RESEARCH ARTICLE

PERFORMANCE EVALUATION OF MAIZE HYBRIDS UNDER RAINFED ENVIRONMENTS ACROSS MIDDLE HILLS OF NEPAL

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ABSTRACT

Hybrid plays an important role in production and productivity increment of maize in potential pockets of middle hills. With an objective of identifying potential hybrids for middle hill environments, coordinated varietal trials on maize hybrids were conducted using randomized complete block design with three replications in various hill stations during summer of 2014/15 and 2015/16. During 2014/015, significant differences were recorded among the genotypes at Khumaltar and Pakhribas, where non-significant at Kabre for grain yield. Combined results of hill stations for grain yield revealed highly significant differences for genotypes, environments and, genotype by environment interactions indicating existence of variability among the tested genotypes at each site except at Kabre, and site specific nature of the tested hybrids was recorded. JM-8 produced the highest grain yield of 8356 kg ha⁻¹ followed by RL-153/RL-105 (8006 kg ha⁻¹), RML-95/RL-105 (7940 kg ha⁻¹) and Khumal Hybrid-2 (7788 kg ha⁻¹), respectively. In 2015/16, among the experimented hybrids highly significant grain yield differences were observed at Pakhribas and Khumaltar, and significant at Dailekh. Combined results over locations showed that RML-95/RL-197 (7365 kg ha⁻¹) outyielded others and followed by RML-95/RL-105 (7010 kg ha⁻¹), RML -151/RL-111 (6717 kg ha⁻¹) and RML -87/RL-105 (6580 kg ha⁻¹). Hybrids having higher grain yield in coordinated varietal trials will be promoted to Coordinated Farmers' Field Trial on Hybrid and these hybrids might be the potential hybrids in future for potential pockets of middle hills of Nepal.

KEYWORDS

Hybrid, single cross, multi-national company hybrid.

1. INTRODUCTION

Maize (*Zea mays* L.) is the livelihood of Nepali hill farmers. It occupies 954158 ha of land with 2,555,847 t production and 2,679 kg ha⁻¹ productivity in Nepal (MoALD, 2018). 8.76, 72.29 and 18.95% of the total maize area in the country belongs to mountain, middle hills and Terai with productivity of 2075, 2461 and 2725 kg ha⁻¹, respectively. The area under summer maize is about 73.9%, where spring and winter maize occupied 14.2% and 11.9%, respectively. Seed replacement rate (SRR) of maize is about 17.83% (Memoire, 2017). Nearly, 12-15% area is covered by hybrids and 85-88% by open-pollinated varieties (OPVs) in the country. Aggressive promotion of high yielding hybrids along with other cost-effective production technologies are the means to narrow down the existing huge gap between the real (2.69 t ha⁻¹) and potential yield (6.5 t ha⁻¹) of maize at farmers' level (Koirala, 2014a).

Farmers initiated growing maize hybrids in the border adjoining districts during 1980s in Nepal by importing seeds from India (Thapa, 2013).

Hybrid maize research in Nepal was initiated in 1987 (Koirala et al., 2002). The single cross hybrids developed using inbred lines from International Institute of Tropical Agriculture (IITA) at NMRP did not do better to Indian hybrids and OPV Rampur Composite when evaluated at Regional Agricultural Research Station (RARS) Parwanipur (Lal et al., 1988). CIMMYT also placed greater emphasis on OPVs till 1985 and then it has started to work on hybrid due to the increased demand in developing countries for hybrids (CIMMYT, 1993). NMRP also initiated systematic hybrid maize research and inbred line development activities in 1995 using own and exotic sources (Koirala, 1997; Koirala et al., 1998; Koirala et al., 2000a, 2000b).

A group of researchers reported for the first time in the history of NMRP that with a view to capture yield potential of hybrids in the potential pockets of the hills, extensive testing and selection of NMRP developed hybrids across the country under observation nursery (OBN) and CVTH was initiated in 1999 (Koirala et al., 2000b). Nepal has released five maize hybrids. Among them, only one

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(Khumal Hybrid-2) has been released for middle hills and rest four along with this Khumal Hybrid-2 for Terai, inner Terai and river basin areas. Gaurav, Rampur Hybrid-2, Khumal Hybrid-2, Rampur Hybrid-4, Rampur Hybrid-6 are the single cross yellow kernel hybrids released in Nepal. To tackle the problem of climate change, as heat stress resilient yellow kernel single cross hybrids, Rampur Hybrid-8 and Rampur Hybrid-10 were registered in 2017 for commercial cultivation in Terai and Inner Terai region of Nepal up to 700m during winter season (Koirala, 2017a, 2017b).

Limited hybrid choice option, low access to improved seeds of released/registered varieties developed by national system, biotic (northern leaf blight, gray leaf spot, stem borer, and fall army worm etc.) and abiotic stresses (high and low temperature, drought and water logging) are the reasons behind lower production and productivity of maize in middle hills of Nepal. Likewise, majority of maize area in the hills is still under OPVs. NSV 2013 visualizes to increase maize SRR up to 33% by 2025. Yield of OPVs could not be increased forever from a certain level even if high inputs are given. 25-30% higher grain yield from hybrids can be harvested compared to better OPVs. It is estimated that yellow kernel maize required for poultry feed is 391538 t annually. Only 25% of this

demand is fulfilled by domestic production and rest is imported from abroad.

Agricultural Development Strategy and NSV 2013 offer clear-cut vision to maize workers both from public and private sectors towards development and promotion of high yielding hybrids to boost maize production and productivity (ADS, 2014). NSV envisaged the development and promotion of 12 and 5 hybrids of maize by public and private sector, respectively by the end of 2025 to fulfill the increasing demand and visualizes as an import substitution measure (NSV, 2013). Realizing the above-mentioned facts, experiments were carried out across the NARC middle hill stations in the country with the aim of identifying the potential hybrids suitable for rainfed environments of middle hill.

2. MATERIALS AND METHODS

2.1 Description of locations

Hybrids were tested in middle hill stations under Nepal Agricultural Research Council (NARC) at Pakhribas, Khumaltar and Kabre in 2014/15, and Pakhribas, Khumaltar, Dailekh and Doti in 2015/16. The short geographic description of the locations is presented in Table 1.

Table 1: Geographic description of experimental locations

Location	Elevation, m (m.a.s.l.)	Annual rainfall (mm)	Longitude	Latitude
Pakhribas (Dhankuta)	1315-2025	1500-1600	87°17'61"E	27°02'96"N
Kabre (Dolakha)	1600-1740	2466.2	86°80'E	27°38'N
Khumaltar (Lalitpur)	1368	1238	85°20'E	27°40'N
Kimugaon (Dailekh)	1230-1290	1500	81°43'19.4"E	28°50'49.8"N
Bhagetada (Doti)	510	<1000	80°55'E	29°15'N

2.2 Planting materials

The experiments consisted two different sets of hybrids i.e. 20 and nine genotypes in 2014/15 and 2015/16 summer, respectively. All the hybrids included in the experiments were developed by NMRP except multinational company hybrid namely Rajkumar and JM series hybrids. Most of the tested hybrids are single crosses except Khumal Hybrid-2//RL-111 which is double cross.

2.3 Experimental design, treatment details and cultural practices

Coordinated varietal trials on hybrids (CVTHs) were carried out using randomized complete block design (RCBD) with three replications. The unit plot size was 4 rows of 4m length with row spacing of 0.75m and plant spacing of 0.20m. Farm yard manure (FYM) @15 t ha⁻¹ in combination with chemical fertilizer @180:60:40 N:P:K kg ha⁻¹ was applied. All agronomic practices were followed as per standard of NMRP, Rampur (NMRP, 2014).

2.4 Data recording

The 50% days to anthesis and silking, plant and ear height, yield and yield attributing traits and disease parameters were recorded according to the procedures described by CIMMYT (CIMMYT, 1985). Grain yield (kg ha⁻¹) at 15% moisture content was calculated using fresh ear weight with the help of the formula given as follows (Koirala et al., 2017c; Shrestha et al., 2019):

$$\text{Grain yield } \left(\frac{\text{kg}}{\text{ha}}\right) = \frac{\text{FW} \left(\frac{\text{kg}}{\text{plot}}\right) \times (100 - \text{HMP}) \times S \times 10000}{(100 - \text{DMP}) \times \text{NPA}}$$

Where,

FW = Fresh weight of ear in kg per plot at harvest
HMP = Grain moisture percentage at harvest
DMP = Desired moisture percentage, i.e. 15%
NPA = Net harvest plot area, m²
S = Shelling coefficient, i.e. 0.8

2.5 Statistical analysis

MS-Excel 2010 was used to record data and was analyzed through ADEL-R software. The significant differences between genotypes were determined using least significant difference (LSD) test at 1% or 5% level of significance, respectively (Gomez and Gomez, 1984; Shrestha, 2019).

3. RESULTS AND DISCUSSION

At Pakhribas in 2014/15, grain yield, plant height and scoring of *Turicum* leaf blight among the tested hybrids differed significantly. Highly significant differences were observed for rest of the traits. Grain yield of the experimented hybrids ranged from 2075 kg ha⁻¹ (Rampur Hybrid-6) to 6695 kg ha⁻¹ (RL-153/RL-105). Results have been presented in table 2.

Table 2: Performance of maize hybrids under coordinated varietal trial (CVTH) at Pakhribas, 2014/15 summer

Genotype	Days to 50%		Height, cm		HC (1-5)	score (1-5)				Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear		BLSB	E Rot	GLS	TLB	
RML-95/RML-96	90	95	207	112	2.3	1.5	1.3	1.8	3.3	3523
Rampur Hybrid-4	87	94	200	96	1.8	2	1.1	1.3	2.5	4005
Rampur Hybrid-6	91	96	220	116	1.8	1.5	3	1.8	3.5	2075
RML-86/RML-96	90	93	222	117	2	1.5	0.5	1.3	2.3	3299
Khumal Hybrid-2//RL-111	88	91	228	122	2.5	2	4.3	1.8	2.8	3052
Khumal Hybrid-2	85	88	245	149	1.8	1.5	2.4	1.3	2	5280
RML-6/RML-19	88	94	205	109	2.3	2	2.1	1.3	1.8	3637
KP45OR/RML-4	84	88	197	103	2.5	2	2.3	1.3	2.3	3060
KP45CB/RL-84	85	89	225	115	2.8	1.5	1.8	1.3	3.3	2630
RML-95/RL-105	96	99	218	126	2.5	2.5	1.3	1.8	3.5	3549
RL-153/RL-105	87	90	210	110	2.5	2	0.3	1	1.8	6695
RML-4/RL-111	88	92	207	111	2.3	2.5	1.8	1.8	3.5	3919
RML-98/RL-105	91	95	212	106	1.8	1.5	0.5	1.3	2.3	4069
JM-1	74	76	189	91	1.5	2	20	1.8	2.8	4844
JM-4	79	83	225	109	1.5	2	7.9	1.3	2.5	5481
JM-7	77	82	186	82	1.5	2.3	16.3	1.8	3.8	4226
JM-8	82	87	231	108	1.8	2.5	0.4	1	1.5	6359
RML-5/RL-105	92	97	237	125	1.8	2	0	1.3	1.8	5356
Rampur Hybrid-2	94	96	215	118	2.8	2	1.9	1.8	3.5	2733
Rajkumar	89	93	213	112	2.8	2.5	1.1	1.3	2.3	3876
Grand mean	87	91	214	112	2.1	2	3.5	1.4	2.6	408
F-test	**	**	*	**	**	**	**	**	*	*
LSD _{0.05}	4.3	4.5	26.4	14.8	0.74	0.17	2.5	0.2	0.5	2147
CV, %	2.4	2.4	5.9	6.4	16.8	4	38.2	7.6	8.3	25.1

** Significant difference at 0.01 level, * Significant difference at 0.05 level, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation, HC=Husk cover, BLSB=

Banded leaf and sheath blight, E-Ear, GLS-Grey leaf spot and TLB-Turcicum leaf blight At Pakhribas in 2015/16, plant aspect of the evaluated genotypes was recorded significant, where scoring of diseases like ear rot, grey leaf spot, root and stalk lodging were non-significant. Rest of the traits including grain yield were found highly significant among the hybrids experimented.

The grain yield of the hybrids ranged from 5400 kg ha⁻¹ (RL-84/RML-62) to 7100 kg ha⁻¹ (RML-57/RL-197). This highest yielded was followed by RML-95/RL-105 (6900 kg ha⁻¹), RML -57/RL-105 (6800 kg ha⁻¹) and RL-36/RL-197 (6500 kg ha⁻¹), respectively. The experimental grand mean was 6300 kg ha⁻¹. The findings are summarized in table 3.

Table 3: Performance of maize hybrids under coordinated varietal trial (CVTH) at Pakhribas, 2015/16 summer

Genotype	Days to 50%		Height, cm		Score (1-5)							Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear	PA	EA	HC	GLS	NLB	RL	SL	
RML-95/RL-105	66	69	227	122	1.5	1.7	1.7	2.0	2.0	2.0	1.7	6900
RML-87/RL-105	64	68	217	121	1.5	1.7	1.7	1.7	2.7	2.0	1.7	6200
RML-57/RL-105	66	69	241	121	1.5	1.0	1.3	1.7	2.3	1.3	0.7	6800
RL-84/RML 62	61	64	234	123	1.7	1.7	2.2	2.7	1.3	1.7	1.0	5400
RL-36/RL-197	61	64	225	119	1.5	1.3	1.8	1.3	2.0	3.0	1.7	6500
RML-57/RL-197	61	65	233	124	1.2	1.5	1.8	1.3	1.7	2.0	0.3	7100
RML-151/RL-111	62	66	232	128	1.7	1.7	1.7	1.3	2.0	1.0	3.0	6000
Rampur Hybrid-2	66	69	211	116	1.2	1.2	1.2	1.7	4.0	1.7	1.0	5800
Rajkumar	57	61	219	109	1.8	1.8	1.7	1.3	2.0	1.7	3.3	5900
Grand mean	63	66	227	120	1.5	1.5	1.7	1.7	2.2	1.7	1.6	6300
F-test	**	**	**	ns	*	**	**	ns	**	ns	ns	**
LSD _{0.05}	2.2	2.1	13	-	0.4	6.4	0.4	-	1.2	-	-	800
CV, %	2	1.9	3.3	5.9	16.2	16.7	15	31.6	30	72	74.6	7.4

** Significant difference at 0.01 level, * Significant difference at 0.05 level, ns= non significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation, PA-Plant aspect, EA-Ear aspect, HC-Husk cover, GLS-Grey leaf spot, TLB-Turcicum leaf blight, RL-Root lodging and SL-Stalk lodging

At Khumaltar in 2014/15, highly significant differences among the tested genotypes were recorded for days to anthesis and silking, plant and ear height, husk cover and scoring of northern leaf blight; significant differences were recorded for plant and ear aspect and non-significant for BLSB. Among the evaluated 20 hybrids, 14 hybrids out yielded popular

company hybrid Rajkumar (10067 kg ha⁻¹). The highest yielding variety was Khumal Hybrid-2 (14660 kg ha⁻¹), RML-95/RML-105 (14595 kg ha⁻¹), Rampur Hybrid-4 (14155 kg ha⁻¹), RML-4/RL-111 (13628 kg ha⁻¹) and RML-98/RL-105 (13001). These genotypes were selected for their higher grain yield and resistant from diseases' point of view. Results have been summarized in table 4.

Table 4: Performance of maize hybrids under coordinated varietal trial (CVTH) at Khumaltar, 2014/15 summer

Genotype	Days to 50%		Height, cm		Score (1-5)					Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear	PA	EA	HC	BLSB	TLB	
RML-95/RML-96	69	72	258	132	2.3	3	1.8	1.5	1.8	12563
Rampur Hybrid-4	66	68	251	111	2	2	1.1	1.8	3	14155
Rampur Hybrid-6	70	73	244	128	2.3	1.8	1	2.3	2.5	11336
RML-86/RML-96	68	70	252	125	3	3.3	2.3	2	1.5	11093
Khumal Hybrid-2//RL-111	67	69	246	127	2.5	2.8	1.5	1.8	1	10377
Khumal Hybrid-2	67	69	251	125	2.8	1.8	1	1	1	14660
RML-6/RML-19	68	69	214	98	3.3	2.8	1.3	2	1.3	6161
KP45OR/RML-4	68	69	228	115	1.8	2	1.5	1.5	1.3	11353
KP45CB/RL-84	66	68	248	127	2.8	3.5	3	1.8	1.5	8828
RML-95/RL-105	70	72	264	150	2.5	2.8	2.3	1.8	1.8	14595
RL-153/RL-105	68	70	259	136	2.3	2.3	1.8	1	1	11733
RML-4/RL-111	68	70	257	138	2	2	1	1.5	1.3	13628
RML-98/RL-105	69	71	266	142	2.3	2	1.5	1.8	1.5	13001
JM-1	61	63	225	102	2	2.3	1.8	1.5	1	8606
JM-4	63	65	257	116	2.5	2	1.8	1	1.3	11012
JM-7	64	66	209	91	3.5	3	1.8	2	1.5	6780
JM-8	65	68	249	116	2.3	2	1	1.5	1	12732
RML-5/RL-105	71	73	262	131	2.8	2.3	1.3	1.5	1	12479
Rampur Hybrid-2	68	70	237	126	2.3	2.5	1.3	1	1.8	8134
Rajkumar	70	72	242	121	2.3	2.3	1.5	1.3	1.5	10067
Grand mean	67	69	246	123	2.5	2.4	1.6	1.6	1.5	11165
F-test	**	**	**	**	*	*	**	ns	**	**
LSD _{0.05}	2.5	2.3	18.8	19	0.8	0.9	0.9	-	0.8	2913
CV, %	1.8	1.6	3.7	7.5	17	17.5	26	37.3	24.1	12.5

** Significant difference at 0.01 level, ns = Non-significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation, PA-Plant aspect, EA-Ear aspect, HC-Husk cover, BLSB-Banded leaf and sheath blight, TLB- Turcicum leaf blight

During 2015/16 at Khumaltar, genotypic variations among the tested hybrids were evident for days to anthesis, plant height, husk cover aspect, scoring of *Turcicum* leaf blight and grain yield. Rest of the traits under observation was at par, statistically. The highest yielder was RL-151/RL-

111 which produced 6400 kg ha⁻¹, and was followed by RML-19/NML-2 (5400 kg ha⁻¹), RML-95/RL-105 (4400 kg ha⁻¹), and multi-national company hybrid Rajkumar (4000 kg ha⁻¹). Detail information about this trial has been given in table 5.

Table 5: Performance of maize hybrids under coordinated varietal trial (CVTH) at Khumaltar, 2015/16 summer

Genotype	Days to 50%		Height, cm		Aspect (1-5)			Disease score (1-5)			Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear	PA	EA	HC	BLSB	GLS	TLB	
RML-95/RL-105	71	73	270	144	2.0	3.0	2.0	1.5	1.0	1.8	4400
RML-87/RL-105	71	72	265	149	2.0	3.0	1.5	1.5	1.0	1.5	5800
RML-57/RL-105	71	72	288	146	1.8	3.0	1.3	1.7	1.0	1.3	3900
RL-84/RML-62	70	73	256	140	2.3	3.0	2.0	1.3	1.0	1.7	2200
RL-36/RL-197	70	72	269	137	1.8	3.0	1.2	1.5	1.0	1.5	4000
RML-19/NML-2	68	69	272	150	2.0	2.7	1.0	1.5	1.0	1.5	5400
RL-151/RL-111	67	71	280	144	2.7	2.7	1.0	1.5	1.0	1.8	6400
Rampur Hyhbrid-2	71	73	236	128	2.3	3.0	1.3	1.5	1.0	2.2	2700
Rajkumar	65	70	261	144	1.7	2.7	1.0	1.5	1.0	1.5	4000
Grand mean	69	72	266	143	2.1	2.9	1.4	1.5	1	1.6	4300
F-test	**	ns	*	ns	ns	ns	*	ns		**	**
LSD _{0.05}	2.9	-	28	-	-	-	0.7	-		0.3	2000
CV, %	2.4	2.8	6.1	8	21.6	11.5	31	9.6		11.1	27.5

** Significant difference at 0.01 level, *Significnat difference at 0.05 level, ns= non significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation, PA-Plant aspect, EA-Ear aspect, HC-Husk cover, BLSB-Banded leaf and sheath blight, GLS-Grey leaf spot and TLB-Turicum leaf blight

The results of 2015/16 summer from Horticulture Research Station Dailekh presented in table 6 showed significant varietal differences of the tested hybrids for grain yield and non-significant results for rest of the traits. Most of the tested hybrids produced better grain yield having 8470

kg ha⁻¹ experimental mean. Four out of nine tested hybrids namely RML-95/RL-105 (9730 kg ha⁻¹), Rampur Hybrid-2 (9600 kg ha⁻¹), RL- 84/RML-62 (9490 kg ha⁻¹) and RL-36/RL-197 (8780 kg ha⁻¹) out yielded multinational company hybrid Rajkumar which is popular among the farmers in Nepal.

Table 6: Performance of maize hybrids under coordinated varietal trial (CVTH) at Dailekh, 2015/16 summer

Genotype	Days to 50%		Height, cm		Stalk lodging, %	Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear		
RML-95/RL-105	74	76	234	125	17.6	9730
RML -87/RL-105	75	77	220	123	8.3	7740
RML -57/RL-105	73	75	234	126	7.4	7750
RL- 84/RML-62	72	74	227	116	7.4	9490
RL-36/RL-197	75	77	230	114	4.6	8780
RML-57/RL-197	74	76	234	119	0.9	7630
RML -151/RL-111	69	71	238	125	4.6	7750
Rampur Hybrid-2	75	77	224	121	3.7	9600
Rajkumar	70	72	224	115	6.5	7750
Grand mean	73	75	230	120	6.8	8470
F-test	ns	ns	ns	ns	ns	*
LSD _{0.05}	-	-	-	-	-	1700
CV, %	5.8	5.5	3.7	5.5	-	11.5

* Significant difference at 0.05 level, ns= non-significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation

During 2015/16 at Regional Agricultural Research Station, Doti, highly significant results among the tested hybrids were observed for days to

anthesis and silking; significant result for plant aspect and non-significant for rest of the traits under observation (Table 7).

Table 7: Performance of maize hybrids under coordinated varietal trial (CVTH) at Doti, 2015/16 summer

Genotype	Days to 50%		Height, cm		Aspect (1-5)		Grain yield, kg ha ⁻¹
	Anthesis	Silking	Plant	Ear	Plant	Ear	
RML-95/RL-105	56	60	305	151	3.0	2.0	4100
RML-87/RL105	56	59	286	147	2.3	2.7	3800
RML-57/RL105	57	60	326	148	2.7	2.3	4700
RL-84/RML-62	56	58	310	159	2.3	2.0	3700
RML-95/RML-96	57	61	307	157	2.0	2.3	5000
RML-19/NML-2	55	58	295	143	2.0	2.3	4600
RL-151/RL-111	53	58	309	160	2.0	2.3	3500
Rampur Hybrid -2	58	61	300	157	2.0	2.3	4300
Rajkumar	53	57	283	134	2.0	2.7	4400
Mean	56	59	303	151	2.3	2.3	4200
F-test	**	**	ns	ns	*	ns	ns
LSD _{0.05}	1.6	1.5	-	-	0.6	-	-
CV, %	1.7	1.4	5.8	7.9	15.4	21.4	21.8

** Significant difference at 0.01 level, * Significant difference at 0.05 level, ns= non-significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation

The experiment conducted at HCRP Kabre in 2014/15 revealed absence of variation among the tested hybrids at this site for grain yield. Highly

significant differences for plant and ear height of the tested hybrids were observed (Table 8).

Table 8: Performance of maize hybrids under coordinated varietal trial (CVTH) at Kabre, 2014/15 summer

Genotype	Height, cm		Grain yield, kg ha ⁻¹
	Plant	Ear	
RML-95/RML-96	230	104	5523
Rampur Hybrid-4	221	107	6005
Rampur Hybrid-6	219	106	3968
RML-86/RML-96	239	114	5365
Khumal Hybrid-2//RL-111	221	109	3876
Khumal Hybrid-2	249	110	4851
RML-6/RML-19	208	102	4549
PU502/RML-4	215	109	5178
PU5CG/RL-84	244	124	3734
RML-95/RL-105	248	107	4805
RL-153/RL-105	238	123	5590
RML-4/RL-111	237	112	5843
RML-98/RL-105	223	114	5098
JM-1	200	108	3825
JM-4	255	142	6039
JM-7	203	111	3945
JM-8	238	130	5643
RML-5/RL-105	246	132	4540
Rampur Hybrid-2	206	96	4311
Rajkumar	203	101	5079
Grand mean	227	113	4888
F-test	**	**	ns
LSD _{0.05}	26.9	18.4	-
CV, %	5.7	7.8	15.8

** Significant difference at 0.01 level, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation

Data from all the hilly stations were combined and analyzed in 2014/15 and 2015/16. In 2014/15, highly significant differences among the tested hybrids for Locations were observed for plant and ear height, and grain yield. Genotypic variations among the tested hybrids were evident for plant height and grain yield, and not for ear height. The interaction between Location × Genotype was absent for ear height and was presented for plant height and grain yield (Table 9). Hybrids found promising were JM-8, RL-153/RL-105, RML-95/ RL-105, KYM-33/KYM-35, RML-4/RML-111, RML-5/RL-105, RML 95/RML-96 and will be tested in farmers' field trials before release as new maize hybrids in Nepal.

Table 9: Combined performance of maize hybrids under coordinated varietal trials (CVTHs) across hill locations, 2014/15

Genotype	Height, cm		Grain yield, kg ha ⁻¹
	Plant	Ear	
RML-95/RML-96	208	104	7072
Rampur Hybrid-4	199	99	7779
Rampur Hybrid-6	203	98	6092
RML-86/RML-96	218	101	6681
Khumal Hybrid-2//RL-111	211	104	5739
KYLM-33/KYM-35	220	105	7788
RML-6/RML-19	196	99	4656
PU502/RML-4	202	99	6962
PU5CG/RL-84	201	99	5299
RML-95/RL-105	220	116	7940
RL-153/RL-105	209	102	8006
RML-4/RL-111	206	98	7758
RML-98/RL-105	209	107	7329
JM-1	202	103	5728
JM-4	217	110	7194
JM-7	202	105	4927
JM-8	218	116	8356
RML-5/RL-105	217	111	7432
Rampur Hybrid-2	203	101	5219
Rajkumar	191	107	6284
Grand mean	208	104	6712
Location (L)	**	**	**
Genotype (G)	*	ns	**
G x L	**	ns	**
LSD _{0.05}	29.8	32.5	2431
CV, %	7.2	15.6	7.7

** Significant difference at 0.01 level, * Significant difference at 0.05 level, ns= non-significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation

Combined results during 2015/16 showed significant differences among the tested hybrids for days to anthesis and plant height, and remaining traits were statistically non-significant. None of the genotypes was found earlier for anthesis than commercial check Rajkumar and none of the hybrids was found dwarf than standard check Rampur Hybrid-2. Plant height ranged from 239 cm to 268 cm (Table 10). Grain yield ranged from 4762 kg ha⁻¹ (Rajkumar) to 6348 kg/ha (RL-84/RML-62) and tested hybrids were observed equally competent and promising for yielding ability as compared with commercial check (Rajkumar) and standard national check (Rampur Hybrid-2). Thus, tested hybrids namely RML-95/RL-105, RML-87/RL105, RML-57/RL105, RL-84/RML-62, RML-95/RML-96, RML-19/NML-2 and, RL-151/RL-111 could be promoted to farmers field trials (CFFTs) to verify their overall performance in on-farm situation.

Table 10: Combined performance of maize hybrids under coordinated varietal trials (CVTH) across the hill locations, 2015/16

SN	Genotype	Days to		Height, cm		Aspect (1-5)		Grain yield, kg ha ⁻¹
		Anthesis	Silking	Plant	Ear	PA	EA	
1	RML-95/RL-105	67	70	259	136	2.17	2.23	6282
2	RML-87/RL105	66	69	249	134	1.83	2.33	6210
3	RML-57/RL105	67	69	268	138	1.77	2.1	5812
4	RL-84/RML-62	64	67	257	135	2	2.33	6348
5	RML-95/RML-96	66	68	253	129	1.87	2.33	6145
6	RML-19/NML-2	65	68	266	135	1.97	2.17	5758
7	RL-151/RL-111	64	67	263	139	2.13	2.23	5138
8	Rampur Hybrid -2	66	69	239	125	1.83	2.3	5975
9	Rajkumar	62	65.3	254	132	1.93	2.17	4762
	Grand mean	65.2	68	256	133.5	1.94	2.24	5825.5
	F-test	*	ns	**	ns	ns	ns	ns
	LSD _{0.05}	2.93	-	11.69	-	-	-	-
	CV, %	3.1		3.1	4.2	11.7	11.8	14.5

** Significant difference at 0.01 level, * Significant difference at 0.05 level, ns= non-significant, LSD = Least significant difference at 0.05 level, CV= Coefficient of variation, PA-Plant aspect, EA-Ear aspect

The evaluated maize hybrids showed variation for agro-morphological traits. The grain yield of maize is the most important and complex quantitative character controlled by numerous genes. The reason for such variation under different locations is due to existence of variation in genetic makeup. The existence of significant genetic variation among maize genotypes for yield and major yield attributing traits was reported (Koirala et al., 2014b; Bhusal et al., 2016; Adhikari et al., 2018; Sharma et al., 2019). Genetic improvement can contribute at least 50-60% yield gains in maize (Duvic, 1992; Vasal and Carlos, 1994). Production and productivity increment through genetic improvement are probably the most cost-effective and ecologically sustainable gains (Koirala et al., 2000a, 2000b). In 1997, four hybrids from Proagro and two OPVs (Narayani and Upahar) were tested and significant differences were not observed for the grain yield (Koirala et al., 1998).

Cultivation of single cross hybrids is one of the economic options for increasing production and productivity of maize in Nepal. Hybrids namely RML-95/RL-105, RL-153/RL-105, RML95/RML-96, RML-24/RL-11, and RML-5/RL105 which were evaluated and performed better in Coordinated Varietal Trials (CVTs) are the potential future hybrids for middle hills of Nepal. These promising hybrids will be promoted to coordinated farmers' field trials (CFFTs) in the next season. These hybrids produced better grain yield because of combination of medium plant height, shorter ear height, shorter anthesis to silking interval (<3 days), and lower incidence of diseases and pests (<2) (Alvi et al., 2003). These single cross hybrids produced higher crop yield only at ABD, Khumatar because of better soil condition as well as better crop management. Beside Khumatar, same hybrids could not do well during summer at other locations. Therefore, these hybrids might be suited only for the production environment similar to Kathmandu valley in the summer season.

4. CONCLUSION

There was significant variation for agro-morphological traits among the maize hybrid genotypes. The highest grain yield is one of the basic criteria for identifying superior hybrid varieties. This study identified maize hybrids namely RML-95/RL-105, JM-8, RL-153/RL-105, RML-87/RL105, RML-57/RL105, RL-84/RML-62, RML-95/RML-96, RML-19/NML-2, and RL-151/RL-111 better and/or equally competent to multi-national company hybrid Rajkumar and standard national check Rampur Hybrid-2 across locations. Thus, these hybrids should be promoted to test in farmers' field trials to identify new hybrids to be released/registered for commercial cultivation.

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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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