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

Mahendra Prasad Tripathi*, Jiban Shrestha, and Dil Bahadur Gurung

[1]Nepal Agricultural Research Council
National Maize Research Program, Rampur, Chitwan, Nepal

*Corresponding author email: mptripathi@gmail.com

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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., Hvderabad. 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

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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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