Grain yield potential and associated traits in maize (*Zea mays* L.) varieties in the forest zone of Nigeria

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ABSTRACT

Grain yield and 15 associated traits were studied in 10 maize varieties (DMR-L-SR-W, SUWAN 1, EV 9043-DMR, TZPB-SR, TZSR-Y, 8321-18, 8535-23, 8644-27, 8644-31, and 8805-4) from 1995 to 1997 at Ibadan, Nigeria. Varietal differences and the relationship between grain yield and associated traits were determined. Variety 8321-18 with the highest grain yield had a 27 per cent yield advantage over the lowest-yielding variety TZSR-Y. Crop growth rates at vegetative and reproductive stages were highest in TZSR-Y while its harvest index was lowest when compared to other varieties. 8321-18 had longer ear and kernel growth duration than most varieties evaluated, and its harvest index was higher than TZSR-Y. Kernels per plant were more in 8321-18, 8805-4, and EV 9043-DMR than in the other varieties. Positive correlations were found between grain yield and kernels per ear (r=0.70***), kernel rows (r=0.30***) and kernels per row (r=0.63***), harvest index (r=0.53**), total dry matter (r=0.50***), ear growth duration (r=0.36***), kernel growth duration (r=0.30***), and crop growth rate at reproductive stage (r=0.17**), except days to 50 per cent silking (r=-0.19*). To improve grain yield, the biological traits that are significantly associated with grain yield could be incorporated into a model for developing improved maize genotypes for the forest zone in Nigeria.

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RÉSUMÉ

AGBAJE, G. O., ABAYOMI, Y. A. & AWOLEYE, F.: *Potentialité de rendement de grain et les traits associés dans les variétés de maïs (* Zea mays *L.) dans la zone forestière du Nigéria.* Le rendement de grain et 15 traits associés étaient étudiés en 10 variétés de maïs (DMR-L-SR-W, SUWAN 1, EV 9043-DMR, TZPB-SR, TZSR-Y, 8321-18, 8535-23,8644-27, 8644-31 et 8805-4) de 1995 à 1997 à Ibadan, au Nigéria. Les différences variétales et le rapport entre le rendement de grain et les traits associés étaient déterminés. La variété 8321-18 avec le rendement de grain le plus élevé avait un avantage de rendement de 27 pour cent par rapport à la variété TZSR-Y ayant de rendement le plus bas. Les proportions de la croissance de culture aux stades végétatifs et reproductifs étaient les plus élevées en TZSR-Y alors que son indice de moisson était le plus bas lorsqu'il est comparé aux autres variétés. 8321-18 avait une durée de croissance d'épi et de grain plus long que les autres variétés évaluées et son indice de moisson était plus élevé que celui de TZSR-Y. Les grains par plante étaient plus nombreux en 8321-18, 8805-4 et EV 9043-DMR que dans les autres variétés. Des corrélations positives étaient découvertes entre le rendement de grain et les grains par épi (r = 0.70 ***), les rayons de grain (r = 0.30 ***) et les grains par rayon (r = 0.63 ***), indice de moisson (r = 0.53 **), le total de matière sèche (r = 0.50 ***), la durée de croissance d' épi (r = 0.36 ***), la durée de croissance de grain (r = 0.30 ***), la proportion de croissance au stade reproductif (r = 0. 17 **) excepté les jour à 50 pour cent de l'apparition des soies (r = -0.19 *). Pour améliorer le rendement de grain les traits biologiques qui sont considérablement associés au rendement de grain pourraient être incorporé dans un modèle pour le développement des génotypes de maïs amélioré pour la zone forestière au Nigéria.

Introduction

Grain yields of maize are very low in the tropics, varying from 1.5 to 3.5 t/ha (Paliwal & Cantrell, 1996). Estimated grain yield potential of maize in Nigeria was 4.0 t/ha for forest and transition zones, 5.0 t/ha for southern Guinea and Sudan Guinea savanna, and 6.0 t/ha for the northern Guinea savanna of Nigeria (Fakorede *et al.*, 1989). The yield differences between the zones were adduced to increased insolation towards the savanna (Kassam & Kowal, 1973). There is, therefore, the need to improve the yield potential of maize in the forest zone through breeding.

Rodgers *et al.* (1983) associated increased grain yield in the US corn belt to improved genotype development. Earlier selections for grain yield had been based on eliminating obvious defects such as susceptibility to diseases or insects, lodging and poor quality, and higher yields (Mock & Pearse, 1975). However, Dwyer *et al.* (1991) reported that the identification of biological traits which contribute to grain yield will improve selection efficiency for genetic gain in maize yield. The important steps in improving genotypic selection of maize involve the identification of easily assessed traits which contribute to yield under specified environmental conditions. The traits to be selected must have high correlation with grain yield, be genetically heritable, and amenable to easy, accurate and rapid measurement (Hageman & Lambert, 1988).

The research of identifying characters that control grain yield in cereals for their incorporation into a single genotype was initiated by Engledow & Wadham (1923). Clarke & Townley-Smith (1984) confirmed that crosses made from parents of known physiological performance gave on the average higher grain yielding progenies than crosses which little was known about their traits.

This study aims at comparing the varietal differences and the relationship between grain yield and some yield-related traits. The results will be used in a multi-disciplinary programme for maize improvement.

Materials and methods

The maize varieties studied are DMR-L-SR-W, SUWAN 1, EV 9043-DMR, TZPB-SR, TZSR-Y, 8321-18, 8535-23, 8644-27, 8644-31, and 8805-4. Studies were conducted under rain-fed condition at the Institute of Agricultural Research and Training (Obafemi Awolowo University) Experimental farm at Ibadan. The plots were arranged in a randomized complete-block design with four replications. Planting was done on 7 Aug 95, 15 Apr 96, 12 Aug 96, and 10 Apr 97 at a population density of 55,000 plants ha^{-1}. Each plot had eight rows of 6 m lengths with an inter-row spacing of 0.90 m and intra-row spacing of 0.40 m. The seeds were pre-treated with Apron-plus (Metalaxyl) before planting to control soil-borne pests and downy mildew disease. Weeds were controlled with a pre-emergence herbicide, atrazine, at 5 kg ai ha^{-1} and two manual weedings before maturity. A total of 120-60-60 kg/ha of N-P-K fertilizer was applied at 2 weeks after planting (WAP), using a compound fertilizer NPK 20-10-10. An additional 60 kg N/ha from urea fertilizer (46 per cent N) was applied at 6 WAP.

Biological traits and grain yield (Table 1) were measured from randomly sampled plants in each plot. At 20 days after planting, during 50 per cent silking and 10 days after 50 per cent silking, five plants from each plot were harvested above the ground level from the 2nd and 7th rows and divided into single plant parts for dry matter determination. At 110 days after planting, four innermost rows were harvested for grain yield. Of these, 10 representative plants were taken for measurement of yield components from the ears and total dry matter. All samples were dried to constant weight in a Gallenkamph oven at 70 °C. Analysis of various simple correlations were computed following the procedures outlined by Steel & Torrie (1960). The ANOVA for grain yield and associated traits were analyzed, with the four planting seasons as random effects and varieties as fixed effects. Duncan's multiple range test (DMRT) was used for mean comparison.

Results and discussion

There were significant differences between maize varieties for grain yield and associated traits. Also, the significant season × variety interactions observed for all the traits, except 100-seed weight and shelling percentage, indicated that varieties

TABLE 1

Grain Yield and Associated Traits Measured in 10 Varieties in Ibadan

Traits +	*Definition, procedure, or calculation**
1. Grain yield (GY), t/ha	Obtained from four innermost rows and corrected to 14 per cent moisture content.
2. Harvest index (HI)	Seed yield per plant/total dry matter per plant at harvest.
3. Total dry matter at harvest (TDM), g/plant	Oven-dried weight of whole plant at 70 °C.
4. Days to 50 per cent silking (DS), d	From sowing to period of 50 per cent silking per plot.
5. Crop growth rate at vegetative stage (CGRv), g/plant/d	Difference between whole plant weight at 20 and at 40 days after sowing divided by 20.
6. Crop growth rate at reproductive stage (CGRr), g/plant/d	Difference between whole plant weight at (4) and at 10 days after sowing divided by 10.
7. Ear growth rate (EGR), g/ear/d	Ear dry matter difference within 10 days from (6) divided by 10.
8. Ear growth duration (EGD), d	Ear weight at harvest/EGR
9. Kernel growth rate (KGR), mg/kernel/d	Kernel dry matter accumulated within 7 days from (4) divided by 7.
10. Kernel growth duration (KGR), d	Mean seed weight from (2)/(9).
11. Leaf area at silking (LAS), $cm^2 \times 10^3$	Obtained from (4) and calculated using L × W × 0.75

+ Traits were measured from 5 to 10 randomly sampled plants in each plot.
* Numbers in parenthesis refer to traits in column 1.
L as leaflet length, cm.
W as broadest width of the leaflet.

TABLE 2

Combined ANOVA Showing Mean Square (MS) for Grain Yield and Associated Traits
(a) Plant Growth Traits

Source of variation	*Degree of freedom*	*MS for* Crop growth rate at vegetative stage, g/d/plt	Crop growth rate at reproductive stage, g/d/plt	Ear growth rate g/ear/d	Ear growth duration d	Kernel growth rate mg/kernel/d	Kernel growth duration d	Leaf area at 50 % silking $cm^2 \times 10^3$
Replicates (R)	3	0.55	1.34	0.21	60.88	0.76	26.68	0.62
Seasons (SE)	3	7.51**	3.52	1.78**	307.63**	19.43**	392.41**	9.93*
SE × R (Error (a))	9	1.25	2.34	0.24	38.47	2.33	63.92	1.87
Varieties (V)	9	2.02***	6.69***	2.29***	276.57***	10.33***	168.69***	2.83***
SE × V	27	1.41***	4.68***	1.37***	115.54***	3.76***	67.57***	1.44***
Error (b)	108	0.53	1.54	0.35	23.68	0.63	24.52	0.58
CV (%)		18.81	29.03	14.71	13.41	10.66	16.11	13.94

*, **, *** Significant at 0.05, 0.01 and 0.001 respectively.

perform differently with season (Tables 2 & 3). This may be attributed to differences in rainfall intensity and distribution (Fig.1). Total rainfall was highest in the late (August) planting seasons of 1995 and 1996, while the lowest was from 1997 early (April) planting season. The late planting season of 1996 had limited rainy days and low total rainfall in October which coincided with the period when maize was silking.

The highest crop growth rates at vegetative

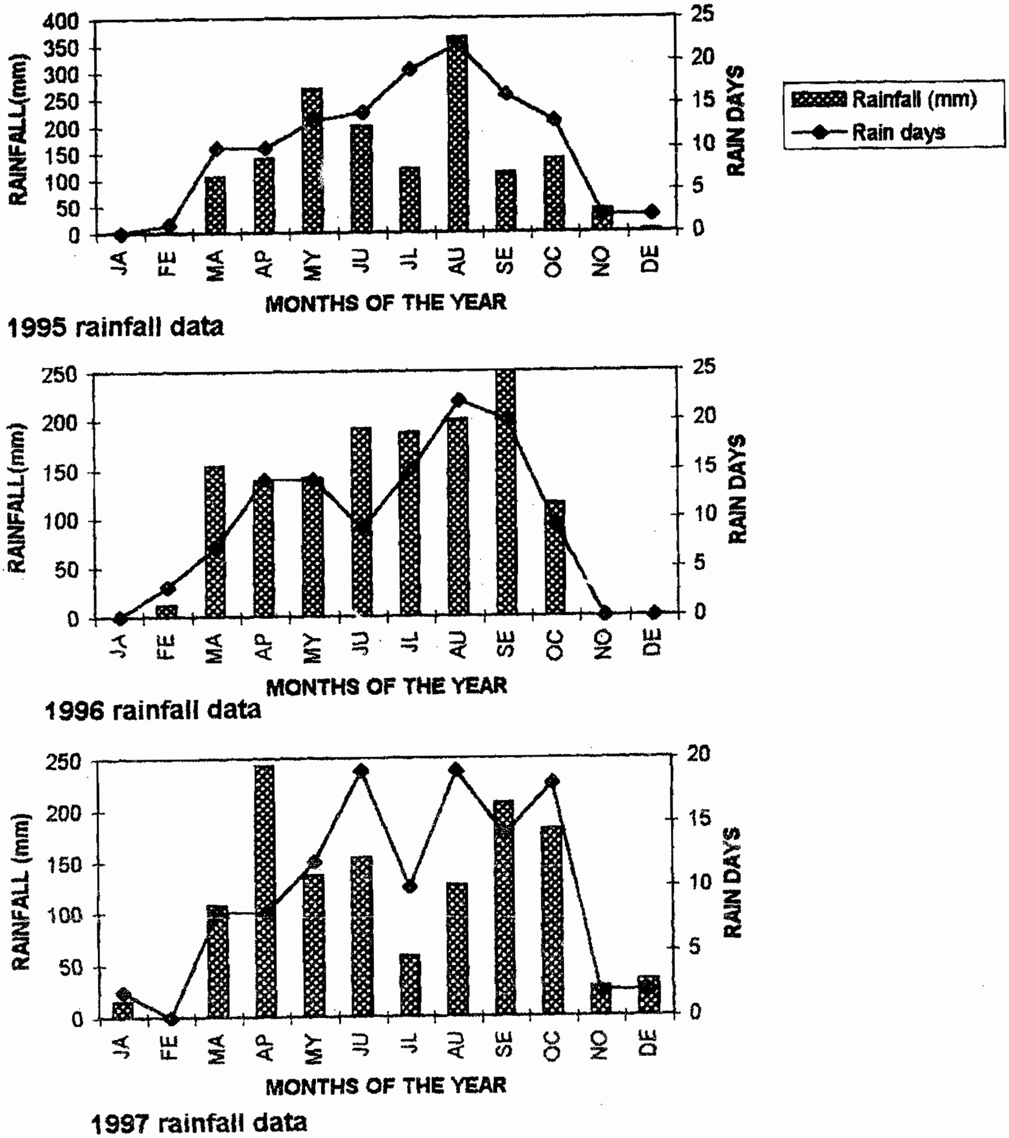

Fig.1. Total rainfall and number of rain days recorded during the years of the experiment.

(CGRv) and reproductive (CGRr) stages were from TZSR-Y. CGRv was higher in TZSR-Y than in 8644-27, 8321-18, and DMR-L-SR-W, but at reproductive stage (CGRr) all the varieties had similar rates. Ear growth rate (EGR) was highest in 8644-27 and similar to those of 8644-31, TZSR-Y, SUWAN 1 and EV 9043-DMR, while the ear growth duration (EGD) was longest in TZPB-SR, DMR-L-SR-W, 8321-18, and 880543. Varieties 8805-4 and TZSR-Y had the shortest EGD. Kernel growth rate (KGR) was higher in 8321-18 than in other varieties, and its duration (KGD) was shorter

TABLE 3

Combined ANOVA Showing Mean Square (MS) for Grain Yield and Associated Traits
(b) Yield Component Traits

Source of variation	Degree of freedom	MS for: Grain yield t/ha	Kernel rows per cob no.	Kernels per row no.	Kernels per ear no.	100-seed weight g	Shelling percentage	Harvest index	Days to 50 % silking d	Total dry matter at harvest g/plant
Replicates (R)	3	0.76	1.41	15.71	2181.99	9.85	28.30	0.005	1.61	1557.31
Seasons (SE)	3	4.29**	3.59*	340.91***	71765.73***	9.00	216.94**	0.015	167.05***	14755.30***
SE × R (Error (a))	9	0.45	0.90	13.25	4716.68	12.55	27.43	0.005	2.21	7780.16
Varieties (V)	9	1.64***	3.14***	39.97***	8874.89***	18.53***	119.20***	0.017***	30.36***	3464.19***
SE × V	27	0.46***	0.81*	15.78***	4886.02***	3.77	17.10	0.005**	6.70***	1589.01**
Error (b)	108	0.27	0.48	7.30	1816.26	0.63	12.88	0.003	2.14	686.02
CV (%)		13.24	5.06	8.58	9.78	8.45	5.52	13.64	2.44	10.66

*, **, *** Significant at 0.05, 0.01 and 0.001, respectively.

TABLE 4

Means of Plant Growth Traits of Maize Varieties Evaluated from 1995 to 1997 at Ibadan, Nigeria

Varieties	Crop growth rate at vegetative stage g/d/plt	Crop growth rate at reproductive stage g/d/plt	Ear growth rate g/ear/d	Ear growth duration d	Kernel growth rate mg/kernel/d	Kernel growth duration d	Leaf area at 50 % silking $cm^2 \times 10^3$
8321-18	3.6^{bc}	4.7^{a}	4.1^{bcd}	42^{a}	9.2^{a}	26^{d}	5.5^{bc}
8535-23	4.1^{ab}	4.4^{ab}	3.7^{de}	36^{cd}	7.0^{def}	31^{bc}	5.7^{b}
8644-27	3.2^{c}	4.3^{ab}	4.5^{a}	37^{bcd}	7.6^{cd}	32^{bc}	5.5^{bc}
8805-4	3.8^{ab}	3.6^{bc}	3.9^{cd}	41^{ab}	6.7^{f}	34^{ab}	5.1^{bc}
8644-31	3.8^{ab}	3.4^{c}	4.3^{abc}	31^{f}	7.8^{bc}	29^{cd}	5.3^{bc}
DMRLSRW	3.7^{bc}	4.5^{ab}	3.5^{e}	38^{abcd}	6.5^{f}	36^{a}	5.0^{c}
TZSR(Y)	4.4^{a}	4.9^{a}	4.3^{abc}	31^{f}	8.2^{b}	26^{d}	6.4^{a}
TZPBSR	3.9^{ab}	3.1^{c}	3.5^{e}	39^{abc}	7.3^{cde}	29^{cd}	5.7^{b}
SUWAN 1	4.4^{a}	4.8^{a}	4.4^{ab}	35^{de}	7.4^{cd}	31^{bc}	5.6^{bc}
EV 9043 DMR	4.0^{ab}	4.9^{a}	4.3^{abc}	32^{ef}	7.0^{def}	31^{bc}	5.1^{bc}

Means in the column with the same letters are not significantly different at 5 % probability level using DMRT.

than most varieties except for TZSR-Y, TZPB-SR, and 8644-31. Leaf area at silking stage was highest in TZSR-Y, while DMR-LSR-W had the lowest leaf area among all varieties (Table 4).

Yield component traits (Table 5) showed that variety 8321-18 had the highest grain yield. SUWAN 1 had the highest number of kernel rows, while 8321-18 had more kernels/row than most varieties. Kernels/ear from 8805-4 was the highest and 8321-18 had the highest 100-seed weight. Shelling percentage was highest in EV 9043-DMR while 8644-27 had better HI than most varieties. Days to 50 per cent silking was shorter in 8321-18, 8644-31, DMR-LSR-W, SUWAN 1 and TZPB-SR, ranging from 58 to 59 days while TZSR-Y and 8535-23 had longer days to silking of 63 and 62 days, respectively. Total dry matter value at maturity was highest in 8321-18, and it was similar to those of TZSR-Y, DMR-L-SR-W, SUWAN 1, and 8644-27. Dry matter from 8644-31 was the lowest among the varieties (Table 5).

A significant positive correlation was found between grain yield and CGRr (r=0.17***), EGD (r=0.36***), KGD (r=0.30**), HI (r=0.53***), and TDM (r=0.50**). The days to 50 per cent silking was negatively correlated to grain yield (r=-0.19*).

TABLE 5

Mean Yield, Yield Components, Days to 50 Per cent Silking, and Total Dry Matter of Maize Varieties Evaluated in Ibadan, Nigeria, from 1995 to 1997

Varieties	*Grain yield t/ha*	*Kernel rows per cob no.*	*Kernels per row no.*	*Kernels per ear no.*	*100-seed weight g*	*Shelling %*	*Harvest index*	*Days to 50 % silking d*	*Total dry matter at harvest g/plant*
8321-18	4.6^{a}	13.9^{abc}	33^{a}	467^{a}	24.1^{abc}	65.9^{bcd}	0.42^{abc}	58^{d}	266.7^{a}
8644-27	4.3^{ab}	13.5^{c}	32^{ab}	437ab	24.3^{a}	63.3^{def}	0.45^{a}	60^{b}	254.8^{ab}
8805-4	4.3^{ab}	14.0^{abc}	33^{a}	469a	22.5^{bcde}	67.6^{ab}	0.42^{abcd}	60^{b}	241.5^{b}
8535-23	3.8^{cd}	13.7^{bc}	30^{c}	418b	23.3^{a}	62.2^{ef}	0.39^{bcd}	63^{a}	242.1^{b}
8644-31	3.8^{cd}	12.8^{d}	33^{a}	424b	22.0^{cde}	66.4^{bc}	0.44^{ab}	58^{d}	210.3^{c}
EV9043 DMR	4.1^{bc}	14.2^{ab}	33^{a}	466a	21.8^{cde}	70.0^{a}	0.41^{abcd}	60^{bc}	243.8^{b}
SUWAN 1	3.9^{bcd}	14.4^{a}	30^{c}	427^{b}	22.4^{cde}	63.8^{cde}	0.38^{de}	59^{bcd}	251.9^{ab}
DMRLSR (W)	3.8^{cd}	13.6^{bc}	31^{bc}	416^{b}	23.1^{abcd}	65.3^{bcd}	0.38^{cde}	59^{bcd}	247.0^{ab}
TZPBSR	3.6^{cd}	14.2^{abc}	30^{bc}	427^{b}	21.1^{c}	63.9^{bcd}	0.37^{de}	59^{bcd}	241.8^{b}
TZSR (Y)	3.5^{d}	13.6^{bc}	29^{c}	400^{b}	21.6^{de}	60.7^{f}	0.34^{c}	62^{a}	254.8^{ab}

Means in the column followed by the same letters are not significantly different at 5 % level using DMRT.

TABLE 6

Correlations Between Grain Yield and Plant Growth Traits in Maize (Zea mays *L.*)

	GY	*TDM*	*DS*	*KGD*	*KGR*	*EGD*	*EGR*	*CGRr*	*CGRv*	*HI*	*LAS*
LAS	-	0.28***	-	-	-	0.18*	-	-	-	-	1
HI	0.53***	-	-	0.23**	-	-	-	-	-	1	
CGRv	-	-	0.22**	-	-	-0.25**	0.20**	-	1		
CGRr	0.17**	0.38***	-	-	-	-0.21**	0.31***	1			
EGR	-	-	-	-	-	0.62***	1				
EGD	0.36***	0.23**	-0.22**	0.24**	-	1					
KGR	-	-	-0.29***	-0.78***	1						
KGD	0.30**	-	-	1							
DS	-0.19*	-0.24**	1								
TDM	0.50***	1									

*, **, ***, Significant at 0.05, 0.01, and 0.001 probability levels, respectively.

EGD was positively correlated to TDM (r=0.223**) and KGD (r=0.24**), but negatively correlated to DS (r=-0.22**). HI was positively correlated to KGD (r=0.23***) (Table 6). All the yield component traits were positively correlated to grain yield (Table 7). Kernels/ear had a correlation coefficient of 0.70***, and kernels/row, seed weight, and shelling percentage had significant positive correlation coefficients of 0.63***, 0.44*, and 0.40**, respectively.

TABLE 7

Correlations Between Yield and Yield Component Traits in Maize (Zea mays *L.*)

	GY	*EGR*	*KGR*	*S%*	*KE*	*KPR*	*KR*	*SW*
SW	0.44***	-	-	0.15*	-	-	-	1
NKRC	0.30***	-	-	-	0.41***	-	1	
NKPR	0.63***	-	-	0.30***	0.89**	1		
TKE	0.70***	-	-	0.28***	1			
S%	0.40***	0.18*	-0.16*	1				
KGR	-	-	1					
EGR	-	1						
GY	1							

* ** *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively.
Abbreviations: GY - grain yield, EGR - ear growth rate, KGR - kernel growth rate, S% - shelling percentage, KE - kernels per ear, KPR - kernels per row, KR - kernel rows, SW - 100-seed weight.

The kernels/ear had the highest correlation coefficient with yield. Spietz (1982) reported that kernel number in wheat is genetically controlled and that grain yield depends more on kernel number than on kernel weight. Tollenaar, Dwyer & Stewart (1992) reported that the higher yield in new maize hybrids in the maize-growing belt of USA was due to higher grain number. HI and TDM also had significant correlation with grain yield. Donald & Hamblin (1976) described yield as a product of HI and TDM. The use of HI had been suggested for yield selection (Niciporovic, 1960; Donald, 1962). Gifford *et al.* (1984) reported that genetic gain in grain yield for many crops has been due to higher HI with little or no increase in total biological yield. However, most tropical maize varieties generated enough above-ground biomass which they failed to convert to grain yield (Bjarnarson, Edmeades & Ortega, 1985; Fischer & Palmer, 1984; Feil *et al.*, 1992). TDM was similar in this study between the highest (8321-18) and lowest (TZSR-Y) grain-yielding varieties, but the former had a significantly higher HI.

The significant relationship between CGRr, EGD and KGD and yield (Table 6) suggests that they can be veritable selection indices for yield improvement. Increased production of dry matter for ear development over a long duration would enhance grain yield in maize, since yield of maize depended on the amount of dry matter produced and translocated to grain after anthesis (Anderson, Kamprath & Moll, 1984). This confirmed the importance of CGRr in maize improvement. KGD is positively correlated to EGD in this study, and it had been found to be genetically controlled and can be used in improving yield through breeding (Cross, 1975; Poneleith & Egli, 1979).

From this study, a multi-disciplinary approach to maize improvement, where available germplasm are classified according to their biological traits, especially on harvest index, kernel growth duration and ear growth duration values, are suggested. Crop improvement techniques could then be used to develop ideotypes from these yield-related traits. This is an area for further work in using biological traits to develop higher maize grain yield in the tropical forest zone.

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