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Performance of Single Cross Maize (*Zea mays* L.) Hybrids under Rainfed Middle Hill Environments of Nepal

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ABSTRACT

Maize is the livelihood of smallholder farmers and priority food crop in the middle hills of Nepal. To achieve maize self-sufficiency in the country we need to shift from open-pollinated varieties to hybrids in potential pockets of middle hills. Coordinated varietal trials on hybrids were conducted for three consecutive years from 2016/17 to 2018/19 across the middle hills during summer to identify high-yielding, biotic and abiotic stresses resistant/tolerant single crosses that fit into the existing rainfed cropping system. We evaluated fifteen, nine, and ten genotypes in 2016/17, 2017/18, and 2018/19, respectively. Trials were replicated thrice using a randomized complete block design with a unit plot size of four rows of 4-m long. Based on acceptable grain yield, anthesis to the silking interval, ear position, and Turcicum leaf blight (TLB) and Grey leaf spot (GLS) reaction, CAH1715 (9.12 t ha^{-1}), RML-4/RL-111(8.72 t ha^{-1}), RML-98/RL-105 (8.25 t ha^{-1}), RL-150/RL-111 (8.18 t ha^{-1}), RL-36/RL-105 (8.04 t ha^{-1}), CAH1521 (7.67 t ha^{-1}) and Rampur Hybrid-10 (7.65 t ha^{-1}) were identified promising. These genotypes will be promoted to farmers' field trials and other participatory variety selection activities.

INTRODUCTION

Maize (*Zea mays* L.) is the second cereal crop which occupies 940886 ha of land with production and productivity of 2653243 t and 2.82 t ha^{-1}, respectively (MoALD 2020). Maize consumption in Nepal was 122 g/person/day in the last decade (FAO 2009), whereas remained 98 g/person/day with the highest consumption of maize among the South Asian countries (Ranum et al. 2014). It contributes 24.97% to the total cereal production (MoALD 2020). The demand for maize as a prime ingredient of animal ration mainly for poultry is an increasing trend. In Nepal, the annual growth rate of chicken was highest among livestock from 1995-2014 (Upadhyay et al. 2017). There is 13 and 8.5% increment in poultry and animal feed industry, respectively over the past five years in Nepal. Thus, 60, 25, and 3% of the maize produced in the middle hills were used as animal feed, food, and seed, respectively (Timsina et al. 2016). Out of the total annual demand of yellow maize for poultry feed of 545,268 t, domestic production fulfills only 30%, and rest is met by importing from other countries (Panday 2019; Bhattarai 2020). Maize import is increasing since 1968 to 2017. Four lakh ninety-six-thousand-ton maize that worth 109,178,000 US dollars was imported in 2017. In 2018 and 2019, 350000 and 400000 t of maize was imported, respectively (Knoema 2019a,b). In addition to grain, Nepal imported 4226.915 t of maize seed in 2017 (MoF 2019). Around 2000 t of maize hybrid seed is imported annually as reported by Dawadi in Kathmandu Post (2020). About two-thirds of the maize produced in the middle and high-hills is used for human consumption (Paudyal et al. 2001). The ratio of human consumption to total production is higher in less accessible areas. However, these days, we can see the shift of maize utilization patterns from food to feed even in the hills (Ghimire et al. 2018).

One of the primary reasons behind the low productivity of 2.82 t ha^{-1} is due to a minimum of 12-15% and a maximum of 85-88% of the total maize area is under hybrids and open-pollinated varieties (OPVs), respectively (Koirala 2020). To boost maize production and productivity, the present seed replacement rate (SRR) of 17.83%

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(Memoire 2017) should reach to 33% by 2025 as envisioned in National Seed Vision (NSV) 2013-2025 (SQCC 2013). Another alternative is the shift from OPVs to hybrids not only in Terai but also in the potential pockets of the middle hills. NSV envisaged the development and promotion of 12 and 5 maize hybrids by the public and private sectors, respectively by 2025. Nepali farmers in Terai near the border have started growing hybrids since the 1980s, importing seeds from India (Thapa 2013). According to an estimation, 80% of winter maize in Terai and 10% spring and early summer maize in middle hills are covered by hybrids (Adhikari 2014). To date, seven hybrids developed by the National Maize Research Program (NMRP)/Nepal Agricultural Research Council (NARC) have been released/registered. Among them, only Khumal Hybrid-2 has been released both for the Terai and middle hills of Nepal in 2014 (Koirala 2017). Nepali hill farmers will be benefitted getting 20-25% higher yields through cultivating native hybrids compared to OPVs. In the middle hills of Nepal, the improved OPVs yielded 106.4% higher than local varieties with an average yield of 2.53 t ha^{-1} (MoALD 2018) which is very low. The only way to meet the ever-increasing demand for maize is the move from OPVs to hybrids urgently and aggressively. Recent NMRP developed hybrids are better or at par with popular multi-national/commercial company hybrids (Sharma et al. 2016).

Another bottleneck that creates a wide yield gap of maize in Nepal is the attack of many diseases. Among them, Turcicum leaf blight (TLB) and Grey leaf spot (GLS) are the major problems for maize farming in hilly regions of Nepal (Subedi 2015). Therefore, due attention was given to identify resistant/tolerant hybrids against these devastating diseases.

Out of the total maize area in the country, 9.80, 73.78, and 16.42%, respectively belong to the mountain, middle hills, and Terai ecological belt (MoALD 2018). To date, we are trying to develop hybrid technology only for Terai and inner Terai regions which occupy only 16.42% of the total maize area. Therefore, hybrid oriented works need to be focused for the promotion of this technology in the middle hills which is the dominant maize growing pocket of the country, which is the innovation of this study. Realizing these facts, coordinated varietal trials on hybrids (CVTHs) were conducted across middle hill stations of NARC from east to west.

MATERIALS AND METHODS

The CVTHs were conducted at Agriculture Research Station (ARS) - Pakhribas, Hill Crops Research Program (HCRP) - Kabre, Agriculture Botany Division (ABD) - Khumaltar, Ginger Research Program (GRP) - Salyan, Horticulture Research Station (HRS) - Dailekh, Regional Agricultural Research Station (RARS) - Lumle, and ARS - Surkhet during summer from 2016/17 to 2018/19. Experiments consisted of fifteen, nine, and ten genotypes, respectively in 2016/17, 2017/18 and 2018/19. Trials were laid out in randomized complete block design (RCBD) with three replications having the unit plot size of 4 rows of 4-m length. The planting geometry was 60 cm row-to-row and 25 cm plant-to-plant. Fertilizers were applied @180:60:40 kg ha^{-1} N: P_2O_5 :K_2O along with 10 t ha^{-1} farmyard manure. Cultural practices were followed as per NMRP's recommendation. CIMMYT's (1985) procedures were used to record various observations. Field weight (kg ha^{-1}) was converted into grain yield (t ha^{-1}) adjusting 80% shelling recovery at a 15% moisture level. Data analysis was computed by using Genstat software. The geographic description of the experimental sites is presented in table 1.

RESULTS AND DISCUSSION

In 2016/17, differences among the genotypes, tested environments, and interaction between genotype and environment (G×E) were recorded both for days to 50% anthesis and silking. The mean values for days to 50% anthesis and silking were 71 and 74 days, respectively with anthesis-silking interval (ASI) of 3 days. Three JM series hybrids were earlier than multi-national company hybrid (MNCH) check P3533 both for anthesis and silking. A total of eight hybrids including check were earlier than NMRP developed and released Rampur hybrid-2 which showed 72 and 76 days for anthesis and silking, respectively. The late flowering genotype was RML-87/RL-105 with 76 days of anthesis and 79 days of silking. Thus, anthesis and silking of the hybrids differed from location to location. The days to 50% anthesis and silking were observed early at ABD Khumaltar (65 and 67 days) followed by ARS Pakhribas (66 and 69 days) and GRP Salyan (72 and 75 days). The

Table 1. A geographic description of experimental locations

Location	Elevation, m (amsl)	Annual rainfall (mm)	Longitude	Latitude
ARS Pakhribas, Dhankuta	1315-2025	1500-1600	87°17'61"E	27°02'96"N
HCRP Kabre, Dolakha	1660-1740	2466.2	86°80'E	27°38'N
ABD Khumaltar, Lalitpur	1368	1238	85°20'E	27°40'N
RARS Lumle, Kaski	1740	3172.85	83°58'27.72"E	28°13'6.8"N
GRP Kapurkot, Salyan	1480	1897.3	82°24'	28°14'N
ARS Dasharathpur, Surkhet	580	1100.3	81°47'E	28°30'N
HRS Kimugaon, Dailekh	1230-1290	1500	81°43'19.4"E	28°50'49.8"N

Table 2. Mean value of quantitative traits of hybrids tested in CVTH combined over locations (Pakhribas, Kabre, Khumaltar, Salyan, and Dailekh), 2016/17 summer

	Days to 50%		ASI	Height, cm		Ear position
Genotype	Anthesis	Silking		Plant	Ear	
RML-76/RL-105	74	77	3	222	114	0.51
RML-87/RL-105	76	79	3	212	116	0.55
RL-180/RL-105	70	72	2	218	120	0.55
RML-95/RL-105	72	74	2	229	127	0.55
RL-153/RL-105	71	73	2	224	121	0.54
RML-98/RL-105	73	76	3	222	115	0.52
RML-5/RL-105	73	76	3	232	125	0.54
RML-85/RL-105	75	78	3	229	130	0.57
RML-57/RL-174	75	77	2	256	141	0.55
RL-36/RL-197	69	72	3	231	127	0.55
JM-4	66	69	3	234	110	0.47
JM-7	67	70	3	201	91	0.45
JM-8	67	69	2	236	115	0.49
P3533	68	70	2	240	121	0.51
Rampur Hybrid-2	72	76	4	202	115	0.57
Minimum	66	69	2	201	91	0.45
Maximum	76	79	4	256	141	0.57
Mean	71	74	3	226	119	0.53
Genotype (G)	**	**		**	**	
Environment (E)	**	**		**	**	
G×E	**	**		ns	ns	
$LSD_{0.05}$	2.6	2.9		-	-	
C.V. %	2.3	2.4		8.6	11.7	

silking (77 days) and tasseling (82 days) was recorded late at HCRP Kabre (data not presented). The ASI among the tested hybrids was between 2 and 4. Six, eight, and a single variety showed 2, 3, and 4 ASI values, respectively. Variance declared insignificant G×E interaction across the locations. Differences among the tested hybrids and environments for plant and ear height were observed. The plant height ranged from 201 cm of JM-7 to 256 cm of RML-57/RL-174 with a mean value of 226 cm. Similarly, ear height varied from 91 of JM-7 to 141 cm of RML-57/RL-174 with a mean ear height of 119 cm. Hybrids namely JM-7, RML-76/RL-105, RML-98/RL-105, Rampur Hybrid-2, RML-87/RL-105, and RL-180/RL-105 produced shorter plant height with lower ear placement. RML-57/RL-174 was the hybrid with the tallest plant height of 256 cm and ear height of 141 cm among the tested hybrids. Ear position of the tested hybrids ranged from 0.45 to 0.53 with an experimental mean of 0.53. JM series hybrids namely produced ears with their position below 0.50, whereas the rest of the hybrids had ear positions above 0.50 (Table 2).

During the summer of 2016/17, differences were observed for GLS severity at GRP Salyan. Most of the genotypes showed a susceptible reaction against GLS. Only the genotype RL-180/RL-105 showed a moderately resistant reaction against GLS at GRP Salyan. Similarly, the moderately resistant hybrids against TLB were RML-76/RL-105, RML-87/RL-105, RL-180/RL-105, RML-95/RL-1, RL-153/RL-105, RML-98/RL-105, RML-5/RL-105, RML-57/RL-174, and JM-8 at ARS Pakhribas and HCRP Kabre (Table 3).

Grain yield differences among the tested hybrids were observed at ARS Pakhribas, GRP Salyan, and HRS Dailekh. At ARS Pakhribas, the highest yielder was MNCH P3533 with a productivity of 9.03 t ha^{-1} followed by RML-98/RL-105 of 7.60 t ha^{-1} and JM-8 of 7.57 t ha^{-1} which were at par statistically among them. At GRP Salyan, again the highest yielder was MNCH P3533 with grain yield of 12.60 t ha^{-1} followed by JM-8 with 10.50 t ha^{-1}, RML-76/RL-105 with 10.40 t ha^{-1}, RML-98/RL-105 with 10.30 t ha^{-1}, RL-153/RL-105 with 10.10 kg ha^{-1} and RML-57/RL-174 with 10.00 t ha^{-1}. These hybrids were at par among them statistically. At HRS Dailekh, an NMRP develop hybrid RML-98/RL-105 and P3533 produced higher grain yields of 11.70 and 11.30 t ha^{-1}, respectively, and were statistically at par among them. Combined analysis across locations revealed significant differences for genotype and

Table 3. The response of maize hybrids against GLS and TLB in CVTH at various locations in middle hills of Nepal, 2016/17 summer

Genotype	GLS (score 1-5)			TLB (score 1-5)		
	Pakhribas	Khumaltar	Salyan	Pakhribas	Kabre	Khumaltar
RML-76/RL-105	1.5	1.5	3.7	1.7	2	2.8
RML-87/RL-105	1.3	1.5	2.7	1.8	1.7	3
RL-180/RL-105	1.5	1.5	2.3	2.3	2	3.2
RML-95/RL-105	1.5	1.5	2.7	1.8	2	2.7
RL-153/RL-105	1.7	1.5	3	1.8	2.3	3.2
RML-98/RL-105	1.5	1.5	3.7	2.2	2.3	2.8
RML-5/RL-105	1.5	1.5	3.7	2.3	2.3	2.8
RML-85/RL-105	2	1.5	3.3	2.5	3	3.2
RML-57/RL-174	1.8	1.5	2.7	1.8	1.7	3
RL-36/RL-197	1.8	1.5	2.7	2.5	2.3	3
JM-4	1.8	1.5	5	2.5	3	3.5
JM-7	2	1.3	4	2.7	2	3.5
JM-8	1.7	1.3	3	2.2	2	2.7
P3533	1.7	1.3	4	2.8	4.7	3.2
Rampur Hybrid-2	2	1.5	4.3	2.7	3	3.5
Minimum	1.3	1.3	2.3	1.7	1.7	2.7
Maximum	2	1.5	5	2.8	4.7	3.5
Mean	1.7	1.5	3.6	2.2	2.4	3.1
F-test	ns	ns	**	*	**	ns
$LSD_{0.05}$	-	-	2.2	0.7	1.2	-
C.V. %	17.7	8.1	35.9	17.4	29.1	12.2

TLB- Turcicum leaf blight, GLS- Grey leaf spot

tested environment. P3533 produced a higher mean grain yield of 8.86 t ha^{-1} followed by RML-98/RL-105 of 7.85 t ha^{-1}, JM-8 of 7.62 t ha^{-1}, and JM-4 of 7.44 t ha^{-1}. The results have been summarized in Table 4.

Combined results across the locations in 2017/18 revealed significant variation for genotypes, environment, and G×E interaction both for days to 50% anthesis and silking. The mean value for anthesis and silking was 70 and 73 days, and ranged from 65-74 and 68-77 days, respectively. Days to 50% anthesis and silking were early in Rajkumar of 65 and 68 days followed by RML-37/RL-105 of 66 and 69 days, RL-150/RL-111 of 68 and 72 days and Rampur Hybrid-10 of 69 and 71 days. The existence of G×E indicated the location-specific nature of tested hybrids for these traits. Among the locations, early days to 50% anthesis and silking was recorded at ABD Khumaltar (58 and 60 days), ARS Pakhribas (61 and 65 days), and HRS Dailekh (70 and 73 days). The longer period for anthesis and silking was recorded at HCRP Kabre (85 and 88 days) (data not presented). All the tested hybrids had the ASI value 3 except Rampur Hybrid-10 and RL-150/RL-111 which showed the ASI value of 2 and 4, respectively.

Regarding morphological traits, the combined analysis showed significant genotypic, environmental, and G×E interactions for plant height. The mean value for plant height was 224 cm that ranged from 207 cm of Rampur Hybrid-6 to 246 cm of RL-150/RL-111. The expression of this trait differed from location to location because of significant G×E. Plant height was observed shorter at RARS Lumle of 175 cm followed by ABD Khumaltar of 229 cm and HRS Dailekh of 242 cm (data not presented). Considerable differences across the locations were observed for ear height. The hybrids with lower ear placement were observed at RARS Lumle with a mean value of 96 cm followed by ABD Khumaltar with 119 cm and HCRP Kabre with 133 cm (data not presented). Only the Rampur Hybrid-10 had ear position of 0.50 which was exactly at the middle point of the stalk and RML-37/RL-105 had the highest ear position of 0.59. The rest of the hybrids had an ear position in between these two hybrids (Table 5).

Table 4. Mean grain yield (t ha^{-1}) of hybrids tested in CVTH at different locations and combined over them (Pakhribas, Kabre, Khumaltar, Salyan, and Dailekh), 2016/17 summer

Genotype	Pakhribas	Kabre	Khumaltar	Salyan	Dailekh	Mean
RML-76/RL-105	6.57	6.66	2.30	10.40	8.90	6.97
RML-87/RL-105	5.10	6.23	3.19	8.60	8.00	6.22
RL-180/RL-105	6.13	4.61	2.10	7.60	8.80	5.85
RML-95/RL-105	6.33	6.83	2.53	8.80	8.40	6.58
RL-153/RL-105	6.80	6.40	2.67	10.10	9.10	7.01
RML-98/RL-105	7.60	6.28	3.36	10.30	11.70	7.85
RML-5/RL-105	6.97	7.31	3.27	9.60	8.50	7.13
RML-85/RL-105	6.47	6.06	2.73	9.20	8.30	6.55
RML-57/RL-174	6.77	7.57	3.03	10.00	8.60	7.19
RL-36/RL-197	4.70	6.22	2.87	9.90	9.00	6.54
JM-4	5.63	9.78	3.48	9.00	9.30	7.44
JM-7	5.23	7.88	2.13	4.30	9.10	5.73
JM-8	7.57	8.61	2.43	10.50	9.00	7.62
P3533	9.03	8.62	2.73	12.60	11.30	8.86
Rampur Hybrid-2	5.87	6.46	2.41	7.50	8.50	6.15
Minimum	4.70	4.61	2.10	4.30	8.00	5.73
Maximum	9.03	9.78	3.48	12.60	11.70	8.86
Mean	6.45	7.03	2.60	9.20	9.40	6.96
Genotype (G)	**	ns	ns	**	**	**
Environment (E)						**
G×E						ns
$LSD_{0.05}$	1.70	-	-	2.70	1.70	-
C.V. %	15.5	40.5	36.6	17.3	10.9	26.4

The analysis of variance revealed significant differences among the tested hybrids for TLB severity at Khumaltar and GLS severity at Kabre during the summer of 2017/18. At Khumaltar, the genotypes moderately resistant against TLB were RL-150/RL-111, RML-37/RL-105, CAH 1521, Rampur Hybrid-10, and Rajkumar. At Kabre, RML-19/RL-6 and Rajkumar showed the resistant reaction against GLS, whereas RL-150/RL-111, RML-37/RL-105, RML-4/RL-111, and RML-98/RL-105 was moderately resistant against GLS (Table 6).

During summer 2017/18, F-test showed differences among the hybrids, tested environments, and interaction (G×E) among them for grain yield when combined across the locations. Averaged grain yield ranged from 5.47 t ha^{-1} of RML-19/RL-6 to 8.19 t ha^{-1} of RML-4/RL-111 with a mean value of 7.16 t ha^{-1}. Regarding individual location, varietal differences were observed at all the locations except at ARS Pakhribas. HRS Dailekh produced a higher mean grain yield of 8.59 t ha^{-1} followed by ABD Khumaltar of 8.18 t ha^{-1} and HCRP Kabre of 6.99 t ha^{-1}. The hybrids produced a lower yield of 5.31 t ha^{-1} at ARS Pakhribas with insignificant results among the tested hybrids (Table 7).

In 2018/19 summer, flowering traits combined over the three locations revealed significant differences for both anthesis and silking among the tested genotypes and tested environments, whereas G×E interaction was found significant only for anthesis. Anthesis ranged from 61 days of Rajkumar to 69 days of RML-98/RL-105 with a mean value of 66 days. Silking ranged from 63 days of RL-243/RML-17 to 71 days of RML-98/RL-105, RML-83/RL-197, and Rampur Hybrid-6 with the mean value of 69 days. Likewise, the ASI value ranged from 1 of RL-243/RML-17 and RML-4/RL-111 to 4 of Rajkumar. Five hybrids with ASI values 2 and two with 3 (RML-84/RML-17 and RML-98/RL-105) ASI values were observed. Early days to 50% anthesis and silking were observed at ARS Surkhet (61 and 64 days) followed by HRS Dailekh (66 and 68 days) and GRP Salyan (73 and 74 days) (data not presented). Differences were resulted in the tested environment, while non-significant for tested genotypes and G×E interaction from the combined analysis for plant and ear height. Among the locations, shorter plant and ear heights were

Table 5. Performance of hybrids tested in CVTH combined over locations (Pakhribas, Kabre, Khumaltar, Lumle, and Dailekh), 2017/18 summer

	Days to 50%		ASI	Height, cm		Ear position
Genotype	Anthesis	Silking		Plant	Ear	
CAH1521	72	75	3	226	116	0.51
Rajkumar	65	68	3	219	114	0.52
Rampur Hybrid-10	69	71	2	228	115	0.50
Rampur Hybrid-6	74	77	3	207	116	0.56
RL-150/RL-111	68	72	4	246	139	0.57
RML-19/RL-6	72	75	3	212	116	0.55
RML-37/RL-105	66	69	3	211	124	0.59
RML-4/RL-111	72	75	3	234	121	0.52
RML-98/RL-105	74	77	3	230	127	0.55
Minimum	65	68	2	207	114	0.50
Maximum	74	77	4	246	139	0.59
Mean	70	73	3	224	121	0.54
Genotype (G)	**	**		*	ns	
Environment (E)	**	**		**	**	
G×E	**	**		*	ns	
$LSD_{0.05}$	8	8		28	-	
C.V. %	14.8	14.9		17	18.1	

recorded at ARS Surkhet (214 and 103 cm) followed by GRP Salyan (218 and 108 cm) and HRS Dailekh (275 and 149 cm) (data not presented). Ear position of the experimented

hybrids varied from 0.46 of RML-57/RL-174 to 0.58 of CAH1715 with a mean value of 0.52. Four hybrids including check Rajkumar had ear position ≤0.50 and the rest had >0.51. Variations among the tested genotypes and locations were recorded for grain yield. The mean value for grain yield was 7.47 t ha^{-1} with a minimum of 5.80 t ha^{-1} of RML-57/RL-174) and a maximum of 9.12 t ha^{-1} of CAH1715. The mean grain yield ranged from 6.69 t ha^{-1} in Surkhet to 8.37 t ha^{-1} in the Dailekh district (Table 8).

We observed genetic variations among the tested hybrids for different traits like Kandel et al in 2019). The selected hybrids from the three years' experiments are CAH1715 (9.12 t ha^{-1}), RML-4/RL-111(8.72 t ha^{-1}), RML-98/RL-105 (8.25 t ha^{-1}), RL-150/RL-111 (8.18 t ha^{-1}), RL-36/RL-105 (8.04 t ha^{-1}), CAH1521 (7.67 t ha^{-1}) and Rampur Hybrid-10 (7.65 t ha^{-1}). They were selected based on acceptable grain yield, ASI, ear position and, lower TLB, and GLS reaction. In case of hybrids, significantly higher grain yield of 6.54 t ha^{-1} was obtained from the population of 85,470 than 55.555 (5.31 t ha^{-1}) and 69.444 (5.92 t ha^{-1}) plants ha^{-1} whereas remained at par with 1.01.010 plants ha^{-1} (6.21 t ha^{-1}) (Thapa and Kandel 2019). In the case of significant G×E interactions, we should go for selecting location-specific genotypes.

The maturity period and ASI of the hybrids are among the valued traits. Among the tested 34 hybrids, the ASI value of 1,2,3 and 4 was recorded in 5.88, 35.30, 50, and 8.82% of the hybrids, respectively. There will be a perfect nick of male and female flowers in the hybrids identified better in the experiments. The finding of the experiment is supported by Tripathi et al. (2011) who mentioned that each year and location for the summer season, anthesis was earlier than silking because of the protandry nature of maize. There should be perfect synchrony of silking with pollen shed for better pollination ensuring higher yields. Due to extreme weather conditions i.e., too cold and/or too hot, anthesis is much affected compared to silking (Lizaso et al. 2018). This also affects the ASI and grain yield (Struik et al 1986).

Plant and ear heights are basic traits that determine the acceptability of hybrids with lodging and fertilizer responsiveness. Ear position of the tested hybrids ranged from 0.45 to 0.59. The preferences of ear height are location specific from low to high. Too high ear height is prone to lodging due to heavyweight on the top during the reproductive phase and the hybrid will not respond positively for higher yields, too low ear height also can be damaged by wild animals. Farmers who grow maize near the forest areas prefer higher ear height to protect it from the damage of wild

Table 6. The response of maize hybrids against TLB and GLS in CVTH at various locations, 2017/18 summer

	TLB (score 1-5)			GLS (score 1-5)	
Genotype	Pakhribas	Khumaltar	Kabre	Pakhribas	Kabre
CAH1521	1.3	2.3	2	2.7	3
Rajkumar	1.3	2.3	2	2.7	1
Rampur Hybrid-10	1.2	2.3	2	2	3
Rampur Hybrid-6	1.7	2.8	2	3.5	3
RL-150/RL-111	1	2	2	2.7	2
RML-19/RL-6	1	2.6	1	2.7	1
RML-37/RL-105	1.7	2.2	1	3	2
RML-4/RL-111	1.3	2.5	1	3.2	2
RML-98/RL-105	1.2	2.7	2	3	2
Minimum	1	2	1	2	1
Maximum	1.7	2.8	2	3.5	3
Mean	1	2.4	**2**	2.81	**2**
Genotype	ns	**	ns	ns	*
$LSD_{0.05}$	-	0.3	-	-	1.09
C.V. %	34.2	8.4	42.00	29.3	28.90

animals, whereas the farmers who grow maize in the wind prone areas prefer lower ear height to protect the plant from lodging. According to Zsuzsanna et al. (2002), lower ear height is unsuitable for grain yield as it makes harvesting

difficult. Thus, an ear position around 0.50 is ideal for solving these problems. Other requirements such as green biomass/fodder yield can be obtained by selecting high-yielding hybrids based on plant height. Increased plant population from 45000 ha^{-1} to 85000 ha^{-1} resulted in increased plant and ear heights as reported by Hegyi et al. (2002).

Host resistance is the most effective approach to combat plant diseases for higher yield gains. Hybrids RML-97/RL-105, RML-76/RL-105, RML-37/RL-105, RML-98/RL-105, and CAH 1521 showed a moderately resistant reaction against TLB and GLS over the years and across the locations. The findings of this experiment are in line with the report of NMRP (2014) as it was revealed that cross combinations of RL-111and RL-105, when

Table 7. Mean grain yield (t ha^{-1}) of hybrids tested in CVTH hills at different locations and combined over locations (Pakhribas, Kabre, Khumaltar, Lumle, and Dailekh), 2017/18 summer

Genotype	Pakhribas	Kabre	Khumaltar	Lumle	Dailekh	Mean
CAH1521	5.20	7.36	8.90	7.61	9.25	7.67
Rajkumar	5.05	6.17	7.93	8.04	8.72	7.18
Rampur Hybrid-10	4.97	7.51	10.09	6.53	9.15	7.65
Rampur Hybrid-6	4.23	9.27	6.40	5.69	7.65	6.65
RL-150/RL-111	5.47	8.11	9.35	7.84	10.14	8.18
RML-19/RL-6	5.51	3.24	5.19	5.48	7.92	5.47
RML-37/RL-105	6.38	4.16	8.50	4.11	7.72	6.17
RML-4/RL-111	4.73	8.99	10.04	7.77	9.42	8.19
RML-98/RL-105	6.24	8.10	7.23	7.71	7.32	7.32
Minimum	4.23	3.24	5.19	4.11	7.32	5.47
Maximum	6.38	9.27	10.09	8.041	10.14	8.19
Mean	5.31	6.99	8.18	6.75	8.59	7.16
Genotype (G)	ns	**	*	**	*	**
Environment (E)						**
G×E						**
$LSD_{0.05}$	-	2.30	3.23	1.46	1.63	1.47
C.V. %	20.9	19.00	22	12.5	10.9	28.4

Table 8. Performance of hybrids tested in CVTH hills at different locations and combined over locations (Salyan, Dailekh, and Surkhet), 2018/19 summer

Genotype	Days to 50%		ASI	Height, cm		Ear position	Grain yield, kg ha^{-1}			
	Anthesis	Silking		Plant	Ear		Salyan	Dailekh	Surkhet	Mean
Rajkumar	61	65	4	234	116	0.50	6.95	8.08	7.08	7.37
Rampur Hybrid-6	69	71	2	230	127	0.55	7.61	6.97	4.98	6.52
RL-243/RML-17	62	63	1	232	125	0.54	7.08	7.20	6.63	6.97
RL-36/RL-105	66	68	2	231	125	0.54	7.56	9.34	7.22	8.04
CAH1715	68	70	2	259	124	0.58	8.88	10.43	8.07	9.12
RML-4/RL-111	69	70	1	232	121	0.52	9.95	8.99	7.21	8.72
RML-57/RL-174	67	69	2	232	107	0.46	5.67	6.39	5.32	5.80
RML-83/RL-197	69	71	2	231	114	0.49	5.68	8.43	6.38	6.83
RML-84/RML-17	66	69	3	236	120	0.51	6.71	7.86	6.66	7.07
RML-98/RL-105	69	71	3	244	120	0.49	7.38	9.99	7.38	8.25
Minimum	61	63	1	230	107	0.46	5.67	6.39	4.98	5.80
Maximum	69	71	4	259	127	0.58	9.95	10.43	8.07	9.12
Mean	66	69	2	236	120	0.52	7.35	8.37	6.70	7.47
Genotype (G)	**	**		ns	ns		**	ns	*	**
Environment (E)	**	**		**	**					**
G×E	*	ns		ns	ns					ns
LSD $_{0.05}$	3.36	-		-	-		1.55	-		-
CV, %	2.5	3.1		6.9	10.6		9.3	14.4	11.6	12.3

used as a tester, produced high yielding hybrids with moderate disease resistance.

CONCLUSIONS

Hybrids namely CAH1715 (9.12 t ha^{-1}), RML-4/RL-111 (8.72 t ha^{-1}), RML-98/RL-105 (8.25 t ha^{-1}), RL-150/RL-111 (8.18 t ha^{-1}), RL-36/RL-105 (8.04 t ha^{-1}), CAH1521 (7.67 t ha^{-1}) and Rampur Hybrid-10 (7.65 t ha^{-1}) were identified promising for the rainfed middle hills condition during the summer due to their acceptable grain yield, ASI, ear position and, TLB and GLS reaction. In the case of significant G×E interactions, we should go for selecting location-specific hybrids. These hybrids will be promoted to farmers' field trials (FFTs) and other participatory variety selection (PVS) activities.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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