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Research Application Summary

Grain filling patterns of CIMMYT early maize inbred lines

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Abstract

Despite the ability of early maize to escape drought and provide food early, it yields 20-30% less than late maize. The challenge is to increase yield while maintaining earliness. A study is on-going at CIMMYT, Harare to determine whether grain fill rate and duration can be used as selection criteria for yield. Fifteen early maize inbred lines characterized revealed genetic variations in grain fill rate and duration that was correlated to yield implying that they are a better method for indirect selection for yield. Therefore, a great potential for increasing the yield of early maize exist using indirect selection methods.

Key words: Grain fill rate, inbred lines, indirect selection methods, maize, Zimbabwe

Résumé

En dépit de la capacité du maïs précoce d'échapper à la sécheresse et de fournir la nourriture tôt, il rapporte 20-30% de moins que le maïs tardif. Le défi est d'augmenter le rendement tout en maintenant la précocité. Une étude est en cours à CIMMYT- Harare pour déterminer si le taux et la durée de suffisance de grain peuvent être employés comme critères de selection pour le rendement. Quinze souches pures de maïs précoce caractérisées ont indiqué des variations génétiques du taux et de la durée de suffisance de grain qui a été corrélée au rendement en impliquant qu'elles constituent une meilleure méthode pour la selection indirecte pour le rendement. Par conséquent, un grand potentiel pour augmenter le rendement de maïs précoce existe en utilisant des méthodes de selection indirectes.

Mots clés: Taux de suffisance de grain, souches pures, méthodes de sélection indirectes, maïs, Zimbabwe

Background

Early maturing maize plays a great role in the food and farming systems of smallholder farmers (Pswarayi and Vivek, 2008). Despite the ability of early maize to provide food early in the season and the ability to escape late season drought (Langyintuo and Setimela, 2007), it is associated with low yield, about 20-

30% less than late maturity genotypes (Beck *et al*., 1990). This means that there is a huge trade-off between yield and the benefits of planting early maturity maize. Developing high yielding but early maturity maize can benefit many producers (Langyintuo and Setimela, 2007). However, the current challenge is to increase yield of early maize while maintaining or further reducing earliness. Despite the general observation that early maturing maize is low yielding, variation exists in parameters associated with yield in both early and late maize (Lee and Tollenaar, 2007). Irrespective of the maturity period, in maize, yield can be expressed as the product of grain fill rate and grain fill duration (Yang *et al*., 2007). This implies that breeding for higher yield in maize can be achieved by a direct selection for higher grain fill rate and longer effective grain fill duration or an indirect selection based on the yield parameters associated with grain fill rate and grain fill duration.

Nevertheless, breeding for high yield in early maize is complicated because of the absence of knowledge on the genetic variability in grain fill rate and grain fill duration yet this information is critical in selecting desirable materials for use in breeding. Furthermore, knowledge of yield parameters associated with grain fill duration and grain fill rate is limited, yet this information is needed in indirect selection for long grain fill duration and high grain fill rate, hence yield. A sizeable number of inbred lines that are early maturing have been developed by CIMMYT (Pswarayi and Vivek, 2008). Characterization of these early maturing maize inbred lines for grain fill duration and grain fill rate reveals some genetic variation that can be exploited in breeding for higher yield in early maize genotypes. The aim of this study was to determine whether grain fill rate and grain fill duration or other yield related traits can be used as selection criteria to improve the yield of early maturity maize genotypes.

Literature Summary

Developing high yielding but early maturity maize can benefit maize producers (Langyintuo and Setimela, 2007). However, the current challenge is to increase yield of early maize while maintaining or further reducing earliness. Typically, early maturity involves a shortened grain fill period, a smaller plant, and therefore a lower grain fill rate. Despite the general observation that early maturing maize is low yielding (Beck *et al*., 1990), genetic variation for the parameters associated with yield is found in both early and late maturing maize (Barnett and Pearce, 1983). In maize, yield can be expressed as a function of grain fill rate and grain fill duration, assuming that each plant produces exactly one cob (Yang *et al*., 2007). Grain fill duration and grain fill rate are related to dry matter accumulation and partitioning and hence yield. The grain fill duration is mainly affected by the leaf area duration and the duration of the functional stay green (Zheng *et al*., 2009). The grain fill rate depends on the sink strength and source efficiency relationships (Barnett and Pearce, 1983). The source efficiency depends on leaf area and photosynthetic rate. The sink strength depends on harvest index, ear prolificacy and size, and number and size of grains per ear (Pedro *et al*., 2007). These factors that affect yield were reported in early maize (Pswarayi and Vivek, 2008). This raises possibilities of selecting early maize inbred lines that give hybrids with higher grain fill rate and longer grain fill duration, hence high yield.

Grain dry matter accumulation is a continuous process that can be divided into; lag phase, linear phase and final phase (Kling and Edmeades, 1997). The lag phase begins immediately after fertilization and continues until the onset of linear dry matter accumulation, about 10 days after fertilization depending on genotype and temperature. This indicates the potential genetic variability available that can be exploited in selection of cultivars that have a longer linear phase period and a longer total grain filling period or shortened lag and final phases. The linear phase is the period of rapid grain filling during which about 90% of total grain dry matter is accumulated. At the final phase dry matter accumulates at a decreasing rate, ending in physiological maturity and black layer formation (Kling and Edmeades, 1997).

The efficiency of a breeding programme depends mainly on the direction and magnitude of the association between yield and its components and also the relative importance of each factor involved in contributing to grain yield. Understanding the contribution of grain fill duration and grain fill rate to yield is critical in improving the selection method for improving the yield of early maturity maize genotypes. It is hypothesized that yield of early maturing maize can be achieved by selecting lines that are early maturing but have longer grain fill duration and a higher grain fill rate (Yang *et al*., 2007).

Study Description

A study was was conducted in Zimbabwe at two sites located in Harare (1500 masl), the CIMMYT station and the Agricultural Research Trust farm. Fifteen early maturing maize inbred lines that belong to heterotic group A and B obtained from CIMMYT gene bank were evaluated in the field. The experimental design was an incomplete block design (alpha-lattice) with two replications. The plots consisted of 4 rows of 5m length, with an in-row spacing of 25cm and inter-row spacing of 75cm. All management practices were done accordingly. The inbred lines were left to open pollinate. From each plot, cobs were harvested weekly from three plants per plot starting a week after pollination. To avoid the edge effects, every second plant of the middle rows was harvested. From each cob, 10 grams of grain fresh mass were obtained from the middle of the cob. These 10 grams of grain were oven dried at 60^{o}C for 24 hours to get the percentage of dry matter. The average dry matter from the three cobs obtained from each plot was calculated. The same procedures were repeated weekly until the plants reached physiological maturity.

Data recorded include dry matter content per week, the time it took from fertilization to the beginning of the linear grain filling stage (length of the lag phase), the time it took from the beginning of the linear grain filling stage to the end of the linear grain fill stage (length of the linear phase/ the effective grain fill duration), and the time it took from the end of linear grain fill stage to physiological maturity (length of the final phase). The grain fill rate was calculated by dividing the dry matter accumulated during the linear phase by the number of days of the linear phase (effective grain fill duration). Other data recorded included grain yield per plot, ear length, ear circumference and 1000 grain weight per plot. The ear circumference was measured on the middle of the cob. Both the ear length and the ear circumference were measured on ten cobs and the average was calculated. All data were subjected to analysis of variance and correlation analysis using Genstat software.

Research Application

The fifteen early maize inbred lines evaluated showed significant differences in grain fill rate (p=0.008), effective grain fill duration (the duration of the linear phase) (p=0.007), and the final percentage of dry mass accumulated (p=0.001). Significant differences were also observed on the grain yield (p=0.005), 1000 grain weight (p=0.004), ear length (p=0.002) and ear circumference (p=0.000) (Table 1). There were some significant ($p<0.05$) positive correlations between yield and 1000 grain weight, yield and ear length; and yield and ear circumference. Both the effective grain fill duration and the grain fill rate were positively correlated with the percentage of total dry mass accumulated by the inbred lines up to the physiological maturity

Table 1. Variations in grain fill rate and grain fill durations and other agronomic traits in fifteen CIMMYT maize inbred lines tested in Harare, Zimbabwe.

Name of inbred line	Grain yield (t/ha)	1000 grain weight (grams)	Ear length (cm)	Ear circum-ference (cm)	Effective grain fill duration (weeks)	% dry mass accumulated in the linear phase	Grain fill rate (g/week)
VL058593	0.2	6.8	28.03	3.58	3.68	80.51	15.42
VL058014	0.2	6.4	16.15	5.07	3.48	91.55	13.18
VL08526	0.2	7.8	26.70	5.00	3.01	96.95	21.00
VL05128	0.2	6.8	17.97	4.37	2.04	83.37	22.85
VL05552	0.1	4.9	24.53	3.19	2.49	68.05	11.97
CML507	0.3	6.1	18.48	4.92	4.08	93.78	14.98
CML508	0.2	7.7	19.27	4.47	3.53	92.36	14.58
VL055063	0.1	5.9	24.02	4.64	4.11	91.24	16.20
VL0536	0.2	4.9	19.70	3.22	2.96	81.19	21.52
CML506	0.1	7.6	13.05	5.17	2.16	92.09	31.47
VL057903	0.2	6.0	17.87	5.13	3.04	100.15	13.44
VL057967	0.2	6.9	21.15	4.72	2.64	83.74	22.53
VL057847	0.2	6.6	23.52	4.16	2.73	91.39	25.49
VL05615	0.1	6.1	20.26	4.88	3.83	94.41	21.50
VL08528	0.1	5.5	22.31	4.48	2.59	93.52	20.94
Mean	0.2	6.4	20.87	4.47	3.09	88.95	19.14
LSD (0.05)	0.06	0.9	6.34	0.72	1.77	9.62	5.57
p value	0.005	0.004	0.002	0.000	0.007	0.001	0.008

stage. However, a significant negative correlation (r=-0.77) occurred between the grain fill rate and the grain fill duration.

The significant differences observed in the traits of the inbred lines shows the presence of genetic variation that can be exploited in improving these genotypes for higher yield. Barnett and Pearce (1983) also reported the existence of genetic variation for the parameters associated with yield in both early and late maize. A strong positive correlation of maize yield and other agronomic traits such as ear length, ear circumference, and 1000 grain weight is not unusual. These traits have been reported to be correlated with maize yield hence are said to be yield components (Lee and Tollenaar, 2007). Ear length is related to the number of kernels per row and ear circumference is related to the number of rows per cob. This study showed a positive correlation of grain yield and grain fill rate and grain fill duration. The percentage dry mass accumulated during the linear phase also varied with the genotype and was positively correlated to yield. This indicates that the accumulation of grain yield is affected by the effective grain filling duration and grain fill rate. Therefore, grain fill rate and grain fill duration can form an indirect method of selection for yield in early maturity maize genotypes. This is because, during the stress conditions the yield and its components can be affected thus making assessment of grain fill rate and grain fill duration a more appropriate and accurate way of assessing the yield potential of a given genotype. Lee and Tollenaar (2007) reported that over the years there has been genetic improvement that resulted in genetic gain of maize yield and now the yield potential has reached the yield plateau. Thus there is a need for an alternative selection method if yield is to be improved further. Therefore, the existence of variation in grain fill rate and grain fill duration shows potential for improving yield with selection based on these traits. The study also revealed that inbred lines with higher grain fill rate had shorter grain fill duration. This negative correlation between grain fill rate and effective grain fill duration ensures a compensatory behavior in grain filling and is essential in crops. For example, during the stress time a maize plant may have its grain filling duration shortened so it will be necessary for that plant to have a faster grain fill rate that will compensate the shortened grain fill duration.

Recommendation

Grain fill rate and grain fill duration are good indexes for indirect selection for grain yield in early maturity maize genotypes. However, the nature of inheritance of grain fill rate and grain fill duration need to be investigated to establish whether these traits are heritable. A great potential for increasing the yield of early maize exist if indirect methods of selection like grain fill rate and grain fill duration are used.

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