mutitu, E. W., & Kimenju, J. W (2007). Reactions of some Kenyan maize genotype to turcicum leaf blight under greenhouse and field conditions. *Asian Journal Plant Science*, *6*, 1190-1196.

Muriithi LM., & Mutinda, C.J.M. (2001). Genetic variability of maize genotypes for resistance to Exerohilum turcicum in Kenya. In: 7th Eastern and South Africa Regional Maize Conference February, pp. 11 -15.

Ogliaril, J.B., Guimarães, M.A., & Camargo L.E.A. (2007). Chromosomal locations of the maize (*Zea mays* L.) HtP and rt genes that confer resistance to *Exserohilum turcicum*. *Genetics Molecular Biology*, *30*(3), 630- 634.

Pandurangegowda, K.T., Naik, P., Shetty, T.A.S., Hattappa, S., Naik, N.P., & Juna, M. (2002). High yielding maize composite NAC 6004 resistant to turcicum leaf blight and downy mildew. *Environmental Ecology*, *20,* 920-923.

Paudel, D. C., & Chaudhary, B. (1989). Note on some aspects maize pathology in Nepal. *In:* Proceedings of the fifteenth summer crop workshop. 26-31 Jan., 1992, Rampur, Nepal.

Payak, M. M., & Sharma, R. C. (1982). Maize diseases and approaches to their management in India. *Tropical Pest Management*, *31*, 302-310.

Ranjdjelovic, V., Prodanovic, S., Tomic, Z., & Simic, A. (2011). Genotype x year effect on grain yield and nutritive values of maize (*Zea mays* L.). *Journal of Animal Veterinary Science Advances,* 10(7), 835-840.

Shah, S. M. (1968). Disease of maize in Nepal. *In:* Proceedings of the Fifth Inter Asian Corn Improvement Workshop. pp. 159-169.

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development*, *1*(1), 21-27. doi:http://dx.doi.org/10.3126/jmrd.v1i1.14241

Singh, R, Mani, V. P., Koranga, K. S., Bisht, G. S., Khandelwal, R. S.,, Bhandari, P. & Pant, S. K. (2004). Identification of additional sources of resistance to *Exserohilum turcicum* in maize (*Zea mays* L.). *SABRAO Journal of Breeding and Genetics*. *36*(1), 45-47.

Thapa, G. B. (1977). Maize disease report. *In: Proceedings of National Maize Development Workshop*, 3, 62-99.

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16221

Ulrich, H. (2011). Assuring food security in developing countries under the challenges of climate change: key trade and development issues of a fundamental transformation of agriculture. United Nations Conference on Trade and Development (UNCTAD). website at http://www.unctad.org.

Welz, H.G., & Geiger, H.H. (2000). Genes for resistance to Northern corn leaf blight in diverse maize populations. *Plant Breeding*, *119*, 1-14.

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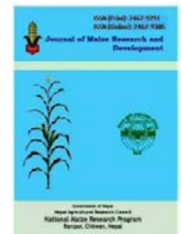
Assessing the effect of phosphorus application on early growth of maize at Sunderbazar, Lamjung, Nepal



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ABSTRACT

Phosphorus (P) is an essential nutrient element for maize production. A pot experiment was conducted during May-June, 2015 to assess the effects of different rates of P on early growth of maize plant at Sundarbazar, Lamjung. Two maize varieties (Rato Makai and Poshilo Makai-1) were subjected to four P levels (0 kg ha^{-1}, 13 kg ha^{-1}, 18 kg ha^{-1}, and 23 kg ha^{-1}) in randomized complete block design with four replications. The effects of different P level on root elongation, root biomass, plant height, root shoot biomass ratio and total dry matter were investigated at 45 days after sowing. For all parameters, the maximum value was obtained when soil was added with 18 kg P ha^{-1} & the minimum value under the control of 0 kg P ha^{-1}. Maize varieties differed significantly in terms of all the parameters under study, and Poshilo Makai-1 performed better than Rato Makai at all P levels. So, from this result, it can be concluded that Poshilo Makai-1 appeared to be P efficient over Rato Makai at early growth stage. However, it would be necessary to look at the response of crop up to maturity and at wider range of P to have the better insight of their relative performance.

Key words: Early vegetative growth, phosphorus fertilizer, maize, root shoot ratio

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INTRODUCTION

Maize (*Zea mays* L.) is one of the most important staple food crops after rice and contributes 23% of the total cereal production in Nepal (Regmi, 2011). It occupies nearly 1 million ha with an average productivity of 2.32 t ha^{-1} (KC et al., 2015). Being a constituent of cell constituents, Phosphorus (P) plays an important role in several plant processes such as photosynthesis, respiration, energy storage and transfer, cell division, and cell enlargement etc. Maize requires P for the higher crop yield (Chen et al., 1994). Adequate level of P not only enhances the early root formation and growth (Hajabbasi and Schumacher, 1994) but also enhances crop quality, and is needed for seed formation (IPNI, 1999; Mohan et al., 2015). P deficiency is considered to be one of the most frequently occurring limitations in the productivity of crops grown in tropical and subtropical ecological regions (Ramaekers et al., 2010) where P can strongly fixed to the soil through adsorption and precipitation thereby reducing its bioavailability to the plants (DoVale & Fritsche-Net, 2013). Being an important constituent of organic compounds in the plants, P deficiency reduces plant growth (Marschner, 1977). Low concentration of soil available P is one of the major constraints to sustain optimal crop production (Wang et al., 2011) and its availability is very important during the early growth stage (Alley, 2009). Absence of the P fertilizer application, especially in the intensive cultivation systems, result in low soil P content (Smaling et al., 1997). Since majority of the Nepalese soils are low in soil available P (Dawadi & Thapa, 2015), P could be limiting factor for the Maize production, especially in the hilly regions of Nepal. The yield of maize, thus, could be increased by the application of soil application of P fertilizer. Existing fertilizer recommendations - including P fertilizer- by government bodies consist of fixed rates without considering the site-specific soil and weather condition. Thus, it is hypothesized that addition of P in the soil would improves the yield attributing parameters of the maize, and its requirement varies with the maize varieties. The objective of this research was to assess the effect of different level of P fertilizer on the early growth of two maize varieties and to screen the P- efficient variety.

MATERIALS AND METHODS

A pot experiment was conducted under diffused light condition in the farm of Lamjung Campus, Sundarbazar, Lamjung (700 masl), Nepal during May-June, 2015. Average daily mean temperature and precipitation during that period were recorded as 17.32^{o}C and 3.19 mm. The experiment included two factors- maize varieties and P levels. Soil was collected from maize field, Lamjung Campus; air dried for 48 hours and filled in poly-pots (5 L) at the rate of 3 kg pot^{-1}. Then soil was treated with nitrogen (N) (40 kg ha^{-1}), potassium (K) (17 kg ha^{-1}) and other nutrients including magnesium (Mg), cupper (Cu), manganese (Mn), calcium (Ca), molybdenum (Mo), zinc (Zn), boron (B) and iron (Fe) (30, 2, 0.2, 71, 0.2, 1, 1 & 2 ppm respectively). For treatment application, soil was treated with four P levels (0 kg ha^{-1}, 13 kg ha^{-1}, 18 kg ha^{-1}, and 23 kg ha^{-1}) through sodium phosphate (NaH_2PO_4). In each pot, three pre-germinated seeds of maize varieties [Rato Makai (a local variety) and Poshilo Makai-1(an improved variety)] were sown at 5 cm depth. Those eight treatments were arranged in randomized complete block design with four replications. Seven days after sowing (DAS), only one seedling per pot was left. Water lost due to evapotranspiration was replaced at every alternative day and maintained at pot's maximum water holding capacity against gravity (field capacity). Before harvesting the plants at 45 DAS, plant height was measured. Root and shoot were separated, washed with water and root length was measured. This was followed by oven drying of roots and shoots at 60^{o}C for 72 hours. Oven dried roots and shoots were then weighed. Data were subjected to the ANOVA using SPSS Windows Version 20 and treatment means were separated using Tukey's test to signify the treatments difference at 5% of probability.

RESULTS AND DISCUSSION

Effect on root length

The mean values of the root length, root dry matter and plant height for maize varieties and P levels are presented in Table 1. When added to the soil, P showed significant effect on root length in maize varieties under study. Irrespective of the maize varieties, length of root was

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highest when they were grown at 18 kg P ha^{-1} (Table 1). This might be due to the P stimulated utilization of assimilates in root system thereby enhancing root length. Root length at 23 kg P ha^{-1} did not significantly differ than at 18 kg P ha^{-1}. Poshilo Makai-1 again expressed longer roots than the Rato Makai when no P was applied. The observed effect of P application on root elongation is consistent with the results of Hajabbasi and Schumacher (1994) and Rosoem et al. (1994), but disagrees the finding of Anuradha and Narayanan (1991).

Effect on root biomass

Initially, increase in level of P appeared to be positively correlated with root biomass. Maize varieties produced least biomass when no P was applied, and highest value was obtained at 18 kg P ha^{-1}. Application of P enhances root elongation and in turn increases root biomass. Amijee et al. (1989) stated that P inflow have direct effect in root weight which in turn increases density of root branching. These effects lead to increase P acquisition as well as other nutrients. This is the reason that plant grown under control of no P application accumulated least root biomass. The root weight, however, was found to be greater in Poshilo Makai-1 than that of Rato Makai.

Effect on plant height

Different level of applied P showed significant effect on plant height (Table 1). Plant height was least at 0 kg P ha^{-1} and the highest value was recorded at 18 kg P ha^{-1}, followed by P at the rate of 23 kg ha^{-1}. This result reveals that P at the rate of 18 kg ha^{-1} might be the optimum rate for the maize and could trigger plant growth. Amin et al. (1989) also observed similar effects of P on plant height in maize. P induced plant growth is strongly associated with the better root growth and nutrient uptake (Hussain et al., 2006). Babatola et al. (2002) also observed the positive effect of P on plant growth. Decreased plant height at 23 kg P ha^{-1} may be due to the antagonistic effect of high soil P on uptake and assimilation of other elements that would have positive role on plant growth (Uguru, 1996). At control treatment, plant height was greater for Poshilo Makai-1 than that of Rato Makai, and could be related to the genetic effect. This result, however, is in contrary to the finding of Eltelib et al. (2006) who reported that plant height of the maize decreased at increasing P levels.

Table 1. Plant height, root length and root biomass of maize varieties as affected by added P in soil

P Level (kg ha^{-1})	Root length (cm)		Root biomass (g)		Plant height (cm)	
	Rato Makai	Poshilo Makai-1	Rato Makai	Poshilo Makai-1	Rato Makai	Poshilo Makai-1
0	13.12 ^{d}	19.17 ^{c}	0.165 ^{c}	0.20 ^{c}	57.20^{b}	62.42 ^{b}
13	20.55 ^{c}	29.32 ^{b}	0.34 ^{b}	0.40 ^{b}	58.00^{b}	65.60 ^{b}
18	50.82 ^{a}	62.02 ^{a}	0.47 ^{a}	0.53 ^{a}	73.72 ^{a}	78.85 ^{a}
23	44.37 ^{b}	57.57 ^{a}	0.42 ^{ab}	0.46 ^{ab}	66.7 ^{ab}	71.00 ^{ab}

Mean values followed by the same lowercase letter in the column are not significantly different by Tukey test (α=0.05; n=4)

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Effect on root shoot ratio

Different level of P showed significant effect on root shoot ratio (Fig 1). Addition of P was positively correlated with root shoot ratio up to a certain P level, and above that, negative effect on root shoot ratio was observed. While the lowest root shoot ratio (0.5) was observed at control of no P application, the highest value was at 18 kg P ha^{-1} (1.6). When no P was applied, root shoot ratio was found to be higher for Poshilo Makai-1 (0.5) than that for Rato Makai (0.4). P induced higher root biomass relative to that of shoot biomass in the maize plant might be due to the roles of P on root growth at early vegetative stage. The opposite effect, however, can be expected at later stage of plant growth and at higher P application. Reduction of root shoot ratio is also associated with higher level of P in growing medium (Wilson & Haydock, 1971). On contrast, P- induced lower root shoot ratio have also been reported (Rychter & Randall, 1994; Ciereszko et al., 1996) and was associated with the partitioning of higher proportion of photosynthetes to the above ground plant part. According to Gregory and Richards (1929) plants grown at low soil P tend to produce a higher photosynthetic rate. This higher photosynthetic rate causes increased leaf biomass. Hence, root shoot ratio is lower.

Effect on dry matter

Soil application of P significantly increased the total biomass yield as compared to the control of no P application; but only up to a level. Maize plants accumulated the least dry matter (0.5g) when no P is applied, while this value reached to 0.8 g at 18 kg P ha^{-1}, and this value did not differ significantly when grown at 13 kg P ha^{-1} (0.73g) & 23 kg P ha^{-1} (0.75g). Irrespective of the P level, Poshilo Makai-1 produced higher biomass (0.74 g) than Rato Makai (0.68 g). This may be attributed to the role of P for the cell division at meristematic tissue and other physiological activities (Russel, 1973). Pellerin et al. (2000) have reported that the soil applied P induced dry matter yield is associated with improvement of root system, increased leaf area index and, in turn, its positive effect on photosynthesis and carbohydrate nutrition of plant. The higher P level (23 kg P ha^{-1}) did not result in increase in dry matter production. This may be due to the Fe accumulation in the roots under higher soil P level (Holmes, 1960).

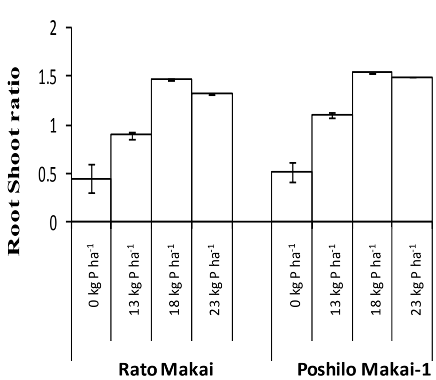

Figure 1. Effect of additional level of P in soil on root shoot ratio at 45 DAS in maize varieties.

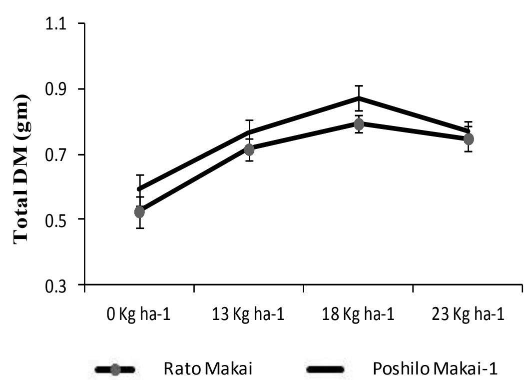

Figure 2. Effect of additional level of P in soil on total dry matter at 45 DAS in maize varieties.

CONCLUSION

The findings of this experiment have revealed that application of P to the soil significantly affects maize growth. At early growth stage, increasing concentration of P to certain level increases root length, root biomass, plant height and root shoot ratio and total dry matter, and 18 kg P ha^{-1} appear to be optimum in context of Lamjung, Nepal. Plant showed relatively poor growth if P is not applied to the soil. Poshilo Makai-1 (improved variety) performs better over Rato Makai (local variety) even for same level of soil P including control of no P application. These conclusions can only be preliminary and further studies need to compare the P response of different genotypes at field condition as well as to the maturity level.

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REFERENCES

Alley, M.M. (2009). Nitrogen and phosphorous fertilization of Corn. Retrieved from https://pubs.ext.vt.edu/424/424-027/424-027.html.

Amin, R., Zia, M.S., Berger, K.C., & Aqil, K. (1989). Effect of fertilizer rate and phosphorus placement methods on corn production. *Sarhad Journal of Agriculture, 5*, 221-227.

Anuradha, M., & Narayanan, A. (1991). Promotion of root elongation by phosphorus deficiency. *Plant and Soil, 136(2),* 273–275.

Babatola, L. A. (2013). Effects of NPK 15:15:15 fertilizer on the performance and storage life of okra (*Abelmuschus esculentus*). *Journal of Agriculture, Biotechnology and Ecology, 6*(1), 95-101.

Chen, M.L., Jiang, X.L., Zoov, B.Y., & Zheri, Z.Y.(1994). Mathematical models and best combination of high yield cultivation technique for rapeseed variety *Zhenyouyoum Acta Agric Zhejiiangenesis, 6*, 22-26.

Dawadi, D.P., & Thapa, M. (2015). Soil fertility status of Nepal: Report from laboratory analysis of soil samples of five Developmental Regions. In: *Proceedings of the Second National Soil Fertility Research Workshop, 24-25 March, 2015*. NARC. pp.42-52.

DoVale, J. C., & Fritsche-Net, R. (2013). Genetic control of traits associated with phosphorus use efficiency in maize by REML/BLUP**.** *Revista Ciência Agronômica, 44*(3), 554-563.

Eltelib, H.A., Hamand, M.A., & Ali, E.E. (2006). The effect of nitrogen and phosphorus fertilization on growth, yield and quality of forage maize (*Zea mays* L.). *Journal of Agronomy, 5,* 515-518.

Gregory, F.G., & Richards, F. J. (1929). Physiological studies in plant nutrition (I) The effect of manorial deficiency on the respiration and assimilation rate in barley. *Annuals of Botany, 43*, 119-61.

Hajabbasi, M.A, & Schumacher, T. E. (1994). Phosphorus effects on references root growth and development in two maize genotypes. *Plant and Soil, 158*, 39–46.

Holmes, R. S. (1960). Effect of phosphorus and pH on iron chlorosis of the blueberry in water culture. *Soil Science,* 90(6), 374-379.

Hussain, N., Khan, A.Z., Akbar, H., & Akhtar, S. (2006). Growth factors and yield of maize as influenced by phosphorus and potash fertilization. *Sarhad Journal of Agriculture,* 22(4*),* 579-583.

IPNI (1999) Phosphorus Improves Crop Quality. *Better Crops, 83*, 28-29

KC, G., Karki, T.B., Shrestha, J., & Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development (2015), 1*(1), 1-9.

Marschner, H. (1997). Mineral nutrition of higher plants. 2nd Edition. London: Academic Press. Hacourt Brace and Company, London.

Mohan, S., Singh, M., & Kumar, R. (2015). Effect of nitrogen, phosphorus and zinc fertilization on yield and quality of kharif fodder- A review. *Agricultural Reviews, 36 (3)*, 218-226.

Pellerin, S., Mollier, A., & Plénet, D. (2000). Phosphorus deficiency affects the rate of emergence and number of maize adventitious nodal roots. *Agronomy Journal, 92*, 690-697.

Ramaekers L., Remans, R., Rao, I. M., & Vanderleyden, J. (2010). Strategies for improving phosphorus acquisition efficiency of crop plants. *Field Crops Research, 117(2-3)*, 169–176.

Regmi, P. (2011). Ensuring food security and securing livelihoods in Nepal: A road map in the Context of Climate Change and Adaptation" (Retrieved from http://www.mope.gov.np/download/Ensuring%20Food%20Security%20and%20Securing%20Livelihoods%20in%20Nepal%20Context%20of%20CC%20and%20Adaptation.docx.6d0f2f40aea4e868d7b84dabff2f2f77).

Rosolem, C.A., Assis, J.S., & Santiago, A. D. (1994). Root growth and mineral nutrition of corn hybrids as affected by phosphorus and lime. *Communications in Soil Science and Plant Analysis shoot, 25*, 2491–2499.

Russell, E.W. (1973). Soil Condition and Plant Growth. The English Language Book Society and Longman, London.

Smaling, E. M. A., Nandwa, S. M., & Janssen, B. H. (1997). Soil fertility is at stake. In: Replenishing soil fertility in Africa. *Soil Science Society of America Special Publication* 51, 47-61

Uguru, M.I. (1996). Crop production techniques. (Revised ed.) Fulladu Publication Co. Nsukka.

Wang, T., Camps-Arbestain, M., Hedley, M., & Bishop, P. (2012). Predicting phosphorus bioavailability from high-ash biochars. *Plant and Soil*, 357(1-2), 173-187.

Wilson, J. R., & Haydock, K. P (1971). The comparative response of tropical and temperate grasses to varying levels of nitrogen and phosphorus nutrition. *Australian Journal of Agricultural Research, 22*, 573–87.

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Estimation of heterosis in yield and yield attributing traits in single cross hybrids of maize

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ABSTRACT

A field experiment was conducted at National Maize Research Program, Rampur, Chitwan, Nepal during winter season from 6th October, 2015 to 5th March 2016 to estimate different heterosis on single cross maize hybrids . Thirteen maize hybrids were tested randomized complete block design with three replications. Hybrid namely RML-98/RL-105 gave the highest standard heterosis (57.5%) for grain yield over CP-666 followed by RML-4/NML-2 (32.6%), RML-95/RL-105 (29%) and RML-5/RL-105 (20.6%). The hybrid RML-98/RL-105 produced the highest standard heterosis (75.1%) for grain yield over Rajkumar followed by RML-4/NML-2(50.2%), RML-95/RL-105(46.6%), RML-5/RL-105 and (35.7%). Mid and better parent heterosis were significantly higher for yield and yield attributes viz. ear length, ear diameter, no of kernel row per ear, no of kernel per row and test weight. The highest positive mid-parent heterosis for grain yield was found in RML-98/RL-105 followed by RML-5/RL-105, RML-95/RL-105, and RML-4/NML-2. For the grain yield the better parent heterosis was the highest in RML-98/RL-105, followed by RML-5/RL-105, RML-95/RL-105, and RML-4/NML-2. These results suggested that maize production can be maximized by cultivating hybrids namely RML-98/RL-105, RML-5/RL-105, RML-95/RL-105, and RML-4/NML-2 .

Key words: Maize, single cross hybrid, heterosis, and grain yield.

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INTRODUCTION

Maize (*Zea mays L.*) is the world's widely grown cereal and primary staple food crop in many developing countries. In Nepal, after rice maize is second most important crop in terms of area and production. The area and productivity of this crop in Nepal is 8.823 million hectare and 2.43 t ha^{-1}, respectively (MoAD, 2015). It is also an important feed ingredient for poultry and livestock. Yan et al., (2011) noticed that more than half of the increased demand in the world food in term of cereals as a whole will be produced from maize farmers and consumers. There are many constraints in maize production one of them is lack of high yielding hybrids. The numbers of maize hybrids developed in Nepal are insufficient i.e. five hybrids released in 13 years duration and those released so far are not also competitive. The dependency over imported hybrid maize seed increased every year due to unavailability of competitive hybrid cultivars within the country and underdeveloped seed industries (Gurung et al., 2011). Thirty-two hybrids of 14 seed companies have been registered in National Seed Board (Koirala et al., 2013). In this context, as the hybrid maize area has been growing extensively in Terai and partly in mid-hill districts, the commercial seed companies are the major source of seed. Hybrid maize seed marketing is flourishing every year but limited commercial hybrids are suited to cultivation owing to existing diverse agro-ecological regime of the country. Since 250 years top innovations in modern agriculture has begun with heterosis discovery in plant crosses (Malik et al., 2004). Heterosis (hybrid vigor) is the enhancement in size, growth, fertility and yield in progeny compared to parents. Hallauer and Miranda (1988) manifested that heterosis depends on the genetic divergence of two parental varieties; also genetic divergence of the parents is inferred from the heterotic patterns manifested in a series of cross combination. As compared to existing cultivars the new maize hybrid should be better for grain yield and other economic traits. The determination of heterosis is important for development of superior hybrids. Such type of research was not sufficient therefore this study was conducted to estimate heterosis in single cross hybrids.

MATERIALS AND METHODS

The experiment was carried out at the research farm of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal from first week of 6 October, 2015 to 5 March, 2016. The mean maximum temperature 27.32°C and minimum temperature 14.33°C were recorded. Maximum temperature ranged from 22.16°C to 32.4°C. The minimum temperature ranged from 8.76°C to 24.08°C. Highest rainfall (42.5 mm) recorded during October 2015, the lowest rainfall (4.66 mm) during January. The total rainfall during crop growing season was 95.66 mm. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications consisting of 11 single cross hybrids and 2 check hybrids. The individual plot size was 3.6 m^2 (2 rows of 3 m length) and spacing was of 60 cm × 25 cm. The soil texture was sandy loam and slightly acidic. The FYM @ 10 t/ha long with 120:64:40 kg NPK ha^{-1} was applied in the experiments. Half nitrogen, full dose of phosphorous and potash (60:60:40 kg N_2, P_2O_5 and K_2O per ha) was applied during sowing. Remaining dose of nitrogen is splitted into two parts and top-dressed during 30 DAS and 45 DAS. Grain yield per hectare was calculated by converting yield per plot into grain yield per hectare. Grain yield was obtained by adjusting the grain moisture at 15% and converted to the grain yield per hectare with the help of the formula adopted by Carangal et al. (1971) and Shrestha et al. (2015).

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Table 1. List of hybrids used in the experiment.

SN	Hybrids	Parentage lines
1	RML-4/RML-17	CA00326/CML-287
2	RML-95/RML-96	PUTU-17/AG-27
3	RML-32/RML-17	CA00320/CML-287
4	RML-86/RML-96	PUTU-20/AG-27
5	RML-5/RL-105	CA00314/UPAHAR-B-20-2-4-1-1
6	RML-95/RL-105	PUTU-17/UPAHAR-B-20-2-4-1-1
7	RML-115/RML-96	PUTU-17/AG-27
8	RML-153/RL-105	POOL-21-12-1-2-1-1-1/UPAHAR-B-20-2-4-1-1
9	RML-85/RL- 105	PUTU-14/UPAHAR-B-20-2-4-1-1
10	RML-98/RL-105	L-3/UPAHAR-B-20-2-4-1-1
11	Rajkumar	-
12	RML-4/NML-2(Rampur Hybrid-2)	CA00326/CML-430
13	CP-666	-

Percent standard heterosis was calculated for using formula as suggested by Falconer and Mackay (1996). This was computed as percentage increase or decrease of the cross performances over the best standard check as: Standard heterosis refers to the superiority of F_1 over the standard commercial check variety. It is also called as economic heterosis or useful heterosis and calculated by using formula.

$$\text{Standard heterosis (\%)} = \frac{\text{F1} - \text{Check variety}}{\text{Check variety}} \times 100$$

Mid parent and better parent heterosis was estimated using below formula;

$$\text{Mid parent heterosis (\%)} = \frac{\text{F1} - \text{Mid parent}}{\text{Mid parent}} \times 100$$

$$\text{Better parent heterosis (\%)} = \frac{\text{F1} - \text{Better parent}}{\text{Better parent}} \times 100$$

The statistical package MSTAT-C was applied to analyze data (Russel & Eisensmith, 1983). The significant differences between treatments were determined at probability level of 0.01 or 0.05 using least significant difference (LSD) test.

RESULTS AND DISCUSSION

Standard heterosis of tested genotypes ranged from –8.6 to 90.4% (Table 2). The positive standard heterosis was shown by most of hybrids for grain yield. Hybrid namely RML-98/RL-105 had the highest standard heterosis of 57.5% over CP-666 followed by RML-4/NML-2(32.6%) and RML-95/RL-105(29%) and RML-5/RL-105 (20.6%) respectively. The RML-98/RL-105 had the highest standard heterosis (75.1%) over Rajkumar followed by RML-5/RL-105 (35.7%), RML-4/NML-2(50.2%) and RML-95/RL-105(46.6%) respectively. Hybrid namely RML-98/RL-105, RML-5/RL-105, RML-4/NML-2, RML-95/RL-105 were superior hybrids, which manifested >15% standard heterosis over check hybrids (CP-666 and Rajkumar). Rosa et al. (2002) were reported similar findings. In this study there was significant level of heterosis for the yield. Semel et al. (2006) estimated the better-parent heterosis primarily for reproductive traits related to yield.

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Table 2. Heterosis for grain yield of single cross hybrids evaluated at NMRP Rampur Chitwan in 2015/16 during winter season.

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	20.9	33.6	185	274
2	RML-95/RML-96	-1.4	9.6	178	175
3	RML-32/RML-17	-4.4	11.5	138	216
4	RML-86/RML-96	12.5	27.2	222	251
5	RML-5/RL-105	20.6	35.7	439	580
6	RML-95/RL-105	29	46.6	371	457
7	RML-115/RML-96	16.2	36.1	210	224
8	RML-153/RL-105	20.6	36.3	170	273
9	RML-85/RL- 105	19.6	35.5	222	320
10	RML-98/RL-105	57.5	30.6	476	590
11	RML-4/NML-2	32.6	50.2	271	353
	P value	0.542	0.883	223.6	223.6
	F test	ns	ns	ns	ns
	$LSD_{0.05}$	51.4	32.76	50.1	50.1
	CV,%	148.4	95.7	50.1	33.3

Table 3 revealed that RML-5/RL-105 had the highest better parent heterosis in ear length (89.3%) followed by RML-95/RL-105(85.95%) and RML-98/RL-105(85.8%). Similarly RML-5/RL-105 had maximum heterosis in ear length (105.5%) followed by RML-98/RL-105(101.3%) and RML-95/RL-105(96.8%) over mid parent. Genotype RML-153/RL-105 had the highest heterosis in ear length (17.3%) followed by RML-5/RL-105(16%) and RML-98/RL-105(15.2%) over CP-666. Similarly, genotype RML-153/RL-105 had the maximum heterosis in ear length (24.5%) followed by RML-5/RL-105(22.6%) and RML-98/RL-105(21.8%) over Rajkumar. Genotype RML-153/RL-105, RML-5/RL-105, RML-98/RL-105 and RML-5/RL-105 had standard heterosis >15% over Rajkumar and CP-666 similarly those genotypes had > 85% heterosis over mid and better parent heterosis. Abdel-moneam et al.(2009) reported that positive significant heterosis values over both their mid and better parents for ear length in maize populations.

Table 4 showed that RML-95/RL-105 had the highest heterobeltiosis in ear diameter (112.3%) followed by RML-4/RML-17(108.6%). Likewise, the maximum heterosis in ear diameter was found in RML-5/RL-105(135.8%) followed by RML-95/RL-105(133.7%). The maximum heterosis was recorded in RML-115/RL-96 (112.3%) in ear diameter followed by RML-4/RML-17(47.81%) over CP-666. RML-115/RL-96 had obtained highest heterosis in ear diameter (59.33%) and same reasult was also found in RML-4/RML-17(58.89%) over Rajkumar. Genotypes RML-115/RL-96, RML-4/RML-1, RML-115/RL-96 and RML-4/RML-17 had standard heterosis > 47% over Rajkumar and CP-666 similarly RML-95/RL-105, RML-4/RML-

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17 and RML-5/RL-105 had mid and better parent heterosis > 108%. Similar reasults were observed by Semel *et al*. (2006).

Table 3. Heterosis for ear length of single cross hybrids evaluated at NMRP, Rampur, Chitwan in 2015/16 during winter season

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	12	18	39.9	60.8
2	RML-95/RML-96	-2.1	3.1	28.8	34.8
3	RML-32/RML-17	11	17.8	39.2	64.8
4	RML-86/RML-96	7.7	13.9	41.6	55.4
5	RML-5/RL-105	16	22.6	89.3	105.5
6	RML-95/RL-105	10.9	16.8	85.9	96.8
7	RML-115/RML-96	-10.1	-6	21.5	30.5
8	RML-153/RL-105	17.3	24.5	11.9	48.8
9	RML-85/RL- 105	7.3	13.3	41.6	67.9
10	RML-98/RL-105	15.2	21.8	85.8	101.3
11	RML-4/NML-2	7.7	13.6	59.8	72
	P value	0.126	0.144	0.287	0.006
	F test	ns	ns	ns	**
	$LSD_{0.05}$	17.94	20.08	69.4	38.92
	CV,%	124.5	81.3	82.2	34

Table 4. Heterosis for ear diameter of single cross hybrids evaluated at NMRP Rampur Chitwan in 2015/16 during winter season

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	47.81	58.89	108.6	117.2
2	RML-95/RML-96	39.39	49.85	86.1	85.2
3	RML-32/RML-17	37.31	47.93	93.9	132.9
4	RML-86/RML-96	41.26	52.22	88	104.8
5	RML-5/RL-105	38.79	49.48	101.2	135.8
6	RML-95/RL-105	47.14	58.59	112.3	133.7
7	RML-115/RML-96	47.98	59.53	96.6	103.1
8	RML-153/RL-105	40.17	51.16	60.6	94.8
9	RML-85/RL- 105	42.53	53.42	92.9	115.8
10	RML-98/RL-105	44.17	54.96	95.8	121.5

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11	RML-4/NML-2	43.17	54.07	93.9	101.1
	P value	0.105	0.103	0.355	0.039
	F test	ns	ns	ns	*
	$LSD_{0.05}$	7.984	8.549	36.54	31.54
	CV,%	11	9.4	22.9	16.4

Table 5 revealed that RML-5/RL-105 had the highest heterobeltiosis in number of kernel row per ear (44.8%) followed by RML-4/RML-17(42.2%). Correspondingly, RML-32/RML-17 had the highest heterosis in no of kernel row per ear (81.4%) and RML-5/RL-105 had (52.2%). Genotype RML-85/RL-105 had observed highest heterosis in no of kernel row per ear (18.5%) followed by RML-95/RL-105(18.5%) over CP-666. Genotype RML-95/RL-105 had the maximum heterosis in no of kernel row per ear (23.8%) same reasult found in RML-85/RL-105(23.8%) over Rajkumar. Genotype RML-85/RL-105, RML-95/RL-105, RML-86/RML-96 and RML-4/NML-2 had standard heterosis >19% over Rajkumar and CP-666. Equally, RML-5/RL-105, RML-4/RML-17, RML-32/RML-17and RML-98/RL-105 had > 42% mid and better parent heterosis in number of kernel row per ear. The heterosis was from 18.2% to 34.5% in temperate sub-tropical and tropical maize germplasm obtained by (Mallik et al., 2004).

Table 5. Heterosis for No of kernel row per ear of single cross hybrids at NMRP Rampur Chitwan in 2015/16 during winter season.

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	9.5	14.3	42.2	34
2	RML-95/RML-96	9.5	14.3	14.3	17.2
3	RML-32/RML-17	4.8	9.5	36.7	81.4
4	RML-86/RML-96	14.3	19	19	28.7
5	RML-5/RL-105	9.5	14.3	44.8	55.2
6	RML-95/RL-105	18.5	23.8	31	44.4
7	RML-115/RML-96	14.3	19	19	35.5
8	RML-153/RL-105	9.5	14.3	15.9	30.5
9	RML-85/RL- 105	18.5	23.8	39	49.5
10	RML-98/RL-105	9.5	14.3	27	38
11	RML-4/NML-2	9.5	19	14.3	25.3
	P value	0.451	0.203	0.122	0.009
	F test	ns	ns	ns	**
	$LSD_{0.05}$	12.33	10.63	25.61	27.74
	CV,%	62.5	37	54.6	40.8

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Table 6 showed that RML-85/RL-105 had the highest better parent heterosis in no of kernel per row (175%) followed by RML-98/RL-105(170%) similarly the genotype RML-5/RL-105 had the highest heterosis in no of kernel per row (223.3%) followed by RML-98/RL-105(203.8%). Similarly, RML-98/RL-105 had the highest heterosis in no of kernel per row (38.39%) followed by RML-5/RL-105(38.7%) over CP-666. The maximum heterosis in no of kernel per row had found in RML-98/RL-105 (35.2%) followed by RML-85/RL-105(34.4%) over Rajkumar. In Spanish maize populations Ordas (1991) and Ali et al. (2014) reported similar results. Flint Garcia et al. (2009) evaluated heterosis of hybrid maize and found similar results.

Table 6. Heterosis for no of kernel per row of single cross hybrids at NMRP Rampur Chitwan during in 2015/16 during winter season.

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	28.2	24.8	117	116.7
2	RML-95/RML-96	9.3	6.3	41	42
3	RML-32/RML-17	28.8	25.9	115	201.9
4	RML-86/RML-96	21.8	18.5	57	80.3
5	RML-5/RL-105	38.7	34.8	156	223.3
6	RML-95/RL-105	33	29.8	91	144
7	RML-115/RML-96	19.4	16.6	54	95.2
8	RML-153/RL-105	32.9	28.9	25	82.9
9	RML-85/RL- 105	34.4	30.4	175	197.9
10	RML-98/RL-105	38.9	35.2	170	203.8
11	RML-4/NML-2	24.2	20.9	71	91.5
	P value	0.050	0.050	0.072	<.001
	F-test	*	*	ns	**
	$LSD_{0.05}$	17.57	16.83	107.1	65.18
	CV,%	36.6	40	64.4	28.5

Table 7 showed that RML-95/RL-105 had the highest heterobeltiosis in thousand kernel weight (118.8%) followed by RML-85/RL-105 (117.9%) similarly RML-115/RML-96 showed highest heterosis in thousand kernel weight (123.9%) followed by RML-86/RML-96 (111.6%). In thousand kernel weight the highest heterosis was recorded in RML-98/RL-105 (18.6%) followed by RML-153/RL-105(13.7%) over CP-666. Similarly RML-98/RL-105 had the highest heterosis in thousand kernel weight (13.8%) followed by RML-153/RML-105(9.8%) over Rajkumar. Genotypes RML-98/RL-105, RML-153/RL-105, RML-4/RML-17 and RML-86/RML-96 had > 8% standard heterosis over Rajkumar and CP-666 similarly RML-95/RL-105, RML-115/RML-96, RML-86/RML-96 and RML-85/RL-105 had > 111% mid and better parent heterosis. Hybrid RML-98/RL-105 manifested highest better parent heterosis in grain yield (476%) followed by RML-5/RL-105(439%) and RML-95/RL-105(371%) respectively. Gadad

(2003) found that significant and positive standard heterosis for test weight in inter-varietal crosses of maize. Gurung (2006) reported -22 to 63.1% heterosis for grain yield in maize populations. Shrestha et al. (2011) also reported that there was more than 40% standard heterosis in single cross hybrids of maize.

Table 7. Heterosis for test weight of single cross hybrids at NMRP Rampur Chitwan in 2015/16 during winter season

SN	Hybrids	Standard (%)		Better parent (%)	Mid parent (%)
		CP-666	Rajkumar		
1	RML-4/RML-17	12.2	8.3	92.9	83
2	RML-95/RML-96	5.7	2.1	93	100
3	RML-32/RML-17	3.2	0.4	77.8	76.1
4	RML-86/RML-96	10.4	7.3	103.1	111.6
5	RML-5/RL-105	12.2	7.8	84.5	109.3
6	RML-95/RL-105	10.9	6.8	118.8	108.7
7	RML-115/RML-96	14	10	108.1	123.9
8	RML-153/RL-105	13.7	9.8	87	95.2
9	RML-85/RL- 105	8.7	4.9	117.9	105.2
10	RML-98/RL-105	18.6	13.8	96.1	102.7
11	RML-4/NML-2	5.2	1.1	81.5	75.8
	P value	0.721	0.719	0.365	0.205
	F test	ns	ns	ns	ns
	$LSD_{0.05}$	15.95	14.62	38.28	36.83
	CV,%	89.7	130.4	23.3	21.8

CONCLUSION

Hybrid namely RML-98/RL-105, RML-5/RL-105, RML-4/NML-2 & RML-95/RL-105 were superior hybrids, exhibited >20% standard heterosis over check hybrids (CP-666 & Rajkumar) for grain yield. Mid parent and better parent heterosis were higher in these hybrids for yield and yield attributing traits such as ear length, ear diameter, no of kernel row per ear, no of kernel per row and test weight. Therefore the findings of this study suggested that farmers to cultivate these hybrids for achieving higher maize production.

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REFERENCES

Abdel-Moneam, M.A, Attia, A.N, El-Emery, M.I., & Fayed, E.A. (2009). Combining ability and heterosis for some agronomic traits in crosses of maize. *Pakistan Journal of Biological Science*, *12*(5), 433-438.

Ali, A., Rahman, H., Shah, L., Shah, K.A., & Rehman, S. (2014). Heterosis for grain yield and its attributing components in maize variety Azam using line × tester analysis method. *Academia Journal of Agricultural Research, 2*(11), 225-230.

Carangal, V.R., Ali, S.M., Koble, A.F., & Rinke, E.H. (1971). Comparison of S1 with testcross evaluation for recurrent selection in maize. *Crop Science, 11*, 658-661.

Falconer, D.S., & Mackay, T.F.C. (1996). *Introduction to quantitative genetics*. 4th ed. Longman, London.

Flint-Garcia, S.A., Buckler, E.S., Tiffin, P., Ersoz, E., & Springer, N.M. (2009) Heterosis is prevalent for multiple traits in diverse maize germplasm. *PLOS ONE,* 4, e7433.10.1371/journal.pone.0007433

Gadad, S.K. (2003). *Genetic analysis for quantitative traits, starch and oil in single cross hybrids of maize* (*Zea mays* L.). M.Sc.(Agri.) Thesis, University of Agricultural Sciences, Dharwad, India.

Gurung, D.B. (2006). *Genetic diversity, heterosis and combining ability within Nepalese maize varieties.* Thesis, Ph.D. Central Luzon State University, Science of Munoz, Nueva Ecija, Philippines. 171 p.

Gurung, D. B., Upadhyay, S. R., Pandey, B. R., Pokhrel, B. B., & Kshetri, J. B. (2011). Hybrid maize seed production: A new initiative for reliable and sustainable hybrid maize seed supply. *Nepal Agriculture Development Journal 8*, 1-8.

Hallauer, A.R., & Miranda, J.B. (1988). *Quantitative Genetics in Maize Breeding*. 2nd ed. Iowa State University Press, Iowa, Ames. USA.

Koirala, K. B., Gurung, D. B., Kunwar, C. B., Tripathi, M., Thakur, P., Bhandari, G., Bhandari, B., Shrestha, J., Karki, T. B., Baral, B. R., Adhikari, P., Achhami, B. B., BK, S. B., Bhurer, K. P., Chaudhary, B. N., & Chhetri, J. B. (2013). Evaluation of multinational companies' maize hybrids during winter season of 2010-2012. *Proceedings of the 27th National Summer Crops Workshop 2.*

Malik, Y., Malik, S.I., & Javed, H.I. (2004). Estimates of heterosis among temperate, subtropical and tropical maize germplasm. *Asian Journal of Plant Science, 3*(1), 610.

MoAD. (2015). Statistical Information on Nepalese Agriculture 2012/13. Government of Nepal, Ministry of Agriculture and Cooperatives. Agri-business Promotion and Statistics Division. Singha Durbar, Kathmandu, Nepal.

Ordas, A. (1991). Heterosis in crosses between American and Spanish populations of corn. *Crop Science*, *31*, 931-935.

Rosa, A., Leon, H., Martinez, G., & Rincon, F. (2002). Heterosis, combining ability and genetic diversity in commercial hybrids of maize. *Agronomia Mesoamerica, 11*,113-122.

Russel, F., & Eisensmith, S. P. (1983). MSTAT-C. Crop and Soil Sci. Deptt. Michigan State Univ. USA. 1983.

Semel, Y., Nissenbaum, J., Menda, N., Zinder, M., Krieger, U., Issman, N., Pleban, T., Lippman, Z., Gur, A., & Zamir, D. (2006). Over dominant quantitative trait loci for yield and fitness in tomato. *Proceedings of Natural Academia Science* USA, *103*, 12981–12986.

Shrestha, J., Gurung D.B., & Rijal, T.R. (2011). Determination of heterosis for grain yield in maize hybrids in Nepal. *International Research Journal of Applied and Basic Sciences*, *2* (6), 233-238, retrived from: http://www. irjabs.com.

Shrestha, J., Koirala, K., Katuwal, R., Dhami, N., Pokhrel, B., Ghimire, B., Prasai, H., Paudel, A., Pokhrel, K., & KC, G. (2015). Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. *Journal of Maize Research and Development,* 1(1), 21-27. doi:http://dx.doi.org/10.3126/jmrd.v1i1.14241.

Yan, J.B., Warburton, M., & Crouch, J. (2011) Association mapping for enhancing maize (*Zea mays* L.) genetic improvement. *Crop Science*, *51*, 433-449.

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Differential resistance reaction of maize genotypes to maize stem borer (*Chilo partellus* Swinhoe) at Chitwan, Nepal

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ABSTRACT

Maize stem borer (MSB), *Chilo partellus* Swinhoe, Lepidoptera: Pyralidae is one of the most important insect pest of maize in Nepal. Host plant resistance is the cost-effective, ecologically sound and stable approach to reduce damage by stem borers. Forty four maize genotypes were screened for resistance to maize stem borer at the research field of National Maize Research Program, Rampur during spring seasons (March to June) of two consecutive years 2013 and 2014. The maize genotypes were evaluated in randomized complete block design with three replications and data were collected on foliar damage rating, tunnel length and number of exit holes made by the borer. The foliar damage and tunnel length damage were significant for genotypes for both the years. The exit holes were not significant in 2013 but significant in 2014 ranging from 2-6 scale. The foliar rating ranged from 2 to 5.5 in 2013 and 1.1 to 4.5 in 2014 on a 1-9 rating scale. The highly resistant genotypes (<2.0 score) were R-POP-2 and RML-5/RML-8. The tunnel length ranged from 3.2 to 22.5 cm in 2013 and 4.2 to 20.4 cm in 2014 on 0- >10 cm scale. The least susceptible genotypes (<5 cm) were RampurSO3F8, RampurSO3FQ02 and RampurS10F18. The genotypes having least exit holes (2.0) in 2014 were RampurSO3F8, RampurSO3FQ02, RampurS10F18. Thus less damage parameters were observed in R-POP-2, RML-5/RML-8, RampurSO3F8, RampurSO3FQ02 and RampurS10F18 and therefore they can be used as parents or as sources of resistance in breeding program.

Key words: Breeding program, *Chilo partellus*, damage, Host resistance, Maize

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INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop in Nepal. It is the major crop among the hilly' people and is increasingly being used as animal and poultry feed as well. Maize plants are affected by biotic and abiotic factors that limit the grain production per unit area (Acchami et al., 2015). Among insect pests, MSB, *Chilo partellus* Swinhoe, Lepidoptera: Pyralidae) is one of the most devastating insect pest in maize production (Neupane et al., 1984; Jyoti & Shivakoti, 1992; Songa et al., 2002, Sharma & Gautam, 2010).

The MSB can cause 20 to 80% plant damage (Thakur et al., 2013; Neupane et al., 1984a). Similarly, Sharma and Gautam (2010) found that stem borer controlled field yielded 28% more harvest of grain yield as compared to uncontrolled one. It attacks maize plants from whorl - to-maturity stage, by creating entry point for disease causing organisms. Leaf damage, stem tunneling, dead heart, peduncle breakage, stunting and white head are the major damages caused by this insect pest, sometimes resulting heavy yield loss up to 83% (Chatterji et al., 1969; Kant et al., 1994; Sekhon & Kanta, 1994).

The maize especially grown in mid-hills, foot-hills and Terai below 1,700 m altitude, is often damaged by this pest (Attri & Sharma, 1968). In the Inner Terai, the subtropical region of Nepal, this pest passes through five generations in a year and pest activity reaches to peak during summer (July-August) causing maximum damage to rainy maize every year (Coppel et al., 1985).

The use of resistant varieties is environmentally safe, economically feasible and socially acceptable approach of pest management. Resistant materials can be used in breeding programs in host plant resistance studies or directly in variety testing prior to recommendation or release. Such type of information is not sufficient in our country therefore; this study was carried out in order to identify resistance genotypes against MSB.

MATERIALS AND METHOD

Plant materials

Field experiments were conducted to identify the sources of resistance for maize stem borer in maize genotypes during 2013 and 2014 spring seasons at National Maize Research Program, Chitwan, Nepal. An experiment composed of 44 elite maize genotypes during 2013 and 51 elite genotypes during 2014 that were pulled from Open Pollinated Varieties (OPV), Quality Protein Maize (QPM) and Hybrids including Rampur composite, Arun 2, Deuti, Posilo makai 1 and Rampur hybrid-2 as a standard checks were evaluated in RCB design with three replications to find out the resistance source of maize stem borer. The experimental site has the latitude of $27^{0}40'$N, longitude of $84^{0}19'$E and altitude of 228 m mean sea level. For each genotype, two rows of five meter long, and the crop geometry 60×25cm were maintained. The individual plot area was 6 m^2. The recommended package of practices was followed during crop growth according to recommendations given by National Maize Research Program (NMRP), Rampur, Chitwan.

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Data collection

Plant damage percentage, number of exit hole and stem tunneling were taken from the tested genotypes to evaluate the resistance level of maize genotypes against MSB.

Plant damage percentage

During the vegetative stage (V8 leaf stage) and just before tasselling stage (V12 leaf stage) plant damage percentage was estimated by counting healthy and damage plants of all evaluated genotypes. For this five sampled plants were counted visually after removing the intact leaves on stem for the exit holes made by stem borer and then proceed for tunnel length measurement. Then the sampled plants were dissected longitudinally, and measurement taken on groove made by stem borer. Plant damage percent was simply calculated by using the formula given below.

$$\text{Damage percentage (\%)} = \frac{\text{Number of infected plant}}{\text{Total number of plant}} \times 100$$

Table 1. Stem borer leaf damage scoring scale (1-9)

Scale	Description	Host reaction
1	No visible leaf feeding damage	Highly resistant (RH)
2	Few pin holes on older leaves	Resistant (R)
3	Several shot-holes injury on a few leaves	Resistant (R)
4	Several shot-hole injuries common on several leaves or small lesions	Moderately resistant (MR)
5	Elongated lesions (> 2 cm long) on a few leaves	Moderately resistant (MR)
6	Elongated lesions on several leaves	Susceptible (S)
7	Several leaves with elongated lesions or tattering	Susceptible (S)
8	Most leaves with elongated lesions or severe tattering	Highly susceptible (HS)
9	Plant dying as a result of foliar damage	Highly susceptible (HS)

Source: Ampofo and Saxena (1987)

Weather data

The weather parameters taken during the experiments were as below;

Table 2. Weather data of cropping season during 2013

Month	Max temp. (^{O}C)	Min temp. (^{O}C)	RH (%)	Rainfall (mm)
February	25.7	7.01	91.15	0.00
March	31.86	12.38	96.35	0.95
April	34.56	15.96	85.31	1.14
May	34.97	23.07	88.00	12.12
June	34.2	26.33	93.18	22.25

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Table 3. Weather data of cropping season during 2014

Month	Max temp. (^{O}C)	Min temp. (^{O}C)	RH (%)	Rainfall (mm)
February	22.90	12.58	84.46	0.73
March	30.62	17.27	76.96	0.32
April	36.66	21.46	66.53	0.13
May	37.06	23.85	73.80	3.23
June	35.26	26.91	92.39	12.98

Tunnel length and exit hole measurement

Five plants from each tested genotypes were sampled for tunnel length and exit-hole measurement. Data related to plant height and tunnel length were noted and their mean was calculated. Keeping in view, data related to stem tunnel length was measured under following 3 categories (Rajasekhar & Srivastav, 2013)

Table 4. Tunnel length and exit hole measurement scale

S.N.	Rating scale	Host reaction
1	0-5	Least susceptible
2	5-10	Moderately Susceptible
3	>10	Highly Susceptible

Data analysis

Using statistical software, Excel and GENSTAT, all collected data were analyzed. The significant differences between treatments were estimated at 5% probability level using least significant difference (LSD) test.

RESULTS AND DISCUSSION

Foliar damage score

The foliar damage was significant for genotypes in both years. The infestation level of MSB was observed comparatively higher in 2013 than 2014. The results indicated that none of the germplasm was highly resistant at whorl stage during both of the experiment years. The foliar rating ranged from 2 to 5.5 in 2013 and 1.1 to 4.5 in 2014 on a 1–9 rating scale. The highly resistant genotypes (<2.0 score) were R-POP-2 and RML-5/RML-8. In 2013 the majority of genotypes showed resistant reaction (1-3 score) except EEYC-1 (4.2 score), Khumal yellow/Pool 17 (4.2 score), RML-4/RML-17 (4.3 score), and RML 4/NML-2 (4.3 score). Siddiqui et al. (1996) evaluated the maize varieties for resistance on the basis of leaf injury. Sharma and Sharma (1992) reported the resistance in maize plants on the basis of lowest leaf damage. Range of percentage damage varied from 23.1 to 61.7% at knee high stage as compared to reproductive stage (9.6-31.7%). Kumar and Asino (1993) considered the parameters like leaf damage, dead heart and stalk damage on maize by MSB to distinguish the resistant and susceptible genotypes. Leaf toughness, trichome density, and stem penetrometer resistance are important forms of

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physical resistance (antibiosis) against maize stem borers while stem sugar contents are reported to promote stem borer feeding in cereals (Padhi, 2004; Sarwar, 2012). Relatively higher level of secondary metabolites such as benzoxazinoid DIMBOA (2, 4 dihydroxy-7-methoxy-(2H)-1, 4-benzoxazin-3 (4H)-one) contain maize plants have resistance properties to MSB infestation (Klun et al., 2009; McMullen et al., 2009). Thus, the similar secondary metabolites produced by plants in our experimental field might be the reasons of variation in plant damage percentage among the tested genotypes. In 2014, most of the genotypes showed less resistance reaction (1-3 score) except Khumal yellow/Pool 17 (4.5 score), Arun-4 (4.3 score), RampurSO3F8 (4.2 score), RML-4/RML-17 (4.3 score) and RML-78/RML-36 (3.8 score). Percent of damage plants per plot was observed higher in younger stages than older stage. Range of percentage damage varied from 23.5 to 50.3% at knee high stage as compared to reproductive stage (11.2-33.4%).

Tunnel length measurement

The tunnel length damage was significant for genotypes during both the years. The tunnel length injury ranged from 3.2 to 22.5 cm in 2013 and 4.2 to 20.4 cm in 2014 on 0->10 cm scale. The least susceptible genotypes (<5 cm) were RampurSO3F8, RampurSO3FQ02 and RampurS10F18. But the intensity of tunnel length damage observed was higher in 2013 than 2014. In 2013, the genotypes SOOTLYQ-B, SO3TLYQ-AB-01, S99TLYQ-AB showed moderately susceptible range (5-10 cm) where as EEYC-1, Narayani, Khumal yellow/Pool 17 and COTAXLA 0024 had maximum damage at a range of 16-23 cm. In the year 2014, Rampur SO3F8, RampurSO3FQ02 Rampur S10F18 reacted less susceptible (4.2-4.6 cm) followed by S99TLYQ-AB, S99TLYQ-B, S03TLYQ-AB-02 S00TLYQ-AB S00TLYQ-B having moderate susceptibility (5.7-7.9 cm) and RML-4/RML-17, RML-95/RML-96, RML-87/RL-105 with the susceptible range of 6.8-8.8 cm. These tunnel length results were similar to the results recorded by Lela and Srivastav (2013). Kumar (1988) reported that stem-tunneling damage had a significant influence on maize plant growth and development. Likewise, Odiyi (2007) and Singh et al. (2011) noticed that for the loss in maize grain yield, the effect of stem tunneling was greater than that of leaf feeding.

Exit holes

The results on exit holes revealed non-significant reaction in 2013 but significant in 2014 ranging from 2-6 scale. In 2014, the genotypes having least exit holes (2.0) were RampurSO3F8, RampurSO3FQ02 and RampurS10F18. These results were similar to the results reported by Munyri et al. (2013).

Table 5. Response of maize genotypes to maize stem borer during spring seasons of 2013 at Rampur, Chitwan

SN.	Genotypes	Score (0-9)scale		Mean score	% damage		Mean damage (%)	Tunnel length (cm)	Exit holes (no.)
		Whorl stage	Tunneling stage		Whorl stage	Tunneling stage			
Open pollinated varieties									
1	Across 9331	3.0	2.0	2.5	31.2	18.4	24.8	10.7	1.5
2	Across 942 × Across 9944	3.4	2.3	2.8	34.6	20.3	27.4	14.2	2.3

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3	Arun-1 EV	3.3	2.7	3.0	33.2	20.9	27.0	11.7	2.6
4	Arun-4	4.3	2.3	3.3	38.2	20.8	29.5	7.9	1.3
5	GGBYPOP	3.0	1.3	2.2	26.8	9.6	18.2	15.5	2.3
6	COTAXLA 0024	3.0	2.3	2.7	30.4	16.3	23.3	11.3	2.7
7	EEYC-1	5.0	3.9	4.5	47.6	25.7	36.7	22.0	3.7
8	HB-B	3.0	2.0	2.5	27.9	14.7	21.3	10.3	1.2
9	HG-A	4.0	3.0	3.5	39.1	23.0	31.0	11.9	2.7
10	HG-AB	2.3	2.3	2.3	25.6	18.3	22.0	14.6	2.3
11	Khumal yellow/Pool-17	5.0	3.3	4.2	42.5	26.0	34.2	10.5	0.9
12	Narayani	2.3	2.3	2.3	28.3	15.1	21.7	22.5	4.2
13	OEHPW	2.3	1.7	2.0	24.1	12.1	18.5	16.9	2.5
14	P501SRCO/P502SRCO	3.3	2.3	2.8	61.7	12.9	24.9	12.7	2.5
15	Pool 17	3.3	3.0	3.2	33.5	18.1	28.5	10.9	1.9
16	POP 445CL	4.3	3.0	3.7	38.1	23.1	31.0	12.8	1.5
17	POP446CL	3.0	2.0	2.5	31.7	23.9	22.7	15.8	1.8
18	Rampur SO3FO2	2.7	1.7	2.2	28.0	31.7	21.3	13.7	1.6
19	RampurSO3F8	3.0	2.3	2.7	31.2	14.6	24.4	5.8	1.5
20	RampurSO3FQ02	3.3	3.3	3.3	35.3	17.6	30.6	8.4	1.2
21	Rampur S10F18	4.0	1.7	2.8	32.2	25.9	23.8	5.9	1.5
22	Rampur S10F20	3.7	1.7	2.7	32.5	15.4	23.7	17.5	3.5
23	Rampur S10F22	2.3	2.0	2.2	23.1	15.0	18.2	8.0	2.0
24	Rampur SO3FO4	3.7	3.3	3.5	36.6	13.3	31.5	10.6	1.5
25	R-POP-1	3.7	3.0	3.3	33.9	26.4	27.7	12.7	3.9
26	R-POP-2	2.7	1.7	2.2	26.0	18.7	18.7	8.4	1.3
27	SP7TEYGHA×B (3)	2.7	1.7	2.2	25.8	17.4	19.5	9.3	1.5
28	SP7TLYGHA×B (3)	3.7	2.7	3.2	33.6	12.9	19.3	9.3	1.5
29	Upahar	2.3	2.0	2.2	27.2	20.2	26.9	14.2	3.3
Standard check									
30	Arun-2	3.3	3.0	3.2	35.1	14.8	21.0	20.8	3.7
31	Rampur composite	5.0	3.7	4.3	45.5	23.7	29.4	11.3	2.1
32	Deuti	2.3	2.0	2.2	26.6	31.0	38.2	13.6	2.4
33	Posilo makai-1	3.0	2.3	2.7	29.5	21.5	23.5	14.6	2.3
Quality Protein Maize									
34	S99TLYQ-AB	2.7	2.0	2.3	25.1	17.6	22.1	8.0	1.0
35	S99TLYQ-B	3.7	3.0	3.3	31.9	16.1	20.6	15.9	3.3
36	SO3TLYQ-AB-01	5.6	5.4	5.5	39.3	20.2	26.0	8.9	1.2
37	S03TLYQ-AB-02	4.0	3.3	3.7	37.7	23.9	31.6	9.2	1.7
38	SOISIWQ-1	3.7	3.0	3.3	36.0	24.9	31.3	10.3	1.5
39	SOISIWQ-3	3.7	2.7	3.2	36.8	22.1	28.7	16.1	2.9
40	SOOTLYQ-AB	2.3	2.0	2.2	26.7	20.5	21.2	17.9	2.5

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41	SOOTLYQ-B	3.7	2.0	2.8	36.9	15.7	27.8	6.9	1.8
Hybrids									
42	RML-4/RML-17	4.7	4.0	4.3	41.9	21.0	35.4	8.1	2.1
43	RML-32/RML-17	3.7	2.7	3.2	34.4	11.3	28.2	3.2	3.5
44	RML 4/NML-2	5.0	3.7	4.3	49.3	18.8	40.4	7.0	1.4
	Grand Mean	3.42	2.51	2.97	33.23	19.64	26.43	12.01	2.22
	F-test	*	*	*	*	*	*	*	ns
	CV%	45.6	45.3	41.3	47.6	34.0	36.7	60.0	66.0

Table 6. Response of maize genotypes to maize stem borer during spring seasons of 2014 at Rampur, Chitwan

SN	Genotypes	Score (0-9)scale		Mean Score	% damage		Mean damage (%)	Tunnel length (cm)	Exit holes (no)
		Knee high stage	Tasselling stage		Knee high stage	Tasselling stage			
Open Pollinated Varieties									
1	Across 9331	3.8	2.4	3.1	42.8	27.3	35.0	9.0	3
2	Across 9942 × Across 9944	3.3	2.1	2.7	36.8	23.1	29.9	9.7	4
3	Arun-1 EV	3.0	2.1	2.5	33.8	23.2	28.5	10.3	2
4	Arun-4	4.3	1.3	2.8	47.6	15.1	31.3	15.1	4
5	BGBYPOP	2.4	1.8	2.1	26.9	20.6	23.7	10.9	3
6	COTAXLA 0024	3.2	1.2	2.2	35.6	13.5	24.5	16.6	4
7	EEYC-1	5.0	4.1	4.5	38.2	13.9	26.0	13.1	2
8	HG-B	3.2	1.4	2.3	35.5	15.6	25.5	13.4	5
9	HG-A	4.1	1.8	3.0	46.1	20.3	33.2	12.8	4
10	HG-AB	4.2	1.7	2.9	46.6	18.8	32.7	14.8	5
11	Khumal yellow/Pool-17	4.5	1.8	3.2	50.3	20.5	35.4	20.4	4
12	Narayani	4.1	2.6	3.4	46.0	29.1	37.5	9.1	3
13	OEHPW	2.9	1.6	2.2	32.3	18.0	25.1	11.9	4
14	P501SRCO/P502SRCO	3.1	1.8	2.4	34.5	19.9	27.2	15.6	4
15	POP 445C1	3.7	2.2	3.0	41.5	24.5	33.0	8.7	3
16	POP446C1	3.0	1.7	2.4	33.1	19.7	26.4	8.3	3
17	Rampur SO3FO2	2.7	2.0	2.3	30.0	22.5	26.2	11.8	5
18	RampurSO3F8	4.2	2.5	3.3	46.4	28.2	37.3	4.2	2
19	RampurSO3FQ02	2.9	1.8	2.3	32.4	19.9	26.1	4.4	2
20	Rampur S10F18	3.0	1.6	2.3	33.8	18.1	25.9	4.6	2
21	Rampur S10F20	3.6	1.4	2.5	39.8	16.3	27.9	9.1	4
22	Rampur S10F22	2.6	2.8	2.7	29.5	31.4	30.4	14.2	6
23	Rampur SO3FO4	3.7	2.5	3.1	41.5	28.0	34.7	13.9	6
24	R-POP-1	2.2	1.2	1.7	24.7	13.9	19.2	14.2	5

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25	R-POP-2	2.4	1.0	1.7	27.4	11.2	19.3	14.4	4
26	SP7TEYGHA×B (3)	3.8	1.2	2.5	42.1	13.2	27.6	9.0	3
27	SP7TLYGHA×B (3)	3.3	1.6	2.4	37.0	17.6	27.2	7.9	4
28	Upahar	3.8	1.6	2.7	42.0	18.0	30.0	10.6	5
Quality Protein Maize									
29	S99TLYQ-AB	4.2	1.8	3.0	46.2	20.1	33.1	5.7	2
30	S99TLYQ-B	3.9	3.0	3.4	43.4	33.4	38.4	7.2	4
31	S03TLYQ-AB-01	2.6	1.5	2.0	29.2	16.9	23.0	13.0	4
32	S03TLYQ-AB-02	3.4	1.2	2.3	37.6	13.3	25.5	7.1	4
33	S01SIWQ-1	3.3	2.6	3.0	37.3	29.0	33.1	10.7	4
34	S01SIWQ-3	3.6	1.6	2.6	40.4	18.2	29.3	16.1	6
35	S00TLYQ-AB	2.5	2.9	2.7	27.6	32.7	30.1	7.7	2
36	S00TLYQ-B	3.2	1.7	2.4	35.4	19.0	27.2	7.9	2
Hybrid									
37	RML-4 /RML-17	2.9	1.7	2.3	32.4	19.8	25.9	6.8	3
38	RML-32 /RML-17	3.8	2.2	3.0	42.5	24.3	33.4	12.9	6
39	RML-95 /RML-96	3.6	2.6	3.1	40.4	28.8	34.6	8.0	3
40	RML-87/RL-105	3.5	2.3	2.9	39.3	25.4	32.3	8.8	4
41	RML-57 /RML-6	2.6	1.9	2.2	29.4	20.9	25.1	10.7	4
42	KYM-33/KYM-35	3.4	2.1	2.7	38.0	23.2	30.6	15.8	4
43	RL-180/RL-105	3.5	2.5	3.0	38.5	28.3	33.4	9.2	3
44	RL150 /RL-111	3.4	1.1	2.2	38.1	12.3	25.2	10.2	4
45	RML-5 /RML-8	2.1	1.7	1.9	23.5	19.3	21.4	9.3	3
46	RML-78 /RML-36	3.8	1.4	2.6	42.3	15.6	28.9	16.8	7
47	RML-86 /RML-96	3.4	1.9	2.7	38.4	21.7	30.0	12.8	5
Standard check									
48	Arun-2	2.9	1.6	2.2	32.2	17.7	24.9	8.5	3
49	Poshilo Makai-1	3.0	2.6	2.8	33.9	29.5	31.7	9.1	2
50	Rampur Composite	4.2	2.4	3.3	46.6	27.0	36.8	16.8	5
51	Rampur Hybrid-2	3.7	1.9	2.8	40.7	21.0	30.8	7.7	3
	Grand Mean	3.4	1.9	2.6	37.4	21.1	29.2	10.9	4
	F-test	*	*	*	*	*	*	*	*
	CV%	44	47	35.4	44	47	35.4	66.1	63

Correlation among the parameters

The correlation coefficients between visual damage score and number of exit holes was positive and high (0.98). Exit hole and tunnel length (0.87), visual damage score and tunnel length (0.83) were highly correlated. Correlation between damage percentage and tunnel length (0.16), damage percentage and exit hole (0.24), visual damage percentage and plant damage percentage (0.34) were comparatively less in 2013. Correlation coefficient between visual damage score and number of exit hole (0.98), tunnel length and number of exit holes (0.93) and visual score and tunnel length (0.90) were positively higher. But, lower degree of correlation between damage percentage and tunnel length (0.14), damage percentage and number of exit hole (0.18), visual damage percentage and plant damage percentage (0.26) were observed in 2014.

CONCLUSION

The overall results ascertained the variability of resistance reaction among maize germplasms against maize stem borer (*Chilo partellus*). The lower level of damage parameters (foliar damage, tunnel length and exit holes) were observed in genotypes namely R-POP-2, RML-5/RML-8, RampurSO3F8, RampurSO3FQ02 and RampurS10F18 revealing their suitability in MSB resistant breeding program of maize in Nepal. Further study is needed to confirm the resistant mechanism of the above genotypes.

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REFERENCES

Achhami, B.B., B.K., S.B., & Bhandari, G.S. (2015). Assessment of maize stem borer damage on hybrid maize varieties in Chitwan, Nepal, *Journal of Maize Research and Development, 1*(1), 53-63.

Ampofo, J. K. O., & Saxena, K. N. (1987). Screening Methodologies for Maize Resistance to *Chilo partellus* (Lepidoptera: Pyralidae). In: Toward Insect Resistant Maize for the Third World, *Proceedings of the International Symposium on Methodologies for Developing Host Plant Resistance to Maize Insects*, held at Mexico, D. F. CIMMYT, 170-177.

Attri, B.S., & Sharma,P.L. (1968). Percentage Infestation by *Chilo zonellus* (Swinhoe) to Maize at Different Elevation in Himachal Pradesh. *Indian Journal of Entomology, 30* (4), 317-318.

Chatterji, S.M., Young, W.R., Sharma,G.C. Sayi, I.V. , Chahal,B.S., Khare, B.P. Rathore, Y.S., Panwar,V.P.S., & Siddiqui K.H. (1969). Estimation of Loss in Yield of Maize due to Insect Pests with Special Reference to Borers. *Indian Journal of Entomology, 31*, 109-115.

Coppel, H.C., Chapman, R.K., & Neupane, F.P. (1985). Monitoring the Maize Borer, *Chilo partellus* (Swinhoe) in Nepal through Light Trap and Life Table Studies. *Nepalese Journal of Agriculture, 16*, 85-92.

Kanta, U., Dhillon, B. S., & Sekhon, S.S. (1994). Evaluation and Development of Maize Germplasm for Resistance to Spotted Stem Borer. Reviewed In: J.A. Mihm (ed) Insect

Resistant Maize Recent Advances and Utilization *Proceedings of an International Symposium* held at Mexico, D.F.: CIMMYT, 246-254.

Klun, J. A., Guthrie, W. D., Halluauer, A. R., & Russell, W. A. (1970). Genetic nature of the concentration of 2,4 dihydroxy-7-methoxy-(2H)-1,4-benzoxazin-3(4H)-one and resistance to European corn borer in a diallel set of eleven maize inbreeds. *Crop Science*, *10*, 87-90.

Kumar, H. (1988). Effect of stalk damage on growth and yield of certain maize cultivars by the maize stalk borer *Chilo partellus. Entomology Experimental Applied*, *46*(2),149-153

Kumar, H., & Asino. G. O. (1993). Resistance of maize to Chile portellus (Lcpidoptera: Pyralidae): Effect of plant phenology. Journal of Economic *Entomology 86*. 969-973.

Lella, R., & Srivastav, C. P. (2013). Screeing of maize genotypes against the stem borer Chilo partellus in kharif season. *International Journal of Applied Biology and Pharmaceutical Technology,4*(4), 394-403

McMullen, M. D., Monika, F., & Jorg, D. (2009). Genetic and biochemistry of insect resistance in maize. *In*: Handbook of Maize: Its Biology, J. L. Bennetzen and S. C. Hake (eds), pp. 271-289.

MoAD (2014). Statistical information on Nepalese Agriculture. Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division, Agri statistics Section, Singha Durbar, Kathmandu, Nepal.

Mohamed, H.M., Khan, Z.R., Overholt, W.A., & Elizabeth, D.K. (2004). Behaviour and biology of *Chilo partellus* (Lepidoptera: Pyralidae) on maize and wild gramineous plants'. *International Journal of Tropical Insect Science*, *24*, 287-297.

Munyiri, S.W., Mugo, S. N., Otim, M., Tefera, T., Beyene, Y., Mwololo, J. K., & Okori, P. (2013). Responses of tropical maize landraces to damage by *Chilo partellus* stem borer. *African Journal of Biotechnology*, 12(11), 1229-1235. Available online at http://www.academicjournals.org/AJB DOI: 10.5897/AJB12.1802

Neupane, F.P., Chapman, R.K., & Coppel, H.C. (1986). Temperature-developmental relationship of the maize borer, *Chilo partellus* (Swinhoe) (Lepidoptera:Pyralidae) in Nepal. *Nepalese Journal of Agriculture, 17*, 23-35.

Odiyi, O.P. (2007). Relationships between stem borer resistance and grain yield reduction in maize: Correlations, path analysis and correlated response to selection. *Agriculture Journal*, *2*, 337-342.

Padhi, G. (2004). Biochemical basis of resistance in rice to yellow stem borer, *Scirpophaga incertulas* Walk. *Madras Agricultural Journal, 91*, 253-256.

Rajasekhar, L., & Srivastav, C.P. (2013). Screening of maize genotypes against stem borer *chilo partellus* l. In *kharif* season Institute of agricultural sciences, Banaras Hindu University. *International Journal of Applied Biology and Pharmaceutical Technology Available online at www.ijabpt.com.*

Sarwar, M. (2012). Management of rice stem borers (Lepidoptera: Pyralidae) through host plant resistance in early, medium and late plantings of rice (*Oryza sativa* L*.). Journal of Cereals and Oil seeds*, 3, 10-14. http://dx.doi.org.10.5897/JCO11.042

Sekhon, S.S., & Kanta, U. (1994). Mechanisms and Bases of Resistance in Maize to Spotted Stem Borer. Reviewed In: J.A. Mihm (ed) *Insect Resistant Maize Recent Advances and Utilization Proceedings of an International Symposium* held at Mexico, D.F.: CIMMYT, 106-111.

Journal of Maize Research and Development (2016) 2 (1): 133-143
ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16226

Sharma, M.L., & Sharma, A.K. (1992). Comparative resistance of maize cultivars/inbreds to stem borer, Chilo partellus (Swin.) *Insect Science, 5*(2), 183-184.

Sharma, P.N., & P. Gautam (2005). Resistance Screening of Maize Germplasms against Maize Stem Borer (*Chilo partellus* Swinhoe) in Nepal. Book of Abstracts. *Ninth Asian Regional Maize Workshop* (9th ARMW) Beijing, China, Sept.5-9, pp. 29.

Sharma, P.N., Thapa, R.B., Gautam, P., Giri, Y.P., Pathak, H.P., & Aryal, S. (2007). Resistance Screening of Promising Maize Genotypes against Maize Stem Borer (*Chilo partellus* Swinhoe). *Proceeding of the 25th National Summer Crop Research Workshop*. National Maize Research Program, Nepal Agricultural Research Council (NARC), Kathmandu, Nepal. pp. 278-280.

Siddiqui, K.H. Singh, N.N. Panwar, V.P.S., & Marwaha, K.K. (1996). Reaction of subtropical and tropical maize inbred lines to Chilo partellus (Swinhoe) and damage effect on silking, ear and plant heights. *Indian Journal of Entomology, 57*(3), 254-258.

Singh, B.U., Sharma, H.C., & Rao, K.V. (2011). Mechanisms and genetic diversity for host plant resistance to spotted stem borer, *Chilo partellus* in sorghum, Sorghum bicolor. *Journal of Applied Entomology*, *135*, 333- 392.

Songa, J.M., Mugo, S., Mulaa, M., Taracha, C., Bergvinson, D., Hoisington, D., & Groote, H.D. E. (2002). Towards development of environmentally safe insect resistant maize varieties for food security in Kenya. *Paper presented to the symposium on: Perspectives on the evolving role of private/public collaborations in agricultural research*. Organized by the Syngenta foundation for Sustainable Agriculture, Washington, D.C., USA.

Thakur, P., Shrestha, J., Bhandari, G. S., & Achhami, B. B. (2013). Insect scenario and its succession in year round weekly interval seeded maize varieties at Rampur, Chitwan, Nepal, *International Journal of Modern Plant & Animal Sciences, 1*(2), 96-104.

Upadhyay, S.R., Sharma, D., Mahato, R.K., Paudel, D.C., Koirala, K.B., Parsad, R.C., Shah, S.N., Katuwal, R.B., Pokhrel, B.B., Dhakal, R., & Dhami, N.B. (2007). Development of QPM (Quality Protein Maize) Varieties for the Hills of Nepal. *Proceedings of the 25th National Summer Crops Research Workshop*, National Maize Research Program, Nepal Agricultural Research Council, Kathmandu, Nepal. pp.31-38.

Journal of Maize Research and Development (2016) 2 (1): 144-150
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Socio-economic analysis of maize seed production in Arghakhanchi district of Nepal

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ABSTRACT

The purpose of this study was to assess the socioeconomic condition of maize seed and non-seed producers. A field survey was carried out in sixty households of Khanchikot VDC of Arghakhanchi district during May, 2014. The district was major seed producing district and Khanchikot was found better in seed production than other VDC in district. Simple random sampling technique was used to collect data using pre-tested interview schedule. About 57% were seed producer among the sample. The average family size of household was 5. Dependency ratio was less in seed producing households (0.41) than non-seed producers (0.72). Farmers were involved in the production of certified seed and the major (50%) source of foundation seed was National Maize Research Program, Rampur, Chitwan. The external input like chemical fertilizer was used in fewer amounts in the study area. The seed test was done at regional laboratory, Bhairahawa and sold to DADO, Arghakhanchi. Decision on loan taking, business operation and bank account were taken by males whereas cropping pattern, deficit labor use, religious and social works related decision were taken by females in the household. Major problem in maize production were lack of technical assistance followed by inadequate irrigation facilities. Proper training, extension service and government support on inputs would help in better socio-economic condition and production of maize.

Keywords: Gender, maize, seed and socio-economic.

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INTRODUCTION

Agriculture that contributes 34.35% in national GDP and consisting of 65.6% of the total population of the country engaged in that sector (AICC, 2014). The share of cereal crop to agriculture is about 61%. Among cereals, maize (*Zea mays* L.) is the main crop in the mid hills of Nepal. It occupies a crucial place than other cereal crops as it is used as food, feed, fodder and other industrial raw material. The total area and production of maize in Nepal is 849,635 ha and

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1999010 t in the year 2012/2013. The present yield level is quite low to fulfill the country's demand; there is a big yield gap of maize in Nepal as affected by various technological and socio-economical factors (KC et al., 2015). Seed is principal factor governing return from almost all agriculture based technological innovations, transfer genetic potentiality to regenerate new crops. The availability of quality seeds in time and suitable to specific location contribute high production to farmers that can helps to reduce pervasive poverty. Crop production can be increased using good quality seeds of high yielding varieties. The conservation of diverse genetic resources, utilization of available resources and effective utilization of experts available in the country are still lacking in Nepal. If utilized properly it can develop niche suitable varieties, their seeds thus increasing investment for seed infrastructure proceeding further for value chain. As a result, Nepalese market is being dominated by global seed business and seed import is rising continuously (MoAD, 2013). Because of increased demand of maize in hilly district, various donor agencies in collaboration with I/NGOs are distributing and contributing maize seeds. This has put an effort to be self-reliant. According to Sulo et al., (2012), discrimination between men and women starts from deep-rooted socio-cultural beliefs and practices. Males are involved in outside job and female spent most of their time in field. Gender inclusion and women participation are much encouraged in the workshops and training conducted regarding nursery development, seed producing, fertilizer treatments, etc. by both private and government sectors (Aregu et al., 2011). The objectives of this study were; to compare socio-economic characteristics of maize seed producers and non-seed producers and also to study the gender role in decision making.

MATERIALS AND METHODS

Study Area

Arghakhanchi district was selected for the study as it was the major seed producing district in the country. In Arghakhanchi, area and production under maize is 16914 ha and 49441 t (ABPSD, 2013). The farmers from Khanchikot VDC were found involving in maize seed production following the recommendations of DADO, Arghakhanchi. So, Khanhikot VDC was selected for the study.

Sampling method and data collection procedure

The Khanchikot VDC is connected to the road corridor. According to Poate and Daplyn (1993), sixty sample size is considered as minimum requirement to generate the appropriate decision making of any region, so total of sixty sample size was collected by using simple random sampling method in May 2014 to represent the district. Simple random sampling technique was used to collect the data, which constitute 34 seed producers and 26 non-seed producers. A pre-tested (10 farmers of Sandhikharka VDC, Arghakhanchi) semi-structured questionnaire was used to collect the necessary data. Focus Group Discussion was carried out to verify the information collected. Key informants such as long term seed producers, technical assistant (Agriculture Service Center), VDC secretary were interviewed to know the seed producing activities in the VDC. The data were entered in Statistical Package of social science (SPSS) software**.** Mean, frequency, percentage, etc. was obtained using descriptive statistical tools. The intensity of problems on maize seed production faced by the farmers was identified

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using six-point scaling techniques: most severe, high severe, medium severe, severe, less severe and scale values were given as 1, (1-1/n), (1-2/n), (1-3/n), (1-4/n) and (1-5/n). From the viewpoint of optimistic nature, the last rank was not provided with the scale zero.

$$I = \sum S_i f_i / n$$

Where, I = index $0 < I < 1$

S_i = scale value at i^{th} severity

f_i= frequency of the i^{th} severity

n = total number of respondents

RESULTS AND DISCUSSION

Socio-economic description of the study area

The average family size was found 5 which were similar with the national data. The family size was found to be more in seed producing household (5.12) than in non-seed producing HHs (4.88). Higher the population higher the involvement in agricultural works that leads to increased production. The maize production was positively related to family size (Karki, 2004). The study area was found male dominated (71.70%) which was true for both seed producing and non-seed producing households (HHs), i.e. majority of household head were male in the study area. Women mostly involved in performing agricultural tasks i.e. seed production where men are main decision maker. This finding was similar to findings of Bhattarai (2002).The dependency ratio was found less in seed producing households (0.41) in comparison with non-seed producing (0.72) HHs. This indicates that economically active population were more in seed producing HHs than non-seed producing HHs. In case of education, there is no any distinct difference between seed producing and non-producing HHs. In male headed HHs 43.08% had achieved primary level education followed by SLC (27.69%). In female headed HHs 27.69% had achieved primary level education followed by SLC (20%). The level of education affects the selection of variety. Alao, (1971), Atala (1980) and Okwoche, (1998) reported that when the education level of farmers increases, then the adoption of improved maize varieties increases, thus there is direct relationship between them. Agriculture was the major occupation in both cases. The average land holding size in the study area was 15.83 ropani whereas average land holding of seed producers was found greater (20.13 ropani) than non-seed producers (12.54 ropani). About 27.9% HHs in male headed and 23.5% HHs in female headed had received agricultural extension service at HH level. This implies that the extension service was poor in the study area. The less contact with the extension agents the less the adoption rate. The economic condition of farmers can be increased by providing proper training and extension service about the maize seed production technology (Kafle, 2010).

Seed production activities and post-harvest operation

The main source of foundation seed was NARC station from which 50% seed were brought. The average area for seed production was 5.54 ropani. Inputs were supplied equally from agro-vets and local markets. Farm Yard manure (FYM) was applied in bulk amount and chemical fertilizers were less used. Around 58% said that they inspect field themselves and rest inspect their field by DADO technicians. Rouging was practiced by only 29.5% HHs, among

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which male HHHs were found doing more roughing in field. About 78% HHs practiced grading. Removal of tip and bottom was found famous than gravity separator. Seeds were sun dried and send for test at regional lab and then sold to DADO, Arghakhanchi. Minimum amount of seed were sold to farmers and others in the village.

Table 1. Different seed production and post-harvest operation in study area

Description		Gender				Total	
		Male		Female			
		Frequency	%	Frequency	%	Frequency	%
Source of seed	NARC	10	52.63	3	42.85	13	50
	DADO	4	21.05	2	28.57	6	23.08
Area		5.59		5.43		5.54	
Source of input	Agro vet	10	52.6	3	42.86	13	50
	Local market	9	42.4	4	57.14	13	50
Amount of input	Manure (Doko)	265		300		275.29	
	Urea (kg)	14.91		15		14.94	
	DAP(kg)	4.5				4.5	
	MOP (kg)	5				5	
Weeding times		1.23		1		1.17	
Inspection of field	Self	10	52.6	5	71.4	15	57.7
	DADO technician	9	42.4	2	28.6	11	42.3
No of rouging		1.9		1.5		1.8	
Method of grading	Removal of tip and bottom	10	66.66	2	40	12	60
	Gravity separator	5	33.33	3	60	8	40
Seed drying (sun)	Yes	19	100	7	100	26	100
Labelling and Packaging	Yes	10	52.6	3	42.9	13	50
Seed test	No	9	47.4	4	57.1	13	50
Seed sold 9kg)	Yes	19	100	7	100	26	100
Seed sold (Kg)		71.42		74.57		72.27	

Source: Field survey, 2014

Gender empowerment

Technological Innovation if properly understood from the gender perspective can encourage to increase agricultural productivity (Tavya et al., 2013). Rahman (2009) noticed that women play major role in food production and processing. From the study, it was clear that decision of business operation was taken by male and decisions on selection of crop were taken by females or jointly. In seed producers and non producers same result was obtained in the study area. In case of deficit labor use, decisions were taken jointly or by female in the majority of HHs in family. In male headed HHs male have control over financial transactions. Decisions on

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loan taking were taken by both male and female members of the family. In some male HHs it was taken by male, but in female HHHs, all the decision were taken jointly. This could be because loan taking is a big decision in rural family so gender role is equal in this context. There was equal participation of male and female in training and workshops but in female HHHs female participation was more.

Table 2. Role of gender on household level decision making (frequency)

Household decision	Gender	Non Seed producer			Seed producer			Total		
		Male	Female	Both	Male	Female	Both	Male	Female	Both
Business operation	Male	17	1	5	16	1	2	33	2	7
	Female	7	1	2	5	2	0	12	3	2
Selection of crop	Male	8	5	11	3	9	7	11	14	18
	Female	3	5	2	1	5	1	4	10	3
Deficit labour use	Male	3	7	10	3	6	9	6	13	19
	Female	4	4	2	1	4	0	5	8	2
Input purchase	Male	8	5	9	1	5	13	9	10	22
	Female	2	4	4	1	6	0	3	10	4
Product sale	Male	5	4	15	4	7	7	9	11	22
	Female	1	5	4	1	6	0	2	11	4
Loan taking	Male	12	1	9	6	1	11	18	2	20
	Female	3	2	4	0	0	6	3	2	10
Training attending	Male	7	3	8	6	7	5	13	10	13
	Female	1	4	3	0	6	1	1	10	4

Source: Field survey, 2014

Problem ranking

The major problem in maize seed production was identified as lack of technical assistance (86.1%) followed by inadequate irrigation facilities (80.2%), high cost of seed (74.4%), low seed quality (73.3%), low price of agricultural products (72.1%) and lack of machinery (72.1%). Availability of technical assistance and adequate irrigation facilities in an areas assist to adopt maize seed production to increase maize production and income (Rogers, 2003; Hintze et al., 2003). Irrigation is one of the major agricultural inputs for the crop production. Hailu (1992) reported that the lack of agricultural inputs is main bottleneck in maize production and productivity). The low use of quality seeds of high yielding crop varieties ialong with other inputs (e.g. fertilizer, farm machinery) lead into low productivity (Gauchan, 2015). In this present study low price of seed was one of the major problems in commercial seed production. Seed marketing is a important bridge between the seed producers and the farmers who ultimately use the seeds (Sasto, 1969; OMaliko, 1998).

Table 3. Problem of commercial seed production in study area

Problem of Seed production	Frequency	%	Index value	Rank
Lack of technical assistance	74	86.1	0.109	I
Inadequate irrigation facilities	69	80.2	0.102	II
High cost of seed	64	74.4	0.095	III
Low quality seed	63	73.3	0.093	IV

Low price of agricultural product	62	72.1	0.092	V
Lack of machinery	62	72.1	0.092	V

Source: Field Survey 2014

CONCLUSION

Most of the households were headed by males who involved in decision making process on business operation outside the home. Females were found involved in agricultural work i.e. maize seed production. The lack of inadequate irrigation facilities, high cost of seed and low seed quality were major problems. The higher number of females was found involved for input purchase, selection of crops and product sales. They have only primary education; the lack of higher level of education had led to low agricultural production and poor socioeconomic condition. Therefore this study suggested that women empowerment using trainings and educational program would help to increase agricultural production.

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REFERENCES

ABPSD. (2013). Statistical information on Nepalese agriculture 2012/13. Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistical Division, Singh Durbar, Kathmandu, Nepal

AICC. (2014). Krishi Diary. Agriculture Information and Communication Centre, Government of Nepal, Kathmandu, Nepal

Alao, J.O. (1971). Community Structure and modernization of Agriculture: Adoption of farm practices among Nigerian Farmers. Unpublished Ph.D thesis, Cornell University.

Aregu, L., Puskur, R., & Sambrook, C.B. (2011). The role of gender in crop value chain in Ethiopia.

Atala, T. K. (1980). Factors Affecting Adoption of Agricultural Innovations: Usage of Source of information and level of living in Two Nigerian Villages. Unpublished M.Sc. Thesis, Iowa State University, America.

Bhattarai, K.K. (2002) Gender dynamics in crop production in the hills of Nepal. Feminization of agriculture. Unpublished M.Sc. Thesis, Department of Agricultural Economics and Rural Sociology, Agricultural university of Norway.

Gauchan, D. (2015). Research and Support Services in Seed Production and Supply in Nepal. Thematic Paper for Seed Submit, 2015. Retrived from: http://sqcc.gov.np/media/publication/Research_by_Devendra.pdf

ISSN: 2467-9291 (Print), 2467-9305 (Online)
DOI: http://dx.doi.org/10.3126/jmrd.v2i1.16227
Hailu, G. (1992). Availability and use of seed in Ethiopia. Program support unit, Canadian International Development Agency, Addis Ababa, Ethiopia.

Hintze, L.H., Renkow, M., & Sain, G. (2003). Variety characteristics and maize adoption in Honduras. *Journal of Agricultural Economics*, 29, 307-317.

Kafle, B. (2010). Determinants of Adoption of Improved Maize Varieties in Developing Countries: A Review. *International Research Journal of Applied and Basic Sciences*, *1*(1), 1-7.

Karki, L.B. (2004). The Impact of Project invention on rural household in Assessment of socio-economic and Environmental implication. A PhD thesis submitted to the University of Giesen, Institute of project and Regional Planning, Giesen, Germany

KC, G., Karki, T.B., Shrestha, J., & Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, *1*(1), 1-9.

MoAD. (2013). National Seed Vision 2013-2025. Government of Nepal, Ministry of Agricultural Development, National Seed Board. Seed Quality Control Center, Hariharbhawan, Lalitpur.

Okwoche, V.A. (1998). Adoption of Agricultural Innovations among members and non-members of women cooperative Societies in Oju Local Government Area of Benue State. Unpublished M.Sc. Thesis, Department of Agricultural Economics and Rural Sociology, Faculty of Agriculture, A.B.U., Zaria, Nigeria.

OMaliko, C.P.E. (1998). Nigeria seed industry and its potential role in food security within the West and Central Africa subregion. Proceedings of the international conference on seed security for food security, 30 December–1 November 1997. Florence, Italy, FAO, Rome (Online) Www.Fao.Org/Ag/Agp/Agps/Georgof/Gerogo14htm.

Poate, C.D. & Daplyn, P.F. (1993). Data for Agrarian Development. Cambridge University Press. UK.

Rahman, S.A. (2009). Gender Issues in Food Security. A paper presented at the first biennial conference on human security in Africa at Center for security, Olusegun Obasanjo Presidential Library, 5-8th March 2009, Abeokuta, Ogun State, Nigeria.

Rogers, E.M. (2003). Diffusion of Innovations (Fourth Edition). New York: Free Press.

Sastry, C.P. (1969). Selling and promoting good quality seed in India today. Proceedings of Seed Specialists Workshop, India International Center. New Delhi, India. 243 p.

Sulo, T., Koech, P., Chumo, C., & Chepngeno, W. (2012). Socioeconomic Factors Affecting the Adoption of Improved Agricultural Technologies among Women in Marakwet County Kenya: *Journal of Emerging Trends in Economics and Management Sciences, 3*(4), 312-317.

Tavya, S., Abdelali-Martini, M., Aw-Hassan, A. Rischkowsky, B., Tibbo, M., & Rizvi, J. (2013) Gender Roles in Agriculture: The Case of Afghanistan. *Indian Journal of Gender Studies, 20*(1), 111-134. doi: 10.1177/0971521512465939

DOI: 10.5281/zenodo.1146074, Published on: 22th December, 2016

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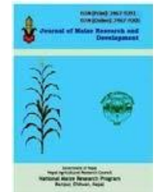

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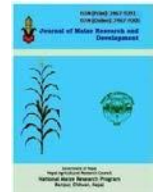

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