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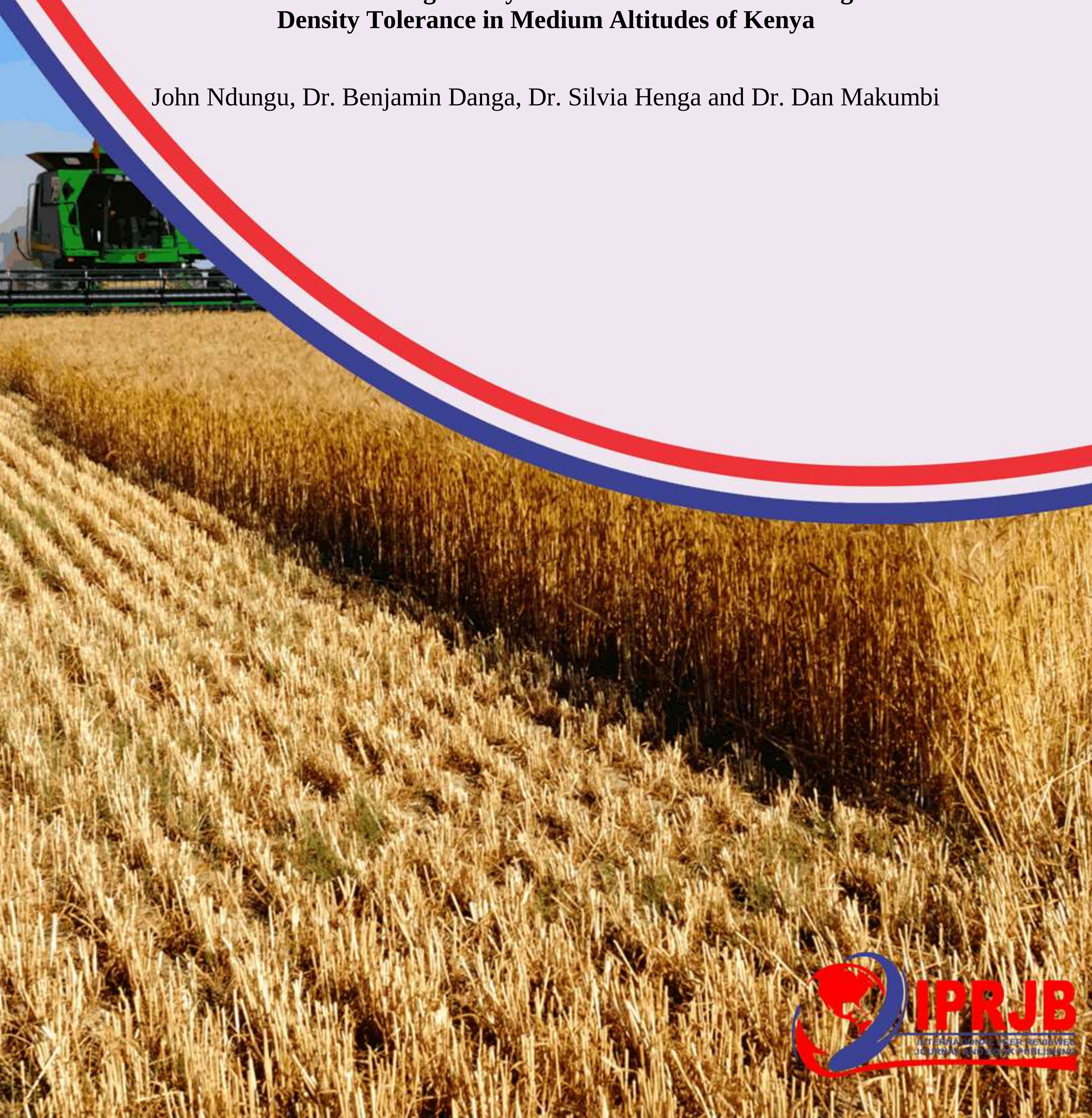
John Ndungu, Dr. Benjamin Danga, Dr. Silvia Henga and Dr. Dan Makumbi



Estimation of Combining Ability of Maize Inbred Lines for High Plant Density Tolerance in Medium Altitudes of Kenya

John Ndungu
Student: Kenyatta University, CIMMYT Kenya
Dr. Benjamin Danga
Department of Agricultural Science and Technology: Kenyatta University.
Dr. Silvia Henga
Department of Agricultural Science and Technology: Kenyatta University.
Dr. Dan Makumbi
Senior Scientist, International Maize and Wheat Improvement Centre- CIMMYT Nairobi

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Abstract

Purpose: The primary objective of any breeding program was to increase yields, thus superior lines based on yields are used as parents. After parents' selection, hybrids may not perform as expected because the performance is influenced by the interactions of genotypes used, which the breeder must be well conversant with for accurate prediction of the ultimate hybrids.

Methodology: This study aimed at characterizing tropical maize germplasm on plant density tolerance and comparing combining abilities for grain yield on 120 hybrids obtained by crossing 24 males with 30 female lines using North Carolina design 2 (sets option). This was done under low (53,333), medium (66,666), and high density (88,888) plants per ha in three different zones; Kiboko (marginal zone), Embu (transitional medium), and Kakamega (upper medium). General combining ability (GCA) of 54 maize inbred lines was estimated and specific combining ability (SCA) established for 120 hybrids in 6 sets of 20 each based on family decent. They were evaluated under optimal conditions in the 3 sites named above. Evaluation was done at low, medium and high plant densities under study. The hybrids were planted in a 31*8 alpha lattice design, four local commercial varieties incorporated as checks, and the experiment replicated twice. Data collected included various agronomical traits associated with tolerance to high plant density. Field book software (CIMMYT) was used to organize data and perform preliminary analysis while SAS program (Frederick, 1999) was used to compute analysis of variance (ANOVA) for North Carolina design 2 (NC2).

Findings: Observation revealed increase in plant height, grain yield, ear height, anthesis silking interval, days to 50% silking but lead to reduction in leaf angle with increase in plant density from 53,333 to 66,666 and then to 88,888. Six hybrids were significantly earlier than the check hybrids CKH10717, H517, WH505 and PHB30G19 under the 3 densities. In contrast, 6 varieties were later than all the above checks for the 3 densities. Line CKL15276 had the highest GCA effects for anthesis and days to silking at the three plant densities and highest grain yield at 66,666 plant density. In contrast female line CKL15303 had the highest negative GCA effects for anthesis and days to silking at the three plant densities revealing earliness traits. Likewise, lines CML444, CML 436 and CKL151431 had highly significant GCA effects for field and grain weights. The hybrid CKH 156598 had the highest significant SCA effects for grain yield at 66,666 plant density and for field weight at the three plant densities.

Unique Contribution to Theory, Practice and Policy: The study was informed by Diallel Crossing Theory and conducting systematic field trials, researchers can gain insights into the genetic effects of combining different maize inbred lines and identify potential candidates for developing maize varieties with improved high plant density tolerance in the specified region. This reveals presence of superior alleles and desirable SCA effects and thus can be utilized as parents in hybrid formation and further breeding work. The study also recommends that support should be garnered from relevant government agencies and policymakers to allocate resources for the collaborative network's activities. Advocate for policies that promote research and development in maize breeding for high plant density tolerance.

Keywords: *Maize, Combining Ability, Superior Alleles, Plant Densities*

INTRODUCTION

Maize is a very important crop in Sub-Saharan Africa (SSA) acting as staple crop in Eastern Africa region and source of income to many in the world. Yields in Sub Saharan Africa is one of the lowest averaging to 1.9 tons per ha in 2018. Average yields in several Asian countries still lag below 3 tons per ha. (Prasanna; Pelacios-Rofas, et al,2020). Productivity of tropical areas is compared to 46% of temperate areas. Yields in most growing areas in Kenya are far much below the potential production. Productivity in Western Kenya and Victoria basin average to 1.3 tons/ha (Hassan, 1998) which is 25% less than potential production of 5tons/ha (Tittonell, Vanlauwe, Leffelaar, Shepherd & Giller., 2005) under rain condition. In rift-valley low plant density, lack of good quality fertilizers, biotic and abiotic stresses such as Maize lethal necrotic disease (MLND), erratic rains and use of low-quality seed has been pinpointed as the major drawback in maize productivity.

Yield in the field is greatly influenced by the crop spacing. There is an optimum plant density for each crop in any particular environment (Mac Robert, J.F 2009). Research has shown that, improved high plant density tolerance through selection have increased total yield potential per unit area rather than yield potential per plant (Duvick et al., 2004; Tollenaar & Lee,2002). This study aimed at examining the performance of several maize germplasm after subjecting them to 3 different planting densities for physiological, grain yields and kernel quality traits attributable to their genetical make-up. The plant populations were varied at; low (53,333 plants/ha), medium (66,666 plants /ha) and high (88,888 plants per ha) in three different environments. A set of 120 progenies were produced by mating 24 males and 30 females using North Carolina mating design 2 with the procedures developed and evaluated statistically by Comstock and Robinson (1952) for evaluating inbred lines for general combing ability (GCA) and specific combining ability (SCA) of the hybrids. The study also had an objective of assessing the traits contributing to higher plant density in maize and evaluating plant density effect on maturity and yield in maize.

Mating was performed among tropical and temperate maize lines with broad diversity whose hybrids crosses were evaluated in 3 sites namely; Kiboko (Marginal zone), Embu (transitional medium), and Kakamega (upper medium). Four local commercial varieties were incorporated in the experiment as checks in the experiment. Each experimental plot was replicated twice.

Problem Statement

The increased food requirement due to the corresponding population growth in Eastern Africa has forced the agriculture sector to adopt farming technique of optimum land use in the available but scarce arable land in order to ensure maximum returns. This therefore calls for adapting to superior and better performing genotypes. This study aims at examining the response of several maize hybrids to 3 different planting densities for physiological, morphological and grain yield quality traits attributable to their genetical make up.

MATERIALS AND METHODS

Genetic Materials

This study used a set of 54 inbred lines developed by the CIMMYT maize breeding program in Kenya, Zimbabwe (11 lines) and Mexico (one line) (Table 1). Out of the 54 lines, seven were CIMMYT maize lines (CML) and the rest were elite breeding lines. Four of the lines from Kenya were doubled haploid (DH) lines. The lines were selected based on their performance in hybrid combinations when tested under various conditions including optimum, managed drought stress, and random drought stress (CIMMYT, unpublished data). The 54 lines were divided into six sets each with nine lines.

The inbred lines were crossed following a North Carolina Design II factorial mating scheme with the sets option. The crosses were made at Kenya Agricultural and Livestock Research Organization (KARLO) Kiboko Research Station (37^{o}75E', 2^{o}15'S, 975m asl) in Kenya. In the nursery, each line was planted on one row; 4 m long spaced 0.75 m between rows and 0.20 m between plants. The lines in a set were crossed by utilizing some as females (five lines) and the others as males (four lines) to minimize the number of hybrids to generate (Table 1). Thirty lines were used as females and 24 were used as males. Six nurseries were planted, one for each set. At planting di-ammonium Phosphate (DAP) fertilizer was applied at the rate of 125kgs/ha. Top-dressing was done four weeks after sowing using CAN fertilizer at a rate of 125kgs/ha. Weeding was done by hand to keep the experimental plot clean. Each of the five female lines was planted in row next to a male line row of the same set. At the on-set of shoot emergence, bagging was done on the emerging ear shoots to prevent possible unwanted pollination. At tasseling, a tassel bag was used to cover the tassel to collect pollen. Reciprocal crosses were made between two lines. Reciprocal seed was bulked to form one hybrid. This setup resulted in formation of 20 hybrids per set, making a total of 120 hybrids among the 54 lines.

Trial Information

The hybrids tested comprised of the 120 hybrid progenies which resulted from crossing 54 lines (30 females and 24 males). Four commercial checks namely; D904-1 a variety developed by CIMMYT, H517 and WH505 both varieties registered by Kenya Seed Company and PHB30G19 registered by Pioneer International limited were incorporated in the experiment. Each plot comprised of 2 rows 4m long spaced at 0.75m apart and inter-plot spacing kept at 0.75m. The distance between the planting hills was set at 25cm, 20cm and 15cm forming the three planting densities under study, which were randomized within entries to optimize precision when evaluating response to the different densities in the experiment set-up. The densities resulted to a population of: 53,333 plants ha^{-1} (PD1), 66,666 plants ha^{-1} (PD2) and 88,888 plant ha^{-1} (PD3). The experiment was conducted under optimum and rain-fed conditions in three sites; Kiboko (marginal zone intermediate), Embu (transitional) and Kakamega (upper medium). Irrigation was done at Kiboko site to supplement rainfall.

Experimental Design

The field layout was alpha lattice design (Patterson and Williams.1976) of 31 incomplete blocks of 4 plots (8 rows) per block and the treatments (varieties) replicated twice. Genotypes were considered fixed effects, while as replications, blocks within replications and environment (locations contributions) were considered random effects.

Experimental Sites and Evaluation of the Hybrids to the Different Plant Densities

Three field trials were planted at Kiboko, Embu and Kakamega in Kenya. Kiboko is situated 37^{0}E75', 2^{0}5'S and 975m ASL. Soil type at Kiboko is sandy clay classified as Acri-Rhodic Ferrasol. Rainfall at Kiboko stands at 595 mm annually, distributed in two seasons per year (April-May and October to-January). Kiboko area receives a mean minimum daily temperature of 14.3^{0}C and a maximum of 35^{0}C. Embu site is situated 37^{0}27' E, 0^{0}30'S; 1510m asl and the soil type is clay loam under the class of Humic Nitisol. Annual average rainfall at Embu is 1200mm, at two times a year (March-July and September- November). Embu area receives an average daily temperature of between 14.1^{0} C to 25^{0} C

Soil type at Kakamega site ($34^0 49^` E, 0^0 16'N$, 1534m asl) is classified as Eutric Nitisol. Kakamega receives an annual rainfall of 1850mm, distributed 2 times per year (March-July and September –November). Minimum average daily temperature in Kakamega is 12.8^{0}C and a maximum of 28.6^{0}C.

Before seeding in the bed, the field was subjected to a deep tillage during the land preparation phase. Pre-emergence herbicide of Glyphosate (Round-up) was incorporated 2 weeks prior to planting. Basal fertilizer of DAP at the rate of 125kgs/ha was well mixed with soil followed by seed sowing. Two seeds per hole were seeded and thinned after two weeks leaving one plant per hill. Experimental plot was kept weed free by regular manual weeding. Top-dressing fertilizer of C. A. N at the rate of 125kgs/ha was used to replenish the nitrogen and calcium levels of the soil four weeks after sowing. Bull dock star was used to control stalk borers and other destructive insect pests.

Data Collection for Agronomic Traits

The parameters were taken on 6 plants per plot; three from each row taken at random avoiding the last plants on either side of the row. The traits were as follows:

1. Anthesis –silking interval- Difference in days when 50% of the plants in the entry began shedding pollen and 50% began producing silks.
2. Ear height-Height from the ground to the point of the upper cob taken using a ruler calibrated in cm.
3. Days to silking (DS)-Number of days from planting to 50% silk emergence in a particular entry.
4. Days to anthesis (AD) - Number of days from planting to 50% pollen shedding in an entry.
5. Root lodging (RL) –Percentage of plants leaning at an angle > 30^0
6. Stem lodging (SL) Percentage of plants with broken stalks at or below the main ear at harvesting.
7. Plan height (PH) – Height from the ground to the point of flag leaf measured with a ruler calibrated in cm.
8. Lower Stem diameter (DB-Av)- Taken by measuring the circumference on third internode below the flag leaf.
9. Upper stem diameter (DA-Av)- Taken by measuring the circumference of the third internode below the flag leaf.
10. Grain yield (based on both cob weight and grain weight) (GY)- GY= Field weight/1000*{(100-grain moisture)/ 87.5* (10,000)/ plot area)} *shelling %
11. Shelling % is determined by subtracting the weight of cobs which is assumed to be 20% of the total cobs.
12. Ears per plant (EPP) - Number of ears with at least one fully developed grain harvested per entry/ No. of plants harvested in an entry.
13. Ear aspect (EA) - Rating on a scale of 1-5 with 1 representing nice uniform and preferred texture and 5 representing ugly wrinkled cobs with undesired texture.
14. Plant aspect (PA) - Visually scored on a scale of 1-5 where 1= excellent overall phenotypic appeal and 5= poor overall phenotypic appeal.
15. Leaf angle (LA) - Measured on the third leaf below flag leaf.
16. Leaf area (estimated total) L. Area. -Ear leaf area (L*W) 0.73+sum of UplfArea*0.73 (weighted factor).

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17. Total leaf area. (TotLfArea)- Ear leaf area (L*W) 0.73+ Area of all leaves above the ear.
18. Leaf number (Novae) - Number of leaves above the upper ear including ear leaf recorded at grain filling stage (blister stage to physiological maturity stage).
19. Tassel branch length (TotTsBrL)- Total tassel branch length taken by measuring all branches and spikelet with a ruler.
20. Tassel branch number. (NoTsBr)- Counts on the number of tassel branches including the spikelet.

Statistical Analysis

The design used in the analysis is a two-way analysis of variance (Anova) and source of variation was separated between males (m), females (f) and male x female interaction. Anova for NCII was carried out according to the model of SAS program (Frederick, 1999).

Combining ability analysis was performed following a linear model using SAS program (Hallauer et al., 2010). Significant difference between value of means in the experiment were calculated using least significant difference (LSD) following Steel et al (1997)

In order to assess the traits contributing to tolerance to high plant density, and deduce the relationship between secondary traits and grain yield in mid-altitude maize germplasm, data on various morphological traits related to the grain yield in sampled maize plants per plot of individual hybrids were taken. The traits were highlighted above.

RESULTS AND DISCUSSIONS

GCA and SCA Effects across Sites for the Three Plant Densities

The mean performances of all the parents and their crosses are presented in Table 2. The female lines CKL14357 had the highest negative and significant GCA effects on anthesis days and days to silking at 66,666 (PD2) and 88,888 (PD3) plant densities. Similarly, the female line CKL15303 had the highest negative significant GCA effects for anthesis days at 53,333 plant densities. This revealed the presence of early maturity alleles in the two lines. The male line CML539 had the highest negative GCA effect for plant height at PD2 and PD3. This line had also the highest negative GCA effect for total leaf area at all the plant densities, field weight at PD3, and upper stem diameter at PD1 and PD2. The line had also the highest negative GCA effects for plant aspect at PD1, plant height at PD2 and PD3. The female line CKL12416 had the highest negative GCA effects for total tassel branch length at PD2 and PD3. This line had also a general negative GCA effects for field weight and grain weight at the three plant densities. In contrast, the male line CML14504 had the highest GCA effect for total tassel branch length and number of tassel branches at all the three plant densities. This line had a general positive GCA effects for field weight and grain weight {Table 2}. The male line CKL 151420 had the highest GCA effects for plant height at PD1 and PD3 which revealed presence of alleles for lateness.

The female line CKL 14337 had the highest GCA effects for ear aspect for PD1 and PD2, negative GCA effects for root lodging at PD2 and a negative GCA for leaf angle at PD3. This line revealed presence of alleles for good standability, and small leaf angle allowing infiltration of light in the lower canopy thus tolerance to higher plant density. The female line CKL14357 had the highest negative GCA effects for days to silking at PD2 and PD3. This expressed the presence of early maturity alleles in the line. The male line CML444 had the highest negative GCA effects for ear aspect at PD1 and PD2, highest GCA effects for field weight at PD1, and highest significant GCA effects for ear height at PD1 and PD2.This revealed the presence of high yield and tallness alleles, The male line CML 536 had the highest significant GCA effects for plant aspect at PD1, PD2 and PD3, number of ears per plant at PD1and PD2 , highest significant GCA effects for total leaf area and highest and significant GCA effects for field weight at PD3. The female line CKL 12416 had the highest negative significant GCA effect for total tassel branch length, at PD2 and PD3. Line CKL 14546 had the highest negative significant GCA effects for field weight at PD1 and PD2. CKL 15388 had the highest negative GCA effects for stem lodging at the three plant densities, while CKL 15363 had the highest GCA effects for the same trait at PD1 and PD2. This shows good standability of the first line and weakness of the second line which is prone to stem lodging. The female line CKL 15276 had the highest GCA effects for anthesis days and days to silking at the three plant densities and grain weight at PD2. Line CKL12128 had the highest negative significant GCA effects for leaf angle at PD2 and PD3. The first line has alleles for lateness and high grain weight. Similarly, male line CKL14162 had the highest GCA effects for field weight at PD2 expressing superiority for yield qualities.

SCA Effects

The hybrid CKH156485 had the highest negative significant SCA effects for anthesis days at PD1 revealing presence of early maturity alleles while as CK156531 had the highest significant SCA effects for the trait at the same density which expressed presence of late maturity alleles. CKH156508 had the highest negative significant SCA effects for anthesis days at PD2 revealing presence of early maturity alleles, while CKH156524 had the highest significant SCA effects at the same density showing presence of late maturity alleles. The hybrid CKH156522 had the highest and significant SCA effects for anthesis silking interval at PD1 while CKH 156505 had the highest negative SCA effects for the trait at the density signifying alleles for earliness. CKH156517 had the highest negative significant SCA effects for anthesis days at PD3 and the highest SCA effects for ASI at the same density. CKH 156503 had the highest significant SCA effects for leaf angle at PD1.These angles reduces at PD2, and further at PD3. The hybrid CKH 156507 had the highest and significant SCA effects for anthesis days at PD3 and highest negative significant SCA effects for the trait at PD3 and highest negative SCA effects for upper stem diameter at PD1. The hybrid CKH156644 had the highest and significant SCA effects for upper stem diameter at PD1 and the highest negative SCA effects for the trait at PD2. Hybrid CKH156501 had the highest negative significant SCA effects for ear aspect at PD3, ear height at PD3 and highest grain weight at PD1. Hybrid CKH156518 had the highest significant SCA effects for ear height at PD1 and PD2 and highest SCA effects for ears per plant at PD1. CKH156522 had the highest significant SCA effect for days to silking at PD1 and PD3. The hybrid CKH156526 had the highest negative SCA effects for days to silking at PD1 and PD2 and highest negative SCA effects for field weight at PD1.

The hybrid has line CML 536 as male parent which had the highest GCA effects for field weight at PD3 showing its effectiveness in transferring yield qualities from the parent to its offspring. The hybrid CKH 156507 had the highest significant SCA effect for anthesis days, highest negative significant SCA effect for anthesis silking interval at PD3 and highest negative significant SCA effect for upper stem diameter at PD1. Hybrid CKH 156496 had the highest significant SCA effect for plant aspect at PD3, highest SCA effect for plant height at PD2 and the highest SCA effects for root lodging at PD1. Also, the hybrid had the highest significant SCA effects for total tassel branch length at PD1and PD3. CKH156488 had the highest negative significant SCA effects for total leaf area at PD3 while CKH156518 had the highest negative significant SCA effects for the same trait at PD2. Both of these hybrids had a general low and negative SCA effects for field weight and grain weight {Table 2c)}. CKH156534 had the highest significant SCA effects for the trait total leaf area at D1 while CKH156542 had the highest negative insignificant SCA effects for the trait at the same density. CKH 156535 had the highest negative significant SCA effects for stem lodging at PD2 while CKH 156552 had the highest significant SCA effects for the trait at the density. The hybrid CKH 156500 had the highest negative significant SCA effects for leaf angle at PD1 and highest negative insignificant SCA effects for the trait at PD2. The hybrid CKH156598 had the highest significant SCA effect for field weight at the three plant densities and the highest significant SCA effect for grain yield at PD2 and PD3 (Table 2). This hybrid had the highest significant SCA effects for number of leaves above the ear at PD2. The hybrid had the highest significant SCA effects for plant aspect at PD2 and PD3. The hybrid also had the highest negative SCA effects for stem lodging at PD3 and the highest significant SCA effects for total leaf area at PD2 and PD3. This hybrid thus has traits for high yields and resistance to stem lodging which are superior qualities during selection

Heritability

This refers to variation in a phenotypic trait due to genetical factors. It is composed of organism's expression of genotype, influence of environmental factors, and the interactions of genes and environment. Heritability is a key factor in achieving genetic gain for timely release of new varieties meeting farmers and consumers expectations and needs. In the table below leaf angle had a heritability of 0.92 at the three plant densities. Leaf length had a heritability of 0.74 at 53,333 plants/ha, 0.94 at 66,666 and 0.95 at 88,888plants/ha. Days to anthesis had a heritability of 0.88 at 53,333 plants/ha, 0.86at 66,666 plants/ha and 0.96 at 88,888 plants/ha. Grain weight had a heritability of 0.64 at 53,333plants/ha, 0.72 at 66,666 plants/ha and 0.88 at 88,888plants/ha (Table 3.1.5). Compared to other traits, field and grain weight has low heritability thus other traits with higher heritability are considered during selection.

Table 1: Heritability in the Three Planting Densities

	53,333 Plants/ha				66,666 Plants/ha				88,888 Plants/ha			
Trait	Min	Max	Mean	Heritability	Min	Max	Mean	Heritability	Min	Max	Mean	Heritability
Lower stem diameter (DA)	5.7	7.79	6.96	0.71	5.76	8.2	6.66	0.61	6.14	8.04	7.03	0.64
Upper stem diameter (DA)	7.56	14.69	8.79	0.24	7.34	12.64	8.42	0.2	7.59	11.13	8.92	0.59
Leaf angle	19.3	50.5	33.64	0.92	19.8	49.58	31.5	0.92	13.4	53	31.12	0.92
Leaf length	74.6	109.5	96.77	0.74	64.4	91.12	78.8	0.94	64.5	91.6	77.9	0.95
leaf width	8	59.75	10.16	0.05	7.31	24.19	8.77	0.3	7.33	10.17	8.68	0.8
Days to anthesis	66	84	75.92	0.88	65.3	85.07	76.7	0.86	63.5	83.42	75.68	0.96
Anthesis silking interval	-5	12.5	0.46	0	-13.5	5.52	0.25	0	-3.58	6.52	0.29	0.48
Days to silking	66	86.5	76.38	0.84	65.9	84.98	76.9	0.95	65.5	83.5	75.97	0.95
Ear aspect	2	3	2.7	0.56	1.75	4.25	2.89	0.79	1.89	4.53	2.7	0.55
Ear height	48.5	139.33	104	0.5	58.6	151.1	113	0.18	70.3	157.02	119.8	0.6
Ears per plant (EPP)	0.78	1.23	1	0.28	0.54	1.44	1.01	0	0.78	2.2	1.05	0
Grain yield (Field weight)	3.75	10.05	7.08	0.64	3.71	11.4	7.03	0.66	3.19	11.78	7.23	0.49
Grain yield (Grain weight)	3.98	9.8	7.03	0.64	3.7	11.38	6.99	0.72	3.3	11.2	7.21	0.43
plant height	185	285	242.8	0.69	196	284.5	246	0.42	215	286.99	254.6	0.5
Root lodging	-3.22	59.93	11.38	0.43	-1.85	32	9.33	0.32	0	63.5	9.48	0.23
Stem lodging	0	23	1.82	0	-2.97	61.2	6.52	0.65	0	39.5	4.71	0.01
Total tassel branch length	457	748.17	560.1	0.69	239	544.2	371	0.69	261	524.08	384.7	0.88

CONCLUSIONS AND RECOMMENDATIONS

Increase of plant density from 53,333 to 88,888 through 66,666 plants per hectare lend to an increase in field grain yield. In the current study, there was an observation of great increase of field grain yield in the initial increase in plant density up to an optimum point where further increase in plant population lend to a decrease in grain yield. This probably due to interspecific competition for growth factors such as nutrients, water, oxygen and light which becomes a limiting factor at a higher planting density.

Increasing plant population from 53,333 to 66,666 plants per hectare corresponded to an increase to the tassel length and grain yield, but a further increase in population lend to reduction in total tassel branch length but an increase in field grain yield. Observation done has shown that, there is a lot of variability in germplasm response to elevated plant density. This implies that elaborate trials on germplasm should be conducted to establish optimum plant density of individual variety for maximum productivity.

Increase in plant density from 53,333 to 66,666 then to 88,888 lend to a consistent reduction in leaf angle at the upper canopy. This is a morphological adjustment of the plant to enable light penetrate to the lower canopy through the upper canopy. Germplasm with ability to adjust leaf angle at higher plant density are associated with tolerance to high plant density thus high yields.

Recommendations

Germplasm identified to be tolerant to high plant density should be evaluated further in multiple locations for validations and then released to farmers.

Germplasm identified to have high yields but undesirable other agronomic traits should be used as donor materials for introgression into high density tolerance to locally adopted materials

Germplasm found to be early but are poor yielders should be used as donor parents for crossing late high yielders to introduce genes for earliness. Selection should be based at both optimum and drought environments and at both high and low density to allow maximum expression of yield potential

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Appendix

Table 2: List of Lines Crossed to Make Single Cross Hybrids for the Study

Entry	Name	Pedigree	Origin	Female	Male	SET
1	DL14337	(CKL05005/PHG39)-B-1-3-1-1-1-B-B-B	Kenya	1		1
2	DL14345	(CKL05010/LH51)-B-3-1-1-3-1-B-B-B	Kenya	2		1
3	DL14354	(CKL05010/LH51)-B-5-1-4-3-1-B-B-B	Kenya	3		1
4	DL14355	(CKL05010/LH51)-B-5-1-4-3-2-B-B-B	Kenya	4		1
5	DL14357	(CKL05013/LH123.HT)-B-1-8-2-1-2-B-B-B	Kenya	5		1
6	CML312	CML312	Mexico		1	1
7	CML395	CML395	Zimbabwe		2	1
8	CML444	CML444	Zimbabwe		3	1
9	CML537	CML537	Zimbabwe		4	1
10	DL14363	(CKL05015/LH51)-B-2-2-2-1-1-B-B-B	Kenya	1		2
11	DL14371	(CKL05019/LH51)-B-2-1-2-2-2-B-B-B	Kenya	2		2
12	DL14380	(CKL05019/LH51)-B-2-5-1-1-2-B-B-B	Kenya	3		2
13	DL14374	(CKL05019/LH51)-B-2-3-1-3-1-B-B-B	Kenya	4		2
14	DL14376	(CKL05019/LH51)-B-2-4-3-1-1-B-B-B	Kenya	5		2
15	CML539	MAS[MSR/312]-117-2-2-1-B*3-B-B-B-B	Zimbabwe		1	2
16	CML536	CML536	Zimbabwe		2	2
17	CML538	ZM621A-10-1-1-1-2-B*11-B-B (CML538)	Zimbabwe		3	2
18	CML540	CML540	Zimbabwe		4	2
19	DL14390	(CKL05024/LH132)-B-1-1-2-1-2-B-B-B	Kenya	1		3
20	DL14397	(CKL05024/LH132)-B-1-3-1-1-1-B-B-B	Kenya	2		3
21	DL14401	(CKL05024/LH132)-B-1-3-1-2-2-B-B-B	Kenya	3		3
22	DL12416	(CKL05004/CML269/TX130-BBB-1-1-B*5-B)-B-8-2-2-3-1-B	Kenya	4		3
23	DL12419	(CKL05004/CML269/TX130-BBB-1-1-B*5-B)-B-8-2-5-1-2-B	Kenya	5		3
24	CL106749	([[CML388/CML391]-BB-5-2/CML390]-2-1-2-1/[[KILIMA(ST94)-S5:101/CML442]-BB-1-1/CML390]-3-3-1-2)-2-5-1-1-B-B-B-B	Zimbabwe		1	3
25	CL115339	(CML537/[[KILIMA(ST94)-S5:101/CML442]-BB-1-1/CML390]-3-3-1-1-1)-B-5-3-2-B-B-B	Zimbabwe		2	3

26	CL114162	([LZ956441/LZ966205]-B-3-4-4-B-5-B*7/LaPostaSeqC7-F71-1-2-1-1-BBB)-1-7-1-1-BB-B-B	Zimbabwe		3	3
27	CL106671	[MAS[MSR/312]-117-2-2-1-B*5/ZM621A-10-1-1-1-2-B*7]-B-10-1-BBB-B-B	Zimbabwe		4	3
28	DL15276	((CKL05003/LH51) BC2F1)-B-5-3-3-B	Kenya	1		4
29	DL15280	((CKL05003/LH123.HT) BC2F1)-B-6-2-1-B	Kenya	2		4
30	DL15284	((CKL05003/LH82) BC2F1)-B-22-1-2-B	Kenya	3		4
31	DL15291	((CKL05006/LH82) BC2F1)-B-4-2-1-B	Kenya	4		4
32	DL15296	((CKL05006/LH82) BC2F1)-B-4-3-3-B	Kenya	5		4
33	DL12128	((KU1403 x 1368)-7-2-1-1-B-B/CML444)-B-8-2-7-1-4-2-1-B-B-B	Kenya		1	4
34	DL12134	((KU1403 x 1368)-7-2-1-1-B-B/CML444)-B-8-7-3-2-4-1-2-B-B-B	Kenya		2	4
35	DL14500	([CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-1-1-B*4/(9071xBabamgoyo)-3-1-BBB)-B-1-2-3-1-1-B-B-B	Kenya		3	4
36	DL14501	([CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-1-1-B*4/(9071xBabamgoyo)-3-1-BBB)-B-1-2-3-1-2-B-B-B	Kenya		4	4
37	DL15303	((CKL05006/LH82) BC2F1)-B-12-2-3-B	Kenya	1		5
38	DL15325	((CKL05017/PHW52) BC2F1)-B-3-3-1-B	Kenya	2		5
39	DL15327	((CKL05017/PHW52) BC2F1)-B-4-4-1-B	Kenya	3		5
40	DL15343	((CKL05022/LH132) BC2F1)-B-12-3-1-B	Kenya	4		5
41	DL15354	((CKL05022/LH82) BC2F1)-B-13-2-1-B	Kenya	5		5
42	DL14504	ECAVL29-2-3-3-1-1-2-B-B-B	Kenya		1	5
43	DL14546	(CKL05017/LaPostaSeqC7-F78-2-1-1-1-B-B-B)-B-2-1-2-1-1-B-B-B	Kenya		2	5
44	DL151420	ECAVL21-37-3-3-1-1-2-B-B	Kenya		3	5
45	DL151431	ECAVL28-91-3-3-3-1-B-B-B	Kenya		4	5
46	DL15363	((CKL05022/PB80) BC2F1)-B-3-2-3-B	Kenya	1		6
47	DL15382	((CKL05022/PHW52) BC2F1)-B-9-2-1-B	Kenya	2		6
48	DL15388	((CKL05022/PHW52) BC2F1)-B-20-1-3-B	Kenya	3		6
49	DL15395	((CKL05004/CML269/TX130-BBB-1-3-B*5-B) BC2F1)-B-3-1-1-B	Kenya	4		6
50	DL15398	((CKL05004/CML269/TX130-BBB-1-1-B*5-B) BC2F1)-B-2-1-1-B	Kenya	5		6
51	DL1558	(CKL05003/CML444//CKL05003) DH5-B-B-B-B-B	Kenya		1	6
52	DL1571	(CKL05003/[CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-1-1-BB-B-B) DH57-B-B-B-B	Kenya		2	6
53	DL1588	(CKL05003/La Posta Seq C7-F180-3-1-1-1-B-B -B) DH56-B-B-B-B	Kenya		3	6

54	DL15183	(CKL05003/[CML444/CML395//DTPWC8F31-1-1-2-2-BB]-4-2-2-2-2-BB-B-B) DH179-B-B-B-B	Kenya		4	6

Table 3a: Estimates Of Combining Ability Effects On Agronomic Traits Of 54 Inbred Lines Across Locations (Kiboko, Embu And Kakamega) Under 3 Plant Densities (October 2016).

	Field weight			Grain weight			Leaf angle			Number of leaves above ear		
PARENTS	**PD1**	**PD2**	**PD3**	**PD1**	**PD2**	**PD3**	**PD1**	**PD2**	**PD3**	**PD1**	**PD2**	**PD3**
CKL14337	-1.29***	-1.17***	-0.99***	0.2	-1.11***	-0.8***	-6.06***	-5.42***	-6.33***	0.06*	0.09*	0.11**
CKL14345	0.75***	0.62***	0.88***	0.28	0.71***	0.77***	1.24**	0.82*	1.26**	0.35***	0.24***	0.25***
CKL14354	0.45**	0.49**	0.37*	0.01	0.52**	0.36*	2.76***	1.1**	2.3***	-0.40***	-0.33***	-0.41***
CKL14355	0.24*	-0.04	-0.06	0.80*	0.01	-0.07	0.45	1.86***	1.93***	-0.20***	-0.06*	-0.16***
CKL14357	-0.15	0.09	-0.2	0.05	-0.13	-0.25*	1.60***	1.63***	0.83*	0.19***	0.06*	0.2***
CML312	0.28**	0.77***	0.52**	0.11	0.78***	0.66***	-1.88***	-3.79***	-1.59***	0.17***	0.04	0.17***
CML395	-0.94***	-0.91***	-1.36***	0.08	-0.96***	-1.41***	7.08***	9.29***	7.73***	-0.16***	0.03	-0.09**
CML444	1.00***	0.67***	0.58***	0.32	0.81***	0.48**	-2.31***	-1.82***	-2.64***	-0.10**	-0.21***	-0.17***
CML537	-0.34**	-0.52***	0.27*	0.12	-0.62***	0.27*	-2.90***	-3.67***	-3.5***	0.09**	0.14***	0.08**
CKL14363	0.33**	0	0.15	-1.14	0.19*	-0.09	-0.62*	1.54***	1*	-0.19***	-0.05*	-0.21***
CKL14371	0.08	0.19*	0.38*	0.47**	0.2*	0.56**	-0.40	0.25	-0.04	0.03	0.02	0.13**
CKL14374	0.09	0.08	-0.05	0.65***	0.03	-0.08	-0.35	-1.69***	-1.38**	0.08*	-0.05*	0.08*
CKL14376	-0.24*	-0.42**	-0.15	0.56***	-0.37**	0.09	2.50***	2.35***	2.49***	-0.04	-0.05*	-0.09*
CKL14380	-0.26*	0.15	-0.32*	-0.81***	-0.04	-0.48**	-1.13**	-2.45***	-2.06***	0.11**	0.14***	0.09*
CML536	0.86***	0.91***	1.17***	-0.64	0.8***	0.86***	4.50***	3.68***	3.9***	0.33***	0.31***	0.32***
CML540	-0.04	-0.09	-0.11	-0.45**	-0.07	-0.09	-2.20***	-2.21***	-2.16***	0.24***	0.26***	0.26***
CML539	-0.60***	-0.93***	-1.37***	0.24*	-0.89***	-1.09***	3.53***	2.56***	3.29***	-0.48***	-0.43***	-0.44***
CML538	-0.22*	0.1	0.31*	-0.23*	0.16*	0.33*	-5.84***	-4.03***	-5.03***	-0.09**	-0.14***	-0.14***
CKL12416	0	0.12	0	-0.88***	0.1	-0.03	0.44	-0.28	-0.41	-0.03	-0.06*	-0.13**
CKL12419	-0.07	-0.38**	-0.48**	0.14*	-0.46**	-0.65**	-1.83***	-0.36	-0.85*	-0.11**	-0.02	-0.08*
CKL14390	0.24*	0.09	0.02	-0.17*	-0.04	-0.14	-0.36	-0.9*	-0.78*	0.09**	-0.04	0.17***
CKL14397	-0.10	-0.04	0.36*	-0.12	0.22*	0.62**	1.83***	2.88***	2.78***	0.09*	0.15***	0.13**
CKL14401	-0.08	0.2*	0.09	0.15*	0.18*	0.21	-0.08	-1.35**	-0.75*	-0.04*	-0.02	-0.09*
CL115339	-0.99***	-1.01***	-1.09***	-0.10	-1.14***	-1.22***	0.28	-0.7*	0.54*	0.28***	0.17***	0.26***
CL114162	0.74***	0.98***	0.88***	0.54***	0.97***	0.91***	-2.06***	-2.04***	-2.24***	0.04	0.11**	0.09**
CL106749	-0.08	-0.19*	-0.06	-1.14***	-0.22*	-0.27*	-2.93***	-2.79***	-3.69***	-0.22***	-0.04	-0.16***

CL106671	0.33**	0.22*	0.27*	0.22*	0.38**	0.57**	4.71***	5.52***	5.39***	-0.1**	-0.23***	-0.19***
CKL15280	0.14	0.1	-0.39*	-0.02	0.49**	-0.24*	2.64***	2.3***	0.35	-0.08*	-0.14***	-0.21***
CKL15276	0.50***	0.9***	0.74***	0.17	1.12***	0.93***	3.30***	2.97***	3.53***	0.25***	0.22***	0.17***
CKL15284	0.72***	0.89***	0.75***	0.14	0.78***	0.67***	-1.54***	-1**	-1.04*	0.17***	0.1**	0.18***
CKL15291	-0.70***	-0.93***	-0.76***	0.02	-1.07***	-0.75***	-0.15	0.48*	0.8*	-0.12**	0.03	-0.07*
CKL15296	-0.66***	-0.95***	-0.35*	-0.31	-1.32***	-0.61**	-4.25***	-4.74***	-3.63***	-0.23***	-0.21***	-0.06*
CKL12128	0.1	0.37**	0.68***	0.58***	0.6***	0.55**	-6.29***	-5.89***	-6.07***	-0.18***	-0.09**	-0.13***
CKL12134	-0.21*	-0.77***	-0.33*	0.34**	-0.98***	-0.31*	-5.23***	-4.15***	-4.82***	-0.32***	-0.22***	-0.2***
CKL14500	0.14*	0.36**	0.07	1.81**	0.36**	0.09	5.19***	4.15***	4.77***	0.02	-0.05*	-0.04
CKL14501	-0.03	0.04	-0.41**	-0.55	0.02	-0.33*	6.32***	5.89***	6.11***	0.48***	0.36***	0.36***
CKL15303	-0.21*	-0.55***	-0.34*	-0.26	-0.89***	-0.69***	-1.15**	-0.7*	-0.17	-0.03	-0.06*	-0.01
CKL15325	0.25*	0.09	0.04	-0.56	0.14	-0.07	-1.65***	-1.89***	-3.49***	0.13***	0.06*	0.03
CKL15327	-0.20*	-0.07	-0.13	-0.31	-0.03	0.13	0.28	-0.82*	0.03	-0.24***	-0.18***	-0.06*
CKL15343	-0.19*	0.04	-0.06	0.27	0.15	0.02	-0.27	2.4***	0.87*	0.42***	0.38***	0.44***
CKL15354	0.34**	0.5**	0.49**	0.86*	0.63***	0.62**	2.78***	1.01**	2.76***	-0.28***	-0.2***	-0.4***
CKL14546	-1.35***	-1.38***	-1.49***	-1.12*	-1.34***	-1.24***	-3.13***	-2.96***	-3.53***	-0.19***	-0.25***	-0.21***
CKL151420	0.21*	-0.05	-0.1	-1.19*	0.03	-0.11	3.7***	3.13***	3.18***	0.42***	0.37***	0.47***
CKL151431	0.93***	1.04***	0.92***	1.05*	0.94***	0.47**	-0.54*	0.99**	0.53*	-0.23***	-0.12**	-0.25***
CKL14504	0.21*	0.39**	0.67***	-0.48	0.36**	0.88***	-0.03	-1.16**	-0.19	0.01	0	-0.01
CKL15398	-0.31**	-0.96***	-1.02***	0.17	-0.89***	-1.16***	4.79***	5.58***	6.1***	0.12**	0.2***	0.23***
CKL15395	-0.26*	-0.42**	-0.32*	0.3	-0.62***	-0.38*	-0.76*	-0.49*	-0.26	0.04	0.05*	0.06*
CKL15363	0.5***	0.84***	0.87***	-0.16	1.04***	1.11***	-2.12***	-3.63***	-2.09***	-0.03	0.04	-0.08*
CKL15388	0.05	0.65***	0.49**	-0.41	0.69***	0.59**	0.55*	-0.12	-1.79***	0.05*	-0.04	-0.03
CKL15382	-0.01	-0.1	-0.02	0.09	-0.23*	-0.17	-2.46***	-1.34**	-1.95***	-0.18***	-0.26***	-0.17***
CKL1558	-0.15*	0.05	0.04	-0.54	-0.1	-0.07	0.68*	1.74***	1.99***	0.41***	0.39***	0.43***
CKL1588	0.17*	-0.24*	-0.12	0.69	-0.21*	-0.08	0.13	-1.1**	-0.68*	-0.43***	-0.46***	-0.37***
CKL1571	0.29**	0.23*	0.35*	0.69	0.2*	0.28*	1.02**	0.03	-0.1	0.18***	0.1**	0.06*
CKL15183	-0.30**	-0.04	-0.27*	-0.37	0.1	-0.13	-1.83***	-0.66*	-1.22**	-0.16***	-0.03	-0.12**
SE GCAf‡	**0.08**	**0.09**	**0.1**	**0.39**	**0.09**	**0.11**	**0.23**	**0.23**	**0.28**	**0.02**	**0.02**	**0.02**
SE GCAm	**0.07**	**0.08**	**0.09**	**0.08**	**0.08**	**0.1**	**0.21**	**0.2**	**0.25**	**0.02**	**0.02**	**0.02**

D1, D2, and D3 refer to 53,333, 66,666, and 88,888 plants per hectare

*Significant at P < 0.05, **Significant at P < 0.01, and *** Significant at P <0.001

‡Standard error of GCA effects

Table 3b: Estimates of Combining Ability Effects on Agronomic Traits of 54 Inbred Lines across Location (Kiboko, Embu and Kakamega) Under 3 Plant Densities

	Days to silking			Ear aspect			Ear height			No. of ears per plot		
PARENTS	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3
CKL14337	-2.16***	-1.43***	-0.92***	0.4***	0.37***	0.18**	5.29**	4.09*	-2.48*	-0.02	-0.01	-0.03*
CKL14345	3.05***	2.94***	2.67***	-0.2**	-0.28***	-0.24***	-8.4***	-4.91*	0.52	-0.01	0	0.02
CKL14354	2.3***	2.07***	1.96***	-0.08*	-0.05	0.08*	4.01*	-4.85*	3.33*	0.01	0.02*	0
CKL14355	1.18***	0.94***	1.17***	0.05	0.18***	0.03	3.51*	6.74**	0.25	0.02	0	0.01
CKL14357	-4.37***	-4.52***	-4.88***	-0.18**	-0.23***	-0.05	-4.4*	-1.07	-1.61	-0.01	-0.01	0.01
CML312	-1.18***	-1.33***	-1.48***	-0.03	0.01	0.1*	-4.66**	-1.4	-1.54	-0.04**	0.02*	0.01
CML395	1.79***	1.81***	2.49***	0.09*	0.18***	0.2***	-5.34**	5.73**	-0.03	-0.03**	0	0.02
CML444	2.06***	1.54***	1.69***	-0.34***	-0.34***	-0.27***	18.59***	13.63***	10.28***	0.02*	-0.02*	-0.03*
CML537	-2.68***	-2.03***	-2.71***	0.28***	0.15***	-0.02	-8.59***	-17.95***	-8.71***	0.05***	0	0.01
CKL14363	3.26***	3.27***	2.38***	0.03	-0.02	0	14.01***	9.63***	10.12***	0.07***	0.02*	0.04*
CKL14371	-0.91**	-0.9***	-0.29*	-0.06	0.05	-0.04	0.58	0.38	2.77*	-0.01	-0.02*	-0.01
CKL14374	-1.83***	-0.9***	-1.46***	0	-0.04	-0.06*	-4.02*	-0.31	-5.75**	-0.03*	0	-0.01
CKL14376	-0.66*	-0.69**	-0.25	-0.04	0	0.08*	-4.83**	-2.65*	-1.46	-0.01	-0.03*	-0.02
CKL14380	0.13	-0.78**	-0.38*	0.07	0	0.02	-5.74**	-7.06**	-5.67**	-0.01	0.03*	-0.01
CML536	2.72***	3.73***	3.33***	-0.12*	-0.25***	-0.32***	9.47***	11.25***	14.18***	0.11***	0.07***	0.04*
CML540	-2.92***	-3.14***	-3.08***	0.08*	0.19***	0.21***	-11.08***	-10.68***	-10.42***	-0.04**	0	-0.02
CML539	-0.65**	-0.61**	-0.54**	0.12*	0.15***	0.23***	-7.43***	-7.4***	-7.73***	-0.03**	-0.03**	-0.01
CML538	0.85**	0.03	0.29*	-0.08*	-0.1**	-0.12**	9.04***	6.83**	3.97**	-0.04**	-0.03**	-0.01

CKL12416	0.7**	0.92***	0.62**	0.04	0.21***	0.02	-3.06*	-4.94*	-3.22*	-0.00	-0.01	0.02
CKL12419	-1.55***	-1.21***	-0.93***	-0.03	0.08*	0.15**	-0.03	-0.38	-3.7*	0.01	0.01	0.02
CKL14390	0.74**	0.92***	1.16***	-0.07	-0.1**	-0.04	7.19***	4.65*	2.55*	-0.06***	-0.02*	-0.03*
CKL14397	-0.09	-0.08	-0.76**	0.1*	-0.02	-0.08*	-4.13*	-1.07	-1.18	0.03*	0.01	0
CKL14401	0.2	-0.54*	-0.09	-0.05	-0.17***	-0.04	0.03	1.74	5.53**	0.03**	0	-0.01
CL115339	-1.58***	-0.53*	-1.09***	0.18**	0.36***	0.35***	-6.83***	-5.66**	-7.83***	-0.03**	-0.01	-0.02
CL114162	2.32***	1.67***	1.81***	-0.18**	-0.22***	-0.26***	0.88	-1.26	0.57	0.01	0.01	0
CL106749	-0.08	-0.8**	-0.46*	0.08*	0.03	0	6.25***	4.76**	10.82***	0.01	0.02*	0.01
CL106671	-0.65**	-0.33*	-0.26*	-0.08*	-0.17***	-0.1*	-0.3	2.16	-3.55**	0.01	-0.01	0.01
CKL15280	0.03	0.21	1.02***	-0.06	-0.06*	0.01	8.75***	6.62**	4.52**	-0.00	0.01	0.01
CKL15276	3.73***	4.42***	4.02***	-0.12*	-0.27***	-0.22***	13.72***	8.4***	10.1***	-0.01	0.03*	-0.02
CKL15284	1.78***	2.04***	1.48***	0.13*	-0.06*	-0.07*	5.81**	-0.88	9.87***	0.04**	0.01	0.08***
CKL15291	-3.68***	-4.38***	-3.78***	0	0.15**	0.08*	-12.59***	-7.44**	-12.09***	0	-0.02*	-0.05*
CKL15296	-1.85***	-2.29***	-2.73***	0.05	0.25***	0.2***	-15.69***	-6.69**	-12.4***	-0.03*	-0.03**	-0.01
CKL12128	-0.72**	-1.21***	-0.83***	-0.04	-0.04	-0.12**	7.77***	1.86	6.3***	0.02*	-0.01	0
CKL12134	-2.55***	-2.41***	-2.07***	0.01	0.16***	0.06*	-11.81***	-9.74***	-11.39***	-0.01	-0.02*	-0.01
CKL14500	1.48***	1.76***	1.5***	-0.02	-0.17***	0	5.32**	3.98*	3.88**	-0.00	0.03**	-0.04**
CKL14501	1.78***	1.86***	1.4***	0.05	0.05*	0.06*	-1.28	3.91*	1.21	-0.01	0	0.05**
CKL15303	-4.96***	-4.13***	-3.76***	-0.08*	0.1**	0.08*	-8.37***	-8.55***	-10.09***	0.01	-0.04**	0.02
CKL15325	3.67***	2.99***	2.95***	-0.08*	0.02	0.12*	11.71***	6.61**	9.04***	-0.06***	-0.01	-0.03*
CKL15327	1.29***	1.08***	0.24	0.15*	0.17***	0.14**	1.39	2.52	2.14*	-0.03*	0.04**	0
CKL15343	0.21	0.24	0.33*	0.17**	-0.04	-0.13**	-9.27***	-5.47**	-4.55**	0	0.02*	0.03*

CKL15354	-0.21	-0.18	0.24	-0.15*	-0.25***	-0.21***	4.54**	4.89*	3.45*	0.07***	-0.01	-0.02
CKL14546	0.63**	0.85***	0.38*	0.12*	0.08*	0	-3.31*	-4.4*	-2.43*	-0.01	0	-0.02
CKL151420	2.19***	1.95***	2.18***	0.05	0.16***	0.25***	8.47***	7.63***	10.37***	0.08***	0.03*	0.04*
CKL151431	-0.38*	-0.32*	-0.05	-0.18**	-0.21***	-0.19***	-1.31	1.38	-3.3*	-0.03**	-0.02*	-0.03*
CKL14504	-2.44***	-2.48***	-2.52***	0.02	-0.03	-0.05	-3.85*	-4.61**	-4.63**	-0.04**	-0.01	0.01
CKL15398	0.18	0.65**	0.97***	0.12*	0.12**	0.14**	-0.93	3.73*	3.95**	0	-0.01	-0.02
CKL15395	0.22	0.19	0.22	0.03	0.16***	0.14**	-3.43*	-10.45***	-7.08***	-0.02	-0.03*	0.02
CKL15363	-2.45***	-2.31***	-2.7***	-0.2**	-0.3***	-0.21***	-8.71***	-5.72**	-6.05***	0	-0.02*	-0.02
CKL15388	0.68**	0.15	0.47*	-0.07	-0.01	-0.05	3.64*	5.14*	1.82	-0.05	0.04**	0.01
CKL15382	1.38***	1.32***	1.05***	0.12*	0.03	-0.03	9.42***	7.3**	7.36***	0.02*	0.02*	0.02
CKL1558	0.63**	0.31*	0.39*	0.08*	0.18***	0.1*	0.83	4.17*	-2.13*	-0.02*	0.01	-0.02*
CKL1588	-0.5*	-0.36*	-0.41*	0.06	0.14***	0.13**	-0.72	-8.54***	0	0.02*	0	-0.01
CKL1571	0.1	0.04	0.06	-0.18**	-0.23***	-0.19***	-3.67*	-2.34*	-0.78	-0.01	0.02*	0.01
CKL15183	-0.23	0.01	-0.04	0.04	-0.09**	-0.04	3.56*	6.71**	2.9*	0	-0.02*	0.03*
SE GCAf‡	**0.17**	**0.15**	**0.13**	**0.04**	**0.03**	**0.03**	**1.11**	**1.29**	**0.97**	**0.01**	**0.01**	**0.01**
SE GCAm	**0.15**	**0.13**	**0.12**	**0.03**	**0.02**	**0.03**	**0.99**	**1.15**	**0.87**	**0.01**	**0.01**	**0.01**

D1 ,D2, and D3 refer to 53,333, 66,666, and 88,888 plants per hectare

*Significant at P < 0.05, **Significant at P < 0.01, and *** Significant at P <0.001

‡Standard error of GCA effects

Table 4: Estimates of Specific Combining Ability Effects on Agronomic Traits of 120 Hybrids across Locations

	Field weight			Grain weight			Leaf angle			No. of leaves above ear		
Lines	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3
CKH156477	-0.45	-0.68	-0.46	-0.65	-0.68	-0.26	-1.79	-0.12	-2.49	-0.03	-0.16	-0.06
CKH156485	0.35	0.81	0.8	0.89*	0.83	0.68	1.89	3.23*	3.51*	0.40*	0.4*	0.4*
CKH156493	0.61	0.49	0.26	0.35	0.56	0.11	-1.14	0.15	-1.14	-0.05	-0.03	-0.08
CKH156497	-0.37	-0.2	-0.3	0.17	-0.39	-0.44	-0.16	-4.31*	-0.42	-0.14	-0.21	-0.13
CKH156501	-0.13	-0.42	-0.3	-0.76	-0.32	-0.09	1.21	1.05	0.54	-0.17	0	-0.13
CKH156478	0.89*	1.16*	1.09*	-0.68	1.24*	1.2*	-1.09	-1.94	0.16	0.07	0.26*	0.18
CKH156486	-0.19	-0.76	-0.47	0.2	-0.93*	-0.45	0.73	-3.39*	-3.37*	-0.22*	-0.42*	-0.28*
CKH156494	-0.81*	-0.8	-0.32	0.07	-0.74	-0.26	-0.46	2.37*	1.2	-0.03	0.07	0
CKH156498	-0.40	-0.61	-1.6*	0.33	-0.71	-1.8*	-0.26	1.82	1.18	0.11	-0.12	-0.03
CKH156502	0.52	1*	1.3*	0.08	1.14*	1.32*	1.08	1.14	0.83	0.07	0.21	0.13
CKH156479	-0.32	0.38	-0.33	-0.43**	0.17	-0.44	0.55	2.17	0.41	0.12	0.16	0.05
CKH156487	-0.52	-0.44	-0.95	-0.25*	-0.56	-0.84	-1.94	-2.07	-2.06	-0.40*	-0.31*	-0.26*
CKH156495	0.43	0.26	0.24	0.74***	0.55	0.23	1.73	-0.77	1.62	0.15	0.05	0.18
CKH156499	0.02	0.33	1.39*	0.06	0.25	1.69*	2.90*	2.8*	1.68	0.15	0.28*	0.15
CKH156503	0.38	-0.53	-0.35	-0.11	-0.4	-0.64	-3.25*	-2.12	-1.66	-0.02	-0.18	-0.13
CKH156480	-0.12	-0.86*	-0.31	-0.13	-0.73	-0.5	2.33*	-0.11	1.92	-0.16	-0.27*	-0.17
CKH156488	0.36	0.39	0.62	0.14	0.66	0.61	-0.68	2.24*	1.92	0.22*	0.34*	0.13
CKH156496	-0.23	0.05	-0.17	0.26*	-0.37	-0.07	-0.13	-1.75	-1.68	-0.07	-0.09	-0.1
CKH156500	0.75*	0.47	0.52	-0.26*	0.86*	0.55	-2.48*	-0.31	-2.45	-0.12	0.05	0.01
CKH156504	-0.77*	-0.05	-0.66	0.35	-0.42	-0.6	0.95	-0.07	0.29	0.12	-0.03	0.12
CKH156506	0.24	-0.1	0.26	0.39	-0.45	-0.39	-1.67	1.4	1.84	0.07	-0.15	-0.1
CKH156518	-0.40	-0.24	-0.01	0.18	0.02	0.31	1.83	0.86	1.35	-0.12	0.19	-0.07
CKH156522	0.04	0.38	-0.07	-0.73	0.7	-0.04	2.43*	0.51	0.55	0.08	0.01	-0.06
CKH156526	0	-0.37	-0.33	-0.18	-0.54	-0.25	2.28*	-0.99	-0.23	-0.02	0.05	0.15
CKH156530	0.13	0.33	0.14	0.01	0.27	0.38	-4.87**	-1.77	-3.52*	-0.01	-0.1	0.08
CKH156508	-1.10*	-0.57	-1.12*	-0.27	-0.4	-0.94	0.67	1.09	1.17	0.11	0.19	0.01
CKH156520	0.49	0.34	0.19	-0.42	-0.08	0.1	-1.17	-1.87	-2.01	-0.02	-0.18	0.07
CKH156524	-0.14	-0.27	0.35	0.72	-0.55	0.33	-1.13	-1.06	-0.03	-0.02	-0.02	0.03
CKH156528	0.42	0.56	0.92	-0.03	0.56	0.68	-1.17	-0.77	-4.12*	0.02	0.06	-0.1
CKH156532	0.32	-0.06	-0.35	0.17	0.47	-0.17	2.80*	2.62*	4.98*	-0.08	-0.05	-0.01
CKH156505	1.41*	1.4*	0.86	0.1	1.52*	1.04	-0.51	-3.35*	-4.25*	0.13	0.05	0.19
CKH156517	-0.07	-0.65	0.13	-0.54	-0.86*	-0.28	-0.70	0.78	1.93	0.11	0.14	0.11
CKH156521	-0.10	0.52	-0.11	0.11	0.73	-0.09	0.06	0.8	1.02	-0.11	0.05	0.01
CKH156525	-0.46	-0.37	-0.59	0.16	-0.28	-0.2	0.36	2.09	2.6	-0.10	-0.2	-0.15
CKH156529	-0.79*	-0.9*	-0.29	-0.53	-1.11*	-0.47	0.78	-0.32	-1.3	-0.03	-0.03	-0.16
CKH156507	-0.54	-0.73	0	-0.22	-0.67	0.28	1.51	0.86	1.24	-0.31*	-0.08	-0.11
CKH156519	-0.02	0.55	-0.31	0.78*	0.92*	-0.12	0.03	0.24	-1.28	0.03	-0.15	-0.11
CKH156523	0.2	-0.64	-0.18	-0.10	-0.88*	-0.2	-1.37	-0.24	-1.55	0.06	-0.04	0.02

CKH156527	0.03	0.18	-0.01	0.06	0.26	-0.23	-1.47	-0.33	1.75	0.10	0.09	0.11
CKH156531	0.34	0.63	0.5	0.17	0.36	0.27	1.3	-0.53	-0.17	0.12	0.18	0.09
CKH156534	0.27	0.28	0.3	0.06	0.06	0.34	-0.96	2.15	-0.46	0.09	0.23	0.13
CKH156542	0.1	0.64	0.7	-0.11	0.48	0.65	1.17	0.81	1.01	0.00	0.19	0.23*
CKH156550	-0.60	-0.39	-0.57	-0.13	-0.45	-0.57	-1.52	-1.94	1.19	-0.12	-0.13	0.06
CKH156554	0.13	-0.18	0.02	0.14	-0.18	0.05	0.29	-1.14	-2.51	0.00	-0.06	-0.26*
CKH156558	0.1	-0.36	-0.45	0.26*	0.1	-0.48	1.03	0.13	0.77	0.02	-0.23	-0.15
CKH156535	-0.27	-0.4	-0.66	-0.26*	-0.25	-0.56	-2.29*	-1.43	0.82	-0.03	-0.17	-0.17
CKH156543	0.01	-0.55	-0.42	0.35	-0.77	-0.6	0.68	0.35	-0.4	-0.09	-0.17	-0.07
CKH156551	0.07	0.66	0.42	0.39	0.89*	0.32	2.70*	1.43	0.5	0.07	0.18	0.09
CKH156555	-0.52	0.14	0.57	0.18	0.17	0.54	1.38	-1.02	-0.64	0.11	0.08	0.13
CKH156559	0.71	0.15	0.1	-0.73	-0.05	0.31	-2.46*	0.67	-0.28	-0.07	0.08	0.02
CKH156533	-0.36	0.07	-0.15	-0.18	0.34	-0.38	2.38*	1.94	1.1	0.10	0.06	0.12
CKH156541	-0.10	-0.27	-0.42	0.01	-0.15	-0.35	0.4	0.85	0.21	0.06	0.06	-0.01
CKH156549	-0.09	-0.3	0.01	-0.27	-0.83	0.07	-0.41	0.06	-1.33	0.05	-0.08	-0.21
CKH156553	0.44	0.31	-0.06	-0.42	0.47	0.05	-1.57	-2.06	-0.36	-0.16	-0.15	0.05
CKH156557	0.11	0.18	0.61	0.72	0.18	0.61	-0.80	-0.79	0.39	-0.06	0.1	0.05
CKH156536	0.36	0.05	0.51	-0.03	-0.15	0.6	0.88	-2.66*	-1.47	-0.16	-0.12	-0.08
CKH156544	-0.01	0.18	0.14	0.17	0.44	0.3	-2.24	-2	-0.81	0.02	-0.08	-0.15
CKH156552	0.62	0.03	0.13	0.1	0.39	0.18	-0.77	0.46	-0.35	-0.01	0.03	0.07
CKH156556	-0.05	-0.28	-0.54	-0.54	-0.45	-0.64	-0.10	4.22*	3.51*	0.05	0.13	0.08
CKH156560	-0.92*	0.03	-0.26	0.11	-0.23	-0.44	2.23	-0.01	-0.88	0.10	0.05	0.08
	Field weight			**Grain weight**			**Leaf angle**			**No. of leaves above ear**		
CKH156561	0.01	0	0.14		-0.14	0.3	-0.05	-1.43	1.82	0.08	0.22	0.33*
CKH156569	0.18	0.35	-0.12		0.79	0.06	-1.35	-0.51	0.39	0.03	-0.1	-0.13
CKH156577	-0.08	0.36	0.53		0.5	0.02	0.04	1.38	-1.41	-0.20	-0.27*	-0.17
CKH156581	-0.03	0.01	-0.35		-0.4	-0.65	-1.23	-0.19	-2.19	-0.04	0.21	-0.2
CKH156585	-0.07	-0.72	-0.19		-0.75	0.27	2.59*	0.74	1.4	0.14	-0.05	0.16
CKH156562	-0.14	0.24	0.48		0.21	0.54	-0.75	-1.24	0.29	-0.02	-0.24*	-0.02
CKH156570	-0.63	-0.44	-0.49		-0.67	-0.53	-1.58	0.8	-1.17	-0.08	0.19	0.08
CKH156578	-0.52	0.09	-0.43		0.15	-0.22	-0.38	0.06	-0.94	-0.08	-0.1	-0.1
CKH156582	0.53	-0.02	0.25		-0.01	0.11	-0.32	-0.46	0.81	0.13	0	-0.02
CKH156586	0.76*	0.13	0.19		0.33	0.1	3.03*	0.84	1.01	0.06	0.16	0.06
CKH156563	-0.01	-0.08	-1.14*		0.02	-1.3*	0.61	2.58*	-1.46	-0.18	-0.03	-0.07
CKH156571	0.43	-0.03	0.51		0.05	0.79	2.09	-0.13	3.27*	0.02	-0.19	0
CKH156579	0.52	-0.28	0.27		-0.37	0.21	-1.04	-2.79*	0.51	0.19	0.15	0.04
CKH156583	-0.70	-0.4	0.04		0.12	-0.07	0.87	0.61	-0.91	-0.02	-0.04	0.18
CKH156587	-0.23	0.8	0.33		0.17	0.36	-2.52*	-0.26	-1.41	-0.01	0.11	-0.16
CKH156564	0.14	-0.16	0.52		-0.09	0.46	0.2	0.09	-0.64	0.12	0.05	-0.25*
CKH156572	0.04	0.13	0.1		-0.17	-0.32	0.84	-0.16	-2.49	0.04	0.1	0.05
CKH156580	0.07	-0.17	-0.36		-0.28	-0.01	1.38	1.35	1.84	0.09	0.23	0.23
CKH156584	0.2	0.42	0.06		0.29	0.6	0.68	0.04	2.3	-0.06	-0.17	0.03
CKH156588	-0.45	-0.21	-0.33		0.25	-0.73	-3.10*	-1.33	-1	-0.19	-0.22	-0.06

CKH156590	1.87**	2.15**	2.03*		2.39**	2*	2.96*	-0.94	1.56	0.08	0.39*	0.08
CKH156598	-0.51	-0.33	-0.17		-0.65	-0.24	-0.46	1.89	-0.97	-0.14	-0.24*	0.06
CKH156602	-1.07*	-1.38*	-1.32*		-1.5*	-0.94	-2.25	-2.15	-1.58	-0.18	0	-0.12
CKH156610	-1.19**	-1.1*	-1.27*		-1.02*	-1.59*	-0.42	-0.99	-0.14	0.05	-0.18	0.21
CKH156614	0.90*	0.66	0.72		0.79	0.78	0.17	2.19	1.13	0.19	0.03	-0.23*
CKH156591	-0.47	-0.71	-0.65		-0.76	-0.78	-1.93	-1.06	-1.76	0.05	0.06	0.01
CKH156599	-0.56	-0.13	-0.49		-0.13	-0.68	1.85	-1.24	-0.07	-0.03	0.18	0.13
CKH156603	0.74	0.69	0.63		0.71	0.3	0.31	1.56	0.29	-0.01	0.09	0.06
CKH156611	0.61	0.63	0.81		0.54	1.23*	-1.01	-0.49	0.46	0.05	-0.14	-0.08
CKH156615	-0.32	-0.49	-0.3		-0.37	-0.06	0.78	1.23	1.09	-0.06	-0.18	-0.11
CKH156592	-0.71	-0.97*	-0.34		-1.14*	-0.46	-1.94	1.57	0.86	-0.06	-0.29*	-0.08
CKH156600	0.83*	0.24	0.6		0.48	0.77	-1.02	0.89	-0.45	0.03	0.13	-0.12
CKH156604	0.42	0.39	0.46		0.56	0.34	2.16	-1.35	0.3	0.22	-0.13	0
CKH156612	0.11	0.44	-0.21		0.27	-0.24	0.23	0.23	-0.78	-0.17	0.31*	-0.19
CKH156616	-0.65	-0.1	-0.52		-0.17	-0.4	0.57	-1.35	0.07	-0.02	-0.03	0.39*
CKH156589	-0.70	-0.47	-1.04*		-0.48	-0.76	0.91	0.43	-0.67	-0.07	-0.16	-0.01
CKH156597	0.24	0.22	0.05		0.3	0.16	-0.37	-1.54	1.49	0.13	-0.08	-0.06
CKH156601	-0.09	0.3	0.23		0.22	0.31	-0.22	1.93	0.99	-0.02	0.04	0.06
CKH156609	0.48	0.03	0.67		0.21	0.61	1.19	1.25	0.47	0.07	0.02	0.06
CKH156613	0.07	-0.07	0.09		-0.25	-0.32	-1.52	-2.07	-2.29	-0.12	0.18	-0.05
CKH156625	0.5	0.22	0.17		0.1	0.2	-0.58	-1.61	-0.92	-0.01	-0.13	-0.14
CKH156629	0.52	0.19	0.69		0.09	0.68	-0.92	-1.01	-0.95	0.04	-0.1	-0.02
CKH156633	0.08	-0.06	0.31		0.04	0.09	-0.09	-0.11	-1.67	-0.03	0.32*	-0.07
CKH156637	-0.81*	-0.43	-0.34		-0.48	-0.36	0.97	3.84*	2.25	-0.02	0.11	0.29*
CKH156641	-0.28	0.08	-0.83		0.26	-0.61	0.62	-1.11	1.3	0.01	-0.21	-0.07
CKH156627	-0.50	-0.4	-0.23		-0.44	-0.18	0.33	-1.9	-1.06	-0.09	-0.08	-0.19
CKH156631	-0.24	-0.06	-0.33		0.08	-0.57	1.12	-1.71	-0.78	-0.04	-0.05	0.07
CKH156635	-0.16	-0.29	-0.33		-0.18	0	-1.82	1.76	-0.03	0.20	-0.09	0.2
CKH156639	0.69	0.82	0.8		0.76	0.68	-0.04	-0.58	-1.38	-0.05	0.08	-0.07
CKH156643	0.21	-0.07	0.09		-0.21	0.06	0.41	2.43*	3.25*	-0.02	0.13	-0.01
CKH156626	0.37	0.82	1.09*		0.86*	1.02	0.47	2.18	2.86*	0.06	0.24*	0.24*
CKH156630	-0.03	-0.49	-0.22		-0.26	0.08	1.02	3.66*	2.05	0.05	0.18	0.11
CKH156634	-0.67	-0.23	-0.62		-0.32	-0.65	0.57	-1.9	0.08	-0.13	-0.14	-0.14
CKH156638	0.2	-0.32	-0.38		-0.63	-0.34	-0.57	-3.62*	-2.41	0.05	-0.19	-0.22
CKH156642	0.13	0.22	0.14		0.35	-0.11	-1.50	-0.32	-2.58	-0.04	-0.09	0.01
CKH156628	-0.37	-0.64	-1.03*		-0.51	-1.04	-0.23	1.33	-0.88	0.03	-0.04	0.09
CKH165632	-0.24	0.36	-0.13		0.1	-0.2	-1.22	-0.94	-0.32	-0.06	-0.02	-0.16
CKH156636	0.74	0.58	0.64		0.46	0.56	1.34	0.25	1.62	-0.04	-0.09	0.01
CKH156640	-0.08	-0.07	-0.07		0.36	0.02	-0.36	0.36	1.54	0.02	-0.01	-0.01
CKH156644	-0.06	-0.23	0.6		-0.4	0.66	0.46	-1	-1.96	0.05	0.17	0.07
SE SCA	0.38	0.42	0.51	0.39	0.43	0.54	1.13	1.11	1.35	0.11	0.11	0.11

Table 5: Estimates of Specific Combining Ability Effects on Agronomic Traits of 120 Hybrids across Location under 3 Plant Densities

	Anthesis days			Anthesis silking interval			Upper stem diameter			Lower stem diameter		
Lines	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3	PD1	PD2	PD3
CKH156477	0.61	0.29	1.64*	0.32	-0.26	0.04	0.17	0.04	0.12	0.22	-0.14	0.21
CKH156485	0.69	0.5	-0.15	-0.31	-0.51	-0.58	0.27	0.11	0.05	0.28	-0.28	0.06
CKH156493	-0.43	-1.04	-1.11	0.07	0.74	-0.08	-0.19	-0.13	-0.08	-0.23	-0.25	0.02
CKH156497	-0.77	0.25	-0.98	0.36	-0.43	0.25	-0.1	-0.15	0.04	-0.14	-0.4	-0.03
CKH156501	-0.1	0	0.6	-0.43	0.45	0.38	-0.15	0.13	-0.13	-0.12	1.07*	-0.26
CKH156478	-2.86*	-1.08	-1.16	0.15	-0.03	-0.13	-0.07	0.05	0.08	-0.12	0.25	0.04
CKH156486	0.73	-0.2	-0.12	-0.31	-0.61	0.42	-0.23	-0.23	-0.22	-0.27	-0.15	-0.06
CKH156494	1.1	0.26	1.26	-0.1	-0.03	-0.08	0.09	0.11	-0.03	0.1	0.13	-0.12
CKH156498	1.6	1.55	1.22	-0.31	0.14	-0.42	0.16	0.01	0.02	0.21	0.05	-0.01
CKH156502	-0.57	-0.53	-1.2	0.57	0.52	0.21	0.07	0.06	0.14	0.07	-0.27	0.15
CKH156479	2.48*	1.09	0.78	-0.62	-0.09	-0.09	-0.18	-0.04	0	-0.08	0	0.01
CKH156487	-1.11	0.13	0.32	0.59	0.49	0.12	-0.14	0.04	0	-0.03	0.04	-0.25
CKH156495	-0.57	0.43	-0.64	0.13	-0.43	0.28	0.2	0.08	0.05	0.16	0.19	-0.03
CKH156499	-0.4	-1.12	-0.02	0.09	0.24	0.28	0	0.05	-0.02	-0.08	0.17	0.16
CKH156503	-0.4	-0.53	-0.43	-0.2	-0.22	-0.59	0.12	-0.13	-0.04	0.03	-0.39	0.1
CKH156480	-0.23	-0.31	-1.26	0.15	0.38	0.18	0.09	-0.05	-0.21	-0.03	-0.11	-0.25
CKH156488	-0.31	-0.43	-0.05	0.03	0.63	0.05	0.1	0.08	0.16	0.02	0.4	0.25
CKH156496	-0.1	0.36	0.49	-0.1	-0.29	-0.12	-0.1	-0.07	0.06	-0.03	-0.07	0.12
CKH156500	-0.43	-0.68	-0.22	-0.14	0.04	-0.12	-0.05	0.09	-0.05	0.01	0.19	-0.12
CKH156504	1.07	1.07	1.03	0.07	-0.75	0.01	-0.03	-0.05	0.03	0.02	-0.4	0.01
CKH156506	0.64	1.6	0.2	-1.4	-1.03	-0.94	0.2	-0.29	-0.08	-0.03	-0.19	-0.22
CKH156518	-0.32	-2.32*	0.28	0.23	1.22	0.31	-0.05	0.02	0.07	-0.49	-0.43	0.04
CKH156522	0.89	0.43	-0.76	0.27	-0.37	1.02	0.1	0.1	-0.04	0.78	0.17	-0.05
CKH156526	0.1	0.56	0.24	0.23	0.13	0.14	-0.16	0.12	-0.05	-0.32	0.25	0.11
CKH156530	-1.32	-0.28	0.03	0.68	0.05	-0.53	-0.09	0.05	0.1	0.06	0.2	0.11
CKH156508	-1.66*	-1.73*	-1.53	-0.97	-0.33	0.19	-0.09	-0.02	0.26*	-0.05	0.11	0.35*

CKH156520	-0.62	4.02**	-0.12	0.83	-2.58*	0.94	-0.26	0.17	-0.09	-0.37	-0.24	-0.16
CKH156524	-1.08	-0.57	2.34*	1.37	1.33	-3.02*	0.21	0.08	0.02	1.13*	0.15	-0.09
CKH156528	0.8	-1.11	1.34	-1.34	0.83	-0.06	-0.57*	-0.13	-0.01	-0.37	-0.12	-0.07
CKH156532	2.55*	-0.61	-2.03*	0.12	0.75	1.94*	0.71*	-0.1	-0.18	-0.33	0.11	-0.03
CKH156505	-0.36	-0.9	0	-0.37	1.47*	-0.04	0.21	0.16	-0.08	0.12	0.02	0.03
CKH156517	0.35	-0.65	-0.08	0.26	1.22	-0.79	0.24	-0.1	0.08	0.25	1.23*	0.06
CKH156521	0.39	0.6	-0.46	-0.03	-1.03	1.08	-0.05	-0.06	-0.05	-1.06*	-0.39	0
CKH156525	-0.23	0.73	-0.96	-0.08	-0.87	-0.13	-0.16	-0.02	0.06	0.78	-0.46	-0.06
CKH156529	-0.15	0.23	1.5	0.22	-0.78	-0.13	-0.24	0.01	-0.01	-0.08	-0.39	-0.03
CKH156507	1.38	1.03	1.33	2.73*	-0.1	0.79	-0.32	0.15	-0.1	-0.03	0.06	-0.17
CKH156519	0.58	-1.05	-0.08	-1.31	0.15	-0.46	0.07	-0.09	-0.06	0.62	-0.56	0.05
CKH156523	-0.21	-0.47	-1.13	-1.6*	0.07	0.92	-0.27	-0.12	0.07	-0.85	0.08	0.15
CKH156527	-0.67	-0.18	-0.63	1.19	-0.1	0.04	0.89*	0.03	-0.01	-0.09	0.33	0.01
CKH156531	-1.08	0.66	0.5	-1.02	-0.02	-1.29	-0.38	0.04	0.09	0.35	0.09	-0.04
CKH156534	-0.21	0.53	0.35	0.71	-0.58	0.2	0.06	-0.17	-0.05	0.21	-0.58	-0.08
CKH156542	0.13	-1.23	1.06	-0.88	1.3	-0.3	-0.02	0.08	-0.1	-0.15	1.33*	-0.21
CKH156550	0.5	0.69	-0.53	0.63	0.59	0.37	0.15	-0.05	0.21	0.14	-0.51	0.29
CKH156554	-0.46	0.61	-0.78	0.08	-0.66	-0.3	-0.12	0.02	-0.12	-0.15	-0.2	-0.14
CKH156558	0.04	-0.6	-0.11	-0.54	-0.66	0.03	-0.07	0.12	0.06	-0.05	-0.04	0.15
CKH156535	1.19	0.96	0.95	-0.43	0.13	0.03	0.14	0.1	-0.12	0.07	0.21	-0.07
CKH156543	-0.48	1.21	-0.18	0.16	-0.33	0.2	-0.03	0.04	-0.09	-0.09	-0.43	-0.2
CKH156551	0.4	-0.54	-0.26	0.33	-0.04	0.03	-0.06	0.16	-0.04	-0.19	0.3	-0.03
CKH156555	0.28	-0.79	0.33	-0.55	0.38	-0.13	0.05	-0.24	0.1	0.2	-0.26	0.23
CKH156559	-1.39	-0.83	-0.84	0.49	-0.13	-0.13	-0.11	-0.05	0.15	0.01	0.17	0.06
CKH156533	0.36	-0.54	-0.35	-0.19	0.09	0.27	-0.05	0.05	0.17	-0.09	0.18	0.13
CKH156541	0.69	0.54	0.19	0.39	-0.2	0.1	0	-0.19	0.16	0.03	-0.65	0.32
CKH156549	-0.77	-0.38	-0.73	-0.78	-0.41	-0.23	0.02	-0.01	-0.16	0.12	0.12	-0.25
CKH156553	-0.23	-0.46	0.03	0.68	0.18	0.27	0.04	0.17	-0.01	-0.01	0.27	-0.04
CKH156557	-0.06	0.83	0.86	-0.11	0.34	-0.4	0.01	-0.02	-0.16	-0.05	0.07	-0.17

CKH156536	-1.34	-0.94	-0.95	-0.09	0.36	-0.5	-0.15	0.03	0	-0.2	0.19	0.02
CKH156544	-0.34	-0.53	-1.08	0.33	-0.77	0	0.05	0.08	0.03	0.21	-0.26	0.09
CKH156552	-0.13	0.23	1.51	-0.18	-0.14	-0.17	-0.11	-0.1	-0.01	-0.06	0.08	-0.01
CKH156556	0.41	0.64	0.43	-0.22	0.11	0.17	0.03	0.05	0.03	-0.04	0.19	-0.06
CKH156560	1.41	0.6	0.09	0.16	0.44	0.5	0.17	-0.05	-0.05	0.09	-0.21	-0.04
CKH156561	1.13	1.03	0.79	0.04	-0.4	-0.88	0.18	0.11	0.21	0.47	0.11	0.29
CKH156569	1.38	0.73	0.75	-0.08	-0.32	0.17	0.06	-0.04	-0.09	0.1	-0.05	-0.26
CKH156577	0.18	0.57	0.33	-0.58	0.06	-0.71	-0.19	-0.01	-0.26*	-0.68	0.09	-0.34
CKH156581	-2.08*	-1.81*	-1.46	0.63	-0.15	1	0.05	-0.12	0.1	0.21	-0.13	0.12
CKH156585	-0.62	-0.52	-0.42	0	0.81	0.42	-0.11	0.06	0.04	-0.11	-0.03	0.19
CKH156562	0.6	1.43	0.13	0.41	0.23	1.36	-0.11	0.01	-0.19	0.06	0.2	-0.16
CKH156570	1.02	0.63	1.42	0.28	-0.18	-0.6	0.26	0.24	0.29*	0.6	0.51	0.55*
CKH156578	1.14	0.47	0.83	0.12	0.19	-0.31	-0.12	-0.12	-0.13	-0.63	-0.21	-0.29
CKH156582	-0.94	-0.91	-0.63	-0.84	-0.35	-0.6	0.1	0.11	-0.11	0.19	-0.07	-0.16
CKH156586	-1.82*	-1.62	-1.75*	0.03	0.11	0.15	-0.13	-0.23	0.14	-0.21	-0.43	0.06
CKH156563	-1.23	-1.31	-0.41	-0.13	0.3	-0.18	-0.03	-0.06	0.01	-0.38	-0.06	0.05
CKH156571	-1.32	-0.43	-0.95	0.08	0.05	-0.13	-0.12	-0.08	-0.19	-0.44	-0.24	-0.15
CKH156579	-0.69	0.23	-0.53	0.75	-0.08	0.66	0.21	-0.15	0.33*	1.6*	-0.31	0.21
CKH156583	1.73*	1.19	1.01	-0.54	0.22	-0.13	-0.25	0.13	-0.08	-0.69	0.24	0.09
CKH156587	1.52	0.32	0.88	-0.17	-0.49	-0.22	0.18	0.16	-0.08	-0.09	0.37	-0.2
CKH156564	-0.5	-1.14	-0.51	-0.33	-0.13	-0.31	-0.05	-0.06	-0.03	-0.15	-0.25	-0.18
CKH156572	-1.08	-0.93	-1.22	-0.28	0.45	0.57	-0.2	-0.12	-0.02	-0.26	-0.22	-0.14
CKH156580	-0.63	-1.27	-0.63	-0.28	-0.18	0.36	0.1	0.28	0.06	-0.29	0.43	0.43*
CKH156584	1.29	1.53	1.08	0.76	0.28	-0.27	0.09	-0.11	0.09	0.29	-0.04	-0.05
CKH156588	0.92	1.82*	1.28	0.13	-0.43	-0.35	0.06	0.01	-0.1	0.4	0.08	-0.05
CKH156590	-0.8	-1.52	-1.63*	0.59	-0.08	0.45	0.07	0.04	0.36*	0.22	0.3	0.44*
CKH156598	-0.93	-0.06	-0.5	0.26	0	0.45	-0.04	0	-0.02	-0.13	-0.44	0.06
CKH156602	1.83*	1.48	1.46	-0.45	-0.29	-0.13	-0.12	-0.37*	-0.23	-0.07	0.01	-0.31
CKH156610	0.95	1.19	0.71	-0.16	0.17	0.03	-0.03	0.18	-0.25*	-0.04	-0.16	-0.33

CKH156614	-1.05	-1.1	-0.04	-0.24	0.21	-0.8	0.12	0.14	0.14	0.02	0.28	0.14
CKH156591	0.1	-0.02	2.01*	-0.04	0.48	-0.48	-0.09	0.06	-0.2	0.03	0.23	0
CKH156599	-0.03	0.44	-1.7*	-0.04	-1.1	1.18	-0.08	-0.05	-0.05	-0.11	-0.5	-0.1
CKH156603	0.06	-0.52	-0.58	0.25	0.44	-0.07	0.3	0.32	0.3*	0.29	0.24	-0.11
CKH156611	0.02	-0.31	0.18	0.04	0.4	-0.07	-0.06	-0.17	0.13	-0.09	0.17	0.39*
CKH156615	-0.15	0.4	0.09	-0.21	-0.23	-0.57	-0.08	-0.16	-0.18	-0.13	-0.14	-0.18
CKH156592	0.7	1.25	0.01	-0.08	0.15	0.25	-0.02	0.03	-0.21	-0.14	-0.01	-0.3
CKH156600	-0.26	0.21	1.63*	0.26	-0.27	-1.25	0.13	-0.06	0.1	0.3	-0.44	0.08
CKH156604	-0.84	-1.08	-0.91	-0.12	0.11	0.17	-0.07	-0.03	-0.06	-0.07	0.09	0.28
CKH156612	0.12	-0.38	-0.33	0.34	0.23	0.17	-0.06	-0.03	0.09	0.04	0.26	0.05
CKH156616	0.28	0	-0.41	-0.41	-0.23	0.67	0.02	0.1	0.07	-0.13	0.11	-0.1
CKH156589	0	0.28	-0.39	-0.48	-0.55	-0.22	0.04	-0.13	0.05	-0.11	-0.52	-0.14
CKH156597	1.21	-0.59	0.57	-0.48	1.37	-0.38	-0.02	0.12	-0.04	-0.05	1.38*	-0.04
CKH156601	-1.04	0.12	0.03	0.32	-0.26	0.03	-0.11	0.09	-0.01	-0.16	-0.34	0.14
CKH156609	-1.08	-0.51	-0.56	-0.23	-0.8	-0.13	0.15	0.02	0.03	0.09	-0.27	-0.11
CKH156613	0.92	0.7	0.36	0.86	0.24	0.7	-0.06	-0.08	-0.03	0.23	-0.25	0.14
CKH156625	0.46	0.59	-0.73	0.03	0.06	0.46	-0.46	-0.28	0.06	-0.71	0.16	0.14
CKH156629	0.13	0.51	0.23	0.33	-0.23	0.25	0.22	0.22	0.01	1.6*	-0.05	-0.07
CKH156633	-0.71	-0.24	-0.06	0.33	0.18	-0.38	-0.11	-0.07	-0.11	-0.34	-0.18	-0.05
CKH156637	0.83	-0.03	0.57	-0.51	-0.15	0	0.38	-0.02	0.1	-0.29	0.01	0.02
CKH156641	-0.71	-0.83	-0.02	-0.18	0.14	-0.33	-0.02	0.15	-0.06	-0.25	0.05	-0.04
CKH156627	-0.91	0.16	0.84	0.53	-0.84	-0.14	-0.5	-0.38*	-0.14	-0.42	-0.28	-0.31
CKH156631	-0.24	-0.59	0.47	0.16	0.7	-0.85	0.01	0.14	-0.2	-0.47	0.33	-0.06
CKH156635	0.26	-0.34	0.01	-0.18	0.12	-0.31	0.06	0.1	0.17	0.4	0.02	0.18
CKH156639	0.13	0.03	-0.2	-0.01	0.12	0.23	0.23	0.15	0.16	0.21	0.01	0.08
CKH156643	0.76	0.74	-1.12	-0.51	-0.09	1.07	0.2	-0.01	0.01	0.28	-0.09	0.1
CKH156626	0.46	-0.91	0.08	-0.27	0.33	-0.68	-0.29	1.04**	0.07	-0.06	0.41	0.31
CKH156630	-0.04	0.18	0.03	-0.14	0.2	0.45	0.08	-0.36*	-0.08	-0.13	-0.17	-0.21
CKH156634	0.46	0.93	0.08	-0.14	-0.05	0.33	0.25	-0.28	-0.06	0.36	0.02	-0.2

CKH156638	-0.5	0.3	-0.47	0.36	-0.05	0.03	-0.16	-0.22	-0.06	-0.4	-0.2	0.01
CKH156642	-0.38	-0.49	0.28	0.19	-0.43	-0.13	0.11	-0.17	0.13	0.23	-0.06	0.09
CKH156628	-0.01	0.16	-0.19	-0.3	0.46	0.36	1.25**	-0.39*	0.01	1.19*	-0.3	-0.14
CKH165632	0.16	-0.09	-0.73	-0.34	-0.67	0.15	-0.31	0.01	0.27*	-1*	-0.12	0.33
CKH156636	-0.01	-0.34	-0.03	-0.01	-0.25	0.36	-0.19	0.26	0.01	-0.41	0.14	0.07
CKH156640	-0.47	-0.3	0.1	0.16	0.08	-0.27	-0.46	0.09	-0.2	0.48	0.18	-0.12
CKH156644	0.33	0.58	0.85	0.49	0.38	-0.6	-0.29	0.03	-0.08	-0.26	0.1	-0.15
SE SCA	0.81	0.82	0.78	0.78	0.7	0.77	0.28	0.18	0.12	0.5	0.41	0.17
	D1, D2, and D3 refer to 53,333, 66,666, and 88,888 plants per hectare											
	*Significant at P < 0.05, **Significant at P < 0.01, and *** Significant at P <0.001											