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HETEROSIS IN CHICKPEA FOR GRAIN PRODUCTIVITY IN EMBU COUNTY, KENYA

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Heterosis

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Hybrid

Grain yield

Kenya

ABSTRACT

Chickpea is a major source of proteins especially in arid and semi-arid areas of Kenya. However, its average yield per hectare is low when compared to neighbouring countries. This research was carried out to determine the levels of hybrid vigour on yield in the F_1 generation. To obtain the F_1s, reciprocal crossing between Mwanza 2 and Chaina I was carried out with controls being the parental lines. The experimental layout was a randomized block design replicated thrice for three seasons. A spacing of 50x20cm was used in plants, while all other agronomic practices were maintained constant. Data on grain yield and biomass per plant was obtained by measuring the weight, then subjecting it to a one-way ANOVA in SAS 9.4 software. Mwanza 2 expressed the highest biomass (2.56g), while both parents attained a maximum grain yield of 1.69g per plant. Chaina I x Mwanza 2 hybrid expressed maximum means of F_1s for biomass (2.31g) and grain yield (1.4g) per plant. Chaina I x Mwanza 2 hybrid recorded the highest biomass and grain yield in better parent heterosis with 14.36% and 330% respectively. Mid-parent heterosis means were also highest at 24.53% and 405.88% for biomass and grain yield respectively. Further, the heritability was maximum for biomass under Mwanza 2 x Chaina I, varying from 93.1% to 100%, while Chaina I x Mwanza 2, expressed maximum grain yield and harvest index. Better parent heterosis and mid-parent heterosis was highest in Chaina I x Mwanza 2 than its reciprocal, Mwanza 2 x Chaina I.

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1 Introduction

Chickpea (*Cicer arietinum* L.) is a legume belonging to the family Fabaceae. It is a self-pollinated, annual crop (Mujjassim et al., 2018; Pratap et al., 2021). The crop has high economic potential for the Sub-Saharan African (SSA) region due to its low production cost and higher economic return (Rao et al., 2012; Merga & Haji 2019; Fikre et al., 2020; Mangena, 2021). It has diversified uses such as protein concentrates in animal feeds and human foods, enrichment of soils with nitrogen, and breaking of pest and disease cycles (Wallace et al., 2016; Hossain et al., 2016; De Camargo et al., 2019; Wood & Scott, 2021). Chickpeacan survive under scanty rainfall conditions with a precipitation range of 152-254 mm and 18-29°C temperatures (McVay & Crutcher 2016; Arif et al., 2021; Wafula et al., 2021). However, for maximum productivity, the crop requires approximately 436.7mm precipitation per growing season (Desta et al., 2015; Księżak & Bojarszczuk, 2020). The average productivity under the area of study is less than 250 kg ha^{-1} compared to the Rift valley region, Kenya where yields are reported to be 1500 to 3000 kg ha^{-1} (Kimurto et al. 2009; Kimu et al., 2020).

Commonly grown chickpea varieties in Kenya are Chaina (Desi 1), ICCV 00108, Saina K 1 (ICCV95423), ICCV 00305 (Kabuli), ICCV 92944 (Desi), and ICCV 97105 (Desi-K) with average yield ranging between 1200 to 1500 kg ha^{-1} (Rao et al., 2012; Wafula et al., 2021). Chickpea cultivation in Kenya is mainly done in marginal parts of Rift Valley and Eastern Kenya (Mallu 2015; Kibe & Thagana, 2017). Production and land acreage of the crop has been declining over the last 9 years leading to a drop in the national yield average from 964 kg ha^{-1} in 2012 to about 357 kg ha^{-1} in 2019 (FAOSTAT 2019). The low productivity in Kenya is due to the low utilization of hybrid seeds that has the potential to raise yield due to hybrid vigour (Abera et al., 2017).

Hybrid vigour (heterosis) has been utilized on a large scale for the production of plants and animals for many years (Birchler 2015). The use of heterosis for legume crop improvement is hampered by flower cleistogamy and artificial hybridization (Gonçalves-Vidigal et al., 2008; Ghaffar et al., 2015). However, through selecting superior breeds, the growth and yield attributes of the crop can be improved (Burton & Brownie 2006; Dodiya et al., 2012; Jadhav & Gawande 2013; Sarode et al., 2016; Gosal & Wani 2020).

Notwithstanding, biological feasibility provides opportunities for exploiting the hybrid vigour for self-pollinated crops (Singh & Chauhan 2011; Panwar et al., 2021). Although it has been difficult to apply heterosis in the case of self-pollinated crops (Ghaffar et al., 2015), the use of cross-combinations showing heterotic vigour can be utilized as a source of populations for improvement of the crop varieties (Yamini et al., 2015). This study, therefore, aimed to assess the degree of hybrid vigour and extent of heritability in F_1 hybrids in selected chickpea varieties in Kenya.

2 Materials and methods

2.1 Site description

The experimental site was at Mbeere South sub-county of Embu County, Kenya. It is located at 0°46'14.4822'S and 37° 22'23.79324'E latitude and longitude respectively. This area is at an altitude of 980 meters above sea level. The annual rainfall is bimodal and ranges from 600 -700 mm (Jaetzold et al., 2006; Wafula et al., 2021). The long rains occur from mid-March to the end of June while short rains are from mid-October to the end of December, giving two cropping seasons per annum. The region is classified as lower midland (LM4) agro-ecological zone with black cotton soils (Wafula et al., 2021). The majority of farmers in this region mostly practice minimal rain-fed farming. The average minimum and maximum temperatures (figure 1) range from 18°C to 20°C and 19°C - 24°C respectively (McVay & Crutcher 2016; Wafula et al., 2021).

2.2 Chickpea planting materials

Mwanza 2 (ICCV00305) and Chaina I (ICCV0108) were sourced from Kenya Seed Company, Nakuru. Development of F_1 hybrids were done through reciprocal crossing (Rooney 2004). Intervarietal hybridization between Mwanza 2 (*Kabuli*) and Chaina I (*Desi*) and their reciprocal were performed under natural field conditions, following emasculation and pollination simultaneously in the morning (Kalve & Tadege, 2017). The emasculation of the female parent was done manually two days before flowering by removing pollen grains with forceps, and cross-pollination was done a day after. The main crosses were Mwanza 2 (*Kabuli*) x Chaina I (*Desi*) while their reciprocals were Chaina I x Mwanza 2 forming two crosses of F_1s denoted as Mwanza 2 x ChainaI and ChainaI x Mwanza 2. Parents were evaluated and selected based on morphological attributes. Heterosis was estimated as a percent decrease or increase over mid- and better parent values as proposed by Zubair et al. (2010).

2.3 Experimental design and layout

Plots were prepared using hoes in a standard way and sowing was done manually in furrows. Sowing of F_1 seeds were done in a randomized block design replicated three times. The plots dimensions were 1.5 separated at a spacing of 1m between plots and 2 m between replicates. Two F_1 hybrid and parents seeds were planted per hole at a spacing of 20 cm. The plants were thinned to one plant per hill two weeks after germination. Standard crop husbandry management practices were applied (Kalungu & Harris, 2013). Three F_1 and parent plants were randomly selected from each replicate for data collection.

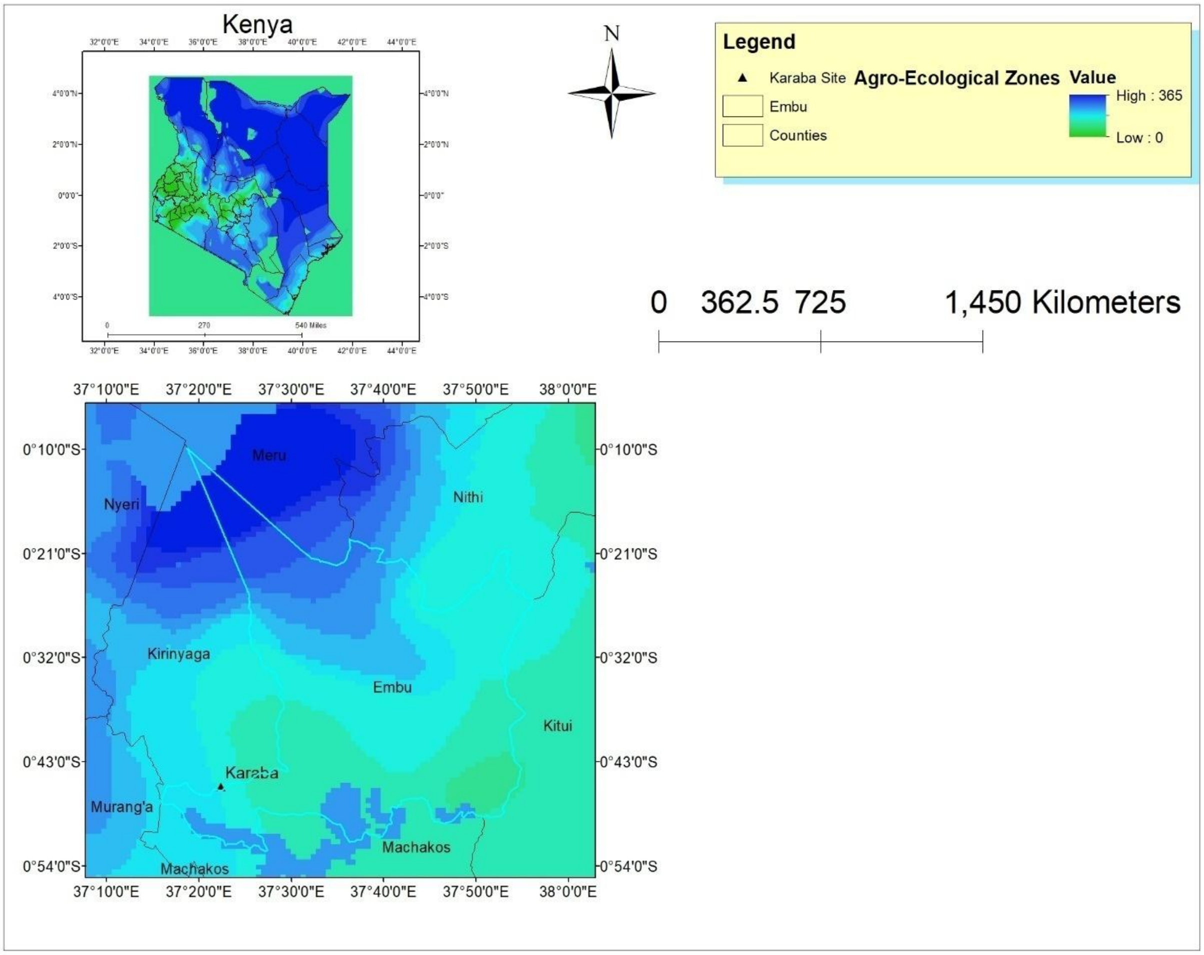

Figure 1 Geographical Location of Karaba (study area)

2.4 Data collection

Data were collected per plant for above-ground biomass (bpp^{-1}), grain yield (Gpp^{-1}), and harvest index. Harvest index was calculated as the ratio of average grain yield per plant to biomass per plant, and then multiplied by 100 (Mengistu et al., 2020; Patil et al., 2021a). Heterosis was calculated by using equations 1 and 2 according to Zubair et al. (2010).

$$\text{Heterosis (Vp)} = \frac{\text{F1} - \text{Mid parent value}}{\text{Mid parent value}} \text{x } 100 \qquad \text{Equation 1}$$

Heterobeltiosis was calculated using equation 2

$$\text{Heterobelttiosis (Vg)} = \frac{\text{F1} - \text{Better parent value}}{\text{Better parent value}} \text{x}100 \qquad \text{Equation 2}$$

Heritabililty estimate was determined using equation 3.

$$\text{Heteritability estimate (h2)} = \frac{\text{Vg}}{\text{Vp}} \text{x } \% \qquad \text{Equation 3}$$

2.5 Data analysis

Collected data were statistically analyzed using one-way analysis of variance (ANOVA) in SAS 9.4 software (SAS, 2015), while the means were separated by the least significant difference (LSD) test at a 95% confidence level. The GLM Model equation described by Eichler-Löbermann et al. (2021) was used as indicated below:

$$Y_{ij}=\mu+R_i+V_j+\alpha\beta_j+\varepsilon_{ij}$$

Y_{ijklm} = n^{th} Observations, μ: constant; overall mean, R_i: Effect due to i^{th} Replication, V_j: Effect due to j^{th}: variety; deviation from the mean of j, ε: random deviation associated with each observation

3 Results

3.1 Influence of chickpea parents and hybrids on the biomass production per plant

In the SR2017, parents (Mwanza 2 & Chaina I) performed better than hybrids (Chaina I x Mwanza 2 & Mwanza 2 x Chaina I). However, in LR2018, Chaina I x Mwanza 2 hybrid performed significantly better than its reciprocal and Chaina I parent in biomass accumulation, while in SR2018, its biomass was not significantly different from those of parents but significantly different with Mwanza 2 x Chaina I hybrid (Figure 2). The performance of parents on biomass per plant within the three seasons was highly significant at $P<0.05$. The biomass per plant for parents ranged from 1.7g in long rains 2018 (Chaina I) to 2.6g (Mwanza 2) in short rains 2017, which was statistically similar to Chaina I during the same period. Within the same period, hybrid performance varied from 1.0 (Mwanza 2 x Chaina I) in short rains 2017 to 2.3g (Chaina I x Mwanza 2) per plant in long rains 2018 as indicated in Figure 2.

3.2 Influence of chickpea parents and hybrids on the grain yield production per plant

In SR2017, although there was no significant difference in grain yield between parents, they gave significantly better results than hybrids (Figure 3). However, in LR2018 and SR2018, Chaina I x Mwanza 2 hybrid was significantly better in grain yield than its reciprocal cross and the parents. Nonetheless, in SR2018 Mwanza 2 x Chaina I hybrid performed significantly lower than parents. The weight of grains per plant in parents fluctuated between a minimum of 0.2g (Chaina I) in long rains 2018 to a maximum of 1.7g (Chaina I) in short rains 2017, which was statistically similar to Mwanza 2 yields of 1.69g. Over the same growth period, hybrid performance for grains varied from 0.34g (Mwanza 2 x Chaina I) in long rains 2018 to 1.4g (Chaina I x Mwanza 2) in short rains 2018 (Figure 3).

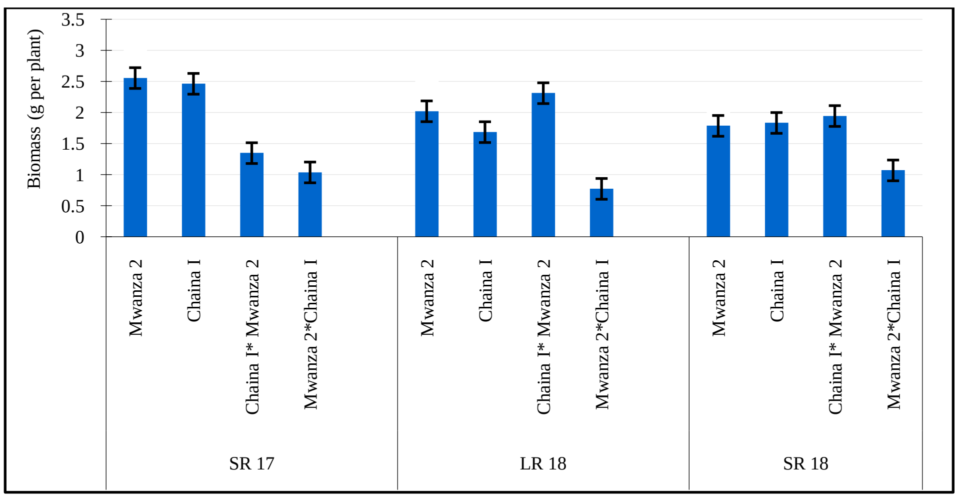

Figure 2 Means of biomass per plant as influenced by parents and hybrids during the three cropping seasons. The bars corresponded to the standard error which represents mean ± SE.

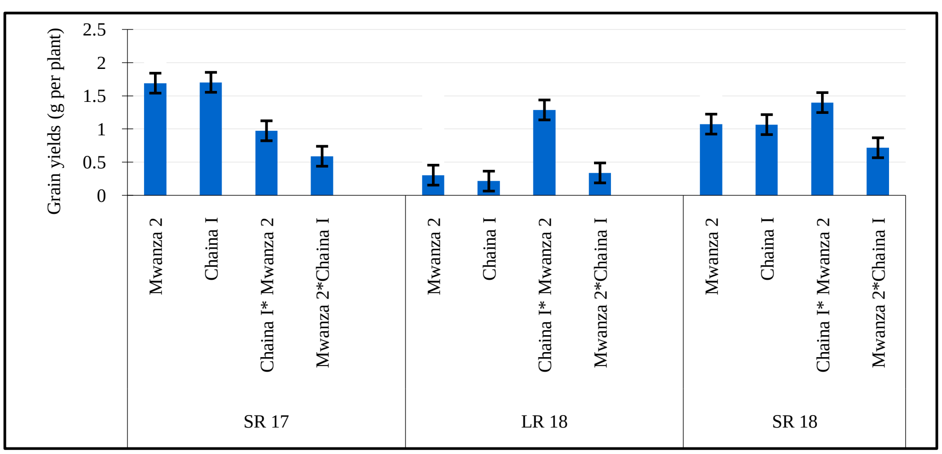

Figure 3 Means of grain yield per plant as influenced by parents and hybrids during the three cropping seasons. The bars corresponded to the standard error which represents mean ± SE.

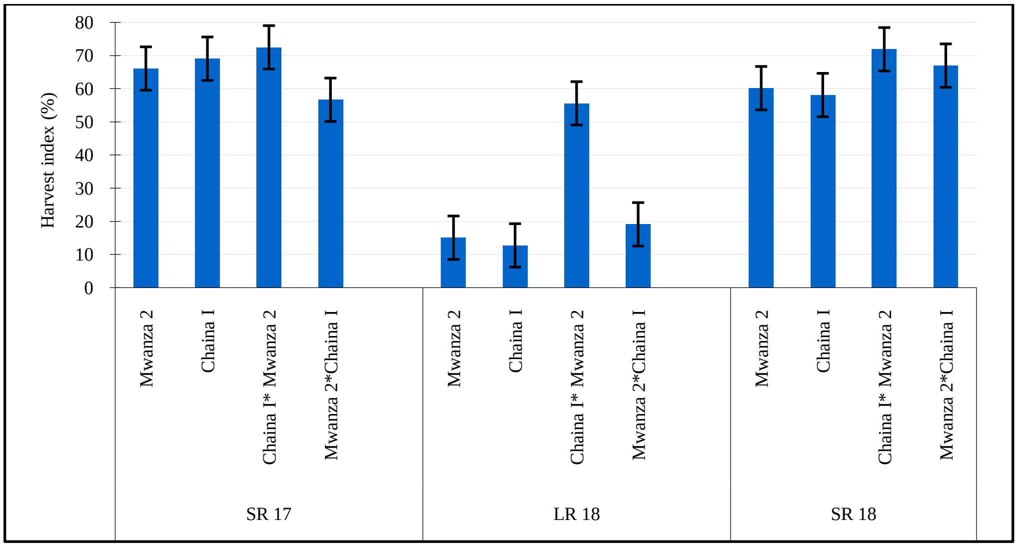

Figure 4 Means of percent harvest index per plant as influenced by parents and hybrids during the three cropping seasons. The bars corresponded to the standard error which represents mean ± SE.

Table 1 Details of lines used and their salient features

Parent	Pedigree	On farm seed production potential (kg ha^{-1})	Salient features
Mwanza 2	ICCV00305	1200	Medium seed size, Medium maturity, Resistance to fusarium wilt, Drought tolerant.
Saina K 1	ICCV 95423	1500	
Chaina desi I	ICCV 00108	1500	
Chaina III (Desi)	ICCV 97126	1500	

Source: Enhancing Chickpea Productivity and Production in Eastern and Southern Africa.

3.3 Influence of chickpea parents and hybrids on percent harvest index per plant

In SR2017, parents and Chaina I x Mwanza 2 hybrid had significantly higher harvest index, though statistically similar to Mwanza 2 x Chaina I (Figure 4). The cross Chaina I x Mwanza 2 posted a significantly better harvest index than its reciprocal and parents in LR2018. However, in SR2018 Chaina I x Mwanza 2 was significantly better, than Chaina I parent, though not significantly different from its reciprocal and Mwanza 2 parent. Outcomes of the percent harvest index in parents varied from 12.7% (Chaina I) in long rains 2018 to 69.1% (Chaina I) in short rains 2017. Nonetheless, the distribution of harvest index for hybrids ranged from 19.1% (Mwanza 2 x Chaina I) to 72.5% (Chaina I x Mwanza 2) in short rains 2017 (Figure 4).

3.4 Influence of mid-parent and better parent values to heterosis and heritability estimates of chickpea biomass per plant

Both hybrids (Chaina I x Mwanza 2 and Mwanza 2 x Chaina I) expressed negative heterosis for both better-parent values (BPH) and mid-parent heterosis (MPH) in SR2017. However, in LR2018 and SR2018, only Chaina I x Mwanza 2 expressed positive heterosis while Mwanza 2 x Chaina I expressed negative heterosis for BPH and MPH (Table 2). The values of better parents (BPV) for biomass per plant across the three cropping seasons ranged from 1.83g in short rains 2018 for Chaina I to 2.56g in short rains 2017 for Mwanza 2. However, mid-parent values (MPV) for biomass ranged from 1.81g to 2.51g over short rains 2018 (SR2018) and short rains 2017 (SR2017) respectively.

The BPH heterosis for Chaina I x Mwanza 2 of biomass per plant ranged from -45.12% (SR2017) to 14.36% (LR2018), whereas mid-parent (MPH) heterosis values, ranged from -46.22% (SR2017) to 24.53% (LR2018). Genetic gain of per plant biomass for Mwanza 2 x Chaina I using better parent heterosis (BPH) values, spread from -96.3% (SR2018) to -54.64% (LR2018), while the gain observed using mid-parent heterosis (MPH) values varied from -96.3% (SR18) to -58.57% (SR2017). The heritability estimates for biomass were higher in Mwanza 2 x Chaina I hybrids than its reciprocal across all seasons. The estimates for Chaina I x Mwanza 2 varied from 58.5% (LR2018) to 97.7 (SR2017), while for Mwanza 2 x Chaina I cross varied from 93.12% (LR2018) to 100% (SR2018), (Table 2).

Table 2 Heterosis and heritability estimates for biomass per plant

Total biomass per plant					
Short rains 2017					
Hybrids	BPVg	MPVg	BPH%	MPH%	%h^2
D_IK_2	2.56***	2.51	-45.1	-46.2	97.7
K_2D_I	2.56***	2.51	-57.7	-58.6	98.6
Long rains 2018					
D_IK_2	2.02*	1.86	14.4	24.5	58.5
K_2D_I	2.02*	1.86	-54.6	-58.7	93.1
Short rains 2018					
DIK2	1.83**	1.81	6.6	7.7	84.8
K_2D_I	1.83	1.81	-96.1	-96.1	100.0

D_IK_2: hybrid between Chaina I x Mwanza 2, K_2D_I: hybrid between Mwanza 2 x Chaina I. Seasons: short rains 2017, long rains 2018 and short rains 2018; MPV: mid-parent value, BPV: better-parent value, MPH: mid-parent heterosis, BPH: better parent heterosis, h^2: heritability estimates,. *, ** and *** means P is significant at <.01, <.05 and <.001.

3.5 Influence of mid-parent and better parent values to heterosis and heritability estimates for chickpea grain yield per plant

There was negative heterosis in both hybrids in SR2017 and for Mwanza 2 x Chaina I hybrid in SR2018. However, Chaina I x Mwanza 2 hybrid posted higher BPH and MPH in LR2018 and SR2018 than its reciprocal. The better parent value, (BPV) for grains per plant ranged from 0.3g (LR2018) for mwanza 2 to 1.96g (SR2017) for Chaina I while mid parent values, (MPV) for both Chaina I x Mwanza 2 ranged from 0.26g (LR2018) to 1.7g per plant (SR2017) during the cropping period, (Table 3). Heterosis due to BPV and MPV was observed for Chaina I x Mwanza 2 cross and its reciprocal under study (Table 3). However, heterosis due to BPH in Chaina I x Mwanza 2 for grain yield per plant varied from -42.01% (SR2017) to 330.0% (LR2018), while positive heterosis (MPH) due to MPV ranged from –42.35% (SR2017) to 405.88% (LR2018) respectively (Table 3).

Better-parent heterosis (BPH) for Mwanza 2 x Chaina I cross for grain yield per plant spread from -81.66% (SR2017) to 13.33% (LR2018), while MPH varied from -81.76% (SR2017) to 33.33% (LR2018) (Table 3). Heritability estimates for the Chaina I x Mwanza 2 cross spread from 81.3% (LR2018) to 100% (SR18), while Mwanza 2 x Chaina I cross heritability spread from 40% over LR2018 to a maximum of 100% over SR2018 (Table 3).

Table 3 Heterosis and heritability estimates for grain yield per plant

Grain yield (g per plant)					
Short rains 2017					
Hybrids	BPV	MPV	BPH	MPH	% h^2
D_IK_2	1.96***	1.7	-42.0	-42.3	99.2
K_2D_I	1.96***	1.7	-81.6	-81.7	99.9
Long rains 2018					
D_IK_2	0.3***	0.26	330	405.8	81.3
K_2D_I	0.3***	0.26	13.3	33.3	40
Short rains 2018					
D_IK_2	1.07**	1.07	30.8	30.8	100
K_2D_I	1.07**	1.07	-32.7	-32.7	100

D_IK_2: hybrid between Chaina I x Mwanza 2, K_2D_I: hybrid between Mwanza 2 x Chaina I. Seasons: short rains 2017, long rains 2018 and short rains 2018. MPV: mid-parent value, BPV: better-parent value, h^2: heritability estimates, MPH: mid-parent heterosis, BPH: better parent heterosis. *, ** and *** means P is significant at <.01, <.05 and <.001.

Table 4 Heterosis and heritability estimates for harvest index

Percent harvest index					
Short rains 2017					
Hybrids	BPV	MPV	BPH	MPH	h^2
D_IK_2	69.07	67.59	4.8	7.12	67.7
K_2D_I	69.07	67.59	-14.4	-16.3	88.5
Long rains 2018					
D_IK_2	15.07	13.89	268.9	300.4	89.5
K_2D_I	15.07	13.89	26.7	37.6	71.2
Short rains 2018					
D_IK_2	62.4	60.25	15.2	19.3	78.7
K_2D_I	62.4	60.25	7.3	11.2	65.7

D_IK_2: hybrid between Chaina I x Mwanza 2, K_2D_I: hybrid between Mwanza 2 x Chaina I. Seasons: short rains 2017, long rains 2018 and short rains 2018. MPV: mid-parent value, BPV: better-parent value, h^2: heritability estimates, MPH: mid-parent heterosis, BPH: better parent heterosis

Table 5 Correlation matrix between studied traits (biomass, grain yield and harvest index)

Correlation Coefficients			
	$Tbpp^{-1}$	Gpp^{-1}	HI
$Tbpp^{-1}$	1.00000	0.61229***	-0.00686
Gpp^{-1}		1.00000	0.77866***
HI			1.00000

Tbpp-1: biomass per plant, Gpp-1: grains per plant, HI: harvest index. *, ** and *** means P is significant at <0.01, <.0.05 and <0.001.

3.6 Influence of mid-parent and better parent values on heterosis and heritability estimates for percent harvest index

Under all cropping conditions (SR2017, LR2018, SR2018) Chaina I x Mwanza 2 hybrid expressed a higher harvest index than its reciprocal for BPH and MPH. The hybrid also expressed high heritability in all seasons except in SR2017, when Mwanza 2 x Chaina I outperformed it. Values of better parents (BPV) for percent harvest index per plant varied from 15.07% for Mwanza 2 over LR2018 to 69.07% for Chaina I over SR2017, whereas the mid parent values (MPV) for the two parents varied from 13.89% over LR2018 to 67.59% over SR2017 respectively. Better-parent heterosis (BPH) in Chaina I x Mwanza 2 of harvest index per plant in percentage ranged from 4.82% (SR2017) to 268.94% (LR2018), while MPH varied from 7.12% (SR2017) to 300.43% (LR2018), accordingly. The computed heritability estimates for Chaina I x Mwanza 2 varied from 67.67% in SR2017 to a maximum of 89.52 in LR2018, (Table 4).

Heterosis for Mwanza 2 x Chaina I due to better-parent values (BPH), for percent harvest index spread from -14.43% (SR2017) to 26.74% (LR2018), whereas, the MPH spread from -16.31% (SR2017) to 37.59% (LR2018). Heritability estimates (h^2) for the Mwanza 2 x Chaina I hybrid in percent harvest index varied from 65.71% (SR2018) to 88.47% (SR 2017) (Table 4).

3.7 Correlation between means of biomass, grain yield, and harvest index per plant

Correlation studies showed that there is a strong relationship between biomass, grain yield, and harvest index. The biomass and grain yield were positively and significantly correlated (r=0.61, p<0.001) while biomass yield and harvest index recorded a weak negative correlation (r=-0.02, p=0.9683). The results also depicted a strong positive correlation between grain yield and harvest index (r=0.78) and significant at P<0.0001 (Table 5).

4 Discussions

In LR2017 hybrids did not perform better than the parents, however in LR2018 and SR2018, Chaina I x Mwanza 2 was significantly superior to its reciprocal in biomass, grain yield, and harvest index. Variations in reciprocal crosses imply maternal influence on biomass, grain yield, and harvest index (Kivrak et al., 2020). Maternal influence has also been reported in the yield and harvest index in sorghum (Mengistu et al., 2020; Shinda et al., 2021), and in legumes (Ofori & Padi, 2020; Kamdar et al., 2020). Thus, to improve yield in chickpea using hybridization choice of parents is critical. This explains why Chaina 1 x Mwanza 2 biomass, grain yields, and harvest index were superior to its reciprocal cross. Maternal effects have been reported to influence hybrid vigour leading to MPH for biomass varying between 112% to 146% and BPH ranging from 63% to 124% in chickpea hybrids (Bayahi & Rezgui 2018). Although most of the previous studies have suggested positive heterosis in the studied parameters while some studies also suggested negative heterosis. Girma et al. (2017) observed negative heterosis in Chickpeas for mid-parent biomass ranging from -8.3% to 15 % and for the better parent from -21.7% to -8%. Similarly, Ceylan et al. (2019) also noted chickpea heterosis in biomass and other yield traits. Negative values for heterosis show the presence of the non-additive effect of genes in the parents (Bekele et al., 2021).

Parents expressed a higher grain yield in SR2017 than its hybrids. However, Chaina I x Mwanza 2 hybrid was superior in LR2018 and SR2018 than its reciprocal and parents. The cross Chaina I x Mwanza 2 posted superior BPH and MPH for grain yield in LR2018 of 330% and 405.88%, respectively compared to Mwanza 2 x Chaina I hybrid. The Mwanza 2 x Chaina I recorded BPH and MPH of 13.33% and 33.33% respectively that was better than the parents. This shows a significant difference between Chaina I x Mwanza 2 and its reciprocal cross. Differences between crosses and their reciprocal for yield improvement have been reported (Yasar et al., 2014) in chickpeas. Other reports are in groundnuts, sorghum, pearl millet (Kamdar et al., 2020; Daudi et al., 2021; Shinda et al., 2021; Patil et al., 2021b). This indicates the existence of maternal influence in *C. arietinum* hybrids. Studies in Chickpeas by Girma et al. (2017), reported positive heterosis in grain yield that ranged from 0.009% to 59.8% for a mid-parent and 0.009% to 39.9% for better parent heterosis. Studies by Rao & Lavanya (2020) also have reported heterosis values ranging from -11.15% to 6.29% for MPH and -12.28% to 4.79% for BPH in the Mung bean, while Sari et al. (2021), established high heterosis in hybrids between pea species (*P. sativum* and *P. fulvum)*.

Ceylan et al. (2019) enhance BPH and MPH heterosis for seed yield in chickpea. Srivastava & Singh, (2013) has also reported a 72.39% better parent heterosis in seed yield per plant in Mung bean. Other reports on yield improvement through heterosis are in pearl millet (Srivastava et al., 2020)**.** Positive heterosis in grain yield indicated the superiority of hybrids over mid-parent and better parent performance, thus providing the possibility of improving grains in chickpea varieties through hybridization.

The harvest index is a measure that indicates the ability of a crop to convert resources into output in form of grain or biomass yield (Pandini et al., 2002; Reynolds & Langridge, 2016). An improvement of crop harvest index means an increase in the economic portion of the crops at a certain level and provides information for the breeder to determine the next breeding method (Asefa, 2019). Heterosis of harvesting index was significantly better in Chaina I x Mwanza 2 hybrid than its reciprocal, which is an indication of better bioconversion of biomass to grains (Kivrak et al., 2020). Chaina I x Mwanza 2 performed better than Mwanza 2 x Chaina I with harvest index data ranging from 19.25% to 242.2% and 23.43% to 262.84% respectively. This existence of maternal influence Chaina I x Mwanza 2 and Mwanza 2 x Chaina I crosses. Panwar et al. (2021) reported an increased harvest index in chickpea cross of over 24.98% for hybrids. Also, increased harvest index ranging from 44 to 89% among mid-parents of chickpea crosses have been reported (Girma et al., 2017). Additionally, Yamini et al. (2015) reported an HI ranging from -40.35 to 23.41% over better parents value in chickpea crosses. Further findings of Kumar et al. (2017) determined increased seed yield and its components through heterosis in chickpea. Heterosis describes the improvement of an existing organism as determined by genetic factors of parents. In crops, heterosis is an agronomically important aspect as it defines superiority in performance in terms of biomass and yield concerning abiotic and biotic stress tolerance (Srivastava & Singh, 2013).

Heritability is a measure of how the contribution of genes in while heterosis is the capacity of F_1 hybrid organisms to exhibit enhanced phenotypes compared to those observed in either parent (McKeown et al., 2013). In this study heritability estimates (h^2) showed improvement of hybrids above the parents. Heritability for biomass was highest in Mwanza 2 x Chaina I (93 to 100%) cross, while Chaina I x Mwanza 2 expressed the highest estimate in grain yield (81.3% to 100%) showing capacity to improve these traits through hybridization. All hybrids expressed some harvest index differences between seasons. This suggests a possibility of additive genes that are prone to environmental influence, which in turn affects the performance of grain yield and biomass (Ref). This indicates the possibility of chickpeas genetic improvement especially for Chaina I x Mwanza 2 that performed that its reciprocal to Mwanza 2 x Chaina I. Sari et al. (2021) reported a heritability of 37% and 28% in biomass and grain yield of pea crosses respectively.

Positive heterosis possibility to select for high yielding F_1 for biomass, grain yield, and harvest index. Hybrid technology has been used to increase by over 20% in both cereal and legume crops (Birchler 2015). Thus, heterosis levels observed in the cross of Chaina I x Mwanza 2 can enable chickpeas yield improvement. This information will be helpful in the development of new higher-yielding chickpea varieties. Besides, the result of the current study indicating that inter-varietal hybridization has a maternal influence on biomass, grain yield, and harvest index is an indicator that screening is required to identify best performing plant candidates for hybrid seed production.

Studies of correlation among yield attributes are important in determining reliable information on the nature and level of interrelationships (Gupta et al., 2003; Panda et al., 2015). The results of the study showing a positive correlation due to genotypic traits (rg) between biomass and grain yield, and between grain yield and harvest index suggests the presence of high genotypic effects. However, results of negative correlation between biomass and harvest index (rg-0.00686) are in contravention with Padmavathi et al. (2013) who obtained a positive correlation rg = 0.52 in chickpea. Studies of correlation between biomass, grain yield, and harvest index were reported by Adem & Fike, (2018) who established a positive and highly significant genotypic correlation between biomass and grain yield (rg= 0.71) and with harvest index (rg= 0.52) in chickpea. Similar findings are reported by Kobraee et al. (2010), who established a positive correlation coefficient of rg=0.798 between biomass and grain yield (rg=0.76) in chickpea. This means that breeding for increased biomass could indirectly lead to yield and harvest index improvement. This is due to the high correlation between grain yield and harvest index.

Conclusion and recommendations

Based on the findings of the current study, there is potential in improving the productivity of chickpeas in the country. The highest mid-parent and better-parent heterosis were observed in Chaina I x Mwanza 2 and it was significantly lower than its reciprocal. Although, there is a maternal influence in chickpeas crossing but heterosis was better in Chaina I x Mwanza 2. Further, heritability estimates on biomass, grain yield, and harvest index were potentially higher for Chaina I x Mwanza 2 hence it has greater potential for higher selection response in the traits improvement. The study recommends Chaina I x Mwanza 2 hybrid for chickpea as grain yield improvement.

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Conflict of interest

There is no possible conflict of interest declared as concerns the publication of this paper.

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