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Identification of High-Yielding Landraces and Hybrids of Maize (*Zea mays* L.) and the Heritability of Yield-Related Traits in Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field research was undertaken at the research site of the Mampong campus of the University of Education, Winneba, Ghana to evaluate the parents and progenies of seven maize varieties. The main objective of the study was to identify high-yielding landraces and hybrids of maize and the

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heritability of yield-related traits using diallel analysis. The seven maize varieties (parents) used were: Aburopa, Aburonenkatie, Aburohoma, Kamaazie red, Kamaazie yellow, Kamaazie light red and Obaatampa. These varieties were crossed using the complete diallel design to generate 49 progenies. The progenies and their parents were evaluated using the Randomized Complete Block Design (RCBD) with three replications. In general, Obaatampa and Kamaazie red performed best for the yield and traits. General Combining Abilities (GCA) and Specific Combining Abilities (SCA) were significant for yield and yield related traits suggesting the importance of both additive and non-additive genes in their inheritance. Maternal gene effect was found to control days to 50% silking, size of seeds, number of seeds per cob and number of husk. It is therefore important to include reciprocals of traits in study. Obaatampa, Aburopa and Aburonenkatie were the best general combiner for 100 seeds weight. High narrow sense heritability was observed for days to 50% tasseling, days to 50% silking, diameter of cob, length of cob, weight per cob, 100 seeds weight and size of seeds. The progeny Aburopa X Kamaazie light red recorded the highest SCA for 100 seeds weight followed by Kamaazie light red X Aburonenkatie.

Keywords: Combining abilities; heritability; maize; yield; yield traits.

1. INTRODUCTION

Maize (*Zea mays*, L.) is an important crop grown in Ghana, occupying over one million hectares, and constituting 50–60% of the country's cereal production. Maize is grown in almost every part of the country, but the Forest–Savannah transition agro-ecological zone, account for more than 80% of the total maize grains produced in Ghana [1]. Maize grains are a major staple for many households, an ingredient for poultry feed and an important industrial commodity in Ghana. Frequent maize crop failures could potentially affect farmers' incomes, make them vulnerable to poverty, and worsen nationwide food insecurity. On the global scale, 60% of maize produced is used for animal feed, 20% for human food (direct consumption), 10% for food processing and 10% for other purposes and as seeds. Maize serves as a staple food for a large proportion of the world's population. The chemical content of the maize grain is very important for human and animal diets. Maize grains have high levels of starch, protein, different sugar derivatives, fiber, and fat content, as well as significant amounts of iron, magnesium, potassium, vitamin A, B1, B3, B9, and C [2]. Additionally, maize flour is considered to be superior to wheat, rice, and oats in terms of nutritional and antioxidant properties [3]. While maize stands out as a significant source of human food in developing countries, it is used more as animal feed and industrial raw material in developed countries. Especially in developing countries, maize accounts for about 60% of the daily intake of protein. It also supplies different vitamins and minerals that are important for the human diet, particularly for children, the elderly and pregnant women [4]. From the ancient time corn has been used to pacify, treat anorexia, general debilities, emaciation and hemorrhoids. It is a potent antioxidant that guards body from harming by free radicals responsible for cellular damage and/or cancer. It has the potential to alleviate pain and possess analgesic activity as well [5].

Despite its enormous benefit, its production is hampered by several factors including low yield of existing varieties, declining soil fertility, pest and disease problems. Maize grain losses contribute to food insecurity and low farm incomes particularly in the tropics, where greater loss is expected due to high temperatures and relative humidity [6].

Understanding the genes controlling yield is fundamental to developing an efficient and successful breeding programme. This study was therefore aimed at understanding the genetic control and heritability of yield and its traits in seven varieties of maize. The study was specifically to identify maize landraces and hybrids, which are high yielding, determine genetic control and heritability of yield traits in maize.

2. MATERIALS AND METHODS

The experiment was carried out at the College of Agricultural Education, University of Education, Winneba, Mampong-Ashanti Campus located in the forest-savanna transition of Ghana from March, 2020 to December, 2020. The experimental area, falls within the transitional zone of Ghana's agroclimatology. It experiences two main seasonal rainfalls annually, with the major season rains falling between late April and late June and the minor season rains between

September and mid-November [7]. The soil at the project site is the Bediese Series of the Savanna Ochrosol. The soil exhibits all the features of sandy loam. It is well drained with thin layer of organic matter [8]. It has the characteristics of deep yellowish red, friable and free from stones. The pH ranges from 6 to 6.5 [8]. The soil is permeable and has moderate water holding capacity [8]. The field had been under continuous cultivation with slash and ploughing as the main methods of land preparation.

The experiment was carried out by growing the parents and the progenies. The experimental design used was the Randomized Complete Block Design (RCBD) with 3 replications. The experimental field measured 17.20 m x 9.20 m, giving a total field size of 158.24m^2. The field was ploughed, pegged and laid out into three blocks. Each plot measured 1.60m x 2.40m (3.84m^2) with 1m path separating blocks and plots. There were seven plots in each replication. Six local landraces and one locally released variety of maize seeds were obtained from subsistence farmers from Nkrankwanta in Dormaa West of the Bono region, Mampong-Ashanti, Wuraso and Wa in the Upper West Region of Ghana. The varieties evaluated were Aburopa, Aburohoma, Aburonenkatie, Obaatanpa, Kamaazie red, Kamaazie light red, and Kamaazie yellow. The Obaatanpa was obtained from a certified seed grower in Mampong in the Ashanti Region of Ghana. The kamaazie varieties were obtained from Wa. The local maize cultivars were selected because they are more resistant to weevil and genetically homogenous. The seeds were sown at 2 seeds per/hill at a spacing of 0.80 m x 0.40 m. Each plot had four rows with 5 hills giving a total of 20 hills per plot. Supplementary irrigation using water hose was applied. Regular weed control was done by hand picking and hoeing whenever necessary. A compound fertilizer NPK was applied as basal at the rate of 37.5-37.5-37.5 kg/ha by side placement 20 days after sowing. Sulphate of ammonia at the rate of 125kg/ha was top-dressed at 6 weeks after sowing. A 7 x 7 complete diallel mating design [9] was used to generate 49 progenies. The progenies (F_1) generated from the various crosses were grown with the parents.

Growth and yield parameters measured included plant height, number of leaves per plant, stem girth, days to 50% tasseling, days to 50% silking, cob length, cob weight, number of seeds per cob and 100 seed weight. Plant height was taken by measuring four (4) plants from each plot at tasseling using a tape measure and a stick. The stick was placed from the ground to the tassel after which the stick was lowered and measured with the tape measure. The number of leaves per plant was taken by counting the leaves on four plants from each plot at tasseling. The girths were taken by measuring the stems of four plants from each plot with a Vernier calliper at tasseling. Days to 50% tasseling and days to 50% silking was recorded for each plot. Four cobs from each plot were sampled and measured with the help of electronic scale. Mean number of seeds per cob was obtained by counting the number of seeds on three cobs from each plot. 100-seed weight was obtained by randomly selecting 100 seeds from three cobs from each plot. The weight of the seeds was then taken with an electronic scale.

2.1 Data Analysis

Analysis of variance and diallel analysis [9] were done using GenStat statistical package. Analysis of general combining ability (GCA) and specific combining ability (SCA) for individual experiments was performed and mean squares of GCA and SCA were used to determine GCA: SCA ratio (Beil and Atkins, 1967). Correlation coefficients for traits of resistance and weight loss were determined to establish the strongest correlation in relation to resistance.

2.2 Genetic Parameters

The relative contribution of genetic components was determined to obtain estimates of GCA variance (δ^2_{gca}) and SCA variance (δ^2_{sca}) for each characteristic. Additive (V_a) and dominance (V_d) variance were estimated as $V_a = (\delta^2_{gca})$ and $V_d = (\delta^2_{sca})$. Phenotypic (V_p) and genotypic variance (V_g) were also estimated as:

$V_g = V_a + V_d$, where $V_p = V_g + V_e$ (environmental variance).

Broad (h^2_b) and narrow (h^2_n) sense heritability was calculated from the estimated components of variance as:

$h^2_b = V_g/V_p$ and $h^2_n = Va/Vp$, respectively.

3. RESULTS AND DISCUSSION

3.1 Variation in Agronomic Traits

There were significant differences (P<0.05) in agronomic traits among the seven genotypes evaluated (Table 1). Obaatampa which is known to be one of the early maturing varieties was the second earliest for tasseling (50%) and silking (56%). Aburonenkatie recorded the highest plant height (288.0cm) and the least was Obaatampa (231cm). Obaatampa had the maximum weight per cob (301.7) followed by Aburonenkatie (281.3) and the lowest was observed in Kamaazie yellow (192.3). For number of seeds, Aburohoma had the highest number of seeds (664) and Kamaazie yellow recorded the least (512). Obaatampa recorded the fifth highest for number of seeds per cob, it however, showed the highest value for seeds weight and size of seeds 46.33 and 48.57, respectively. The length of ear tip ranged from 9.33 to 11.57, and the highest was observed in Aburopa whiles the minimum was recorded in Obaatampa. Kamaazie red recorded the second highest value for 100 seeds weight whiles Aburohoma had the least value (28.33) (Table 1).

Genetic variability is the backbone of plant breeding. Plant breeders use selection from the available genetic variability for crop improvement [10]. The analysis of variation revealed great variability in the evaluated agronomic traits of parents evaluated, which suggest that their genetic makeup is not the same. This variability corroborates the report of Muchie and Fentie [11] in maize. This implies the great potential of these landraces for utilization in future breeding programmes. The significance difference in the traits among the accessions gives room for selection of the superior ones. For the purpose of crop improvement, plant breeders can consider Kamaazie yellow for early maturing, Obaatampa for shortness of plant, size of seeds and 100 seeds weight. Aburohoma could be considered for number of seeds per cob and Aburopa for length of ear tip. Among the landraces, Kamaazie red was the best in terms of yield.

3.2 Mean Squares for GCA, SCA and GCA: SCA Ratios for Different Maize Agronomic Traits

Table 2 indicates diallel analysis of each of agronomic traits. From the table, the GCA effect was highly significant ($p<0.05$) for all the parameters with the exception of plant girth. The SCA effect was highly significant for day to 50% silking, number of leaves, plant height and diameter of a cob. SCA was not significant for day to 50% tasseling and plant girth. The reciprocal effect was significant ($p<0.05$) for days to 50% silking, size of seeds, and number of seeds per cob. GCA: SCA ratio was high for all the parameters. GCA: SCA ratio closer or higher than a unit indicates that GCA controls the trait in question. On the other hand, if the ratio is less than a unit it means non-additive genes influence the trait. However, the GCA: SCA ratio for day to 50% silking was very high.

Significantly high GCA for all the yield traits indicates that additive genes controlled the traits. This affirmed results of Soengas et al., [12] who reported similar findings on grain yield in maize. With the exception of days to 50% tasseling and plant girth, all the other traits were controlled by both additive and non-additive genes. The significant reciprocal effect for days to 50% silking, size of seeds and number of rows per cob means these traits were being controlled by maternal genes. Though GCA and SCA control a lot of the traits, the GCA: SCA ratios indicate that GCA was higher than SCA in all the traits.

3.3 Estimation of General Combining Ability (GCA)

Table 3 indicates the GCA of the various traits studied. Aburonenkatie recorded the highest positive GCA for days to 50% tasseling (1.73) and days to 50% silking (2.18) and the least GCA effect for days to 50% tasseling and 50% silking was seen in Kamaaize yellow (-1.39 and 1.49), respectively. The maximum GCA for plant height was observed in Aburopa (11.35) whiles Obaatampa recorded the least GCA effect for plant height (-10.20). For cob weight, the highest GCA was observed in Obaatampa (25.30) and the least was observed in Aburoma (26.99). Kamaaize red had positive GCA for days to 50% tasseling, number of leaves, diameter of cob, length of cob, weight per cob, number of rows per cob and number of seeds per cob. Kamaaize yellow recorded poor GCA effects for all the traits as all the values were negative. The highest GCA for length of ear tip was observed in Aburopa (1.78) followed by Aburohoma (1.13) (Table 3).

The negative values of GCA for days to tasseling and silking implies that the accessions are good combiners as it indicates the tendency of earliness and the reverse is true for those with positive GCA effects. Among the landraces, Kamaazie yellow had the highest negative GCA value, which indicates that it has the tendency to reduce the number of days to tasseling in the hybrid progenies. In maize shorter plant height is desirable for lodging resistance, the landraces which had the highest negative GCA values for height which is in the desire direction were Kamaazie yellow, Kamaazie red and Kamaazie light red. The high positive GCA for ear tip length is desired as the length of the ear tip is a trait that confers resistance to field infestation of maize weevil [13]. Aburopa and Aburohoma were the best combiners for ear tip length and would respond favourably to direct selection as the length of the ear is controlled by additive genes in this study. Brewbaker and Uddin, et al. [14] also observed similar findings in maize. Obaatampa that had exposed ear tips recorded negative GCA for length of ear tip which indicates that it has the tendency to reduce ear tip length in the progeny. Aburopa and Aburonenkatie recorded high positive GCA for 100 seeds weight and size of seeds among the landraces and hence are suitable parents for hybrid formation.

3.4 Specific Combining Ability (SCA)

Table 4a and 4b indicates SCA and their reciprocal effects on the various agronomic traits. Both positive and negative SCA were observed. Many of the crosses were ranked as top crosses for one or more characters. None of the crosses was found desirable simultaneously for all the characters. The cross, which exhibited highest and the lowest SCA effect for days to 50% were seen in the reciprocals in the crosses Kamaazie yellow X Aburohoma (1.67) and Aburohoma X Aburopa (-2). For diameter of a cob, cross Aburonenkatie X Obaatampa exhibited the best SCA (0.35), whereas Aburopa X Obaatampa exhibited the poorest SCA (-0.15) but performed best for cob length (1.05). The poorest SCA for cob length was observed in the cross Aburohoma X Kamaazie light red (-1.57). With respect to cob weight, cross Obaatampa X Aburonenkatie showed the best SCA effect (31.33) in the reciprocals. Next to this was Kamaazie red X Kamaazie light red (22.27). Aburopa X Kamaazie yellow cross showed the highest negative SCA value (-30.97) for cob weight. The crosses Aburopa X Kamaazie light red and Kamaazie light yellow X Aburonekatie exhibited the highest SCA for 100 seeds weight, (4.26) and (3.17) in order of merit and the lowest performance Aburoppa X Kamaazie red (-4.26) followed by Kamaazie red X Kamaazie light red (-3.07). Cross Kamaazie red X Kamaazie yellow and Aburopa X Kamaazie yellow were the highest (1.03) and poorest (-1.17) SCA for length of ear tip, respectively. The highest SCA for number of husk was observed in Obaatampa X Kamaazie yellow (1.46) and the smallest SCA was seen in Kamaazie yellow X A burohoma (-1.3667) (Table 4.a).

The high positive SCA effect of Aburopa X Kamaazie red and Kamaazie red X Kamaazie light red for weight per cob and Aburohoma X Kamaazie yellow, Kamaazie red X Kamaazie light red and Obaatampa X Kamaazie yellow for number of seeds per cob indicates significant deviation from what would have been predicted based on their parental performances. The results revealed great genetic variance. This affirmed Uddin [13] who observed similar findings in maize agronomic traits. Maternal gene effect was found with days to tasseling and length of ear tip. The positive value for days to tasseling and negative value of the reciprocal between Aburonenkatie and Kamaazie yellow indicates the influence of maternal genes. Dhliwayo et al. [15] also found similar maternal effect among agronomic traits in maize. The crosses with high positive SCA effect could be selected for their specific combining ability to use in maize improvement programme. However, the progenies Aburopa X Kamaazie yellow, Aburohoma X Aburopa and Kamaazie red X Aburohoma with high negative SCA values for days to tasseling and Aburopa X Aburonenkatie and Kamaazie red X Kamaazie light red with high negative SCA for plant height are desirable as they are indication of early maturing and shortness, respectively. Some of the parents with high positive GCA resulted in poor SCA and the reverse was observed in some of the crosses. Aburopa and Aburonenkatie which recorded the highest GCA for days to tasseling and plant height resulted in progenies with low SCA in both crosses. Again, the two best general combiners for 100 seeds weight (Obaatampa and Aburopa) resulted in very poor progeny in both crosses. Obaatampa and Kamaazie yellow recorded low GCA for days to tasseling but resulted in progenies with high SCA in both crosses. This affirmed the results of Senthil and Bharathi [16] who reported that two general combiners do not necessarily give the best SCA result. Aburopa with positive GCA and Kamaazie light red with negative GCA for size of seeds resulted in a progeny with the best seeds size. The potentiality of a cross of high and low SCA was attributed to the interaction between dominant alleles from good general combiner and a recessive allele from a poor combiner [16]. The extreme value for weight of cob in the cross Obaatampa X Aburonenkatie with regard to their relative GCA values could be due to transgressive segregation where the appearance of an individual results from the combination of alleles from both parents that have effects in the same direction.

Table 1. Performance of parents for yield traits

Parents	D50%T	D50%S	NL	PG	PH	DOC	LOC	WPC	NOSPC	NOH	SOS	NORPC	100SW
Aburopa	55.33	62.67	17.67	2.37	288.0	4.43	19.23	259.7	569	10.70	8.73	13.77	37.33
Aburohoma	51.00	57.00	19.00	1.97	273.3	3.53	18.83	202.3	671	12.93	29.73	16.00	28.33
Aburonenkatie	57.00	63.00	18.00	2.40	282.7	4.23	21.60	281.3	664	11.60	41.20	13.30	36.33
Obaatampa	50.00	56.33	14.67	2.47	231.3	4.73	21.37	301.7	642	9.70	48.57	13.53	46.33
Kamaazie R	52.33	57.67	18.00	2.40	273.3	4.57	20.67	261.3	651	11.47	43.33	15.10	42.00
Kamaazie Y	49.67	55.67	17.00	2.20	252.3	3.87	16.93	192.3	512	12.27	39.67	13.33	37.33
Kamaazie L.R	51.00	57.00	17.33	2.47	275.3	4.33	22.20	265.0	673	13.03	37.40	16.00	35.67
LSD(P= 0.05)	2.21	2.52	1.23	0.39	19.96	0.85	1.45	35.69	155.2	2.29	7.09	1.45	9.752

D50%T= Day to 50% tasseling, D50%S= Day 50% silking, NL= Number of leaves, PG= Plant girth, PH= Plant height, DOC= Diameter of a cob, LOC= Length of a cob, WPC= Weight per cob, NOSPC=Number of seeds per cob, NHK= number of husk, SOS= Size of seed, NORPC=Number of rows per cob, 100SW=100 seeds Weight

Table 2. Mean squares for GCA and SCA and GCA: SCA ratios for different maize agronomic traits studied in a diallel trial

Sources of variance	D 50% T	D50% S	N L	P G	P H	DOC	LOC	WPC	100SW	NORPC	SOS	NOSPC	NOH
GCA	20.63***	24.25***	1.87***	0.04**	647.01***	0.71***	10.98***	6505.72***	111.30***	3.19***	134.97***	9829.07***	0.61
SCA	0.73	2.09***	0.33***	0.01	94.19***	0.04***	0.93***	554.16***	10.99***	0.77***	12.16***	2589.52***	1.27***
Reciprocals	1.01	1.61***	0.11	0.01	29.05	0.02	0.19	181.31	4.80	0.18	5.17**	711.01**	1.19***
Error	0.66	0.54	0.13	0.01	20.02	0.01	0.15	161.42	4.09	0.22	2.45	398.91	0.19
GCA:SCA	28.42	11.57	5.68	3.48	6.87	16.30	11.76	11.74	10.12	4.13	11.09	3.79	0.48

D50%T=Day to 50% tasseling, D50%S= Day to 50% silking, NL=Number of leaves, PG= Plant girth, PH=Plant height, DOC=Diameter of a cob, LOC=Length of cob, WPC=Weight per cob, 100SW=100 seeds Weight, NORPC=Number of rows per cob, SOS=Size of seed, NOSPC=Number of seeds per cob, NOH=Number of husk, GCA=General combining ability, SCA=Specific combining ability

****P<0.001; **P<0.05>0.001; *P=0.05*

Table 3. Estimation of general combining ability (GCA) effects on 14 agronomic traits

Parents	D50%T	D50%S	NL	P G	P H	LOET	DOC	LOC	WPC	100SW	NORPC	SOS	NOSPC
Aburopa	1.52	1.42	0.40	0.01	11.35	1.78	-0.03	-0.56	-10.99	0.74	-0.70	0.39	-44.33
Aburohoma	0.27	- 0.44	0.31	- 0.11	1.37	1.13	-0.38	-0.93	-26.99	-4.19	0.41	-4.72	23.24
Aburonenkatie	1.73	2.18	0.19	0.04	4.04	- 0.86	0.037	1.00	17.30	0.5	-0.18	1.13	17.58
Obaatampa	-1.05	- 0.99	- 0.69	- 0.06	- 10.20	- 0.93	0.34	0.76	25.30	5.02	0.17	5.52	9. 93
Kamaazie R.	0.11	- 0.25	0.05	- 0.01	- 0.34	0.12	0.18	0.10	15.04	-0.10	0.36	-0.167	10.15
Kamaazie Y.	-1.39	- 1.49	- 0.05	- 0.00	- 4.96	- 0.78	-0.10	-1.15	-26.87	-2.02	-0.54	-1.90	-31.30
Kamaazie L. R.	- 0.65	- 0.44	- 0.17	0.02	- 1.25	- 0.46	-0.05	0.77	7.20	0.05	0.48	-0.24	14.72
SD (Gi)	0.20	0.18	0.09	0.02	1.11	0.12	0.03	0.10	3.14	0.50	0.12	0.39	4.94
SD (Gi- Gj)	0.31	0.28	0.13	0.03	1.69	0.19	0.05	0.15	4.80	0.76	0.18	0.59	7.55

D50%T=Day to 50% tasseling, D50%S= Day to 50% silking, NL=Number of leaves, PG= Plant girth, PH=Plant height, LOET= length of ear tip, DOC=Diameter of a cob, LOC=Length of cob, WPC=Weight per cob, 100SW=100 seeds Weight, NORPC=Number of rows per cob, SOS=Size of seed, NOSPC=Number of seeds per cob, SD (Gi) standard error for any GCA effect, SE(Gi - Gj) standard error of the difference between any two effects

Table 4a. Specific combining ability effect on different agronomic traits

Crosses	D 50% T	Da50% S	NL	PG	P H	DOC	LOET	LOC	WPC	100SW	NORPC	SOS	N0SPC	NOH
1x2	1.08	-0.35	0.12	0.02	0.65	-0.00	0.26	0.59	4.15	0.67	-1.38	-0.18	-30.41	-0.30
1x3	-0.59	0.70	-0.10	-0.01	-3.18	-0.02	-0.71	-0.96	-11.47	-0.19	0.62	-0.61	12.42	0.68
1x4	0.53	0.20	0.45	-0.04	6.72	-0.15	-0.17	1.05	3.37	2.62	0.49	3.03	18.90	0.88
1x5	-0.14	-3.20	-0.40	0.06	7.5	-0.01	-0.59	0.17	23.30	-4.26	-0.25	-4.53	-23.82	-0.47
1x6	-1.14	0.20	0.48	-0.02	-1.68	-0.12	-1.17	-0.52	-30.97	-1.0	-0.22	-1.01	-15.20	0.23
1x7	0.29	0.65	-0.07	-0.05	1.77	0.13	0.44	-0.51	-25.04	4.26	-0.07	5.16	28.11	0.07
2x3	-0.80	0.56	-0.5	-0.05	6.54	-0.19	-0.28	-0.14	13.37	2.24	0.51	1.84	3.02	0.15
2x4	-0.02	0.06	0.05	-0.03	8.70	-0.09	0.04	0.22	-5.80	-1.12	-0.05	-1.45	-15.01	-0.58
2x5	0.82	0.65	-0.31	0.06	-2.32	0.12	-0.26	0.41	-7.87	-0.83	-0.36	-0.28	-4.39	0.19
2x6	-0.18	0.06	-0.26	0.07	4.63	0.13	-0.62	-0.05	-6.97	-1.57	0.50	-1.32	82.06	-0.42
2x7	-0.09	-0.82	-0.14	0.05	1.42	0.07	-0.16	-1.57	-8.20	1.86	-0.05	2.01	-12.46	0.58
3x4	-0.35	-1.06	0.17	0.04	3.87	0.35	0.01	0.25	-2.92	-0.64	0.21	0.61	31.99	0.11
3x5	-0.52	0.20	0.31	0.08	4.01	0.11	-0.08	0.03	-18.66	1.64	0.59	1.38	-7.89	0.15
3x6	1.15	-1.39	0.02	-0.05	6.63	0.05	0.54	0.60	18.42	-2.10	0.00	-3.31	-28.44	-0.77
3x7	-0.09	0.39	-0.19	-0.03	-2.25	-0.14	0.49	0.79	-0.49	1.67	-1.23	0.95	8.04	-0.29
4x5	0.10	1.37	0.02	0.10	-2.09	0.01	0.81	-0.95	-22.32	2.29	-0.35	1.62	-10.24	1.13
4x6	0.27	0.27	0.07	0	2.20	0.18	-0.10	0.17	8.58	1.05	0.32	0.82	58.21	1.46
4x7	-0.09	-1.11	0.52	-0.05	5.99	-0.03	0.75	-0.40	13.01	-2.52	0.54	-2.37	-58.32	-0.40
5x6	-0.23	0.03	0	0.10	3.34	0.03	1.03	-0.22	17.01	0	-0.23	1.46	0.33	0.50
5x7	0.20	0.82	-0.33	-0.15	-7.37	-0.13	-0.51	0.26	22.27	-3.07	0.57	-3.52	62.97	-0.67
6x7	0.03	0.22	-0.12	0.11	-0.25	-0.01	0.13	0.96	-7.16	0.19	-0.42	-0.32	-24.24	-0.64
SE (Sij)	0.50	0.45	0.22	0.05	2.75	0.07	0.31	0.24	7.81	1.24	0.29	0.96	12.27	0.27
SE (Sij- SkI)	0.68	0.62	0.30	0.08	3.78	0.10	0.42	0.33	10.74	1.71	0.39	1.32	16.88	0.37
SE (Rij)	0.57	0.52	0.25	0.06	3.16	0.09	0.35	0.28	8.98	1.43	0.33	1.11	14.12	0.31

D50%T=Day to 50% tasseling, D50%S= Day to 50% silking, NL=Number of leaves, PG= Plant girth, PH=Plant height, LOET= length of ear tip, LOC=Length of cob, WPC=Weight per cob, 100SW=100 seeds Weight, NORPC=Number of rows per cob, SOS=Size of seed, NOSPC=Number of seeds per cob NOH= number of husk

Table 4b. Specific combining ability effect on different agronomic traits

Reciprocal crosses	D 50% T	D50% S	N L	P G	P H	DOC	LOET	LOC	WPC	100SW	NORPC	SOS	NOSPC	NOH
2X1	-2	0.33	0.17	0.07	-1.5	-0.02	-0.32	0.83	-6.5	0.5	0.22	0.98	-17.5	-0.95
3X1	0.33	1	-0.17	-0.05	2	0.05	0.37	-0.02	-8.17	-0.67	0.1	-0.17	0	-0.2
3X2	0.67	-1.67	0.33	0.02	2.33	0.07	0.22	0.07	-2	-1.5	-0.2	-1.28	-10.17	0.78
4X1	-0.33	1	0.5	0	7.67	-0.18	0.53	0.52	22.67	0	0.12	-0.13	-9.5	0.83
4X2	0	0	0.33	0.08	6	-0.13	0.27	-0.15	6.5	1.67	0.22	1.82	18.5	0.42
4X3	0.67	1.17	0	0.06	6.83	0.02	-0.62	0.05	31.33	2.17	0.1	0.38	12.17	-0.22
5X1	-0.17	2	0.33	-0.03	-0.33	0.07	-0.03	-0.02	-3.67	-1.67	-0.23	-1.92	6.67	0.08
5X2	-1	-1.33	0	-0.08	6.5	-0.08	0.38	-0.05	1.83	-0.83	-0.77	-0.87	-43.67	1.15
5X3	0.67	1.17	-0.17	-0.02	-2.83	0.15	-0.75	-0.27	-3.67	-2.67	0	-2.47	11.17	1.25
5X4	-0.17	0.5	0	0	1.17	-0.02	0.7	-0.12	-4.67	-0.83	-0.1	-1.7	-10.83	-1.33
6X1	0.67	0.17	-0.17	-0.03	5.17	0.02	0.18	-0.13	4.5	0	0	1.07	-34.5	-0.32
6X2	1.17	0.5	0.33	0	1.17	0.02	0.68	-0.3	0.5	-0.5	0.27	-0.05	-11.67	-1.37
6X3	-0.5	0.33	0.17	0.13	2.17	0.05	0.17	-0.02	-0.83	1.67	-0.12	1.22	19.83	0.67
6X4	0.5	0.17	0.33	0.07	-0.17	0.05	-0.18	0.05	-1.67	-0.33	0.45	-0.03	-3.17	-0.67
6X5	0.17	0	0	0	1.5	0.27	0.17	-0.07	-9.5	0.83	0.72	2.25	6.5	-0.87
7X1	0.5	0.33	0.17	-0.02	6	0	0.75	-0.17	6.17	2.67	0.17	3.1	-1.83	0.45
7X2	0.67	0	0	0	4.33	0.23	0.03	0.43	-0.33	1.67	0.23	1.65	-0.5	-0.57
7X3	0.67	1.5	-0.17	0.03	1	-0.03	0.27	0.33	-3	3.12	0.33	3.1	-2	0.57
7X4	-0.67	-0.5	0.33	0.13	-1.33	0.02	-0.15	0.1	-0.5	0.17	0.23	0	46.83	0.12
7X5	0.33	0.5	-0.17	-0.03	-2.17	-0.07	-0.02	0.55	6.17	-2.17	-0.12	-1.7	-4.5	0.75
7X6	0	0	0	-0.03	-1.67	0.07	0.02	0.24	7.81	1.24	0.29	0.96	12.27	0.27
SE (Sij)	0.50	0.45	0.22	0.05	2.75	0.07	0.31	0.33	10.74	1.71	0.39	1.32	16.88	0.27
SE (Sij- Skl)	0.68	0.62	0.30	0.08	3.78	0.10	0.42	0.28	8.98	1.43	0.33	1.11	14.12	0.37
SE (Rij)	0.57	0.52	0.25	0.06	3.16	0.09	0.35	0.1	-0.5	0.17	0.23	0	46.83	0.31

D50%T=Day to 50% tasseling, D50%S= Day to 50% silking, NL=Number of leaves, PG= Plant girth, PH=Plant height, LOET= length of ear tip, LOC=Length of cob, WPC=Weight per cob, 100SW=100 seeds Weight, NORPC=Number of rows per cob, SOS=Size of seed, NOSPC=Number of seeds per cob NOH= number of husk

3.5 Genetic Control and Heritability

Table 5 indicates the genetic control and heritability of agronomic traits. The GCA variances were high, in general, compared to SCA variance. GCA variance was higher than SCA for days to 50% tasseling, days to 50% silking, diameter of cob, length of cob, weight per cob, 100 seeds weight, size of seeds and length of ear tip. However, the SCA variance for plant height (42.26), number of rows per cob (1248.14) and number of husk (0.61) were higher than the GCA variance. Variances of additive genes were also generally higher than dominant genes. This was due to GCA: SCA ratios which were greater than a unit. Higher additive variance was observed for days to 50% tasseling, day to 50% silking, diameter of cob, length of cob, 100 seeds weight, size of seeds, weight per cob and length of ear tip. However, higher variance was observed for dominance genes as compared to additive genes for number of leaves, plant height, number of rows per cob and number of husk. High broad sense heritability values were recorded for all the agronomic traits. Narrow sense heritability was high for days to 50% tasseling, diameter of cob, length of ear tip, days to 50% silking and weight per cob (Table 5).

The higher GCA variances than SCA variances for most of the agronomic traits suggest that selection of these characters will respond favourably to direct selection. When GCA variance was higher than the SCA variance, it is an indication that additive genes contribute more to the trait than non- additive genes [17]. High GCA variance for anthesis and silking showed the preponderance of additive gene action in controlling these traits. Betran et al. [18] also observed that additive gene action was more important in controlling anthesis and silking in maize.

The additive variance was generally higher than the dominant variance indicating the importance of additive genes in predicting the progeny performance for expressing higher yield. If plants are selected for characters such as weight per cob, size of seeds and 100 seeds weight, it is expected that these traits are expressed desirably in the offspring. Soengas et al. [12] reported the preponderance of additive gene effects relative to non-additive gene effects in controlling grain yield. In contrast Bhatnagar et al. [19] reported the predominance of non-additive genetic effects relative to additive genetic effects for grain yield in diallel crosses in maize. The additive genetic effect for grain yield observed in this study could be due to variable genetic effects for grain yield, the type of parents and environments under consideration.

Narrow sense heritability is important for breeding programmes as it estimates the relative importance of the additive portion of the genetic variance that can be transmitted to the next generation. The lower narrow sense heritability for most of the agronomic traits studied could be due to high influence of environment on these traits. This supports the findings of Falconer and

Table 5. Genetic control and heritability of agronomic traits

Characters	δ^2gca	δ^2sca	δ^2e	δ^2A	δ^2D	H^2(b)%	h^2(n)%
D50%T	1.42	0.04	0.66	5.69	0.16	89.90	87.47
D50%S	1.59	0.89	0.54	6.34	3.54	94.79	60.83
NOL	0.11	0.12	0.13	0.44	0.46	87.69	42.86
PG	0.00	0.00	0.01	0.01	0.01	68.23	33.35
PH	39.61	42.26	20.02	158.44	169.03	94.24	45.60
DOC	0.05	0.02	0.01	0.19	0.06	94.48	70.42
LOC	0.72	0.45	0.15	2.88	1.78	96.85	59.79
WPC	425.76	223.78	161.42	1703.05	895.10	94.15	61.71
100SW	7.18	3.93	4.09	28.70	15.73	91.56	59.15
NORPC	0.17	0.32	0.22	0.69	1.26	89.98	31.91
SSZ	8.79	5.53	2.45	35.15	22.14	95.90	58.85
NOSPC	520.75	1248.14	398.91	2082.99	4992.55	94.66	27.87
LOET	1.07	0.41	0.25	4.29	1.65	95.95	69.26
NOH	0	0.61	0.19	0	2.46	92.79	0

D50%= Day to 50% tasseling, D50%S= Day to 50% silking, NOL= Number of leaves, PG= Plant girth, PH= Plant height, DOC= Diameter of a cob, LOC= Length of a cob, WPC= Weight per cob, 100SW= 100 seeds weight, NORPC= Number of rows per cob, SSZ= Size of seeds, NOSPC= Number of seeds per cob, LOET= Length of ear tip, NOH= Number of husk, H^2(b) broad sense heritability, h^2(n) narrow sense heritability

Mackay [20] who reported that lower narrow sense heritability could be due to high influence of environment.

4. CONCLUSION

There were significant variations in agronomic traits among the genotypes of maize. Obaatampa and Kamaazie red performed best for yield and its traits. Both GCA and SCA were significant for the traits suggesting importance of additive and non-additive genes in inheritance of these traits. Broad sense heritability was high for the traits. Aburopa X Kamaazie light red, Kamaazie light red X Aburonenkatie and Kamaazie light red X Aburopa were the best specific combiners.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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