Estimating Final Grain Yields Using Primordial Leaf Area in Ten Kenyan Hybrid Maize

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Abstract

A study was carried out to evaluate initial leaf area as an indicator of final grain yield for selected Kenyan long and short rain hybrid maize varieties. The project was carried out at Moi university Chepkoilel campus farm in two phases, in the field and in the greenhouse using a completely randomized design. Data collection included primodial leaf destructive collection in the greenhouse and the final grain yield in the field. The key parameters were leaf area index, cob length and weight of threshed grains. Results showed that there was significant difference between varieties (p=0.05). The final grain yield was significant and positively related to the primordial leaf area with an r=0.85 at p=0.05 having the following relationship; GY=1.50LA+1.47; where GY=grain yield, LA=leaf area and r=correlation. There was also a significant and positive correlation between grain yield, and the other dependent variables which included length and circumference of cob before and after threshing, number of rows per cob and number of grains per row. Based on this study, the regression and correlation of the primordial leaf area can be used to predict final grain yield, which has proved to be a useful selection criteria for high yield varieties of Kenyan hybrid maize.

Key Words: Maize, Primodial leaf area, Final grain yield

Introduction

Maize (Zea mays) is one of the world's most important crops and oldest food grains. Approximately 7000 years ago, maize a domesticated grass, originated in Mexico (Gwirtz and Garcia-Casal, 2014), from where it spread to various parts of the world. Maize does not grow in the wild, cannot survive in nature and is completely dependent on human husbandry (Dowswell *et al.,* 1996). Consequently, cultivated maize as well as being a fully domesticated plant is also one of the most productive species of food plants. It is a C_4 plant with a high rate of photosynthetic activity. On a per plant basis its multiplication ratio is 1:600 to 1000 (Aldrich *et al.,* 1975). Maize has a high potential for carbohydrate production per unit area per day and has multifarious uses. It is the only cereal that can be used as food at various stages of plant development. The demand for maize has continued to grow and between 1990 and 2011 the millions of hectares from which maize was harvested ranged from 129.1to 163.9 (Zea Production Maps and Statistics, 2017).

Maize is classified into two distinct types, depending on the latitude and environment in which it is grown. Tropical maize is grown in warmer environments located between the equator and 30 ^{0}N 30 ^{0}S while temperate maize is grown in cooler climates beyond 34 ^{0}N and 34 ^{0}S. Globally, maize is grown on 140 million ha with annual production of about 600 million tonnes. Tropical maize is grown in 66 countries and is of major economic significance in 61 of these, with each having 50,000 ha or more. Average maize yield in the tropics is 1.8 tonnes/ha, against a global average of 4.2 tonnes/ha. The average yield of temperate maize is 7 tonnes/ha (International Maize and Wheat Improvement Centre [CIMMYT], 2000).

In many parts of Kenya, maize is the most important staple food. This aspect is of particular importance as the pressure on limited land increases requiring the practice of more intensive cropping patterns to produce enough food for a vastly increased population. Due to food insecurity, unpredictable climatic variations and political instabilities (Shaw, 2009), it is important to develop technologies that can project food availability and security. Maize has not yet reached its limit of diffusion in production in this environment and its high productivity potential in the tropics can be exploited.

Early assessment of yield can help in strategic planning and decision making (Baez-Gonzalez et al, 2005). However, its use in large areas has been limited due to lack of the required inputs at field site. Remote sensing provides observation over large areas at regular intervals, making it useful in large scale crop modeling (Raynolds *et al*, 2000). Simulation of maize grain yield variability within a surface irrigated field showed that the characterization of factors causing spatial variability of crop yield is a necessary prerequisite for successful implementation of precision agriculture. However the existing tools for a quantitative description of these factors and their relationship to crop yield lack effectiveness and completeness (Carvero *et al.*, 2003).

In a study on correlation and path coefficient analysis in maize (*Zea Mays L.*), Asrar-ur-Rehman Saleem, *et al* (2005) found that grain yield per plant was positively and significantly correlated with days to 50 % tasseling, days to 50 % silking, plant height, cob height, leaf area, number of rows and grains per cob and 1000-grain weight, showing a positive direct effect on grain yield. However, plant height, cob height and days to 50 % tasseling exhibited negative direct effect on grain yield. In another study on Mexican hybrid maize, Serrem, (2006) showed that final grain yield was significant and positively related with primordial leaf area. This concept has not yet been used to project maize grain yield to enhance food security in Kenya. Therefore, the objective of this study was to evaluate initial leaf area as an indicator of final grain yield for selected Kenyan long and short rain hybrid maize varieties.

Materials and Methods

Research Area and Plant Materials

The study was carried out in university of Eldoret campus, ($0^0$32'N, $35^0$17E) at an altitude of 2134 m above sea level, with a mean annual rainfall of 1124 mm and mean temperature of 16.6 ^{0}C. The study involved two phases; the first in the field till final yield and the second in the School of Agriculture and Biotechnology greenhouse.

Tropical hybrid maize varieties were obtained from Simlaw seeds and were mainly highland long and short rain varieties which included H6210, H614, H624, H515, H520, H629, H516, H6213, H6212 and H513.

Field and Greenhouse Experiments

The experiment was laid in a completely randomized design. The fertilizer used was Diammonium Phosphate (DAP) (18:46:0). Taking into consideration that not all farmers can afford fertilizer all the time, there was application of DAP at different rates. There were three treatments; the controls with no DAP, treatment 2 with 37.5 Kgs DAP (half the recommended rate) and treatment 3 with 75 Kgs (recommended rate). The mode of application was by broadcasting. The three treatments were replicated to avoid bias.

In the field, maize seeds were planted in 4 x 4 m plots at a spacing of 75 x 30 cm. The varieties in each plot were randomized also to avoid bias. In the greenhouse, planting was done in 20 litre pots which was arranged in the same manner and received DAP at the same rate as in the field. The pots were irrigated daily and all other routine practices like weeding and top dressing were conducted twice during the growing season.

Data Collection and Analysis

Data was collected 10 days after germination in the greenhouse. The area of the primordial leaf was obtained upon destructive collection of leaf and then measured using a leaf area inter-grader (Model ΔTMK 2) that gave total leaf area in $cm^{2.}$ Maize was left in the greenhouse until maturity. In the field, data was collected for each maize variety after the maize was harvested and dried. The parameters determined were: length of cob, (LC); number of rows per cob, (RO); circumference of the cob before threshing, (C1); number of grains per row, (GR); weight of the threshed grains, (GY) and circumference of the cob after threshing (C2). To validate the yield model, the measured yield was regressed and the root mean square computed.

Data was analyzed using a Statistical Analysis for Scientists (SAS) (version 14) separation of Mean was done using ANOVA and LSD.

Results and Discussion

Initial Soil Characterization and Greenhouse Temperatures

Table 1: Initial soil characterization

Parameter	Value
Soil PH	5.10
Olsen P	1.812
% N	0.927
Organic C (%)	2.1
Textural Class	Sandy loam

The temperatures registered during the experiment showed that the maximum varied from 44 ^{0}C to 35 ^{0}C and the minimum from 20 ^{0} C to 13 ^{0}C. The maximum and the minimum temperatures varied from 44 ^{0}C to 13 ^{0}C in the greenhouse during the experimental period. The minimum temperature of 13 ^{0}C is above the base temperature of maize which is 7.5 ^{0}C (Lopez *et al.,* 1996). The most important effect of high temperature on crops is fast growth and development which finally translates to high yield. According to Al-Khatib and Paulsen (1984), an optimum temperature of 20 ^{0}C is favorable for photosynthesis and maximum growth. However, temperatures above 35 ^{0}C could cause heat stress to the plants (Slafer and Rawson, 1995).

Table 2: Comparison of parameters within and along varieties of maize

	LA	GY	LC	CI	C2	RO	GR
H629	5.44a	9.16a	18.61ab	15.11a	10.00a	14.44a	41.33a
H520	4.22abcd	8.76ab	20.44a	14.05ab	9.77a	14.00a	40.66ab
H624	4.77ab	8.53abc	17.66ab	11.77ab	8.56ab	12.44ab	36.22ab
H6212	4.22abcd	8.27abc	17.33ab	12.88ab	8.50ab	13.33ab	36.22ab
H6213	3.94bcd	8.03abc	15.33b	11.27ab	6.94b	11.00ab	29.88b
H6210	3.33cd	6.90abc	13.83b	11.05b	7.66ab	10.00b	31.11ab
H515	2.94d	6.90abc	17.16ab	12.27ab	8.22ab	11.33ab	34.33ab
H614	4.66abc	6.58bc	16.27ab	12.16ab	8.50ab	11.55ab	34.77ab
H516	3.16d	6.28c	14.55b	11.00b	7.11b	10.00b	31.22ab
H513	3.50bcd	6.20c	14.50b	12.66ab	8.66ab	12.00ab	29.55b
LSD	1.400	2.43	5.07	3.93	2.51	3.69	11.11

Means with the same letter are not significantly different.

LC= length of cob; RO= number of rows per cob; CI= circumference of cob before threshing; GR= number of grains per row; GY= weight of threshed grains; C2= circumference of cob after threshing.

The pooled statistical analysis showed that there was significant difference among the hybrid varieties for the leaf area (LA) of the primordial leaf with 4 groupings and LSD of 1.40. The other variables also had significant differences. This is due to the differences in the varieties tested. H629 had the highest LA, and was significantly different from H6213, H6210, H515, H516 and H513.

Correlation between Primordial Leaf Area and Grain Yield

The final grain yield was found to be significant and positively related with the primordial leaf area with an r=0.85 at p=0.05 having the following relationship; GY=1.50+1.47 where, GY=grain yield, LA=leaf area and r=correlation. It is evident that the relationship found in the present study can be used to predict maize yield as early as the first primordial leaf matures. Similarly there was also a significant and positive correlation between grain yield, length of cob, circumference of the cobs before and after threshing and also with the number of grains per row. Similar results were reported by Serrem (2006) who studied 10 Mexican maize hybrids.

Correlation of Primordial Leaf Area with Other Dependable Variables

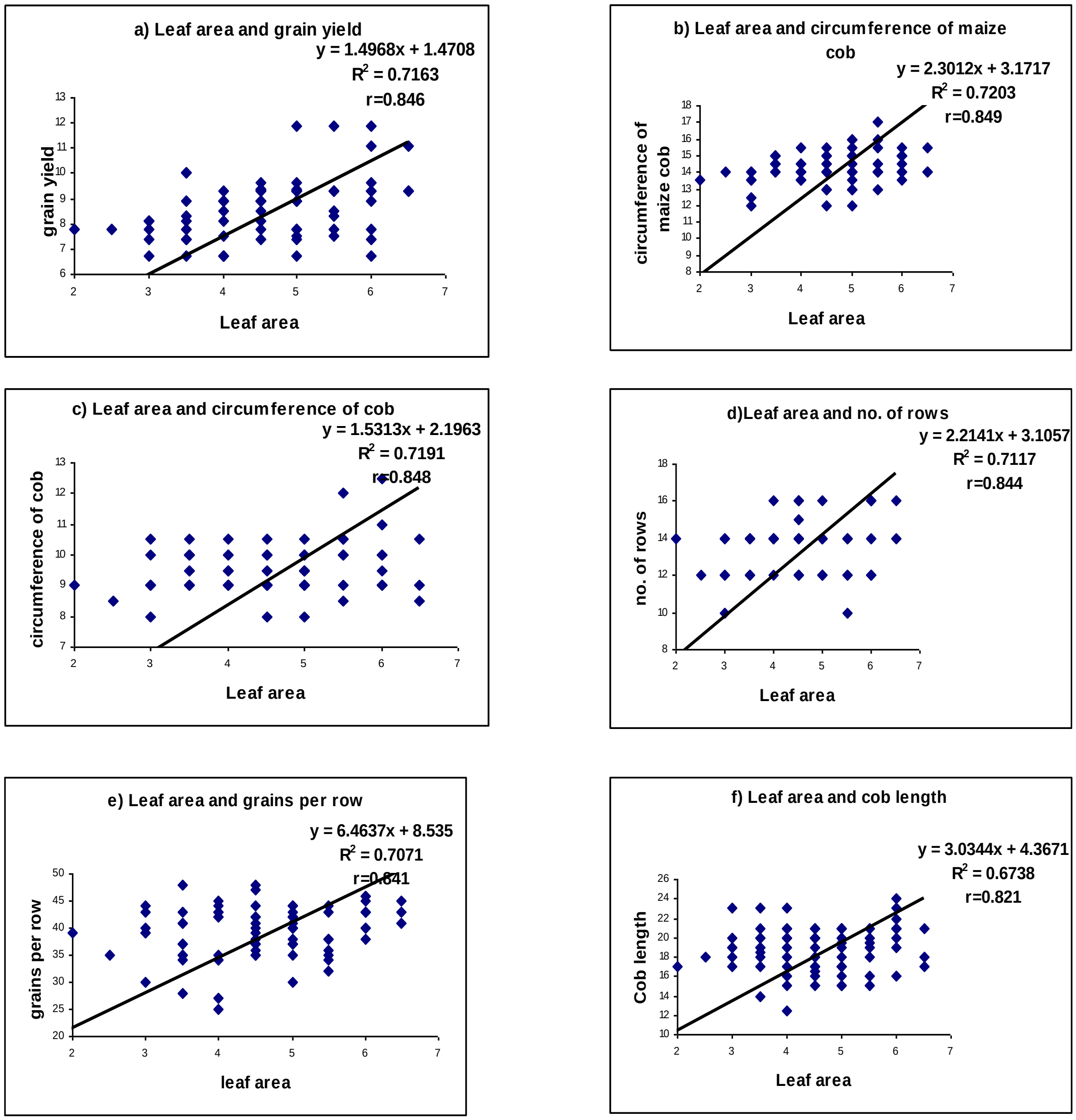

Fig 1: a) Leaf Area and grain yield
b) Leaf area and circumference of maize cob
c) Leaf Area and circumference of empty cob
d) Leaf area and no. of rows
e) Leaf area and grains per row
f) Leaf area and cob length

The other variables had a positive correlation with the grain yield showing that physical appearance of the maize really indicated the reason for its yield. The circumference of the maize cob before and after threshing did not affect the grain yield. The other dependent variables showed the following correlations;

Length of cob; LC= 3.0344x +4.3671 ; r =.82
Circumference of maize; C1=2.3012x +3.1717; r =85
Circumference of threshed cob;= C2=1.5313x +2.1963; r =.85
Number of row; RO =2.2141x +3.1057 ; r =0.84
Grains per row; GR =6.4637x +8.535 ;r =.84

Conclusion

Based on the findings of this study, it is evident that the correlations of the primordial leaf area can be used to predict final grain yield. The primordial leaf area gives good indication of final grain yield for Kenyan maize hybrids.

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