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Heterosis for Grain Yield and Quality Traits in Maize (*Zea mays* L.)

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ABSTRACT

Heterosis was estimated in 63 experimental hybrids obtained by crossing 9 productive inbred lines and 7 QPM (Quality protein miaze) inbred lines using line × tester mating design in maize. Sixty three hybrids along with 16 parents and two standard checks were evaluated for seventeen characters during Kharif 2014. Heterosis studies indicated the expression of standard heterosis and heterobeltiosis in several crosses for most of the characters in both desirable and undesirable direction. Over standard check, experimental hybrid HKI 1128 x HKI 163 manifested high heterotic effect for grain yield and other traits i.e plant height, ear height, number of cobs per plant, number of grains per cob over check 2 i.e HM 5 and for 100 grain weight over check 1 i.e HQPM 1, whereas, HKI 659-3 x HKI 194-6 showed highest standard heterosis for number of grains per cob, 100 grain weight and grain yield per plant indicating such experimental hybrids may be used for early maturing hybrids with high grain yield. The experimental hybrid HKI 1126 x HKI 161was found to exploit highest standard heterosis for phonological traits i.e days to 50 % taselling, days to 50 % silking, days to maturity (over HQPM 1) and grain yield per plant (over HM 5). HKI 488 x HKI 170(1+2) and HKI 659-3 x HKI 193-2 menifested high heterosis for both lysine and tryptophan content over HQPM 1as well as for protein content (over HM 5) and HKI 1040-4 x HKI 163 showed high heterosis for lysine content, tryptophan content and 100 grain weight over HQPM 1 as well as for number of grains per cob and grain yield per plant suggesting that these experimental hybrids can be used in QPM hybrid breeding programmes.

Key words: *Heterosis, Hybrids, Inbred, QPM*

INTRODUCTION

Maize is the third important cereal food crop in the world as well as in India after wheat and rice and is also known as queen of cereals. Enhancement of maize production and productivity can be achieved by identifying elite parent materials which can be used to develop high yielding varieties and by forming broad based source population serving the breeding program. The dramatic increase in production and yield levels of maize during the last four decades is mostly due to genetic improvement of hybrids and better production technology but it is deficient in essential amino acid such as lysine and tryptophan.

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Lysine is the first limiting amino acid followed by tryptophan and threonine in the diets of non-ruminants and humans. Substituting normal maize with high lysine maize on an equal weight basis can maintain proper amino acid balance[15]. The single cross quality protein maize hybrids have become popular all over the world due to their high yield potential and excellent uniformity. The success depends on the availability of productive diverse quality protein maize inbred lines and clear knowledge of gene action for specific traits to develop QPM hybrids. As maize is a highly cross pollinated crop and the scope for the exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological feasibility and the type of gene action involved. In the development of hybrids, the foremost step is the development and evaluation of the inbreds and to know the nature and magnitude of heterosis for grain yield and its component traits. Genetically diverse parents are expected to produce high heterosis[13]. The magnitude of heterosis provides information on extent of genetic diversity of parents in developing superior F_1s so as to exploit hybrid vigour and thus it is essential in maximizing the effectiveness of hybrid development. Therefore the objectives of this study were to: (1.) to determine extent of heterosis in respect of yield and its component traits and quality traits (2.) to identify best experimental hybrids having balanced level of grain yield and quality traits.

MATERIALS AND METHODS

The 63 experimental hybrids were generated by Line X Tester mating design between 9 productive inbred lines and 7 QPM (Quality protein miaze) inbred lines (Kampthorne[6]) during *rabi* 2013. These 63 crosses along with 16 parents and 2 standard checks (HQPM 1 and HM 5) were grown in a randomized block design with 3 replication in experimental field at CCS, Haryana Agricultural University, Regional Research Station, Uchani, Karnal during *Kharif* 2014. Each genotype was planted in a single row of 3 meter length and the distance between rows and plants was kept at 75cm and 20 cm, respectively. From every row 5 competitive plants were randomly selected from each replication and observations on following quantitative characters *viz.*, days to 50 % taselling, days to 50 % silking, days to maturity, plant height (cm), ear height (cm), number of cobs per plant, cob length (cm), cob diameter (cm), 100 grain weight (g), grain yield per plant (g), shelling percentage, protein content (%), lysine content (%), tryptophan content (%), oil content (%) and starch content (%) were recorded for the analysis of the data. Quality traits *viz*., were determined at quality laboratory.

The heterosis in negative direction (indicated earliness) is considered to be desirable for days to 50 per cent tasselling, days to 50 per cent silking, days to maturity and ear height and for rest of the traits positive heterosis is considered desirable. All type of heterosis is desirable for plant height. For fodder purpose positive heterosis is considered useful whereas, for grain types negative to average heterosis is preffered. It has been observed that per se performance of parents gives misleading results. Therefore to know the precise genetic worth of crosses, the magnitude of heterosis for yield, its contributing characters and grain quality traits was estimated in relation to better parent and 2 standard check hybrid *viz*., HQPM 1 (quality protein maize) and HM 5 (normal maize). They were thus, calculated as percentage increase or decrease of F_1s over better parent (Heterobeltiosis) and standard check (Standard heterosis) for all characters was carried out as per procedure suggested by Fonesca and Patterson[4] and standard heterosis according to Virmani[16] with the following formula:

Heterosis over better parent (heterobeltiosis) = F1-BP/ BP

Heterosis over check (standard heterosis) = F1 – CC/ CC

where, F_1 = Mean performance of F_1

BP = Mean performance of better parent

CC = Mean performance of the best commercial check

RESULTS AND DISCUSSION

The pertinent results based on *Per se* performance of 81 entries (63 hybrids + 16 parents and 2 checks) and percentage of heterosis measured as increase or decrease over better parent, and best checks have been presented in Table 1. Considerable amount of heterosis was observed for all the characters under study, however the magnitude varied with characters. In the present study out of 63 crosses studied, heterosis for grain yield per plant was significant in all the 63 crosses over better parent and 4 crosses over standard check respectively. Cross HKI 1126 x HKI 161 showed highest magnitude of standard heterosis for this trait. The range of heterobeltiosis from 16.24 (HKI 1105 x HKI 194-6) to 128.73 (HKI 536YN x HKI 193-1) and range of standard heterosis varied from -38.16 (HKI 536YN x HKI 5072-BT(1-2)-2) to 8.62 (HKI 1126 x HKI 161) for this trait. Similar observation on high heterosis for grain yield was reported by Singh *et al.*[8].

Among 63 hybrids studied, significant negative heterosis and heterobeltiosis was recorded in all the hybrids for days to 50 per cent tasselling ranged from -17.82 (HKI 1126 x HKI 161) to -1.79 (HKI 1105 x HKI 193-2) whereas the range of standard heterosis was from -9.49 (HKI 1126 x HKI 161) to 8.22 (HKI 1128 x HKI 163) in a total of 26 hybrids over HQPM 1. For days to 50 percent silking the range was from -13.22 (HKI 1126 x HKI 170(1+2)) to 2.38 (HKI 1105 x HKI 193-2) for heterobeltiosis and from -9.04 (HKI 1126 x HKI 170(1+2)) to 7.23 (HKI 1128 x HKI 163) was recorded as standard heterosis over HQPM 1. 50 crosses exhibited significant heterobeltiosis whereas 27 crosses showed significant standard heterosis. For maturity traits, out of 63 crosses 61 crosses exhibits significant heterobeltiosis and 52 crosses over HQPM 1 showed significant negative effects. Heterobeltiosis ranged from -13.72 (HKI 1126 x HKI 170(1+2)) to 0.00 (HKI 536YN x HKI 170(1+2)) and the range of standard heterosis was recorded as -9.13 (HKI 1126 x HKI 170(1+2)) to 2.66 (HKI 1128 x HKI 163). Heterosis in earliness was observed by Appunu *et al.*,[1] Jabeen *et al.*,[3] and Jawaharlal *et al.*[5].

In case of plant height, only 1 cross (HKI 1128 x HKI 163) showed significant standard heterosis over HM 5 and the range was recorded as -39.10 (HKI 659-3 x HKI 161) to 11.28 (HKI 1128 x HKI 163). None of the hybrid showed significant negative heterobeltiosis for ear height whereas standard heterosis from -19.22 (HKI 1105 x HKI 170(1+2)) to 12.1 (HKI 1128 x HKI 163) over HM5 was recorded and the number of crosses varied from 3 for this trait. The range of heterobeltiosis from -44.44 (HKI 288-2 x HKI 193-1) to 46.15 (HKI 1128 x HKI 163) and range of standard heterosis from -18.03 (HKI 1128 x HKI 170(1+2)) to 55.74 (HKI 1128 x HKI 163) was observed for number of cobs per plant. Out of 63 crosses, 14 crosses showed positive significant heterobeltiosis while 29 crosses showed significant standard heterosis over HM 5. Shahwani *et al.*[12] noticed positive and significant heterosis in 17 hybrids, while 11 hybrids showed heterobeltiosis for ears per plant. For cob length, in all the crosses heterosis over better parent ranged from 4.31 (HKI 323 x HKI 163) to 98.03 (HKI 1126 x HKI 161) and from -30.88 (HKI 1040-4 x HKI 170(1+2)) to 7.31 (HKI 536YN x HKI 170(1+2) over HM 5 was recorded towards this trait and number of crosses varied from 8 for this trait. Likewise for cob diameter, 47 crosses showed significant heterobeltiosis and ranged from -16.35 (HKI 323 x HKI 163) to 41.97 (HKI 323 x HKI 193-1). For standard heterosis, the range was found to be from -15.95 (HKI 323 x HKI 163) to 11.19 (HKI 1040-4 x HKI 193-2) and 22 crosses showed significant positive heterosis over HM 5 for this trait. The heterosis for number of grains per cob was significant in all the crosses while 6 crosses showed significant positive standard heterosis over HM 5. The cross HKI 536YN x HKI 193-2 showed highest positive standard heterosis. The range of 100 grain weight varied from -24.25 (HKI 659-3 x HKI 193-1) to 48.74 (HKI 323 x HKI 161) over better parent whereas from -42.87 (HKI 1105 x HKI 170(1+2)) to

10.31 (HKI 536YN x HKI 193-2) over standard check HQPM 1 and 7 crosses showed significant positive heterosis for this trait. For shelling percentage, only 1cross *i.e* HKI 1040-4 x HKI 170(1+2) showed significant positive standard heterosis over HM 5. Heterosis over better parent ranged from -7.91 (HKI 1105 x HKI 194-6) to 14.01 (HKI 288-2 x HKI 161) and for standard heterosis range varied from -11.90 (HKI 659-3 x HKI 193-1) to 2.48 (HKI 1040-4 x HKI 170(1+2)).

High and significant heterosis for grain yield accompanied by significant heterosis for one or more yield contributing characters was earlier reported by several workers Premalatha and Kalamani[9], Bhavana *et al*.,[2] Sumalini *et al*.,[14] Jawaharlal *et al.*,[5] and Raghu *et al.*[10] Reddy *et al.*[11]

Among the quality traits, for protein content all the 63 crosses showed significant positive standard heterosis over HM 5 and range varied from 10.47 (HKI 323 x HKI 193-2) to 37.88 (HKI 1128 x HKI 5072-BT(1-2)-2) whereas positive heterobeltiosis for this trait ranged from -15.5 (HKI 1128 x HKI 161) to 22.15 (HKI 659-3 x HKI 193-1). For lysine content, 25 crosses showed significant positive heterobeltiosis whereas 5 crosses showed significant positive standard heterosis over HQPM 1. The range varied from - 42.01 (HKI 488 x HKI 163) to 65.12 (HKI 488 x HKI 170(1+2)) for heterobeltiosis whereas for standard heterosis the range varied from -54.15 (HKI 659-3 x HKI 193-1) to 5.42 (HKI 1126 x HKI 163). Likewise for per cent tryptophan content 8 crosses were having positive significant heterosis over better parent and range recorded as -64.29 (HKI 1040-4 x HKI 5072-BT(1-2)-2) to 49.09 (HKI 659-3 x HKI 5072-BT(1-2)-2). The range for standard heterosis over HQPM 1varied from -62.03 (HKI 1040-4 x HKI 5072-BT(1-2)-2) to 7.56 (HKI 488 x HKI 170(1+2)) and 4 crosses were found to show significant standard heterosis over HQPM 1. For oil content, 7 crosses showed significant heterobeltiosis and the range varied from -38.06 (HKI 1105 x HKI 163) to 45.87 (HKI 323 x HKI 170(1+2)) whereas highest positive standard heterosis over HQPM 1 was recorded for 17 crosses ranged from -20.49 (HKI 536YN x HKI 170(1+2)) to 16.34 (HKI 323 x HKI 170(1+2). The range of heterobeltiosis for starch content ranged from -14.18 (HKI 323 x HKI 193-2) to 3.03 (HKI 1040-4 x HKI 163) whereas none of the cross showed positive standard heterosis. The range for standard heterosis varied from -10.16 (HKI 323 x HKI 193-2) to 3.68 (HKI 1128 x HKI 161) and 4 crosses showed positive standard heterosis over check 2 *i.e* HM 5. For quality characters, similar heterotic response was observed by Elmyhum[7].

Table 1: The range of heterobeltiosis (over better parent) and standard heterosis (over standard check) showing significant heterobeltiosis and standard heterosis for various characters in maize

Character	Range of heterobeltiosis	Range of standard heterosis	No. of crosses showing significant	
			Heterobeltiosis	Standard heterosis
Days to 50 % tasseling	-17.82 to -1.79	- 9.49 to 8.22	63	26
Days to 50 % silking	-13.22 to 2.38	- 9.04 to 7.23	50	27
Days to maturity	-13.72 to 0.00	- 9.13 to 2.66	61	52
Plant height	2.79 to 83.07	- 39.10 to 11.28	58	1
Ear height	0.84 to 73.53	-19.22 to 12.1	59	3
No. of cobs per plant	- 44.44 to 46.15	-18.03 to 55.74	14	29
Cob length	4.31 to 98.03	-30.88 to 7.31	63	8
Cob diameter	-16.35 to 41.97	-15.95 to 11.19	47	22
Number of grains / cob	10.41 to 156.08	- 42.87 to 10.31	63	6
100 grain weight	- 24.25 to 48.74	- 33.59 to 5.09	43	7
Grain yield per plant	16.24 to 128.73	- 38.16 to 8.62	63	4
Shelling percentage	- 7.91 to 14.01	- 11.90 to 2.48	23	1
Protein content	-15.5 to 22.15	10.47 to 37.88	36	63
Lysine content	- 42.01 to 65.12	- 54.15 to 5.42	25	5
Tryptophan content	- 64.29 to 49.09	- 62.03 to 7.56	8	4
Oil content	- 38.06 to 45.87	-20.49 to 16.34	7	17
Starch content	- 14.18 to 3.03	- 10.16 to 3.68	-	4

Table 2: Number of cross combinations showing significant heterobeltiosis and standard heterosis for 17 characters in maize

Characters	Cross combinations for heterobeltiosis	Cross combinations for standard heterosis
Days to 50 % tasseling	HKI 1126 x HKI 161 (-17.82), HKI 323 x HKI 193-2 (-16.67) HKI 1126 x HKI 163 (-16.09)	HKI 1126 x HKI 161(-9.49), HKI 323 x HKI 193-2 (-8.24), HKI 1126 x HKI 163 (-7.59)
Days to 50 % silking	HKI 1126 x HKI 170(1+2) (-13.22), HKI 323 x HKI 5072-BT(1-2)-2 (-13.22), HKI 1126 x HKI 161 (-11.49)	HKI 1126 x HKI 170(1+2) (-9.04), HKI 323 x HKI 5072-BT(1-2)-2 (-9.04), HKI 1126 x HKI 161 (-7.23)
Days to maturity	HKI 1126 x HKI 170(1+2) (-13.72), HKI 1126 x HKI 161 (12.36), HKI 659-3 x HKI 193-2 (-11.47)	HKI 1126 x HKI 170(1+2) (-9.13), HKI 1126 x HKI 161 (-7.98), HKI 1040-4 x HKI 170(1+2) (-7.98)
Plant height	HKI 288-2 x HKI 161 (83.07), HKI 488 x HKI 161 (80.00), HKI 1128 x HKI 163 (78.74)	HKI 1128 x HKI 163 (11.28)
Ear height	HKI 488 x HKI 5072-BT(1-2)-2 (73.53), HKI 1126 x HKI 5072-BT(1-2)-2 (58.23), HKI 1126 x HKI 194-6 (54.80)	HKI 1128 x HKI 163 (12.1), HKI 288-2 x HKI 193-2 (11.03), HKI 488 x HKI 161 (8.18)
No. of cobs per plant	HKI 1128 x HKI 163 (46.15), HKI 536YN x HKI 161 (18.18), HKI 488 x HKI 161 (18.18)	HKI 1128 x HKI 163 (55.74), HKI 1040-4 x HKI 161 (22.95), HKI 288-2 x HKI 170(1+2) (14.75)
Cob length	HKI 1126 x HKI 161 (98.03), HKI 1040-4 x HKI 161 (88.27) HKI 1040-4 x HKI 5072-BT(1-2)-2 (74.12)	HKI 536YN x HKI 170(1+2) (7.31), HKI 288-2 x HKI 193-2 (5.13), HKI 488 x HKI 194-6 (6.55)
Cob diameter	HKI 323 x HKI 193-1 (41.97), HKI 323 x HKI 194-6 (38.01) HKI 288-2 x HKI 161 (37.79)	HKI 1040-4 x HKI 193-2 (11.19), HKI 488 x HKI 193-1 (7.14), HKI 323 x HKI 5072-BT(1-2)-2 (4.76)
Number of grains / cob	HKI 488 x HKI 5072-BT(1-2)-2 (156.08), HKI 536YN x HKI 193-2 (148.25), HKI 1040-4 x HKI 5072-BT(1-2)-2 (138.93)	HKI 536YN x HKI 193-2 (10.31), HKI 1128 x HKI 163 (7.16), HKI 659-3 x HKI 194-6 (6.96)
100 grain weight	HKI 323 x HKI 161 (48.74), HKI 536YN x HKI 193-1 (47.25) HKI 488 x HKI 161 (47.18)	HKI 1040-4 x HKI 163 (5.09), HKI 1128 x HKI 163 (4.73), HKI 659-3 x HKI 194-6 (3.54)
Grain yield per plant	HKI 536YN x HKI 193-1 (128.73), HKI 1040-4 x HKI 5072-BT(1-2)-2 (122.95), HKI 488 x HKI 194-6 (115.42)	HKI 1126 x HKI 161 (8.62), HKI 323 x HKI 161 (8.22), HKI 659-3 x HKI 194-6 (7.93)
Shelling percentage	HKI 288-2 x HKI 161 (14.01), HKI 1040-4 x HKI 170(1+2) (13.59), HKI 1040-4 x HKI 161 (10.80)	HKI 1040-4 x HKI 170(1+2) (2.48)
Protein content	HKI 659-3 x HKI 193-1 (22.15), HKI 1105 x HKI 170(1+2) (20.27), HKI 1126 x HKI 193-2 (18.83)	HKI 1128 x HKI 5072-BT(1-2)-2 (37.88), HKI 659-3 x HKI 193-1 (37.53), HKI 288-2 x HKI 170(1+2) (36.71)
Lysine content	HKI 488 x HKI 170(1+2) (65.12), HKI 323 x HKI 170(1+2) (56.98), HKI 1128 x HKI 170(1+2) (49.42)	HKI 1126 x HKI 163 (5.42), HKI 488 x HKI 170(1+2) (2.53), HKI 659-3 x HKI 193-2 (3.97)
Tryptophan content	HKI 659-3 x HKI 5072-BT(1-2)-2 (49.09), HKI 1126 x HKI 163 (35.59), HKI 488 x HKI 170(1+2) (13.33)	HKI 488 x HKI 170(1+2) (7.56), HKI 1040-4 x HKI 163 (2.53), HKI 659-3 x HKI 193-2 (3.80)
Oil content	HKI 536YN x HKI 194-6 (36.56), HKI 1126 x HKI 194-6 (21.24), HKI 323 x HKI 194-6 (12.81)	HKI 323 x HKI 170(1+2) (16.34), HKI 1105 x HKI 193-1(16.34), HKI 659-3 x HKI 5072-BT(1-2)-2 (13.41)
Starch content	HKI 1040-4 x HKI 163 (3.03)	HKI 1128 x HKI 161 (3.68), HKI 323 x HKI 163 (3.26) HKI 288-2 x HKI 5072-BT(1-2)-2 (2.96)

A perusal of heterotic behaviour and magnitude of heterosis in the superior experimental hybrids revealed that heterosis for grain yield may be because of the fact that atleast one parent involved in these crosses is desirable should also taken in to account for heterosis breeding. The most promising combinations selected separately on the basis of heterotic effect over better parent and best checks *i.e* HQPM 1 and HM-5 (Table 2.), therefore, suggested that the experimental hybrid HKI 1128 x HKI 163 manifested high heterotic effect for grain yield and other traits i.e plant height, ear height, no. of cobs per plant, number of grains per cob over check 2 *i.e* HM 5 and for 100 grain weight over check 1 *i.e* HQPM 1 whereas HKI 659-3 x HKI 194-6 showed highest standard heterosis for number of grains per cob (6.96), 100 grain weight (3.54) and grain yield per plant (7.93) indicating such experimental hybrids may be used for early maturing hybrids with high grain yield.

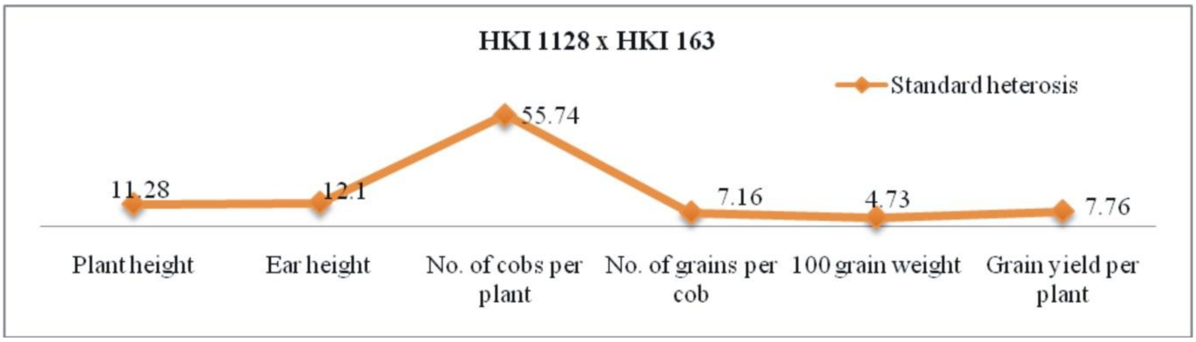

Fig.1: Top hybrid identified based on heterotic effects over best check for yield characters

The hybrid which manifested high heterosis for grain yield (over HM 5) as well as for phonological traits (over HQPM 1) was identified as HKI 1126 x HKI 161 and HKI 1126 x HKI 170(1+2) manifested high heterosis for days to 50 % tasselling (-6.97), days to 50 % silking (-9.04) and days to maturity (-9.13).

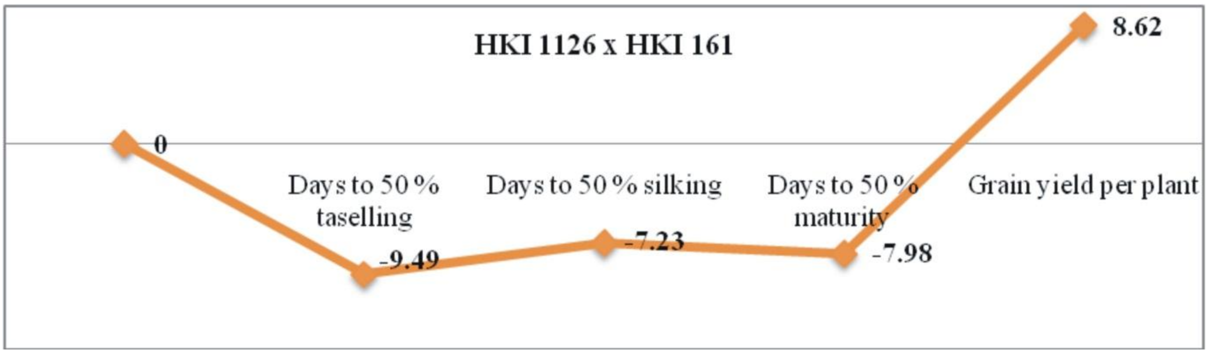

Fig. 2: Top hybrid identified based on heterotic effects over best check for phenological and grain yield characters

For quality traits, experimental hybrid HKI 1126 x HKI 163 showed high heterosis for lysine content (5.42) and tryptophan content (1.26) as well as for days to 50% tasselling (-7.59) over HQPM 1 and cob length (4.75) over HM 5. HKI 488 x HKI 170(1+2) and HKI 659-3 x HKI 193-2 menifested high heterosis for both lysine and tryptophan content over HQPM 1 as well as for protein content over HM 5 suggesting that these experimental hybrids can be used in QPM hybrid breeding programmes. Whereas HKI 1040-4 x HKI 163 showed high heterosis for lysine content, tryptophan content and 100 grain weight over HQPM 1 as well as for number of grains per cob and grain yield per plant over HM 5 suggested that this hybrid by chain crossing may be composited to make a gene pool and this may be advanced for further generations to derive and isolate lines with gene combinations for high grain yield with high quality characters. For oil content over HQPM 1(16.34) and starch content over HM 5 (2.87), HKI 323 x HKI 170(1+2) manifested high heterotic effects and also showed significant standard heterosis for days to silking (-6.63).

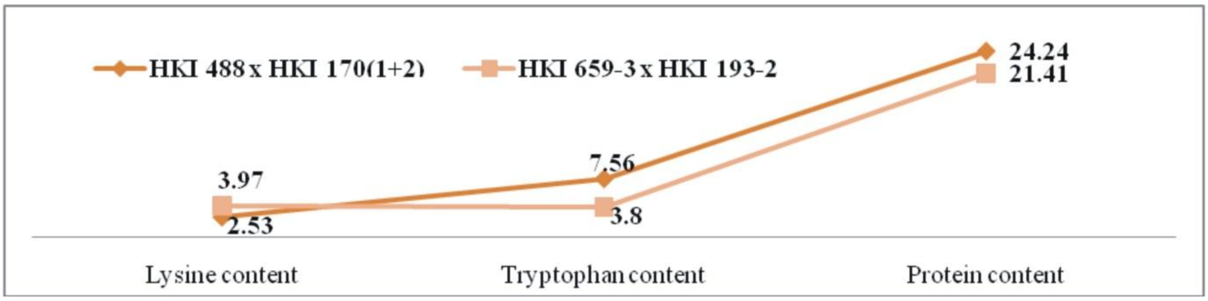

Fig. 3: Top hybrid identified based on heterotic effects over best check for quality traits

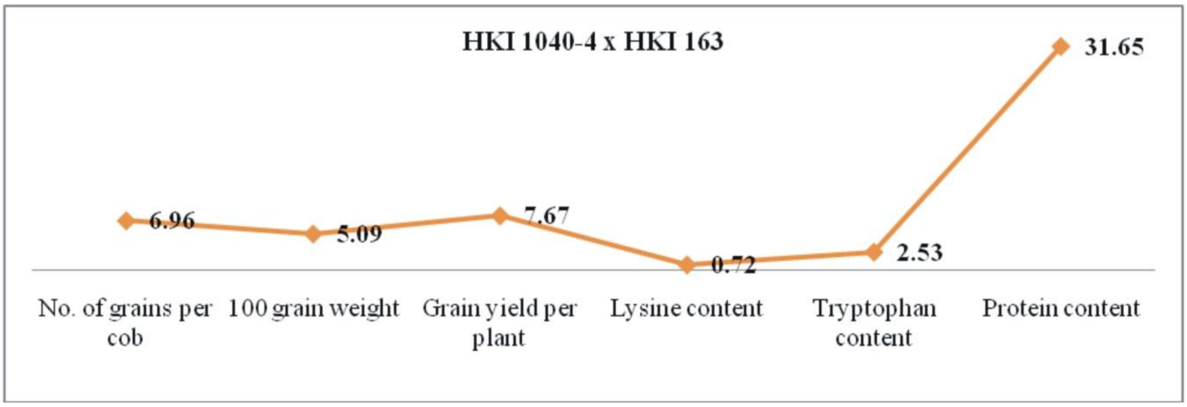

Fig. 4: Top hybrid identified based on heterotic effects over best check for both yield and quality traits

For maturity, yield and quality traits Sorsa *et. al.*[17] reported the presence of heterosis over better parent and standard check which is in contrast to the present findings.

CONCLUSION

The parents of highly heterotic crosses explained the existence of genes with some degree of dominance controlling the character. The expression of heterosis also depends on the divergence between genotypes, as differences in allele frequencies are required at loci involved in the expression of desirable characteristics. Whereas, low heterotic effect is likely due to low genetic complementarily of loci with non-additive effects, possibly because these crosses displayed some degree of parental relationship. It could be concluded that the values of heterosis for grain yield were high positive for most of the crosses indicating the absence of bidirectional dominance derivatives. The high positive heterosis for grain yield and its components was found for more than half of the hybrids studied. These results indicated that these crosses could be selected and used in breeding programs for improving these traits. The most promising combinations selected separately on the basis of heterotic effect over best checks therefore, suggested that as such these results will be useful for choosing populations to be used in developing new improved maize populations. Also the acceptable level of protein quality in the QPM is very important since the protein contrast in QPM is affected by heterotic pattern indicating recognition of heteroric pattern as one step onward in the improvement of QPM varieties.

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REFERENCES

1. Appunu, C., Satyanarayana, E. and Nageswar rao, T., Heterosis for grain yield and its components in maize (*Zea mays* L.) *J. Res., ANGRAU.*, **70 (3)**: 257-263 (2007).
2. Bhavana, P., Singh, R.P and Gadag, R.N., Gene action and heterosis for yield and yield components in maize (*Zea mays) Indian J. Agric. Sci*., **81 (2):** 163-166 (2011).
3. Farzana Jabeen, Hussain Sahib, K and Satyanarayana, E., Combining ability analysis in quality protein maize (*Zea mays* L.*). Crop Res.*, **34 (1):** 171-175 (2007).
4. Fonesca, S and Patterson, F.L., Hybrid vigour in a seven parent diallel cross in common wheat (*Triticum aestivum* L.). *Crop Sci.*, **8:** 85-88 (1968).
5. Jawaharlal, J., Reddy G.L and Kumar, R. S., Heterosis for yield component traits in maize (*Zea mays*L.). *Indian J. Agric. Res*., **46 (2):** 184-187 (2012).
6. Kampthorne, O., *"An introduction to Genetical Statistics"*, John Willey and Sons, New York, pp 323-331 (1957).

7. Melkamu Elmyhum, Estimation of combining ability and heterosis of quality protein maize inbred lines. *African. J. Agric. Res.*, **8(48):** 6309-6317 (2013).
8. P. K. Singh, Nitish Singh, A. K. Singh, J. P. Shahi and M. Rao, Heterosis in relation to combining ability in Quality protein maize (Zea mays L.), *Biolife*, **1(2):**-65-69 (2013).
9. Premalatha, M and Kalamani, A., Heterosis and combining ability studies for grain yield and growth characters in maize (*Zea mays* L.). *Indian J. Agric. Res*., **44 (1):** 62-65 (2010).
10. Raghu, B., Suresh, J., Geetha, A., Saidaiah, P and Sudheer Kumar, S., Heterosis for grain yield and its component traits in maize (*Zea mays* L.). *J. Res. ANGRAU.*, **40 (1):** 83-90 (2012).
11. Ram Reddy, V., Seshagiri Rao, A and Sudarshan, M.R., Heterosis and combining ability for grain yield and its components in maize (*Zea mays* L.). *J. Res. ANGRAU.*, **39 (3):** 6-15 (2011).
12. Shahwani, M. N., Salarzai, A., Bangulzai, B. A., Shahwani, M. A. and Hengl, N. M., Hybrid vigour for grain yield and its components in maize crosses. *Sarhad J. Agric.*, **17:** 571-576 (2001).
13. Shazia, G., Dar, Z.A., Lone, A.A., Khan, M.A., Bhat, M.A., Ali, G., Yousuf, N., and Lone, R.A., Genetic Diversity in Maize (*Zea mays* L.) Inbred Lines from Kashmir, *Int. J. Pure App. Biosci*. **5(1):** 229-235 (2017).
14. Sumalini, K and Shobha Rani, T., Heterosis and combining ability for polygenic traits in late maturity hybrids of maize, (*Zea mays* L.). *Madras Agric. J*., **97 (10-12):** 340-343 (2011).
15. Vassal S. K ., High quality protein corn. In: Hallauer A. R. (eds.). Speciality Corns. 2nd ed. CRC Press, Washington, D.C., USA,. 85-129 (2001).
16. Virmani, S.S., Aquino, R.O and Khush, G.S., Heterosis breeding in Rice (*Oryza sativa* L.). *Theoret. and Applied Genet*., **63:** 373-380 (1982).
17. Zemach Sorsa, Hussain Mohammed and Mandefro Nigussie, Test cross performance and heterosis of selected Quality Protein Maize (QPM) (*Zea mays* L.) inbred lines. *Int. J. Plant Breed Genet*., **8(2):** 78-88 (2014).