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Correlation analysis for grain yield and other agronomic parameters for 90 single crosses hybrid maize evaluated in three agrological zones in Ghana

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A trial was conducted to determine the correlation between grain yield and agronomic parameters of 90 F_1 early maturing maize hybrids in 2012 in Fumesua, Ejura and Kpeve; representing the Forest, Forest-Savannah Transition and Coastal- Savannah Transition zones of Ghana, respectively. The objective of the work was to determine the correlation between grain yield and other agronomic parameters of maize across three locations. Randomized Complete Block Design (RCBD) with two replicates was used for each location. Results from the correlation analysis revealed that grain yield was significantly and positively correlated with plant height (r = 0.633), cob length (r =0.610) ear height (r =0.410), and cob diameter (r = 0.401). However, there were nonsignificant correlation between grain yield and days to silking. Nevertheless, among agronomic traits, ear height, plant height seed length, seed diameter, cob length and cob diameter were positively and significantly correlated, indicating that increase in any one of these traits could lead to increase in the other. It was recommended that hybrids that showed the highest correlation with grain can be selected to improve grain yield.

Key words: Maize, correlation, genotype, hybrid, adaptability, yield, agroecology.

INTRODUCTION

Maize (*Zea mays* L.) is the most widely grown cereal in the world, and it is the third most important cereal crop after wheat and rice which serves as a primary staple food in most developing countries (Khalil et al., 2011; Badu-Apraku et al., 2010; Obeng-Bio, 2010). The maize plant has wider adaptability hence can be cultivated in different growing conditions from latitude 58°N to 40°S, below sea level and at altitude higher than 3000 m, and in areas with rain-fall of about 250 to 5000 mm per annum and with growing season ranging from three months to about 13 months (Golam et al., 2011).

Its high yield potential, wide adaptability, relative ease

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Table 1. Description of the test environment used in the trial.

Location	Latitude	Longitude	Altitude	Rainfall (mm)	Ecology
Fumesua	6° 43'N	1° 36W	228	142.4	Forest
Ejura	7° 24'N	1° 21E	229	117.4	Forest Savanna Transition
Kpeve	3° 20'N	0° 17E	69	121.5	Coastal Savanna Transition

Rainfall data from April to August (2012).

of cultivation, processing, storage and transportation has increased its potential for combating food security challenges posed by population increase and changes in climatic conditions due to global warming in West and Central Africa (Badu-Apraku et al., 2010).

Maize is grown in approximately 25 million hectares in Sub-Saharan Africa, largely by subsistence farmers that produced 38 million tons in 2005 to 2008, primarily for food (Smale et al., 2011). From 2005 to 2008, maize represented an average of 27% of cereal area, 34% of cereal production and 8% of the value of all primary crop production (FAO STAT, 2014; Smale et al., 2011).

In Ghana, maize is the highest ranking cereal in terms of production and consumption followed by rice (Twumasi-Afriyie et al., 1992). The domestic demand is growing because it serves as a major source of daily calories and dietary protein for most people who are under privileged, since poverty makes it difficult for such people to afford meat (MiDA, 2006).

According to a MOFA (2006) annual report, maize accounted for 50 to 60% of total production area of cereals with average yield approximately at 1.6 metric tons per hectare, but yields as high as 4.5 to 5.0 metric tons per hectare can be realized by farmers using improved seeds and good management practices.

MATERIALS AND METHODS

Research location

The experiment was conducted in three agro-ecological zones of Ghana. The locations where the experiment was conducted were different in mean seasonal rainfall (Table 1). Fumesua lies in the Forest ecology zone of Ghana. Ejura lies in the Forest –Savannah Transition ecology and Kpeve lies in the Coastal-Savanna Transition. The three experimental sites experience a bimodal rainfall pattern. The major season stretches from April through July, and the minor season from August to November (Table 2).

Research materials

Experimental design

The ninety F_1s were constituted into a hybrid trial and planted in a random complete block design at each of the sites. Prior to planting, the site was thoroughly prepared with plough and harrow using tractor. Each entry was planted in a one row of 5 m, spacing between hills of 0.45 m and spacing between rows of 0.75 m with two replications at each of the three evaluation sites. Each plot in the trial contained 11 hills, and each row contained 22 plants to obtain a target plant density of approximately 60,000 plants ha-^{1}.

Crop husbandry

Pre-emergence and post emergence chemical weed control was done with an application of Gramoxone and Atrazine respectively. Hand weeding was also done when necessary to control weeds during the growing period. NPK 15-15-15 fertilizer was applied at the rate of 30 kg N ha^{-1}and 60 kg P_2O_5 ha^{-1} as basal fertilizer at two weeks after planting and top-dressed with additional N at 60 kg N ha-^{1} at 4 weeks after planting. The trials were conducted under rain-fed condition, and other management practices were done according to the recommendations of the specific areas.

Data collection

Data were collected on the following parameters prior to harvesting:

Days to 50% tasseling

This was calculated as the number of days from the date of sowing to the day at which 50% of plants in a plot showed full tassel emergence.

Days to 50% silking

The number of days from the date of sowing to the day on which 50% of the plants in a plot showed complete silk emergence.

Plant height

The height of five randomly selected plants in a plot were measured in centimeter with a graduated measuring stick from the ground level to the node bearing the flag leaf and averaged.

Ear height

The ear heights of the five previously selected plants in each plot were measured in centimeters from ground level to the node bearing the uppermost ear and averaged.

Cob length

The length of the cob was measured in centimeters using Vernier caliper (from the base of the ear to the tip). Five cobs were chosen at random from each plot and averaged.

Cob width

The widths of five randomly selected cobs were measured in centimeters as the thickness of the ear using Vernier caliper. Ten cobs were chosen at random from each plot and averaged.

Table 2. List of 90 single cross hybrid maize evaluated at three locations in southern during 2012 growing season.

Entry no.	Code	Entry name	Entry no.	Code	Entry name
1	P1	TZEI-9 × TZEI-12	46	P46	TZEI-19 × TZEI-46
2	P2	TZEI-24 × TZEI-23	47	P47	TZEI-36 × TZEI-20
3	P3	TZEI-48 × TZEI-20	48	P48	TZEI-14 × TZEI-15
4	P4	TZEI-4 × TZEI-2	49	P49	TZEI-12 × TZEI-9
5	P5	TZEI-3 × TZEI-1	50	P50	TZEI-34 × TZEI-46
6	P6	TZEI-2 × TZEI-19	51	P51	TZEI-1 × TZEI-19
7	P7	TZEI-9 × TZEI-11	52	P52	TZEI-22 × TZEI-48
8	P8	TZEI-41 × TZEI-47	53	P53	TZEI-33 × TZEI-19
9	P9	TZEI-41 × TZEI-30	54	P54	TZEI-39 × TZEI-22
10	P10	TZEI-11 × TZEI-15	55	P55	TZEI- 9 × TZEI-10
11	P11	TZEI-46 × TZEI-34	56	P56	TZEI-25 × TZEI-27
12	P12	TZEI-10 × TZEI-11	57	P57	TZEI-22 × TZEI-20
13	P13	TZEI-32 × TZEI-5	58	P58	TZEI-14 × TZEI-16
14	P14	TZEI-38 × TZEI-35	59	P59	TZEI-22 × TZEI-45
15	P15	TZEI-12 × TZEI-13	60	P60	TZEI-19 × TZEI-48
16	P16	TZEI-35 × TZEI-19	61	P61	TZEI-33 × TZEI-2
17	P17	TZEI-39 × TZEI-34	62	P62	TZEI-12 × TZEI-20
18	P18	TZEI-22 × TZEI-20	63	P63	TZEI-22 × TZEI-18
19	P19	TZEI-39 × TZEI-36	64	P64	TZEI-28 × TZEI-14
20	P20	TZEI-45 × TZEI-47	65	P65	TZEI-2 × TZEI-34
21	P21	TZEI-36 × TZEI-34	66	P66	TZEI-34 × TZEI-22
22	P22	TZEI-17 × TZEI-16	67	P67	TZEI-36 × TZEI-38
23	P23	TZEI-11 × TZEI-12	68	P68	TZEI-2 × TZEI-22
24	P24	TZEI-13 × TZEI-17	69	P69	TZEI-27 × TZEI-19
25	P25	TZEI-35 × TZEI-16	70	P70	TZEI-18 × TZEI-46
26	P26	TZEI-25 × TZEI-23	71	P71	TZEI-36 × TZEI-35
27	P27	TZEI-48 × TZEI-45	72	P72	TZEI-14 × TZEI-17
28	P28	TZEI-42 × TZEI-47	73	P73	TZEI-27 × TZEI-14
29	P29	TZEI-31 × TZEI-18	74	P74	TZEI-36 × TZEI-33
30	P30	TZEI-9 × TZEI-15	75	P75	TZEI-31 × TZEI-7
31	P31	TZEI-47 × TZEI-34	76	P76	TZEI-22 × TZEI-46
32	P32	TZEI-17 × TZEI-15	77	P77	TZEI-42 × TZEI-30
33	P33	TZEI-39 × TZEI-30	78	P78	TZEI-34 × TZEI-7
34	P34	TZEI-41 × TZEI-46	79	P79	TZEI-33 × TZEI-3
35	P35	TZEI-30 × TZEI-47	80	P80	TZEI-46 × TZEI-47
36	P36	TZEI-11 × TZEI-9	81	P81	TZEI-41 × TZEI-22
37	P37	TZEI-27 × TZEI-9	82	P82	TZEI-33 × TZEI-46
38	P38	TZEI-36 × TZEI-22	83	P83	TZEI-25 × TZEI-14
39	P39	TZEI-13 × TZEI-10	84	P84	TZEI-34 × TZEI-3
40	P40	TZEI-36 × TZEI-39	85	P85	TZEI-19 × TZEI-18
41	P41	TZEI-45 × TZEI-34	86	P86	TZEI-48 × TZEI-16
42	P42	TZEI-12 × TZEI-15	87	P87	TZEI-10 × TZEI-12
43	P43	TZEI-30 × TZEI-31	88	P88	TZEI-18 × TZEI-26
44	P44	TZEI-4 × TZEI-3	89	P89	TZEI- 24 × TZEI-12
45	P45	TZEI-23 × TZEI-15	90	P90	TZEI-38 × TZEI-36

Grain yield

Grain yield kg ha^{-1} was calculated for every entry from the data of harvested ear weight per plot using the following formula:

Grain yield (kg ha^{-1}) was calculated as = Harvested ear weight (kg plot-1) × (100-MC) × 0.8 × 10,000/ (100-15) × 3.75 m^2 (at 15% moisture).

Seed length

The length of ten randomly selected seeds were measured in centimeters using Vernier caliper and averaged.

Seed diameter

The widths of ten randomly selected seeds were measured in centimeters as the thickness of the seed using Vernier caliper and averaged.

Data analysis

The Analysis of Variance (ANOVA) according to Steel and Torrie (1980) for grain yield and agronomic parameters was conducted using Statistical Analysis System version 9.2 (SAS, 2003). Least significance difference test (p≤0.05) was used to determine the level of significance among measured parameters. Pearson coefficients of correlation were calculated using the hybrids' least square means for all parameters to determine associations among these parameters. Correlation coefficients ranged in values between -1 and +1; a perfect negative relationship and a perfect positive relationship respectively

RESULTS AND DISCUSSION

Mean performance of the genetic materials evaluated

Mean performance of the crosses are presented in Table 4. Mean grain yield was 4598 kg ha^{-1} with yield ranging from 1058.4 kg ha^{-1} (TZEI-45 × TZEI-47) to 6296 kg ha^{-1} (TZEI-36 × TZEI-39). The mean performance for plant height showed that differences among genotypes were highly significant (p<0.01) (Table 3).

Mean plant height across environments (Table 4) was 160.9 cm, and ranged from 115 to 186.4 cm. TZEI-12 × TZEI-13 recorded the lowest height (115 cm) while TZEI-39 × TZEI-22 recorded the highest height (186.4 cm). The result showed that there were highly significant differences among genotypes (P<0.01) for ear height (Table 3). Mean ear height (Table 4) was 76.9 cm ear height ranged from 52.1 cm (TZEI-12 × TZEI-13) to 97.2 cm (TZEI-35 × TZEI-19).

Meanwhile, TZEI35 × TZEI19 recorded the highest ear height while TZEI12 × TZEI 13 recorded the lowest ear height.

The result for days to silking showed that there were highly significant differences among genotypes (P<0.01). Days to silking ranged from 38 to 54 days. The mean days to silking (Table 4) was at 50 days. TZEI-45 × TZEI-47 was the latest to reach mid-silk, while TZEI-9 × TZEI-12 was the earliest to reach mid- silk.

From the result (Table 3), differences in days to tasseling among genotypes were highly significant (p<0.01). Mean days to tasseling (Table 4) was 47.6 days. Days to mid-tasseling ranged from 43 to 51.2 days. TZEI-12 × TZEI-13 recorded the highest number of days to tasseling while TZEI-9 × TZEI-12 recorded the lowest days to tasseling. The mean square (Table 3) for seed diameter showed highly significant differences among genotypes (p<0.01).

Seed diameter ranged from 0.7cm (TZEI-14 × TZEI-17) to 0.9 cm (TZEI-3 × TZEI-1). The result from the analysis for seed length (Table 3) indicated that differences among the genotypes were significant (P<0.05). Seed length ranged from 0.8 cm (TZEI-28 × TZEI-14) to 1.5 cm (TZEI-41 × TZEI-30) (Table 4). The data analysis for cob length (Table 3) revealed that differences among genotypes were highly significant (P<0.01). Mean cob length was 13. 4 cm and cob length ranged from 9.4 cm (TZEI-28 × TZEI-14) to 15.2 cm (TZEI-24 × TZEI-23) (Table 4).

The mean square analysis for cob diameter (Table 3) revealed that differences among genotypes were highly significant (P<0.01). Mean cob diameter (Table 4) was 4.2 cm. TZEI-42 × TZEI- 22 recorded the highest value (5.6 cm) while TZEI-28 × TZEI-14 recorded the lowest value (2.9 cm) for cob diameter.

Correlations among agronomic parameters measured

Identification of superior hybrids

The primary trait, grain yield, is a quantitatively inherited trait with low heritability. Several studies have indicated that highly significant phenotypic correlations between yield and many secondary traits can be found (Nzuve et al., 2014). The use of secondary traits in breeding can increase breeding progress as compared to selection for yield alone (Edmeades et al., 1997).

A superior maize hybrid must be high yielding and also must possess desirable agronomic characters. The correlation studies revealed that plant height was strongly associated with grain yield, ear height, days to tasseling, cob length and diameter, seed length and seed diameter. This indicates that any one of these traits could be used to select for the other.

The significant differences recorded for the different traits among the genotypes studied (Table 3) implied that the maize genotypes included in this study had diverse genetic backgrounds (Vashistha et al., 2013; Reddy et al., 2012).

Thus, the genetic variability recorded in this study could be exploited by plant breeders to develop hybrids adapted to the diverse environments in sub Saharan Africa to improve food security status (Feuillet et al., 2012). The significant genotype by environment interaction showed a wide variability with regard to the tested genotypes and the environments involved in this study (Alake et al., 2008).

Results on correlation among parameters are presented in Table 5. The correlation studies among traits showed that grain yield was positively correlated to days to tasseling, ear height, plant height, cob length, cob

Table 3. Mean squares values of combined ANOVA for agronomic traits of early maturing maize single cross hybrids evaluated during 2012 growing season.

Source of variation	Mean squares								
	DF	PHT	EHT	DS	DT	SDD	SDL	CL	CD
Replication	1	38.6	32.6	195.6	170	0.00794	0.00997	11.06	0.041
Environment	2	5878**	2297**	3135**	4253**	0.025*	0.0845**	147.95**	7.86*
Genotype	89	1156**	446**	19.07**	14.3**	0.0071**	0.01047*	6.318**	0.63**
Error	269	254	116	4.73	3.6	0.0042	0.0065	1.608	0.239
Total	539	-	-	-	-	-	-	-	-
Lsd	-	18.1	12.2	2.5	2.2	0.07	0.09	1.4	0.56
CV%	-	9.9	14	4.3	4	7.8	8.1	9.5	11.6

*= Significant (0.05%) **= Significant (0.001) ns= Non Significant Degree of Freedom = DF, Plant height = PHT, ear height = EHT, days to silking = DS, days to tasseling = DT, seed diameter = SDD, seed length = SDL, cob length = CL and cob diameter.

Table 4. Combined mean grain yield ($kgha^{-1}$) and agronomic performance of maize hybrids evaluated across three locations in Ghana during 2012 growing season.

Entry	Yield (kg)	Rank	DS	DT	PHT (cm)	EHT (cm)	CL (cm)	CD (cm)	SDL (cm)	SD (cm)
TZEI-36 × TZEI-39	6296	1	47.7	45.5	179	78	14.3	4.2	1	0.88
TZEI-33 × TZEI-19	6066	2	51.2	48.2	174	87	14	4.6	1.1	0.87
TZEI-35 × TZEI-19	5850	3	51.5	48.3	183	97	13.7	4.4	1.1	0.83
TZEI-45 × TZEI-34	5838	4	51	48.2	175	78	13.6	4.4	1	0.79
TZEI-22 × TZEI-45	5784	5	51	48.3	178	90	14.3	4.3	1	0.83
TZEI-2 × TZEI-22	5770	6	50.7	47.5	183	91	13.4	4.5	1.1	0.88
TZEI-34 × TZEI-7	5682	7	46.3	44.2	164	80	12.6	4.4	1	0.86
TZEI-10 × TZEI-11	5617	8	48	45.7	162	80	14.1	4.1	1	0.85
TZEI-48 × TZEI-45	5514	9	51.2	48.2	164	85	14.9	3.9	1	0.85
TZEI-22 × TZEI-48	5456	10	51	48.3	173	94	13.6	4.3	1	0.83
TZEI-34 × TZEI-46	5453	11	51.5	48.3	155	69	14.5	4.3	1	0.8
TZEI-11 × TZEI-15	5436	12	48.5	45.8	159	76	14.7	4.2	1	0.8
TZEI-41 × TZEI-30	5406	13	49.8	47.2	168	85	13.5	6	1	0.82
TZEI-25 × TZEI-23	5380	14	48	45.3	156	81	14	4.1	1	0.85
TZEI-48 × TZEI-20	5352	15	49.8	47.2	175	92	14.5	4.3	1	0.8
TZEI-12 × TZEI-15	5280	16	47.5	45.2	165	70	14.5	4.3	1	0.85
TZEI-3 × TZEI-1	5266	17	49.7	47.2	181	81	13.9	4.6	1	0.9
TZEI-41 × TZEI-47	5234	18	51	48.2	152	74	13.3	4	1.5	0.83
TZEI-31 × TZEI-7	5221	19	49.5	47	174	80	14.5	4.4	1.1	0.88
TZEI-36 × TZEI-35	5189	20	48	45.5	166	78	14.7	4.1	1.1	0.82
TZEI-30 × TZEI-47	5185	21	48	51	184	82	14.5	4.3	1	0.82
TZEI-42 × TZEI-30	5179	22	50.5	47.8	176	82	13.4	4.4	1	0.85
TZEI-27 × TZEI-19	5143	23	52.7	49.3	179	79	13.1	4.4	1.1	0.88
TZEI-13 × TZEI-10	5124	24	49.2	46.8	150	71	13.8	4.2	1	0.82
TZEI-25 × TZEI-14	5115	25	51.8	48.7	157	77	15	4.3	1	0.78
TZEI-38 × TZEI-36	5076	26	50	47.5	166	78	12.8	4.2	1	0.83
TZEI-1 × TZEI-19	5022	27	51.5	48.5	181	91	12.7	4.2	1	0.83
TZEI-22 × TZEI-46	5008	28	51	47.7	175	80	14.4	4.3	1	0.8
TZEI-17 × TZEI-15	4995	29	49	46.5	148	76	13.7	4.3	1	0.84
TZEI-13 × TZEI-17	4987	30	49.8	47	148	71	14.2	4.4	1	0.82
TZEI-14 × TZEI-17	4984	31	51.5	48.7	147	70	13.8	3.9	0.9	0.77
TZEI-35 × TZEI-16	4949	32	51	48.3	164	77	13.6	4.2	1	0.85
TZEI-48 × TZEI-16	4943	33	49.2	46.8	163	87	14.5	4	1	0.83
TZEI-12 × TZEI-20	4940	34	49.8	47.3	157	76	13.6	4.4	1	0.87

Table 4. Contd.

TZEI-19 × TZEI-48	4926	35	51.5	48.5	176	89	13.9	4.2	1	0.85
TZEI-46 × TZEI-34	4917	36	51.2	48.5	166	77	14	4.5	1.1	0.81
TZEI-39 × TZEI-36	4915	37	48	43.7	182	85	14.3	4	1	0.82
TZEI-14 × TZEI-15	4888	38	50.3	47.5	144	70	13.9	4.2	1	0.82
TZEI-36 × TZEI-34	4877	39	49	46.5	176	83	13.7	4.2	1.1	0.83
TZEI-36 × TZEI-33	4838	40	49.2	46.8	170	79	13.5	4.3	1	0.83
TZEI-11 × TZEI-9	4738	41	49.8	47.7	152	69	13.7	4.2	1	0.85
TZEI-12 × TZEI-9	4821	42	47.5	45	149	74	13.6	4.2	1	0.8
TZEI-24 × TZEI-12	4820	43	51.5	48.8	155	68	15.1	4.2	1	0.83
TZEI-4 × TZEI-3	4802	44	49.2	46.8	168	82	13.4	4.6	1	0.87
TZEI-36 × TZEI-38	4800	45	51.2	48.3	162	75	12.6	4.2	1	0.83
TZEI-2 × TZEI-19	4784	46	51.2	48.3	165	92	13.1	4.6	1	0.8
TZEI-22 × TZEI-18	4779	47	49.8	47.2	163	76	12.7	4.3	1	0.92
TZEI-27 × TZEI-14	4766	48	51.3	48.8	158	79	13.7	4.2	1	0.85
TZEI-25 × TZEI-27	4740	49	51.5	48.8	167	73	14.9	4.1	1.1	0.87
TZEI-19 × TZEI-46	4705	50	52.5	49.7	169	88	13.2	4.2	1.1	0.8
TZEI-9 × TZEI-12	4698	51	46	43.5	151	72	14.5	4	1	0.8
TZEI- 9 × TZEI-15	4676	52	46.3	44	142	68	12.8	4	1	0.87
TZEI-2 × TZEI-34	4675	53	50.2	47.5	154	74	13.1	4.5	1	0.81
TZEI-41 × TZEI-36	4642	54	48.7	47.2	159	71	13.2	4.1	1.1	0.8
TZEI- 33× TZEI-46	4631	55	52.7	49.7	166	80	13	4.2	1	0.85
TZEI- 33× TZEI-3	4587	56	50.7	47.7	165	79	11.9	4.8	1	0.82
TZEI-9 × TZEI-11	4558	57	52.3	49.3	147	69	11.7	4.1	1	0.87
TZEI-31 × TZEI-18	4521	58	49.7	46.7	167	77	13.7	4.2	1	0.87
TZEI- 10× TZEI-12	4509	59	49.5	46.8	149	71	13.6	4.1	1	0.8
TZEI- 18× TZEI-26	4505	60	50.5	47.3	166	83	12.4	4.2	1	0.83
TZEI9- × TZEI-10	4499	61	48.3	47.8	151	72	14.4	4	1	0.8
TZEI-42 × TZEI-47	4482	62	50.8	48.2	154	78	14.2	4.4	1.1	0.83
TZEI-22 × TZEI-20	4364	63	49.2	46.2	167	78	13.7	4	1	0.83
TZEI-47 × TZEI-34	4333	64	50.5	47.7	164	77	13.6	4.3	1	0.87
TZEI-36 × TZEI-22	4308	65	50.5	47.8	168	76	13	4.1	1	0.85
TZEI-34 × TZEI-3	4285	66	50	47	159	69	12.6	4.6	1.1	0.82
TZEI- 4 × TZEI-2	4261	67	51.5	48.7	161	73	12.2	4.6	1	0.85
TZEI-34 × TZEI-22	4228	68	51.2	48.5	165	77	12.1	4.3	1	0.82
TZEI33- × TZEI-2	4174	69	51.2	48	176	68	12.2	4.6	1	0.83
TZEI-22 × TZEI-20	4161	70	51.2	47.7	158	76	13.4	4.2	1	0.85
TZEI-39 × TZEI-22	4106	71	50.5	47.7	186	88	12.3	4.3	1	0.84
TZEI-39 × TZEI-34	4082	72	52.5	49.3	153	72	12.7	4.3	1	0.83
TZEI-14 × TZEI-16	4081	73	53.3	50.5	154	71	12.7	3.8	1	0.79
TZEI-30 × TZEI-31	4078	74	50.5	47.5	164	67	12.1	4.5	1.1	0.87
TZEI-41 × TZEI-22	4037	75	51.2	48.2	173	85	12.6	5.6	1	0.9
TZEI-24 × TZEI-23	4012	76	46.8	44.8	136	56	12.9	4.3	1	0.82
TZEI-39 × TZEI-30	3950	77	49.7	47.2	181	81	12.9	4.2	1	0.8
TZEI-19 × TZEI-18	3923	78	51.2	48.7	172	87	13.5	4.2	1	0.83
TZEI-27 × TZEI-9	3919	79	47.8	45.5	146	82	12	4	1	0.83
TZEI-23 × TZEI-15	3898	80	49.3	46.5	149	70	12.1	4.1	1	0.82
TZEI-18 × TZEI-46	3712	81	52.2	49	161	79	14.7	4.1	1.1	0.83
TZEI-36 × TZEI-20	3462	82	50.7	47.8	137	71	13.1	4.1	1	0.85
TZEI-38 × TZEI-35	3263	83	50.7	47.7	159	77	12.3	4.5	1	0.8
TZEI-17 × TZEI-16	2987	84	53.8	50.3	134	61	12.7	3.5	0.9	0.82
TZEI-32 × TZEI-5	2983	85	51.3	48.5	168	86	12.5	4.5	1	0.83
TZEI-11 × TZEI-12	2847	86	52.3	49.7	140	64	13.6	3.7	0.9	0.8

Table 4. Contd.

TZEI-28 × TZEI-14	2354	87	53.8	50.8	133	59	9.4	2.9	0.8	0.65
TZEI-46 × TZEI-47	1817	88	54.2	50.3	140	67	11	3.6	1	0.81
TZEI-12 × TZEI-13	1194	89	54.3	51.2	116	52	10.9	3.6	0.9	0.83
TZEI-45 × TZEI-47	1058	90	54.3	51	127	55	11.7	3.3	0.9	0.8
Grand mean	4598	-	50.3	48	161	77	13.6	4.2	1	0.83
CV (%)	20.7	-	4.3	4	9.9	14	9.5	11.6	8.1	7.8
LSD	1082	-	2.5	2.2	18.1	12.2	1.4	0.6	0.09	0.07

DS = 50 % days to silking, DT = 50 % days to tasseling, PHT = plant height, EHT = ear height, CL = cob length, CD = cob diameter, SDL = seed length, and SDD = seed diameter.

Table 5. Correlations among nine parameters of maize single cross hybrids evaluated across three locations in Ghana during 2012 growing season.

Variable	GY	DS	DT	EHT	PHT	SD	SDL	CL	CD
GY	1	-	-	-	-	-	-	-	-
DS	0.00328	1	-	-	-	-	-	-	-
DT	0.11558**	0.96858**	1	-	-	-	-	-	-
EHT	0.41004**	-0.36908**	-0.3321**	1	-	-	-	-	-
PHT	0.63331**	0.01782	0.10692*	0.66877**	1	-	-	-	-
SD	0.1900**	0.05539	0.07106*	0.11741**	0.22043**	1	-	-	-
SDL	0.36267**	0.03122	0.05746	0.25501**	0.33965**	0.47017**	1	-	-
CL	0.60951**	-0.04789	0.033	0.339**	0.45683**	0.24388**	0.39668**	1	-
CD	0.40185**	-0.00732	0.04979	0.30371**	0.39895**	0.31541**	0.38844**	0.3347**	1

** Highly significant ($P<0.001$), *significant ($P<0.05$), DT = days to 50% tasseling, DS = days to 50% silking, PHT = plant height, EHT = ear height, SD = seed diameter, SDL = seed length, CL = cob length, CD = cob diameter GY = grain yield.

diameter, seed length and seed diameter with the highest effect on plant height (r = 0.633) and cob length (r = 0.610) and ear height (r = 0.410).

The associations were highly significant ($p < 0.001$). This indicates that improvement on any of these characters could help improve grain yield. Similar results were reported by Bocanski et al. (2009) and Malik et al. (2005). They observed high and positive correlation between grain yield and plant height (r = 0.953), ear height (r = 0.867), and cob length (r = 0.959). Meanwhile, days to silking has no significant correlation with grain yield, plant height, seed length, seed diameter, cob length and cob diameter. This result is in agreement with Golam et al. (2011), who reported that grain yield and plant height did not correlate with days to silking. However, among agronomic traits, ear height, plant height, seed length, seed diameter, cob length and cob diameter were positively and significantly correlated, indicating that increase in any one of these traits could lead to increase in the other.

Ear height significantly correlated with plant height seed length, seed diameter, cob length, and cob diameter. The strong correlation between ear height and plant height with grain yield suggested that tall plants with high ear placement gave better yields compared to the shorter plants with lower ear placement. This could be attributed to the high dry matter accumulation function carried out by the high number of leaves possessed in the case of tall plants (Al-Tabbal et al., 2012).

There were negative correlations between ear height and days to silking and days to tasseling (r = - 0.369 and r = - 0.332). This result is in agreement with that of Malik et al. (2005). The negative correlation indicates that increase in days to silking and tasseling could indirectly reduce yield through stalk and root lodging (Malik et al., 2005). Plant height had low correlation with days to silking, but highly correlated with ear height (r = 0.668), days to tasseling (r = 0.10692), seed diameter (r = 0.2204), cob length (r = 0.4568), cob diameter (r = 0.3989) and seed length (r = 0.3396).

This result indicates that increase in plant height could lead to increase in these characters which could result in yield increase, since plant height has been observed to be controlled by the expression of many genes and the interactions between these genes (Bello et al., 2012). Therefore, traits that positively contribute the highest correlation with grain yield such as plant height, cob length, and ear height and cob diameter can be chosen as superior characteristics to help improve maize grain yield (Table 5).

Conclusion

The correlation studies among traits showed that grain yield was highly correlated with plant height, ear height, days to tasseling, cob length, cob diameter, seed length, and seed diameter with plant height contributing the highest effect (r = 0.633) followed by cob length (r = 0.610) and cob diameter (r = 0.402).This genetic diversity and the strong genetic association between grain yield and the agronomic traits would help in indirect selection thereby aiding breeders in the development of better hybrids for resource poor farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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