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Maize (*Zea mays* L.) hybrids for Terai ecological belt of Nepal

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ABSTRACT

Aim: The study was aimed to identify suitable hybrids for Terai and inner Terai environment which are potential pockets for hybrid cultivation.

Materials and Methods: Different sets of varietal trials were conducted using randomized complete block design in different research stations under Nepal Agricultural Research Council across the Terai and inner Terai region of the country during the summer of 2016/17 to 2018/19.

Results: Significant genotypic differences were observed for grain yield and major agronomic traits. This study identified maize hybrids better and/or competent to standard check namely CAH1721, CAH1715, RML-222/NML-2, RML-86/RML-96, RML-95/RML-96, CAL-1421/CML-451 and CAL-1465/CML-451 for the targeted environment.

Conclusion: The hybrids identified better based on overall performances should be promoted to farmers' field trials to get feedback from them. Hybrids namely CAH1715, RML-86/RML-96, and RML-95/RML-96 should be proposed for release for commercial cultivation as they performed well across the years and locations, and are preferred by farmers, too.

Keywords: Hybrid, multi-national company hybrid, single cross, Terai region.

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Introduction

Maize (*Zea mays* L.) is the second most important cereal crop in Nepal. It occupies 9,56,447 ha of land with 27,13,635 t production and 2.84 t ha^{-1} productivity (MoALD, 2020). About 16.42% of the maize area in the country belongs to Terai and inner Terai with a productivity of 2.73 t ha^{-1} (MoALD, 2018). Maize is being used as food, feed, fodder, and industrial raw-materials, virtually every part of the plant has an economic worth. The highest per capita consumption of 98 g per day of maize is in Nepal among the South Asian countries (Ranum, Pena-Rosas and Garsia-Casal, 2014). Maize contributes 25.4% of the total edible production of the country (MoALD, 2020). Still, 51.8% and 25.2% of households are food insecure and under the poverty line, respectively (Sharma and Pudasaini, 2020). The maize area under open-pollinated varieties (OPVs) during summer is still 73.9% of the total maize area. According to an estimation, a minimum of 12-15% and a maximum of 85-88% of the total maize area is under hybrids and OPVs, respectively (Koirala, 2020), which is the major reason for lower production and productivity of the crop. The contribution of hybrids should reach 10% of the total seed replacement rate (SRR).

Mostly, the commercially grown winter maize in potential pockets of Terai is hybrid. In the border adjoining districts, farmers initiated growing maize hybrids in the 1980s by importing seeds from India (Thapa, 2013). Hybrid maize research was initiated formally in 1987 (Koirala et al., 2002) by making single crosses from exotic inbred lines from the International Institute of Tropical Agriculture (IITA) at NMRP Rampur (Lal et al., 1989). Systematic hybrid maize research and inbred line development activities were initiated in 1995 (Koirala, 1997). CIMMYT placed greater emphasis on OPVs till 1985 and then onward it has started to work on hybrid due to the increased demand for hybrids in developing countries (CIMMYT, 1993). Then, NMRP also initiated developing its inbred lines, and evaluation and selection of hybrids from exotic sources (Koirala, 1997; Koirala et al., 1998, 2000a, 2000b). Extensive testing and selection of

NMRP developed hybrids across the country was initiated in 1999. So far, five single cross yellow kernel type maize hybrids i.e Gaurav, Rampur Hybrid-2, Khumal Hybrid-2, Rampur Hybrid-4, Rampur Hybrid-6 are released, and Rampur Hybrid-8 and Rampur Hybrid-10 were registered as heat stress resilient hybrids for commercial cultivation in Terai and Inner Terai up to 700-m during the winter season (Koirala, 2017a, 2017b), except Khumal Hybrid-2 which is recommended for both Terai and mid-hills' condition. The yield of OPVs could not be increased beyond a certain level even if high inputs are provided. Hybrids can yield 25-30% higher compared to better OPVs. The annual requirement of yellow kernel maize for poultry feed is 5,45,268 t and only 30% of this demand is supplied by domestic production and the rest is imported from abroad (Panday, 2019; Bhattarai, 2020). Increased maize import is observed from 1968 to 2017. Four lakh ninety-six thousand ton maize that worth 10,91,78,000 US dollars was imported in 2017. Approximately, 3,50,000 and 4,00,000 t of maize grain was imported in 2018 and 2019, respectively (Knoema, 2019a,b). Likewise, 4,226.915 t of maize seed was also imported in 2017 (MoF, 2019). According to Dawadi as published in Kathmandu Post (2020), around 2,000 t of maize hybrid seed is annually imported. Critically analyzing the present maize scenario, National Seed Vision (NSV) 2013-2025 envisioned the development and promotion of 12 and five maize hybrids by the public and private sectors, respectively by 2025 (SQCC, 2013).

The way to meet the ever-increasing demand for maize is the shift from OPVs to hybrids urgently and aggressively both in Terai and potential pockets of middle hills (Koirala et al., 2020a, b, c) that will help to narrow down the existing huge yield gap between the national (2.84 t ha^{-1}) and potential yield (6.5 t ha^{-1}) of maize at farmers' level (Koirala, 2014) in Nepal. Nepal to become a self-sufficient country for maize, the national average yield should reach 4 t ha^{-1} with increased maize area under hybrids having a seed replacement rate of 33% for OPVs which according to Memoire is 17.83% (2017).

Realizing the above-mentioned facts, sets of experiments were carried out across the command areas of Nepal Agricultural Research Council (NARC) stations situated in the Terai and inner Terai belt of the country to identify the suitable hybrids for the target environment which is potential pockets for hybrid cultivation.

Materials and Methods

Description of locations

Experiments were conducted in the Terai and inner Terai belt from east to west of the country at Maharanijhoda, Jhapa; Tarahara, Sunsari; Belachapi, Dhanusha; Parwanipur, Bara; Rampur, Chitwan; and Nepalgunj, Banke in different years. The short geographic description of the locations was presented (Table 1).

Table 1: Geographic description of experimental locations

Location	Elevation (masl)	Annual rainfall (mm)	Longitude	Latitude
Maharanijhoda, Jhapa	103	2500	87°42′15″E	26°34′41″N
Tarahara, Sunsari	136	1935	87°16′38.43″E	26°42′16.85″N
Belachapi, Dhanusha	107.1	1280	85°57′E	26°53′N
Parwanipur, Bara	115	1550	84°53'E	27°2'N
Rampur, Chitwan	228	2215	84°20′20.9″E	27°39′0.3″N
Nepalgunj, Banke	181	1000-1500	81°35′23″E	28°06′48″N

Genetic materials

During 2016/17 winter, 15 genotypes including checks were tested at Rampur and Parwanipur. Likewise, two different sets comprising nine genotypes were evaluated at Tarahara, Belachapi, and Parwanipur, and the next set experimented at Ramur and Nepalgunj during winter 2017/18. Similarly, three different sets of hybrid trials consisting of eight genotypes were evaluated at Jhapa and Tarahara (set 1) and Belachapi and Parwanipur (set 2), and a third set consisting of 14 hybrids was tested at Rampur and Nepalgunj during 2018/19. All the hybrids included in the experiments were developed by NMRP Rampur except some company hybrids as checks. All the tested hybrids are single crosses except Rampur Hybrid-6/RML-17 which is a three-way cross.

Experimental design and cultural practices

Experiments were laid out in randomized complete block design (RCBD) in three replications at each location and year. The unit plot size was 4 rows of 4-m length having spacing between rows of 0.75-m and plant spacing of 0.20-m. Farmyard 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 the standard of NMRP Rampur.

Data recording

The 50% days to anthesis and silking, plant and ear height, yield and yield attributing traits were recorded according to the procedures described by CIMMYT (1985). Grain yield (kg ha^{-1}) at 15% moisture content was calculated using fresh ear weight with the help of the formula adopted by Koirala et al. (2017c).

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

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, m^2

S = Shelling coefficient, i.e. 0.8

Statistical analysis

The data were recorded and analyzed through ADEL-R software. The significant differences between genotypes were determined using the least significant difference (LSD) test at 1% or 5% level of significance, respectively (Gomez and Gomez, 1984). Among checks, only the best check has been presented in summary tables.

Results and Discussion

Tested genotypes differ significantly for days to anthesis, silking, plant height, ear height, and grain yield at Parwanipur and Rampur in 2016/17 winter. Days to anthesis ranged from 83 days to 91 days while silking from 86-94 days and none of the hybrids was observed significantly earlier than Rampur Hybrid-6. Likewise, none of the tested hybrids found short in height than standard check Rampur Hybrid-6 while RML-68/RL-101 and CAH158 were found significantly taller. Mean grain yield over the location of the experimented hybrids ranged from 3,500 kg ha^{-1} of Rampur Hybrid-2 (only best check is shown) to 10,350 kg ha^{-1} of CP808. CP808 and CAH1515 were observed as high yielders over the location to standard Check. However, tested genotypes at the individual location were observed at par for yielding ability with the standard check (Table 2).

Experimental results from Tarahara, Belachapi, Parwanipur, Rampur, and Nepalgunj during the 2017/18 winter showed significant genotypic differences for anthesis, silking, plant height, ear height, and grain yield (Table 3 and 4). CP808 observed high yielder across locations while RML-95/RML-96 was also found promising in the eastern part of the country.

Similarly, genotypic differences were observed among tested hybrids for yield and other agronomic traits in eastern, central, and western Terai regions during winter 2018/19. CAH1721, RL-222/NML-2 were observed earlier than the standard check variety (Table 5-7). CAH1715, CAH1721, P3396 and RML-86/RML-96 were observed high yielder than the standard check variety Rampur Hybrid-10 for eastern Terai condition (Table 5) and genotypes P3396, CAL-1421/CML-451, CAL-1465/CML-451 for central Terai (Table 6) and RML-95/RML-96, RML86/RML-96 and P3396 for western Terai (Table 7).

The experimental results showed a variation in agro-morphological traits among hybrids. Improvement in any crop depends largely on exploiting the available genetic variation. The existence of significant genetic variability among maize genotypes for yield and major yield attributing traits was reported by Sharma et al. (2019). Koirala et al. (2014) also reported genetic variability on hybrid maize. Genetic improvement can contribute to at least 50-60% yield gains in maize (Duvic, 1992; and Vasal and Carlos, 1994). Production and productivity increment through genetic improvement is probably the most cost-effective and ecologically sustainable gains (Koirala et al., 2002). Cultivation of single-cross hybrids is one of the economic options for increasing the production and productivity of maize in Nepal. Hybrids namely CAH1721, CAH1715, RL-222/NML-2, RML-86/RML-96, RML-95/RML-96, CAL-1421/CML-451, and CAL-1465/CML-451 which were evaluated and performed better in respective locations are the potential future hybrids for winter planting for Terai belts of Nepal. Hybrid CAH1715 was identified promising for the rainfed middle hill environment for the summer season, too (Koirala et al., 2020b). Koirala and his colleagues (2020a) conducted an on-farm evaluation of hybrids both in Terai and mid-hill ecologies and found that CAH1715 and RML-86/RML-96 were high yieldings, and RML-86/RML-96 and RML-95/RML-96 were stable across the tested environments. These promising hybrids will be promoted to on-farm testing in their respective locations. These hybrids produced better grain yield because of a combination of medium plant height, shorter ear height, shorter anthesis silking interval (<3 days), and lower incidence of diseases and pests (<2, data not shown). RML-95/RML-96 showed a resistant reaction against post-flowering stalk disease for the Terai region of Nepal (Subedi et al., 2020). This finding is following the earlier findings of Alvi et al. (2003) and Koirala (2014).

Table 2: Mean of quantitative traits of hybrids evaluated in CVTH combined over locations (Parwanipur and Rampur), 2016/17 winter

Genotype*	Days to 50%		Height, cm		Grain yield, kg ha^{-1}		
	Anthesis	Silking	Plant	Ear	Parwanipur	Rampur	Mean
CAH1515	83	86	188	92	9800	8400	9100
CAH158	91	94	251	116	3500	5800	4650
RML-4/RML-62	88	90	204	107	7700	7400	7550
RML-85/RL-105	91	93	207	94	4300	4800	4550
RML-76/RL-105	90	94	205	98	6200	6500	6350
RML-68/RL-101	86	90	249	104	3600	4800	4200
RML-95/RL-105	86	89	193	98	6000	6600	6300
RL-180/RML-5	88	92	197	90	7300	7600	7450
CAH1521	90	93	197	84	2700	7500	5100
Rampur Hybrid-10	86	90	182	79	6700	8700	7700
Rampur Hybrid-8	86	90	196	86	7300	7600	7450
Rampur Hybrid-6	88	84	196	100	7600	7200	7400
CP808	85	82	205	96	11200	9500	10350
Mean	87	91	204	95	6300	6900	6708
F-test	**	*	*	*	**	**	*
$LSD_{0.05}$	3.0	3.1	33.8	16.7	2200	2600	1480
CV, %	2.2	2.2	10.2	10.8	20.5	22.5	28.5

*Only best check is shown

Table 3: Results of CVTH combined over locations (Tarahara, Belachapi, and Parwanipur), 2017/18 winter

Genotype	Days to 50%		Height, cm		Grain yield, kg ha^{-1}			
	Anthesis	Silking	Plant	Ear	Tarahara	Belachapi	Parwanipur	Mean
CP-808	111	114	201	80	6485	7819	9459	7921
HK-11344/HK-111378	112	116	189	91	6479	4802	5155	5479
Rampur Hybrid-10	111	115	200	67	3127	5578	4449	4385
RL-150/RL-111	109	113	218	100	7653	7043	6933	7210
RML-68/RL-101	110	113	203	93	6122	5590	5964	5892
RML-85/RL-105	114	117	210	89	6821	5653	4172	5549
RML-95/RML-96	112	116	190	81	5733	6487	6049	6090
RML-97/RL-105	111	113	188	73	5052	5689	4477	5073
RML-98/RL-105	117	120	201	81	-	5908	4581	5245
Mean	112	114	201	84	5825	6108	5897	5923
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**				ns
G × E	ns	ns	**	ns				ns
$LSD_{0.05}$	-	-	20.72	-	1837	1167	1726	-
CV, %	6.15	5.73	11.04	15.63	18.1	11.7	17.6	24.06

Table 4: Results of CVTH combined over Rampur and Nepalgunj (common genotypes), 2017/18 winter

Genotype	Days to 50%		Height, cm		Grain yield, kg ha^{-1}		
	Anthesis	Silking	Plant	Ear	Rampur	Nepalgunj	Mean
CP808	100	102	192	84	12033	8720	10376
Rampur Hybrid-10	102	104	183	72	5824	7177	6500
RML-57/RL-105	104	108	201	97	4458	7345	5902
RML-57/RL-174	101	105	217	111	5101	8631	6866
RML-83/RL-197	99	102	196	90	7527	8027	7777
Mean	101	104	198	91			7631
Genotype (G)	**	**	**	**			*
Environment (E)	**	**	**	*			ns
G × E	**	**	**	*			*
$LSD_{0.05}$	36	37	23	20			-
CV, %	30.3	30.2	9.8	18.5			28.5

Table 5: Performance of hybrids tested in CVTH combined over Jhapa and Tarahara, 2018/19 winter

Genotype	Days to 50%*		Height, cm		Grain yield, kg ha^{-1}		
	Anthesis	Silking	Plant	Ear	Jhapa	Tarahara	Mean
CAH1715	111	115	225	104	11421	11546	11483
CAH1721	104	106	172	77	10109	9418	9763
CAL-1465/CML-451	109	111	193	76	7469	6541	7005
P3396	107	109	203	76	13406	9082	11244
Rampur Hybrid-10	109	113	189	79	8620	6481	7551
Rampur Hybrid-6/RML-17	107	109	175	79	8062	8446	8254
RML-86/RML-96	111	113	197	94	10700	8776	9738
RML-95/RML-96	108	110	203	96	9942	8620	9281
Mean	108	111	195	85	9966	8614	9290
Genotype (G)	**	**	**	**	*	**	**
Environment (E)	ns	ns	**	ns	ns	ns	**
G × E	ns	ns	ns	ns	ns	ns	*
$LSD_{0.05}$	2.50	3.09	-	-	2363	1910	2046
CV, %	1.3	1.6	5.8	9.8	13.5	12.7	13.2

Table 6: Performance of hybrids tested in CVTH combined over Belachapi and Parwanipur, 2018/19 winter

Genotype	Days to 50%		Height, cm		Grain yield, kg ha^{-1}		
	Anthesis	Silking	Plant	Ear	Belachapi	Parwanipur	Mean
CAL-1421/CML-451	1116	122	192	92	6768	6546	6657
CAL-1465/CML-451	116	121	182	73	3364	4253	3809
P3396	114	120	184	72	5744	7712	6728
Rampur Hybrid-10	119	124	174	71	4048	3327	3688
Rampur Hybrid-6/RML-17	119	124	154	67	5200	4516	4858
RML-85/RL-105	122	127	176	89	7154	5776	6465
RML-86/RML-96	121	126	158	76	6076	6160	6118
RML-95/RML-96	117	122	155	76	6705	6095	6400
Mean	118	123	172	77	5632	5548	5514
Genotype (G)	*	*	**	**	**	**	**
Environment (E)	**	**	**	**			ns
G × E	ns	Ns	ns	ns			*
$LSD_{0.05}$	-	-	-	-	1350	1568	1529
CV, %	3.5	3.4	9.2	13.6	13.7	16.1	16.4

Table 7: Performance of hybrids tested in CVTH at Nepalgunj and Rampur, 2018/19 winter

Genotype	Days to 50%		Height, cm		Grain yield, kg ha^{-1}		
	Anthesis	Silking	Plant	Ear	Rampur	Nepalgunj	Mean
P3396	117	118	208	81	7867	7421	7644
Rampur Hybrid-10	121	122	192	94	4575	4027	4301
Rampur Hybrid-6/RML-17	124	124	170	82	4355	5643	4999
RL-151/RL-111	124	125	201	108	6887	7252	7070
RL-180/RL-105	122	124	193	99	5471	4978	5225
RL-213/RML-17	119	120	186	95	4311	4280	4295
RL-219/RL-111	118	120	207	103	4128	8169	6148
RL-222/NML-2	114	120	197	100	3570	7782	5676
RL-236/RML-96	118	119	212	110	6954	8082	7518
RL-35A/RL-105	124	126	176	79	6310	3235	4772
RML-68/RL-101	122	124	188	92	2420	5159	3790
RML-86/RML-96	123	124	187	87	6678	8733	7705
RML-95/RML-96	122	122	188	92	7368	8077	7722
ZH141592	121	122	165	68	3912	3248	3580
Mean	120	122	191	92	5343	6149	5734
Genotype (G)	**	**	**		**	**	**
Environment (E)	**	**	**				**
G × E	ns	Ns	ns				**
$LSD_{0.05}$	-	-	-		1373	2483	1979.4
CV, %	2.7	1.4	7.1		15.3	24.1	21.0

Conclusion

It was concluded that maize hybrids namely CAH1721, CAH1715, RL-222/NML-2, RML-86/RML-96, RML-95/RML-96, CAL-1421/CML-451, and CAL-1465/CML-451 which found better and/or equally competent to standard check hybrids in different Terai belts from east to west. Therefore, should be promoted to farmers' field trials to identify new hybrid for commercial cultivation.

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