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Performance evaluation of single-cross maize hybrids for flowering and yield traits

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Abstract

The present experiment was conducted at Bharatpur-15, Fulbari, Chitwan, Nepal from 1st Dec 2017 to 9th May 2018 to evaluate the performance of eight single cross maize hybrids. The single cross maize hybrids were Shresta, Bioseed 9782, Rajkumar, Ganga kaveri, Rampur hybrid-6, RML-86/RML-96, Rampur hybrid-4 and RML-95/RML-96 and were evaluated in a randomized complete block design with three replications. Data were recorded on flowering traits, yield attributes and grain yield. The results revealed that the lowest days to tasseling and days to anthesis were found in Shrestha and these traits were highest in Rampur hybrid-6. The hybrid Bioseed9782 produced the highest cob length (21.33 cm) and cob diameter (17.67 cm). The hybrid Bioseed 9782 produced the highest grain yield (15.96) followed by Gangakaveri (14.26 t ha^{-1}) and Shresta (12.12 t ha^{-1}). The hybrid Bioseed 9782 produced the highest standard heterosis (64.81%) followed by Gangakaveri (47.16%) and Shresta (25.14%). The finding of this experiment suggested that maize hybrids Bioseed 9782, Gangakaveri and Shresta can be commercially grown for higher grain production in Chitwan and similar agro-climatic regions.

Keywords: Flowering, maize, heterosis, single cross hybrid, yield

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1 Introduction

Maize is one of the most important cereal crops, which is cultivated throughout the world for the purpose of food grain, feed, and forage and it has the highest productivity among cereals. Maize has a very high yield potential than any other cereal and thus is popularly known as the 'queen of cereals' (Singh, 2002). In Nepal agriculture contributes to an average 33% to GDP and 65.6% people depend on agriculture for livelihood (MoAC, 2014). Cereal crop share about 49.41% to agriculture GDP. The total production of maize was 2.30 million tonnes and the national average yield of maize is 2.5 t ha^{-1} (MoAD, 2017). Beside direct consumption as food, it is also an important source of industrial raw materials such as starch, dextrose, oil sugar, syrup, enzymes, adhesive paper and plastics (Kandel et al., 2018). Demand of maize in Nepal has been growing by about 7% each year because of the growth of demand for food and livestock feeds for milk, meat and egg production in approachable areas including the hill region (Pathik, 2002). Development of hybrids is the best alternative to increase production and productivity of maize in Nepal (KC et al., 2015). Nowadays, maize hybrids with chilling tolerance become great concern; because Nepalese farmers growing hybrids mainly in subtropical southern plain including Bara, Chitwan (October/November to March/April) in commercial-scale (Adhikari et al., 2015). Therefore, anthesis and grain filling coincide with subtropical chilling winter in the plain. Chilling damages phenomena of preparation of microsporogenesis to pollen metabolism. It leads to serious irreversible yield loss. So, Nepalese plant breeders must work in this direction.

Flowering is the major trait of any crop species. Flowering in maize indicates the dehiscence of anthers in male inflorescence and the emergence of silks from ears. Maize is a monoecious plant species but male and female inflorescences are found in a different region in the plant. Male staminate flowers located on the apical inflorescence (tassel) with central main spike and lateral branches and female pistillate flowers located on one or more lateral inflorescence are unbranched grain bearing ear (Cheng and Pareddy, 1994).

The development of hybrid maize is the most significant milestone in agriculture (Reif et al., 2003). In the nineteenth century, hybrids production was common through the selection of individual desirable plants (Duvick, 1985).While Darwin and other naturalists recognized heterosis or hybrid vigor. Heterosis is defined as the superiority of the F1 hybrid over both the parents in terms of yield and/or some other characters. The term heterosis was first used by Shull in 1914 (Shull, 1948). Three main hypothesis have been used to explain heterosis, Jones (1917) through dominance, Hull (1945) through over dominance and Powers (1944) through epistasis. Hybrid maize was almost immediately accepted by farmers because hybrid phenotypes were homogeneous provided better yields with good quality grain, resistance to disease, insect and pest and some other desirable agronomic traits and it was more convenient to let a supplier manage collection, storage and packaging of seed for the new crop (Mukherjee, 2014). Therefore, researchers are more concern to developed superior hybrids for grain yield and other agronomic as well as flowering traits. This study was conducted to support everlasting process for the exploitation of superior maize hybrid for grain yield and yield attributing character along with flowering behaviors.

2 Materials and Methods

2.1 Description of the study site

This experiment was carried out at Bharatpur-15, Fulbari, Chitwan, Nepal. Geographically, the location was situated at 27°63′ N latitude and 84°36′ E longitude with an elevation of 194 masl. The soil type is sandy loam and the climatic pattern of the research area was humid sub-tropical with an annual rainfall of 2000 mm (mostly distributed from June to September in summer). The climatic data during the experiment was given in Table 1.

2.2 Planting materials

Eight single cross maize hybrids were received from Agriculture Botany Division, Khumaltar, Nepal and Dawadi Agrovet, Narayangarh, Chitwan, Nepal and were used as experimental materials. The details of these hybrids were given in Table 2.

2.3 Experimental design, treatment details and cultural practices

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into two blocks of four genotypes with 3.75 m^2 (2.5m × 1.5m) of plot size in each. Block and replication were separated with 0.5 m. Each plot included 20 plants to keep plant density 53333 plants ha^{-1}. The hybrids were planted at on 1st Dec 2017 and harvested on 9th May 2018. The hybrids were used as treatments. The transplanting was done manually with 1-2 seed per hill with a cropping geometry of 75 cm × 25 cm. Then organic manure was applied @ 33 t ha^{-1} after the rice harvest. The field was finely tilled and well leveled by rotavator 2 days prior to sowing. Chemical fertilizers @120:60:40 kg N_2, P_2O_5 and K_2O ha^{-1} be applied through urea, DAP and MOP. Fifty percent N, full doses of DAP and MOP were applied at basal dose (Kunwar and Shrestha, 2014). The remaining half dose N was top-dressed at 49 and 89 days after sowing (DAS) with furrow Irrigations through a shallow tube well of 4" pipe. Soil loosening and weed removal and earthing-up was done manually first on 31 DAS and second on 43 DAS. Crop harvested on 160 days and threshing was done manually.

2.4 Data collection

The data on cob length, cob diameter, biomass, harvest index, grain yield, days to tasseling, days to anthesis, days to silk initiation and days to silk senescence were recorded according to the protocol developed by National Maize Research Program, Rampur, Chitwan, Nepal. Grain yield was obtained by adjusting the grain moisture at 15% and converted to the grain yield ha^{-1} with the help of the formula adopted by Carangal et al. (1971) and Shrestha et al. (2019). Standard heterosis had been computed for yield and yield attributing traits considering Rampur hybrid-6 as reference. Standard heterosis was estimated using the formula suggested by the Falconer et al. (1996).

2.5 Statistical analysis

The significant differences between genotypes were determined using least significant difference (LSD) test at the probability level of 0.01 or 0.05 where the effects of the treatments were significant at 1% or 5%

Table 1. Climatic data of the study site during the experiment

Date	RH%	Temperature (°C)		Rainfall (mm)
		Max. temp.	Min. temp.	
2017-Dec	94.85	25.49	11.62	0
2018-Jan	95.5	20.92	8.52	0.6
2018-Feb	86.84	26.4	12.64	0
2018-Mar	70.61	32.62	18	26
2018-April	68.07	34.49	22.27	35.1
2018-May	71.21	34.38	24.32	14.5

Table 2. Name and sources of planting materials used in the study

SN	Maize hybrids	Sources
1	Shresta	Hamro Agrovet, Narayangarh, Chitwan, Nepal
2	Bioseed 9782	Hamro Agrovet, Narayangarh, Chitwan, Nepal
3	Rajkumar	Hamro Agrovet, Narayangarh, Chitwan, Nepal
4	Ganga kaveri	Hamro Agrovet, Narayangarh, Chitwan, Nepal
5	Rampur hybrid-6	Agriculture Botany Divison, Khumaltar, Lalitpur, Nepal
6	RML-86/RML-96	Agriculture Botany Divison, Khumaltar, Lalitpur, Nepal
7	Rampur hybrid-4	Agriculture Botany Divison, Khumaltar, Lalitpur, Nepal
8	RML-95/RML-96	Agriculture Botany Divison, Khumaltar, Lalitpur, Nepal

level of probability, respectively (Gomez and Gomez, 1984). All collected data were entered in Microsoft Excel 2016 and analyzed by using GENSTAT (version 14; VSN International, Hemel Hempstead, UK).

3 Results and Discussion

3.1 Yield and yield attributing traits

Hybrids have exhibited significant differences from stand point of cob length, cob circumference, biomass, Grain yield, Days to 50% tasseling, anthesis, silk initiation and 100% Silk senescence (Table 3). In this experiment, Bioseed-9782 showed significantly higher grain yield followed by Gangakaveri and Shresta whereas Rajkumar was the lowest yielder. Higher grain yielder Bioseed-9782 characterized by higher cob length, cob diameter, biomass lower Days to 50% tasseling, Days to 50% anthesis, Days to 50% silk initiation and Days to 100% silk senescence. Berhanu (2009) reported ear diameter was positively correlated with grain yield. The lowest grain yielder hybrid Rajkumar was characterized by the lowest harvest index, cob length and cob diameter. The maize hybrids developed by different seed companies with various genetic backgrounds might be the major causes of variability in performance among them. Shrestha et al. (2015) from two years observation recorded that there was significant variation in eighteen maize hybrids for flowering and grain yield.

Heterosis in the reference of Rampur hybrid-6 has been computed (Table 4 and Table 5). Standard heterosis of tested single cross maize hybrids were ranged from −17.74% (RML-86/RML-96) to 3.23% (Bioseed 9782) for cob length, only the hybrid Bioseed 9782 show positive heterosis for cob length. The standard heterosis for cob circumference was ranged from −10.64% (Rampur Hybrid-4) to 12.77% (Bioseed 9782). The highest positive standard heterosis for cob circumference of check variety (Rampur hybrid-6) was recorded in hybrid 12.77 (Bioseed 9782) fallowed by 10.64 (Shresta) and 8.51 (Rajkumar), whereas Sharma et al. (2016) reported >15% standard heterosis for cob length and >45% standard heterosis for cob circumference in their tested single cross maize hybrids. Similarly standard heterosis for plant height ranged from −14.89 (RML-86/RML-96 and Rampur Hybrid-4) to 14.89 (Rajkumar). Upreti et al. (2020) also reported similar finding. Standard heterosis for days to 50% anthesis of plant population, 50% tasseling and days to 100% plant senescence were ranged from −9.42, −10.09 and −6.08 (shresta) to −0.91, −0.61 and −0.83 (Rampur hybrid-4), respectively. Days to 50 % silking was ranged from −7.74 (shresta) to −0.31(RML-95/RML-96). The results indicated that all the tested varieties were early flowering than check variety (Rampur Hybrid-6). Tripathi et al. (2016) reported genotypic variability among maize hybrids at Rampur, Chitwan, Nepal. The genotypic variability in maize was also reported by Kandel et al. (2018), Dhakal et al. (2018), Shrestha et al. (2015), Shrestha et al. (2016) and Prasai et al. (2015). Standard heterosis for grain yield of hybrids ranged from −10.35 (Rajkumar) to 64.81 (Bioseed 9782) fallowed by 47.16 (Gangakaveri) and 25.14 (Shresta). Shrestha

Table 3. Mean performance of maize hybrids for grain yield and yield attributing traits

Maize hybrids	Cob length (cm)	Cob diameter (cm)	Grain yield (t ha^{-1})	Biomass (t ha^{-1})	HI
Shresta	20ab	17.33ab	12.12c	25.81c	0.47b
Bioseed 9782	21.33a	17.67a	15.96a	32.92a	0.46c
Rajkumar	20.33ab	17abc	8.68d	25.45c	0.36f
Gangakaveri	19.67abc	16.33bcd	14.26b	29.21b	0.48a
Rampur hybrid-6	20.67ab	15.67d	9.69d	26.21c	0.36e
RML-86/RML-96	17d	16cd	9.38d	21.69d	0.43d
Rampur hybrid-4	18.67bcd	14e	9.67d	29.04b	0.36f
RML-95/RML-96	17.67cd	15.33d	9.88d	27.41bc	0.36e
Mean	19.42	16.17	11.21	27.21	0.41
SEm (±)	1.46	0.36	0.31	1.13	0
LSD(0.05)	2.12	1.05	0.98	1.86	0
F test	**	**	**	**	**

**= highly significant at P ≤0.01, Mean followed by common letter (s) within each column are not significantly different (P ≤0.05) by DMRT.

Table 4. Heterosis (%) of cob length, cob diameter, days to 50% tasseling, biomass and harvest index in reference of Rampur hybrid-6

Maize hybrids	Cob length	Cob diameter	Days to 50% tasseling	Biomass	Harvest index
Shresta	−3.23	10.64	−10.09**	−1.52	31.03
Bioseed 9782	3.23**	12.77**	−7.34	25.58**	27.83
Rajkumar	−1.61**	8.51	−7.03	−2.91	−1.3*
Gangakaveri	−4.84*	4.26	−6.42	11.45	32.58**
RML-86/RML-96	−17.7*	2.13*	−1.83*	−17.22*	19.33
Rampur hybrid-4	−9.68*	−10.64*	−0.61*	10.78	−0.88
RML-95/RML-96	−14.5*	−2.13*	−1.53	4.58*	−0.45*

Statistical significance is indicated by ** (p<0.01) and *(p<0.05)

Table 5. Heterosis (%) of days to anthesis, days to silking, days to silk senescence and grain yield in reference of Rampur hybrid-6

Maize hybrids	Days to 50% anthesis	Days to 50% SI	Days to SS	Grain yield (t ha^{-1})
Shresta	−9.42**	−7.74**	−6.08**	25.14*
Bioseed 9782	−6.38	−3.72	−4.42	64.81**
Rajkumar	−5.78	−3.72	−3.59	−10.35*
Gangakaveri	−5.78	−4.33	−1.66	47.16*
RML-86/RML-96	−0.91*	−0.62*	−1.1*	−3.19*
Rampur hybrid-4	−0.91*	−1.24	−0.83*	−0.22
RML-95/RML-96	−1.52*	−0.31*	−1.38	1.99

Statistical significance is indicated by ** (p<0.01) and *(p<0.05); SI = silk initiation, SS = silk senescence

Table 6. Days to tasseling and days to anthesis interval in maize hybrids

Maize hybrids	Days to tasseling				Days to anthesis			
	(25%)	(50%)	(75%)	(100%)	(25%)	(50%)	(75%)	(100%)
Shresta	97.00d	98.00d	99.33c	101.7c	98.00d	99.33d	100.7d	102.3e
Bioseed 9782	99.67c	101.0c	102.3b	103.3b	101.3c	102.7c	103.7c	104.3d
Rajkumar	100.0c	101.3c	102.3b	103.7b	102.3c	103.3c	104.3c	105.3cd
Gangakaveri	100.7c	102.0c	103.0b	104.3b	102.3c	103.3c	104.3c	106.0c
Rampur hybrid-6	108.7a	109.0a	109.7a	110.0a	109.3 a	109.7a	110.3a	111.0a
RML-86/RML-96	106.0b	107.0b	108.0a	109.0a	107.7ab	108.7ab	109.0b	109.3b
Rampur hybrid-4	106.7b	108.3ab	108.7a	109.7a	108.3ab	108.7ab	109.7ab	110.0ab
RML-95/RML-96	106.3b	107.3ab	108.0a	109.0a	107.3b	108.0b	109.0b	109.7b
Mean	103.13	104.25	105.17	106.33	104.58	105.46	106.38	107.25
SEm (±)	1.26	1.07	0.98	0.66	1.02	0.6	0.41	0.36
LSD(0.05)	1.96	1.81	1.74	1.42	1.77	1.35	1.23	1.06
F test	**	**	**	**	**	**	**	**

** = highly significant at P $\leq$0.01, Mean followed by common letter (s) within each column are not significantly different (P $\leq$0.05) by DMRT.

Table 7. Days to silk initiation and days to silk senescence interval in maize hybrids

Maize hybrids	Days to silk initiation				Days to silk senescence			
	(25%)	(50%)	(75%)	(100%)	(25%)	(50%)	(75%)	(100%)
Shresta	98.33d	99.33d	100.7d	102.3c	106.3d	108.7d	111.0e	113.3d
Bioseed 9782	102.7c	103.7c	104.0c	105.0b	109.3c	111.7c	113.7d	115.3c
Rajkumar	102.0c	103.7c	104.3c	105.0b	110.7c	113.3bc	115.0cd	116.3c
Gangakaveri	102.0c	103.0c	104.0c	105.3b	113.0b	115.0ab	116.7bc	118.7b
Rampur hybrid-6	106.7a	107.7a	108.3a	109.0a	116.0a	117.3a	119.0a	120.7a
RML-86/RML-96	106.3ab	107.0ab	107.7ab	108.3a	114.3ab	116.0a	117.3ab	119.3ab
Rampur hybrid-4	105.3b	106.3b	107.0b	108.0a	114.3ab	116.0a	117.7ab	119.7ab
RML-95/RML-96	106.3ab	107.3ab	107.7ab	108.3a	114.3ab	115.7ab	117.0ab	119.0ab
Mean	103.71	104.75	105.46	106.42	112.29	114.21	115.92	117.79
SEm (±)	0.42	0.38	0.41	0.31	1.48	1.79	1.15	0.95
LSD(0.05)	1.14	1.07	1.12	0.98	2.13	2.34	1.88	1.71
F test	**	**	**	*	**	**	**	**

** = highly significant at P $\leq$0.01, Mean followed by common letter (s) within each column are not significantly different (P $\leq$0.05) by DMRT.

Table 8. Tasseling anthesis interval, days of active tasseling and days of active silk initiation of the maize hybrids

Maize hybrids	Tassleling anthesis interval		Days to active		
	(50%)	(100%)	tasseling	anthesis	silk initiation
Shresta	1.3abc	0.7 b	4.7a	4.3a	4.0a
Bioseed 9782	1.7ab	1.0ab	3.7 ab	3.0abc	2.3bc
Rajkumar	2.0a	1.7a	3.7ab	3.0abc	3.0abc
Ganga kaveri	1.3abc	1.7a	3.7ab	3.7 ab	3.3ab
Rampur hybrid-6	0.7bc	1.0ab	1.3c	1.7 c	2.3bc
RML-86/RML-96	1.7ab	0.3b	3.0b	1.7c	2.0c
Rampur hybrid-4	0.3c	0.3b	3.0 b	1.7 c	2.7bc
RML-95/RML-96	0.7bc	0.7b	2.7bc	2.3bc	2c
Mean	1.21	0.92	3.21	2.67	2.71
SEm (±)	0.45	0.21	0.71	0.78	0.44
LSD(0.05)	1.18	0.8	1.47	1.55	1.16
F test	*	*	*	*	*

*=significant at P ≤0.05, Mean followed by common letter (s) within each column are not significantly different (P ≤0.05) by DMRT.

et al. (2018) reported the ranged of heterosis from −0.03 to 73.4%. Similarly, Gurung (2006) and Sharma et al. (2016) also reported the ranged of heterosis from −22% to 63.1% and more than 20% heterosis in single cross maize hybrid, respectively. Standard heterosis for above ground biomass was ranged from −17.22% (Bioseed 9782) to 25.58% (RML-86/RML-96).

3.2 Flowering and reproductive behaviors of single cross maize hybrids

Variance analysis has been done by dissecting days to tasseling as earliest 25%, second earliest 25% designated as 50%, third earliest 25% tasseling designated as 75%, terminally dissected 25% population designated as 100%. In maize poor seed set occur at the temperature above 380c mainly because of reduction in pollen germination and pollen tube elongation (Dupuis and Dumas, 1990). Due to high temperature during this experiment, flowering, tasseling, anthesis, silk initiation and silk senescence become changes more rapid that's why active duration and interval between them are very short. However, the duration from silk initiation to silk senescence could not affect silk receptivity Adhikari et al. (2015). The maize hybrids were highly significant different from the standpoint of days for tassel emergence, days to anthesis, days to silk initiation and days to silk senescence at all designated (25%, 50%, 75% and 100%) population (Table 6 and Table 7). Rampur Hybrids-4, RML-86/RML-96 and RML-95/RML-96 required higher days for tasseling and Shresta hybrid required minimum day for tasseling. Whereas, Rampur Hybrid-6 has been completed anthesis earlier and Shresta hybrid required more days to complete anthesis. Shresta hybrid fallowed by Bioseed 9782 starts to emerge silk at minimum days whereas Rampur hybrid-6 required more days to start.

Eight hybrids have been found significant for active tasseling, anthesis and silk initiation period (days from starting 25% to 100% plant population) (Table 8). Shresta Hybrids has been more active duration of all (tasseling, anthesis and silk initiation). Rampur Hybrid-6 has low active duration of tasseling and anthesis and RML-86/RML-96 has been minimum active duration for silking. Terminal percent of late silk emerging population may not receive pollen from the same population (Adhikari et al., 2015). So, minute analysis of flowering must be done from earlier step of hybrid evaluation to the final. Variance analysis has been done by dissecting days to TAI at 50% and 100% plant populations. The eight hybrids have been found significant for TAI at both (50% and 100%) plant populations (Table 8). Rajkumar hybrid has long TAI in both 50% and 100% and Rampur hybrid-4 has short interval.

4 Conclusion

The hybrids Bioseed 9782, Gangakaveri and Shresta were superior than others in terms of grain yield and standard heterosis for grain yield. Similarly, these hybrids were early flowering compared to other evaluated hybrids. Moreover, hybrid Shresta required the least days for flowering and long active duration for tasseling, anthesis and silk initiation; which indicates that Shresta hybrid may have the potential for more grain yield. Therefore, this study suggested that these hybrids can be utilized commercially for higher grain production.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Adhikari NR, Ghimire SK, Sah SK, Koirala KB. 2015. Flowering, reproductive behaviors and their effects on grain yields of newly bred single cross hybrids of yellow maize (*Zea mays* L.) in winter in subtropical Nepalese Himalayan foot plain. PeerJ PrePrints 3:e897v2. doi: 10.7287/peerj.preprints.897v3.

Berhanu T. 2009. Heterosis and combining ability for yield, yield related parameters and stover quality traits for food-feed in maize (*Zea mays* L.) adapted to the mid-altitude agro-ecology of Ethiopia. Thesis, School of Graduate Studies, Haramaya University, Ethiopia.

Carangal VR, Ali SM, Koble AF, Rinke EH, Sentz JC. 1971. Comparison of S1 with testcross evaluation for recurrent selection in Maize 1. Crop Science 11:658–661.

Cheng PC, Pareddy DR. 1994. Morphology and development of the tassel and ear. In: The Maize Handbook. Springer, New York, USA.

Dhakal B, Shrestha KP, Joshi BP, Shrestha J. 2018. Evaluation of early maize genotypes for grain yield and agromorphological traits. Journal of Maize Research and Development 3:67–76. doi: 10.3126/jmrd.v3i1.18923.

Dupuis I, Dumas C. 1990. Influence of temperature stress on in vitro fertilization and heat shock protein synthesis in maize (*Zea mays* L.) reproductive tissues. Plant Physiology 94:665–670. doi: 10.1104/pp.94.2.665.

Duvick DN. 1985. State of temperate maize breeding programs. Relazioni e Monografie Agrarie Subtropicali e Tropicali. Nuova Serie, Italy.

Falconer DS, Mackay TFC, Frankham R. 1996. Introduction to Quantitative Genetics (4th Edn). Longman, London, UK.

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research (2nd Edn). International Rice Research Institute, Laguna, Philippines.

Gurung DB. 2006. Genetic diversity, heterosis for grain yield in maize 35 and combining ability within Nepalese maize varieties. Phd Thesis, Central LuzonState University, Science of Munoz, Nueva Ecija, Philippines.

Hull FH. 1945. Recurrent selection for specific combining ability in corn 1. Agronomy Journal 37:134–145. doi: 10.2134/agronj1945.00021962003700020006x.

Jones DF. 1917. Dominance of linked factors as a means of accounting for heterosis. Genetics 2:466–469.

Kandel M, Ghimire SK, Ojha BR, Shrestha J. 2018. Analysis of genetic diversity among the maize inbred lines (*Zea mays* L.) under heat stress condition. Journal of Maize Research and Development 3:86–97. doi: 10.3126/jmrd.v3i1.18925.

KC G, Karki TB, Shrestha J, Achhami BB. 2015. Status and prospects of maize research in Nepal. Journal of Maize Research and Development 1:1–9. doi: 10.3126/jmrd.v1i1.14239.

Kunwar CB, Shrestha J. 2014. Evaluating performance of maize hybrids in Terai region of Nepal. World Journal of Agricultural Research 2:22–25.

MoAC. 2014. Statistical Information on Nepalese Agriculture. Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives, Kathmandu, Nepal.

MoAD. 2017. Statistical information on Nepalese Agriculture (2017). Monitoring, Evaluation and Statistics Division, Agriculture Statistics section, Ministry of Agriculture Development, Government of Nepal, Singhadurbar, Kathmandu, Nepal.

Mukherjee S. 2014. A next generation of studies: Heterosis and inbreeding depression. https://lib.dr.iastate.edu/etd/13878.

Pathik DS. 2002. Maize research achievements and constraints. In: Rajbhandari NP, Ransom JK, Adhikari K, Palmer AFE (Eds) Sustainable maize production systems for Nepal. Proceeding of a Maize Symposium, December 3-5, 2001, Kathmandu, Nepal, NARC and CIMMYT.

Powers L. 1944. Meiotic studies of crosses between *Fragaria ovalis* and f. × ananassa. Journal of Agricultural Research 69:435–448.

Prasai HK, Kushwaha UKS, Joshi BP, Shrestha J. 2015. Performance evaluation of early maize genotypes in far western hills of Nepal. Journal of Maize Research and Development 1:106–111. doi: 10.3126/jmrd.v1i1.14248.

Reif JC, Melchinger AE, Xia XC, Warburton ML, Hoisington DA, Vasal SK, Srinivasan G, Bohn M, Frisch M. 2003. Genetic distance based on simple sequence repeats and heterosis in tropical maize populations. Crop Sci. 43:1275–1282. doi: 10.2135/cropsci2003.1275.

Sharma HP, Dhakal KH, Kharel R, Shrestha J. 2016. Estimation of heterosis in yield and yield attributing traits in single cross hybrids of maize. Journal of Maize Research and Development 2:123–132. doi: 10.3126/jmrd.v2i1.16223.

Shrestha J, Gurung DB, Rijal TR. 2018. Standard heterosis for grain yield in maize hybrids. Farming and Management 3:30–36. doi: 10.31830/2456-8724.2018.0001.6.

Shrestha J, Koirala KB, Katuwal RB, Dhami NB, Pokhrel BB, Ghimire B, Prasai HK, Paudel A, Pokhrel K, KC G. 2015. Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal. Journal of Maize Research and Development 1:21–27. doi: 10.3126/jmrd.v1i1.14241.

Shrestha J, Kunwar CB, Upadhyaya J, Giri M, Katuwal RB, Acharya R, Gurung SB, Adhikari BN, Paudel AP, Paneru RB. 2016. Genotype × environment interaction of quality protein maize grain yield in Nepal. Journal of Maize Research and Development 2:66–73. doi: 10.3126/jmrd.v2i1.16216.

Shrestha J, Subedi S, Timsina KP, Gairhe S, Kandel M, Subedi M. 2019. Maize Research. New India Publishing Agency (NIPA), New Delhi, India.

Shull GH. 1948. What is "heterosis"? Genetics 33:439–446.

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

Tripathi MP, Shrestha J, Gurung DB. 2016. Performance evaluation of commercial maize hybrids across diverse Terai environments during the winter season in Nepal. Journal of Maize Research and Development 2:1–12. doi: 10.3126/jmrd.v2i1.16210.

Upreti J, Acharya P, Upadhyaya J, Shrestha J. 2020. Estimation of heterosis in maize hybrids in Dang district of Nepal. Fundamental and Applied Agriculture 5:188–193. doi: 10.5455/faa.82914.

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