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Association of Seed Yield and Yield Traits of Maize (*Zea mays* L.) in Inbred Lines at Bako, Ethiopia

Megersa Bayisa[1, *], Bulti Tesso[2], Abebe Atilaw[3]

[1]Department of Seed Science, Ethiopia Institute of Agricultural Research, Bako National Maize Research Centre, Bako, Ethiopia
[2]Department of Plants Science, College of Agriculture, Haramaya University, Haramaya, Ethiopia
[3]Department of Seed Science, Ethiopia Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Bishoftu, Ethiopia

Email address:
megersabayisa582@gmail.com (M. Bayisa)
[*]Corresponding author

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Abstract: Seed yield of any hybrid maize (*Zea mays* L.) variety emerges depending on parental characteristics of inbred lines used. Even though, traits of each inbred line are recorded there is no clear information about parental traits that contribute to yield and associations among those characters. The present study was conducted using 14 inbred lines at Bako National Maize Research Centre in 2018/2019 based on Randomized complete block design with three replications. Determining type and level of associations among certain parental traits of inbred lines were the primary objectives of the study. Data of PH, EH, EPO, 50% AD, 50% SD, MD, EPP, ED, EL, KPR, and TKW were collected. Analysis of variance was carried out using SAS9.3 and correlation and linear regression were tested using past 3.4 software. The mean squares revealed that there were highly significant differences existed among inbred lines for most of the traits except EPP, EA, and ED. Correlation analysis indicated that a strong positive relationship (r=0.57) exist between grain yield and plant height, ear length (r=0.57), kernel/row (r=0.62) and thousand kernel weight (r=0.58). A negative learner association was observed for grain yield with the ear aspect (r=-0.36) and plant aspect (r=-0.28) which is important for quality seed production. Linear regression shows that plant height, ear height, ear length, number of kernel/row, and thousand kernel weight are closely associated with grain yield. Hence, based on correlation and regression analyses, we conclude that these traits should be considered in selecting inbred lines in breeding programs.

Keywords: *Zea mays* L., Inbred Ines, Correlation, Regression, Yield Components

1. Introduction

Maize (*Zea mays* L.) plays a critical role in meeting the high food demand and is globally one of the most widely cultivated crops [9]. Both the land area used for maize grain production and the amount of maize produced per unit area has been increasing in recent years [7]. Today, maize is grown over a wide range of environmental conditions indicating its importance to millions of people depending on the crop to meet food security and livelihoods. Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 300 million people in SSA [6]. Over 30% of the caloric intake of people in sub-Saharan Africa comes from maize. For these reasons, several African countries that depend on maize as a staple food crop, have adopted agricultural policies to maintain a steady supply of the commodity through increased production and productivity of the crop. However, still Africa imports 28% of its required maize grain from countries outside the continent as most of the maize production in Africa is done under rain-fed conditions, [10].

The fast-growing maize crop is very promising in Ethiopia for its multipurpose uses. Since the 1990s, the research system has developed more than 50 maize varieties that have a high yielding capacity and are adapted to different agro-ecologies of the country. The use of the varieties with improved agronomic practices has helped farmers to produce a mean grain yield of 4.37 t/ha [2].

In 2020, maize production for Ethiopia was 8,600 thousand tons. Maize production of Ethiopia increased from 971 thousand tons in 1971 to 8,600 thousand tons in 2020, [9]. The development of hybrid maize is the main reason for the increment in yield yearly. Inbred lines are of importance in formation, determining the future usefulness and commercial potential of hybrid production. The yield of maize like rest crops is the final product attributed to a complex chain of interrelating effects of different characters [14]. Therefore, the knowledge of association among characters with yield is precious to plant breeders as it helps in the selection of traits as well as genotypes with better accuracy. The study of quantitative and qualitative traits of inbred lines has a great role to select the good parents forming hybrids. Even though a lot of mid-altitude inbred lines were developed and introduced by the Bako national maize research center there is limited information addressing the association among yield and yield-related traits of these inbred lines. Hence, this study was conducted to fill the information gap through addressing the correlation and regression study among 14 released inbred lines of maize. This concept has been very important in the commercial success of maize breeding and hybrid development. Correlation is a measure that describes the strength and direction of a relationship between two or more variables. Thus, this study was conducted to identify the association of different traits with seed yield of maize inbred lines and to investigate the degree of association among traits to know which traits more contributed to yield.

2. Materials and Methods

2.1. The Study Area, Genotypes, and Experimental Design

The experiment was conducted at Bako National Maize Research Centre (BNMRC) in Western Ethiopia. Bako Maize Research Centre lies between 906' North latitude and 37009' east longitude at an altitude of 1650 meters above sea level (m.a.s.l.) in the sub-humid agro-ecology of Ethiopia. Fourteen (14) maize inbred lines [(BKL001, BKL002, BKL003, BKL004, CML161, CML165, CML395, CML312, CML202, 142-1-e, CML444, CML536, 124-b (109), and CML204)] were used in RCBD design with three replications were used. Two seeds were sowed for each seed bed and later thinned to one plant. Each experimental unit consisted of two rows of 5.1m long with a spacing of 0.75m between rows and 0.25m between plants.

2.2. Agronomic Management

The experimental materials were hand planted with two seeds per hill, which were later thinned to one plant to get a planting density equivalent to 44, 444 plant population per hectare. Planting was conducted on the onset of the main rainy season (June 5, 2019) after an adequate soil moisture level was reached to ensure good germination and seedling development. Pre-emergence herbicide, Primagram–Gold was applied at the rate of three liters per hectare at planting to control weeds. Hand weeding and slashing were used when necessary to control weeds throughout the growing season. Di-ammonium phosphate (DAP) and urea fertilizers were applied at the rate of 150 kg/ha and 200 kg/ha respectively. DAP fertilizer was applied once at planting time, while urea was applied in split, half at planting and the remaining half at knee height.

2.3. Data Collected

Data collected on plot basis were: Days to Anthesis (DA), Days to Silking (DS, Anthesis- Silking Interval (ASI), Days to physiological maturity (DM, Actual Moisture Content (AMC), 1000 Kernel Weight (TKW), and Grain yield (GY). For sampled /ear basis plants analysis, five plants/ears were randomly taken from each experimental unit and the required measurements for each parameter were recorded from each plant/ear; then the mean values of each sample were calculated for data analysis. The parameters measured in the trial included: Ear height (EH), Plant Height (PH), Ear length (EL), Ear Position (EP), Ear Diameter (ED), Number of Rows per Ear (NRE), and Number of Kernels per Row (NKR).

2.4. Data Analysis

The data collected for each character were subjected to analysis of variance (ANOVA) using SAS version 9.3. Pearson correlation coefficient analysis was performed to determine the degree of relationship among physiological parameters. The relationship between grain yield and each variable was calculated by using two variables linear model/equation below [11].

2.5. Pearson Correlation Analysis

Pearson Correlation was used to evaluate linear relationships between the traits. Pearson correlation coefficient was calculated using the formula below [1].

$$r=\frac{\sum(xi-xaverage)-(yi-yaverage)}{\sqrt{\sum(xi-xaverage)^2*\sum(yi-yaverage)^2}}$$

Where: r=Correlation coefficient=Average of observations of variable XY=Average of observations of variable Y.

2.6. Leaner Regression Analysis

The relationship between Grain yield and each variable was calculated by using two variables linear model/equation below [12].

Yi=β0 + β1 Xi + EYi=Dependent variable β0=Y intercept, expected value of Y when X=0 β1=Slope, expected change in Y per unit change in Xi=Independent variable E=Random error. There are Yield and different attributes of maize inbred line regression line below to seen the association.

3. Results

3.1. Analysis of Variance (ANOVA)

The analysis of variance showed highly significant and significant differences among the inbred lines for most of the traits except for EA, EPP, and ED (Table 1). The presence of highly significant difference among the mean squares of different traits indicating the presence of genetic variation among the materials which could be a source for further improvement in feature parental lines trait. In agreement with this finding, significant mean square due to genotypes for grain yield and yield-related traits in maize were also reported by previous authors [3-6, 8, 11, 12, 15].

Table 1. *The ANOVA for 14 inbred lines of Maize.*

Traits	Mean squares for Source of variation			
	Rep (df=2)	Treatments (df=13)	Error (df=26)	Coff.Var.5%
GY	0.361	2.607*	0.831	20.816
AD	1.523	57.254**	0.992	1.124
SD	1.142	57.518**	0.899	0.980
ASI	0.380	7.267**	0.765	22.022
PH	53.642	2465.787**	11.445	6.605
EH	34.357	1018.031**	7.405	8.341
EPO	0.009	0.005**	0.026	5.177
MD	18.309	63.620**	1.805	1.175
EPP	0.330	0.338^{ns}	0.363	27.080
PA	0.095	0.143*	0.238	19.817
EA	0.090	0.347^{ns}	0.449	27.028
ED	35.992	35.476^{ns}	5.975	13.001
RPE	0.046	1.972**	0.566	4.214
KPR	14.019	50.507**	2.716	9.378
EL	5.135	8.557**	1.003	7.219
TKW	2363.738	2608.549**	20.516	7.006

N.B. Rep=Replication, DF=degree of freedom, CV (%)=Coefficient of Variation at α (%). *=0.05 and **=0.01 significant probability level respectively. ns=non-significant, GY=Grain yield, DA=Days to an thesis, DS=Days to silking, ASI=An thesis silking interval, EH=Ear height, PH=Plant height, EPO=Ear position, DM=Days to maturity, EPP=Number of ears per plant PA=Plant aspect, EA=Ear aspect, ED=Ear diameter, RPE=Number of rows per year, KPR=Number of kernels per row, EL=Ear length, TKW=1000 kernel weight.

3.2. Pearson Correlation Results

The degree of Association among 16 traits of 14 inbred lines is shown below.

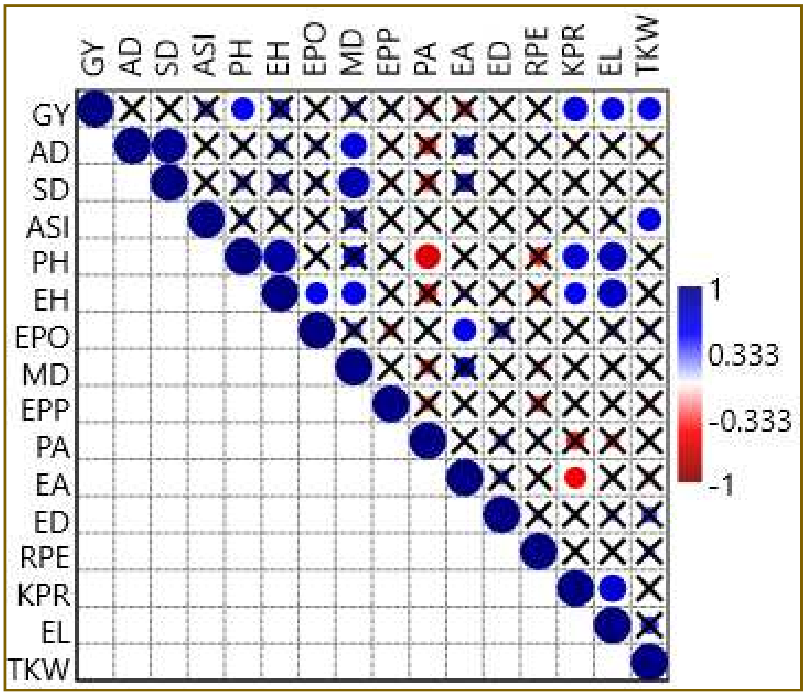

Figure 1. *Half diagonal showing Pearson Correlation coefficient among 16 traits of inbred lines.*

*Bold blue dot stands for the strong positive association while bold red dot indicates a very strong negative association among the traits. The relationship observed among traits of inbred lines indicate the true association as they exclude the environmental influences. In this study, the highest significant positive correlation with grain yield was shown by plant height, Kernel per row, ear length, followed by 100-seed weight. Similar results have been reported in maize by [4, 16, 13]

4. Discussion

Anthesisdate (AD), Silking date (SD), Anthesis silking date interval (ASI), Plant height (PH), Ear height (EH), Ear position ratio (EPO), Maturity date (MD), Rows per ear (RPE), Kernel per row (KPR), Ear Length (EL), Thousand kernel weight (TKW) possess highly significant variability among the selected traits for evaluation while significant variation were observed for Plant aspect (PA), Grain yield while no significant variation was observed for Ear per plant (EPP), Ear aspect (EA), Ear diameter (ED).

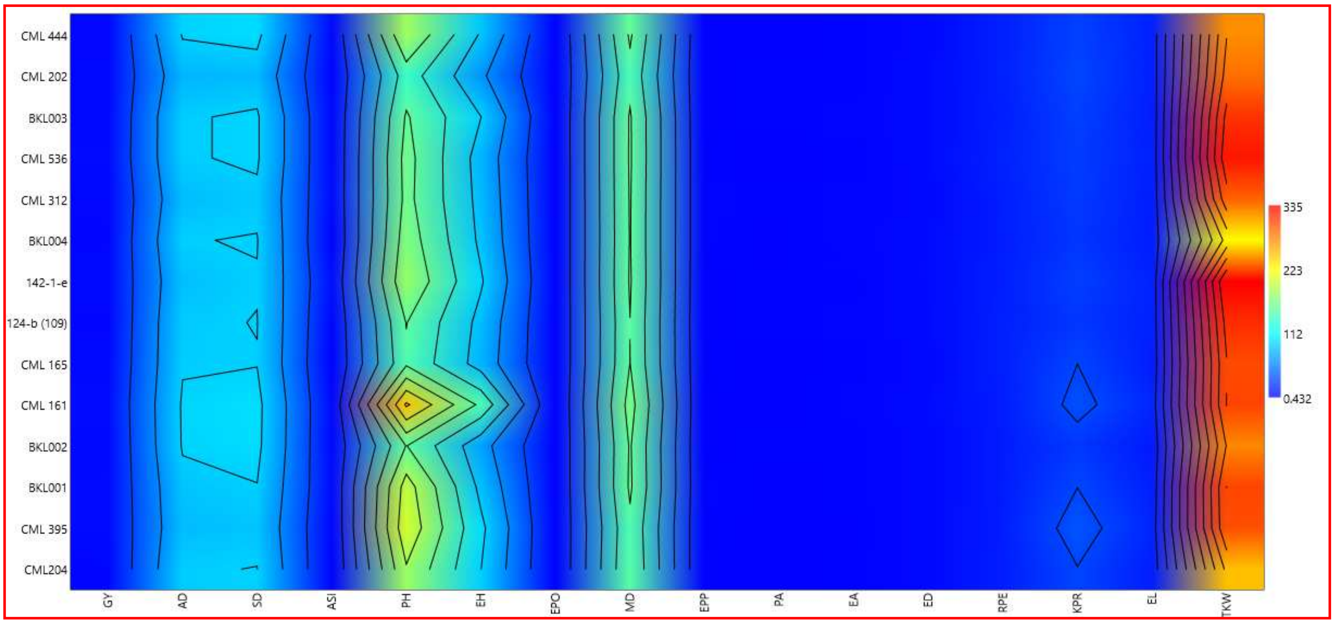

Figure 2. *Graphical description for Association of 14 inbred lines with the corresponding 16 traits distribution.*

From the graph above the trait with highly heterogeneity is described in zigzag line line while the less quantative value or more homogenous traits among for each inbred lines were indicated in thin continuous lines.

The blue color stands for the lowest quantitative value of corresponding traits while the grey to the purple moderately corresponds with the medium value and the yellow color indicates the highest numerical value with corresponding strongly correlated traits with GY for corresponding parents among 14 maize inbred lines. From the bar graph below (figure 3) we understand that the plant height, maturity date, thousand kernel weight, and ear height are the major contributors in deviation among the traits including grain yield, which could help breeder creating variability for the target traits. The maturity date is highly associated with plant height. The reason that TKW is highly associated with maturity date might be due to the high MC% and different compositions of the maize kernel. To verify the main ingredient for the association further kernel composition experiment for early, intermediate and late maturity should be conducted.

Table 2. *Land mark leaner regression showing Relation of GY and related trait.*

Variable	Slope	Intercept	Error	R	P
AD	-0.019	88.386	5.621	-0.004	0.989^{ns}
SD	0.587	89.436	5.591	0.123	0.674^{ns}
ASI	0.606	1.050	1.871	0.357	0.208^{ns}
PH	17.971	101.374	30.147	0.576	0.030^{ns}
EH	9.276	51.665	21.009	0.463	0.095^{ns}
EPO	-0.001	0.516	0.057	-0.027	0.926^{ns}
MD	1.693	146.774	5.574	0.338	0.236^{ns}
EPP	0.075	1.035	0.434	0.201	0.489^{ns}
PA	-0.068	1.475	0.269	-0.287	0.318^{ns}
EA	-0.133	2.197	0.407	-0.362	0.202^{ns}
ED	0.004	4.372	0.355	0.014	0.960^{ns}
RPE	-0.115	13.896	1.034	-0.130	0.655^{ns}
KPR	2.796	17.779	4.115	0.626	0.016^{*}
EL	1.061	9.649	1.771	0.578	0.030^{*}
TKW	18.625	218.282	30.892	0.580	0.029^{*}

ns=non-significant relation *=significant relation.

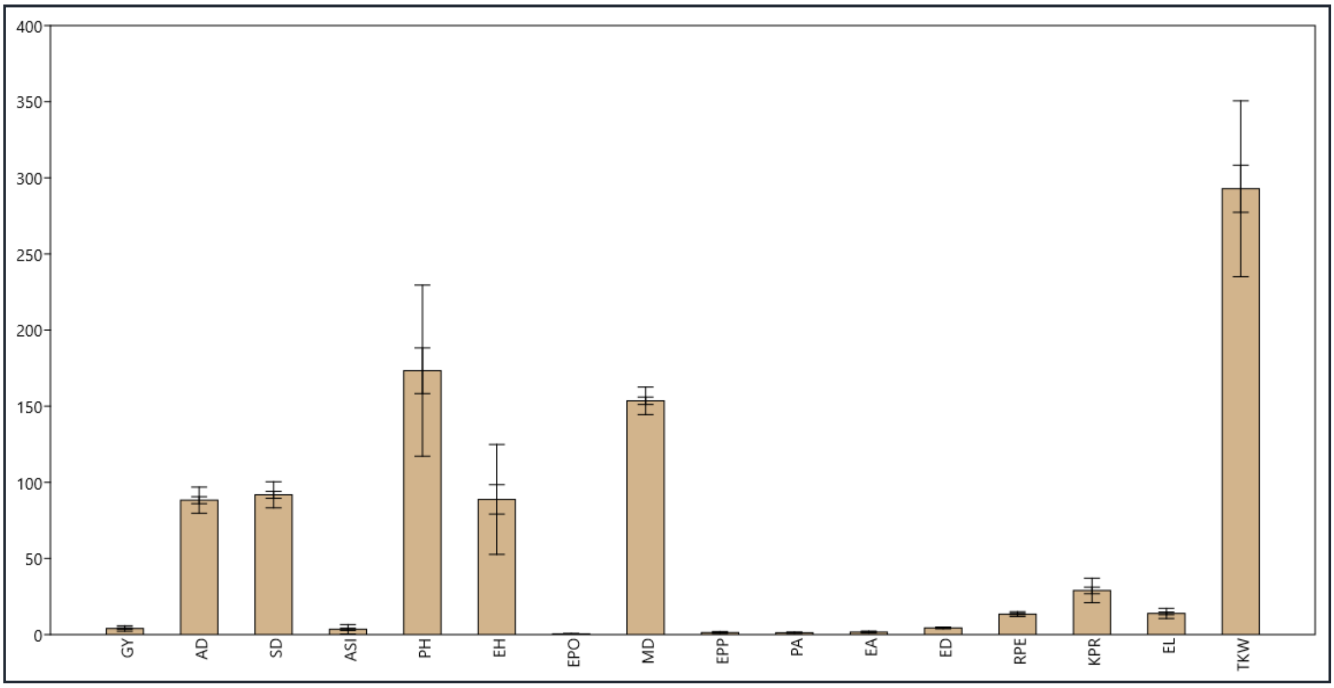

Figure 3. *Bar chart showing the distribution of each trait.*

Grain yield and other trait associations are displayed in the table 2 above. The linear regression suggests that higher plant heights tend to produce higher grain yield, but the relationship was not perfect. Thus knowledge of plant height does not suffice for an entirely accurate prediction of grain yield. A deduction can be made that either the effect of plant height on grain yield differs among individuals. R-value of 57.6% meant that 57.6% of grain yield was attributable to plant height and that the remaining was attributed to other traits. A positive strong correlation (0.58) was found between grain yield and plant height. Meanwhile, EH showed that an R-value of 46.3% meant that 46.3% of grain yield was attributable to ear height. A positive (0.46) or moderate correlation was found between grain yield and ear height. The linear model of days to 1000 kernel weight accounted for only 5.8% of the total variation in grain yield, ear length, and kernel per row accounts for 5.78%, 6.2%, and another variation in yield was determined by other traits. A positive (0.62) or strong correlation was found between grain yield and numbers of kernel per row (Figure 3). In addition, Anthesis silking interval was responsible for grain yield. A positive (0.357) and weak correlation were found between grain yield and Anthesis silking interval.

Grain yield possesses a significant relationship at (P=0.05) for Kernel per row, Ear Length, and Thousand kernel weight with Regression values of {(0.62652), (0.57821) and (0.5807)} respectively. This indicated that these traits have a direct relation with the Grain yield of the inbred lines.

Linear regression describes the direction of association between GY and 15 quantitative traits of maize inbred line are shown as follows.

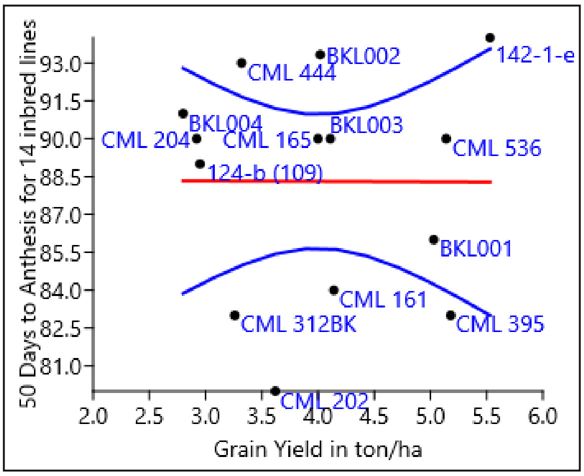

Figure 4. *Linear regression between AD & GY.*

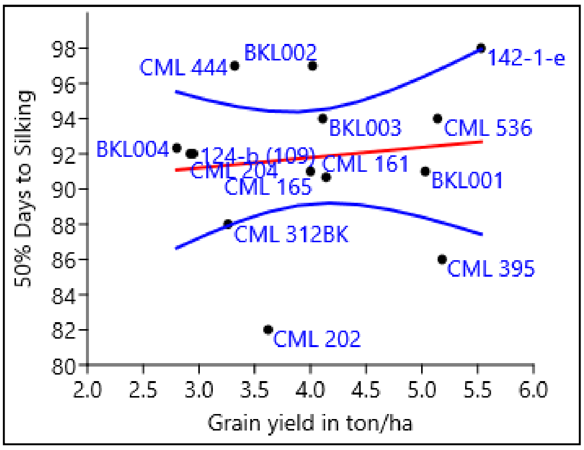

Figure 5. *Linear regressions between SD & GY.*

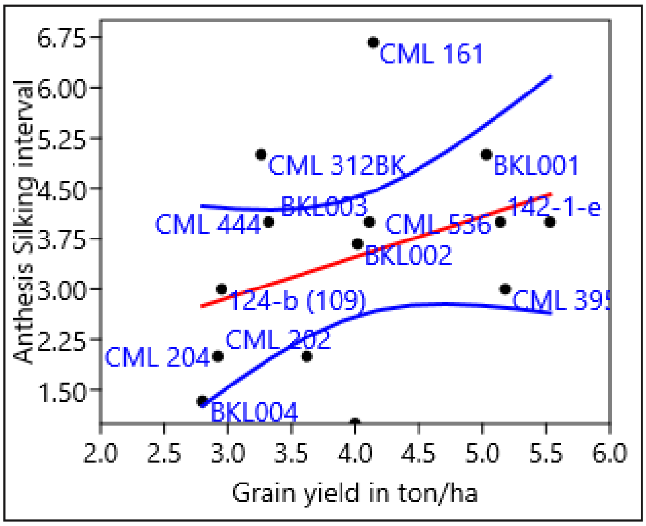

Figure 6. *Linear regression b/n GY and ASI.*

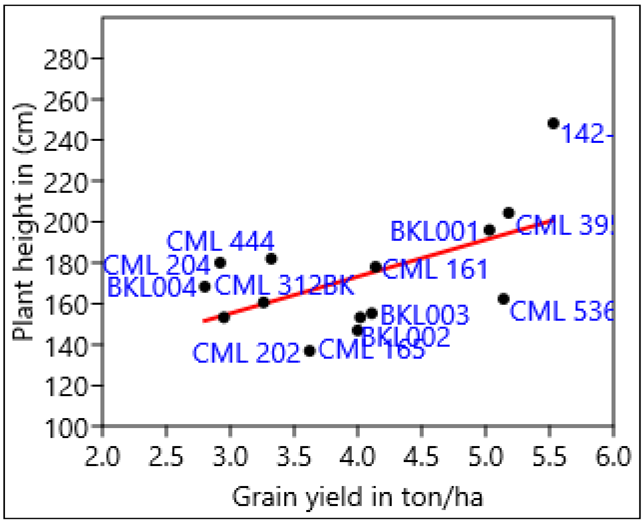

Figure 7. *Linear regression b/n GY and PH.*

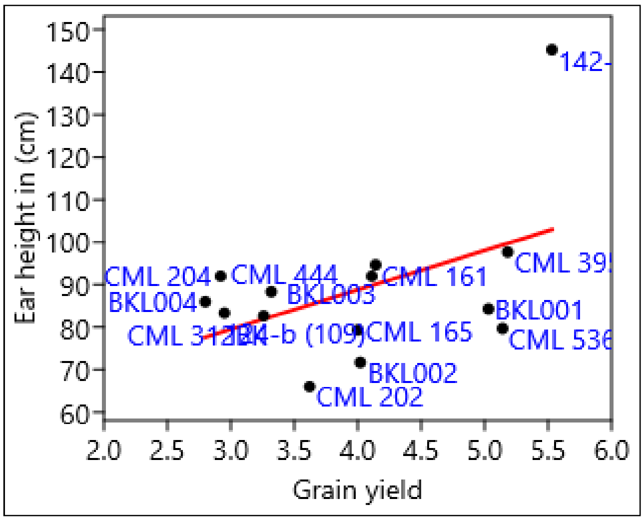

Figure 8. *Linear regressions between EH & GY.*

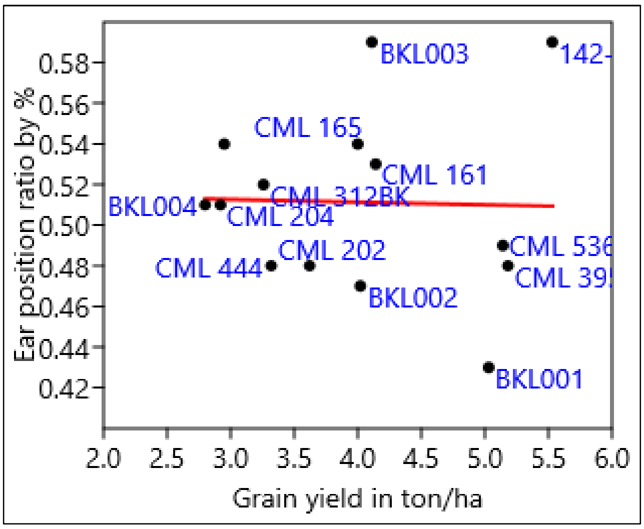

Figure 9. *Linear regressions between EPO & GY.*

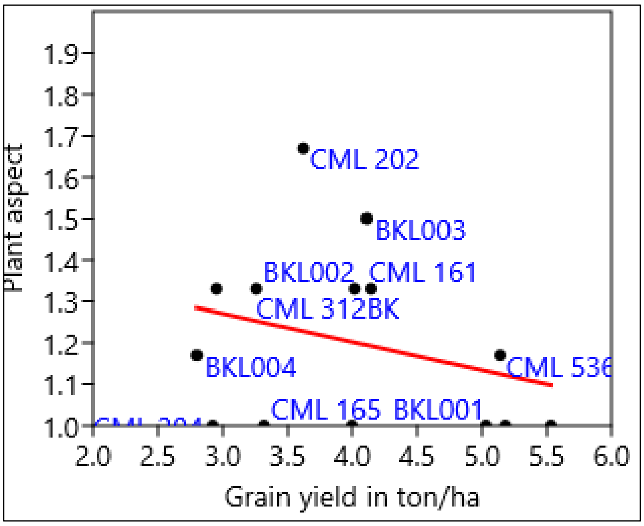

Figure 10. *Linear regression between PA & GY.*

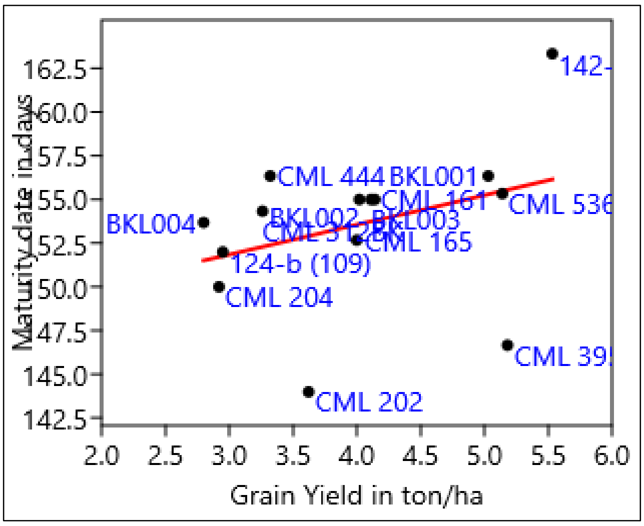

Figure 11. *Linear regressions between MD & GY.*

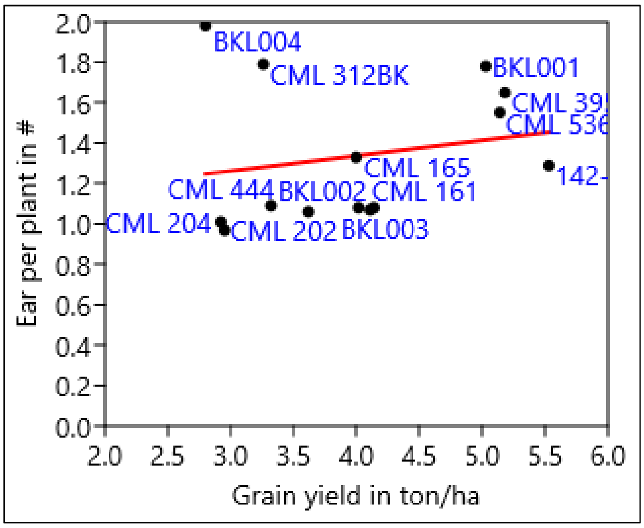

Figure 12. *Linear regressions between EPP & GY.*

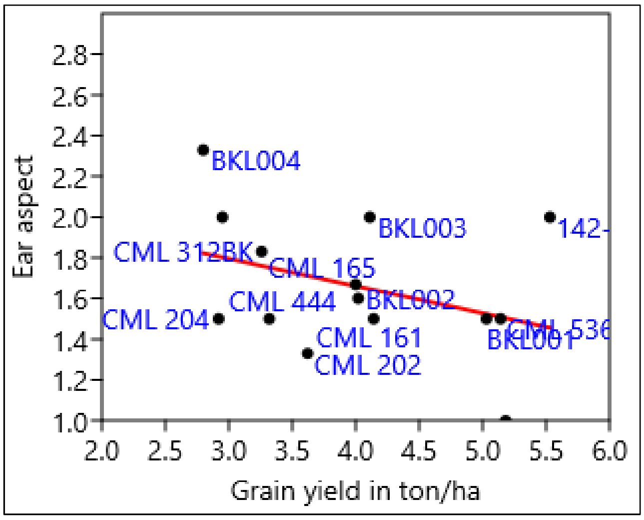

Figure 13. *Linear regressions between EA & GY.*

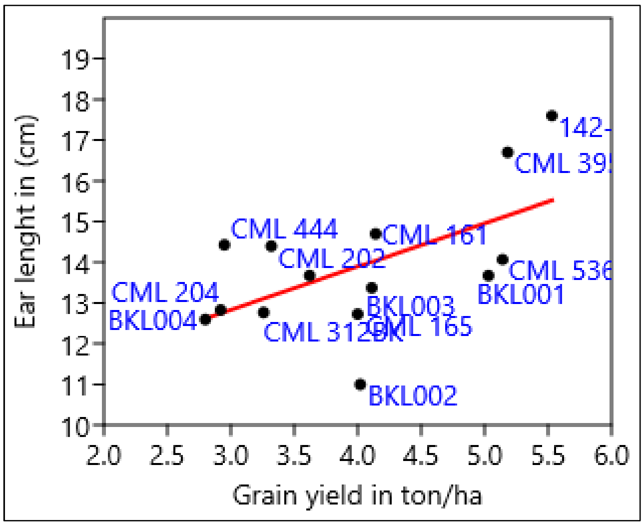

Figure 14. *Linear regressions between EL & GY.*

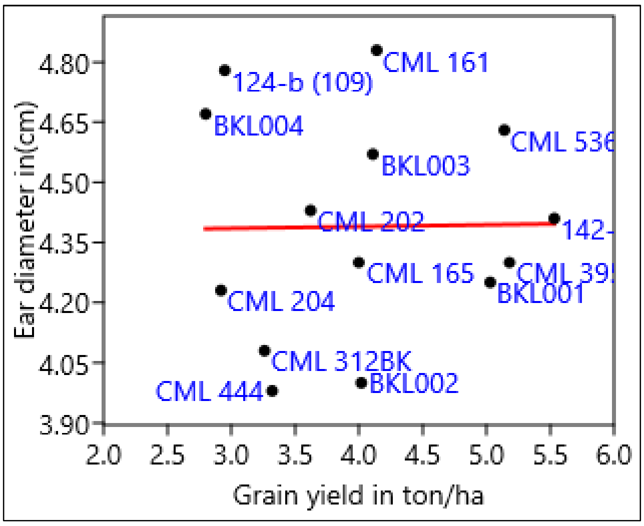

Figure 15. *Linear regressions between ED & GY.*

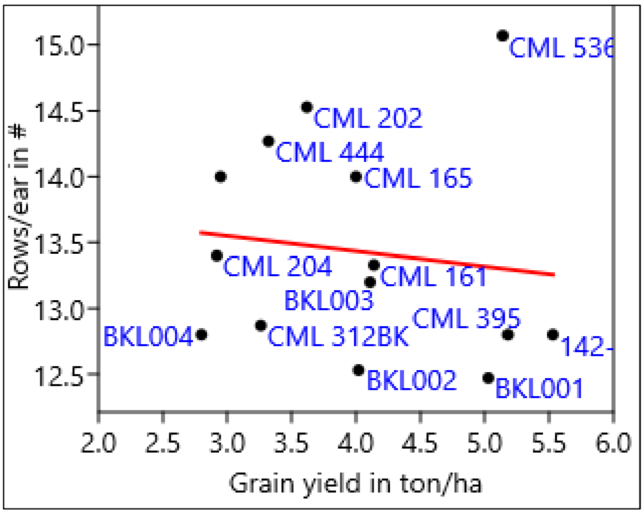

Figure 16. *Linear regressions between RPE & GY.*

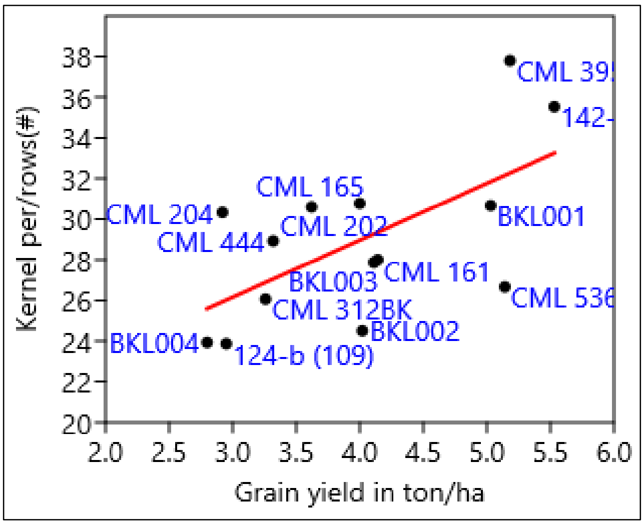

Figure 17. *Linear regressions between KPR & GY.*

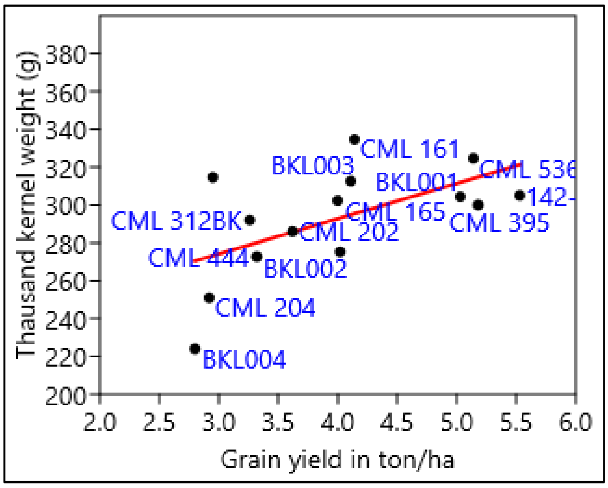

Figure 18. *Linear regressions between TKW & GY.*

From figures 4 to 18, Seed yield had posative linear association with Anthesis date, silking date, plant height, Ear height, Maturity date, Ear lengh, ear per plant and Thausand kernel weight, While leaner negagive association with Plant aspect and ear aspect which could help to improve seed quality. Grain yield possesses a significant relationship at (P=0.05) for Kernel per row, Ear Length, and Thousand kernel weight with Regression values of {(0.62652), (0.57821) and (0.5807)} respectively. This indicates that these traits have a direct relation with the Grain yield of the inbred lines.

5. Conclusion

The result of the study shows that grain yield has a strong positive association with plant height (r=0.58), ear length (r=0.57), and thousand kernel weight (r=0.5807). This could use as an input for breeders to consider these traits to develop high yielder inbred lines as well as to improve hybrid traits in a cross formation.

Linear regression association of grain yield with each trait reveals that PH contributed for yield with R (57.6%), EH contributed for GY with R (46.3%), and TKW, EL and KPR Contributed for yield with an R-value of (5.8%), (5.78%) and (6.2%) respectively. Grain yield had a significant Linear relationship at (P=0.05) for kernel per row, ear length and thousand kernel weight with regression values of {(0.62652), (0.57821) and (0.5807)} respectively. This indicated that these traits have a direct relation with the grain yield of the inbred lines. From this result perspective improving those traits will have a significant positive impact to increase yield. For further identification of yield-enhancing traits, further Marker-assisted research at the molecular level should be made.

Appendix

Table 3. *The mean, std dev, sum, minimum and maximum.*

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
GY	42.000	3.999	1.12299	167.98	1.520	6.650
AD	42.000	88.309	4.34201	3709	79.000	95.000
SD	42.000	91.785	4.33666	3855.00	81.000	99.000
ASI	42.000	3.476	1.64151	146.000	0.000	8.000
PH	42.000	173.287	29.4538	7278134	252.000	265.000
EH	42.000	88.785	18.95378	3729.000	65.000	150.000
EPO	42.000	0.511	0.04737	21.488	0.403	0.619
MD	42.000	153.547	4.80956	6449.000	142.000	165.000
EPP	42.000	1.337	0.45587	56.163	0.118	2.143
PA	42.000	1.202	0.29341	50.500	1.000	2.000
EA	42.000	1.661	0.49236	69.800	1.000	3.000
ED	42.000	4.390	0.36438	3.730	5.300	
RPE	42.000	13.433	0.91162	564.200	11.800	15.600
KPR	42.000	28.966	4.63137	1217.000	21.600	39.000
EL	42.000	13.895	1.90391	583.600	10.000	19.400
TKW	292.8	34.777	12298.000	214.000	352.000	360.000

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