(IJRST) 2015, Vol. No. 5, Issue No. IV, Oct-Dec **e-ISSN: 2249-0604; p-ISSN:2454-180X**

GENETIC CORRELATION AND CONTRIBUTION OF SOME PHYSIOLOGICAL TRAITS TO YIELD IN SOME SELECTED MAIZE GENOTYPES

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ABSTRACT

Yield components have influence on ultimate yield both directly and indirectly. Splitting of total correlation into direct and indirect effects, therefore, would provide a more meaningful interpretation of such association. An experiment was conducted to study the genotypic correlation and character contributions of some physiological traits (stomatal conductance, canopy temperature, leaf temperature and chlorophyll content) to yield in maize. Genotypes used were Sammaz 14, Sammaz 29, 2009 EVDT, 2009 TZE–W, TZE COMP-5 and 2009 TZEE,laid out in a randomized complete block design with three replications. Genotypic and phenotypic correlations were estimated. Path analysis was used to determine the direct and indirect effects of the physiological traits on grain yield. The results obtained revealed no significant difference between the genotypes for yield and physiological traits observed. However, the genotype showed good responses to the physiological traits and these can be manipulated to develop drought tolerant genotypes. Heritability, phenotypic and genotypic coefficient of variation was observed to be low. These can be attributed to high environmental variance than genotypic and phenotypic variance. However, stomatal conductance had heritability of 30%. Canopy temperature had a negative direct effect on yield. But the indirect effects were low. Leaf temperature had an indirect effect on yield through canopy temperature. The direct effect of stomatal conductance was high and positive. Stomatal conductance had a positive genotypic and phenotypic correlation with grain yield whilecanopy temperature had a negative genotypic and phenotypic correlation with grain yield.

Keywords: genotypic correlation, heritability, path analysis, physiological traits, yield

INTRODUCTION

Maize (*Zea mays* L.) has high potential for production and productivity in the savanna ecology of sub-Saharan Africa due to high solar radiation and low night temperatures. As a result of its commercial importance in the Nigerian economy, maize is complementing the traditional crops such as guinea corn [*Sorghum bicolor* (L.) Moench] and millet [*Pennisetumglaucum*(L.) R. Br.] in parts of the Sudan, Sahel and Guinea savanna ecologies(Bello, 2012).

In view of the importance of maize in Nigeria, researchers are utilizing available genetic resources to reconstruct the ideotype of the plant in order to meet the ever increasing requirements of the population through improvement in grain yield, other desirable agronomic and phenological characters as well as quality (Bello, 2012).In general, average yields in tropical and sub-tropical regions are far lower than in temperate ones, with sub-Saharan Africa way below other regions with average values across countries of around 1 t ha^{-1}. This is in spite the fact that maize is one of the main crops in these regions, where the effects of climate change including rising temperatures, evapotranspiration losses and eventually, decreasing rainfall are expected to be particularly negative (World Bank, 2007). The possibilities for alleviation of water stress are limited. The majority of tropical maize is grown under rain fed conditions and poor farmers from these regions are unable to implement crop management strategies that might at least mitigate some constraints (Araus*et al*., 2012).

Water is an integral part of plant body and itplays an important role in growthinitiation, maintenance ofdevelopmental process of plant lifeand hence has pivotal function in cropproduction.Drought stress has deleterious effects on the seedlingestablishment, vegetative growth,photosynthesis, root growth, anthesis,anthesis-silking interval, pollination and grain formation in maize crop(Aslam *et al*., 2012).

Drought is arising threat of the world. Most of thecountries of the world are facing the problem of drought. Itis the creeping disaster, slowly taking hold of an area andtightening its grip with time (Misra*et al*., 2002).Annual maize yield loss due to drought is estimated to be 15% in West and Central Africa and losses may be higher in the marginal areas where the annual rainfall is below 500mm and soils are sandy or shallow (Edmeades*et al*., 1995).

In 2020, demand for maize in developing countries is expected to exceed 500 million tons, and will surpass the demand for both rice and wheat (Pingali and Heisey, 2001). This projected rapid increase in demand is mainly explained by growth in the demand for maize as livestock feed (for poultry and pigs, particularly in East and Southeast Asia) (Araus*et al*., 2012).

The effect of selection under stress on yield performance of genotypes under optimal conditions and vice versa has been an ongoing debate among plant breeders for decades. Secondary traits can improve the precision with which drought tolerant genotypes are identified, compared with measuring only grain yield under drought stress. Secondary traits such as canopy temperature, stomata conductance, ears per plant and anthesis silking interval have been found to possess strong correlations with grain yield under drought conditions and have been used to select for higher levels of tolerance to drought (Badu-Apraku *et al*., 2011).

Measurement of correlation coefficient helps identify the relative contribution of componentcharacters towards yield (Panse, 1957). Moreover, the correlation between grain yield and acomponent character may sometimes be misleading due to an over estimation or underestimation forits association with other characters. Thus, yield components have influence on ultimate yield bothdirectly and indirectly (Tukey, 1954). Splitting of total correlation into direct and indirect effects,therefore, would provide a more meaningful interpretation of such association. Path coefficient, whichis a standard partial regression coefficient, specifies the cause and effect relationship and measures therelative importance of each variable (Wright, 1921). Therefore, correlation in combination with pathcoefficient analysis will be an important tool to find out the association and quantify the direct andindirect influence of one character upon another (Dewey and Lu, 1959). The study was conducted to assessphysiological characterassociation and contribution of these characters towards grain yield of maize and to find outthe direct and indirect effect of component characters on grain.

MATERIALS AND METHODS

The experiment was conducted at the Research and Teaching Farm of Department of Agronomy, Faculty of Agriculture, Bayero University, Kano (Lat $11^0$58'N, Long $8^0$25'E and 475m above sea level).The materials used for the experiment were six (6) maize genotypes (Sammaz 14, Sammaz 29, 2009 EVDT, 2009 TZE–W, TZE COMP-5 and 2009 TZEE).The treatments were laid out in a randomized complete block design (RCBD) with three replications. The land used for the experiment was ploughed and harrowed to a fine tilt.One ridge was used to represent a plot and each ridge was 4m long.Seeds were sown manually into their respective ridges at the rate of 2 seeds per hole on 9^{th} July 2014, when the soil was moist after an earlier rainfall. The seeds were sown at intervals of 75 x 40cm inter and intra row spacing, respectively.Weeding was carried out twice. First weeding was carried out manually using hoe, 2 weeks after sowing. Second weeding was carried out using animal traction, 4 weeks after sowing.The recommended dose of fertilizer for maize, 120:60:60 – N: K_2O: P_2O_5 kg/ha was applied. It was applied two weeks after sowing, by side placement. Nitrogen was supplied in two split doses first dose at two weeks together with phosphorus and potassium and second dose at 4 weeks after sowing.

Data was recorded on days to 50% silking and anthesis, plant and ear heights as well asplant aspect. Data was also recorded for some physiological traits; canopy temperature was measured using infrared thermometer, leaf temperature was measured using leaf porometer (Decagon Devices),stomatal conductance was measured using leaf porometer in fairly calm weather between 8am – 12pm and chlorophyll content was measured using SPAD.Grain yield inkilograms per hectare was computed using the formula below. The yield were adjusted to 15% moisture and a shelling percentage of 80 was assumed

$$\text{Grain Yield (kgha}^{-1}) = \text{Field weight x } \frac{(100 - \text{moisture})}{85} \text{ x } \frac{1000}{0.4 \times 0.75 \times 11} \times \frac{80}{100}$$

Data collected wereanalyzed usingthe PROC MIXED statement. The analysis was done using SAS 9.0 (2001). Replication was considered as a random effect and the genotypes were considered as fixed effect.

The mean sum of square (MS) of errorand phenotypic variances were estimated followed by Johnson *et al*. (1955). The error meansquare was considered as error variance (δ^2e). Genotypic variances (δ^2g) were divided by subtractingerror mean square from the genotype mean square and dividing by number of replications.

Genotypic variance = $\frac{GMS-EMS}{r}$

GMS and EMS = genotype and error mean sum of square and
r = Number of replication
The phenotypic variances (δ^2p), were derived by adding genotypic variances with the error variances (δ^2e), as given by the following formula,

$$\delta^2p = \delta^2g + \delta^2e$$

Genotypic and phenotypic coefficient of variation were calculated by the formula suggested byBurton (1952).

Genotypic coefficient of variation (GCV) = $\frac{\delta g}{m} \times 100$

Where, δg = Genotypic standard deviation and m = Population mean

Phenotypic coefficient of variation (PCV) = $\frac{\delta p}{m} \times 100$

Where, δp = Genotypic standard deviation and m = Population mean

Broad sense heritability (H^2) was estimated (defined by Lush 1949) by the formulasuggested by Johnson *et al*. (1955), Hanson *et al*. (1956).

$H^2 = \frac{\delta^2 g}{g^2 p} \times 100$

Where,
H^2 = Heritability in the broad sense
δ^2p = Genotypic variance
δ^2p = Phenotypic variance

The expected genetic advance (GA) for differentcharacters under selection was estimated using the formula suggested by Lush (1949) and Johnson *etal*. (1955).

GA = $\frac{\delta^2 g}{\delta^2 p} \times k \times \delta p$

Where,
k = Selection differential, the value of which is 2.06 at 5 % selection intensity
δp= Phenotypic standard deviation

Genetic advance in percentage of mean (GAM) was calculated from the formula given byComstock and Robinson (1952).

$$GAM = \frac{GA}{M} \times 100$$

Where, M = population mean

Estimation of genotypic and phenotypic correlation co-efficient: For calculating the genotypic andphenotypic correlation coefficient for all possible combinations the formula suggested by Miller *et al.*(1958), Hanson *et al.* (1956) and Johnson *et al*. (1955) were adopted. The genotypic co-variancecomponents between two traits and the phenotypic co-variance component were derived in the sameway as for the corresponding variance components. These co-variance components were used tocompute genotypic and phenotypic correlation between the pairs of characters as follows:

$$rg = \frac{COVg\ 1.2}{\sqrt{\delta^2 g\ 1 \times \delta^2 g\ 2}}$$

rg = Genotypic correlation coefficient
COVg 1.2 = Genotypic covariance of traits 1 & 2
δ^2g 1 = Genotypic variance of trait 1.
δ^2g 2 = Genotypic variance of traits 2.

$$rp = \frac{COVp\ 1.2}{\sqrt{\delta^2 p\ 1 \times \delta^2 p\ 2}}$$

rp = Genotypic correlation coefficient
COVp 1.2 = Genotypic covariance of traits 1 & 2
δ^2p 1 = Genotypic variance of trait 1.
δ^2p 2 = Genotypic variance of traits 2.

Estimation of path co-efficient: Correlation coefficients were further partitioned into components of direct and indirect effects by path coefficient analysis originally developed by Wright (1921 and1923) and later described by Dewey and Lu (1959).Path coefficient was estimated for 4physiological charactersrelated to yield viz., canopy temperature, leaf temperature, stomatal conductance, chlorophyll content and grain yield. Grain yield was considered asresultant variable.

RESULTS AND DISCUSSION

The mean performances of the genotypes for some agronomic traits are presented in Table 1. There was no significant difference (P>0.05) for all the traits except for days to anthesis, silking and anthesis silking interval (ASI). The variability in these traits is due to differences in the maturity group of the genotype. Also the lack of significant difference for other traits measured can be due to low rainfall observed during the experimental period. The shortened

ASI observed in these cultivars is desirable because it hasbeen reported that low ASI enhance maize tolerance tostresses during flowering and is ensures good grainingfilling (Edmeades, *et al*., 1993; Bolanos*et al*., 1996).

Table 1: Mean performance forsome agronomic traits of different maturity group of maize

Entry	**Days to anthesis**	**Days to silking**	**Anthesis silking interval**	**Plant aspect**	**Plant height (cm)**	**Ear height (cm)**	**Yield (kgha^{-1})**
SAMMAZ 14	63.00	65.67	2.67	2.50	184.00	63.67	2022.44
SAMMAZ 29	54.33	60.33	2.00	2.83	171.67	54.67	1510.46
2009 EVDT	55.33	57.00	1.67	2.00	174.67	56.00	1965.25
2009 TZE-W	54.67	56.67	2.00	1.50	172.67	60.33	2291.22
TZE-COMP 5	55.33	61.67	6.33	2.33	177.00	58.00	2054.39
2009 TZEE	55.00	56.67	1.67	2.33	168.00	50.00	1891.19
SE $\pm$	1.38	1.71	0.77	0.33	7.46	4.28	262.48
Genotype	**	*	**	NS	NS	NS	NS

*, ** = significant at 5% and 1% level of probability, respectively

NS = Not significant

Table 2: Mean performance for some physiological traits of different maturity groups of maize

Entry	**Leaf temperature (˚C)**	**Canopy temperature (˚C)**	**Stomatal conductance**	**Chlorophy ll content**
SAMMAZ 14	32.87	29.23	1859.67	45.48
SAMMAZ 29	32.77	29.37	2533.07	44.17
2009 EVDT	32.40	28.00	2366.47	49.37
2009 TZE-W	32.60	28.87	1880.33	42.78
TZE-COMP 5	32.40	28.20	2092.53	42.25
2009 TZEE	32.60	27.57	2104.00	49.28
SE $\pm$	0.34	1.07	340.02	3.09
Genotype	NS	NS	NS	NS

NS = Not significant

The mean performances of some physiological traits are presented in Table 2. There was no significant difference (P>0.05) among genotypes for all the traits measured. SAMMAZ 14 has the highest canopy temperature (29.23^{o}C) while 2009 TZEEhas the lowest canopy temperature (27.57^{o}C). SAMMAZ 29 has the highest stomatal conductance (2533.07) while SAMMAZ 14 gave the lowest value for stomatal conductance (1859.67). Stomatal conductance estimates the rate of gas exchange (i.e., carbon dioxide uptake) and transpiration (i.e., water loss) through the leaf stomata as determined by the degree of stomatal aperture (and therefore the physical resistances to the movement of gases between the air and the interior of the leaf). Hence, it is a function of density, size and degree of opening of the stomata allowing greater conductance, and consequently indicating that photosynthesis and transpiration rates are potentially higher (Pietragalla and Pask, 2012).The lack of significant difference observed in the physiological traits of the genotypes measured was indications that irrespective of the difference in maturity group the physiological response of the maize genotypes are the same. However, these cannot be said to be valid because of the low rainfall observed during the experiment. The maize genotypes showed a good response in terms of improving them towards becoming drought tolerant genotypes.

Canopy temperature had negative direct effect (-0.365) on grain yield. The indirect effect through leaf temperature (-0.011), stomatal conductance (0.075) and chlorophyll content (0.029) were low (Table 3). Leaf temperature had a high indirect effect to grain yield through canopy temperature (0.109). The direct effect and indirect effect of leaf temperature through stomatal conductance and chlorophyll content were low. Stomatal conductance had a positive direct effect (0.291) on grain yield. However, the indirect effect were low. Chlorophyll content had a negative direct effect (-0.161) to grain yield and had a low indirect effects.

Table 3: Direct (Bold) and indirect effect of some physiological traits on grain yield of maize

	Canopy temperature	Leaf temperature	Stomatal conductance	Chlorophyll content
Canopy temperature	**-0.365**	-0.011	0.075	0.029
Leaf temperature	0.109	**0.037**	-0.029	0.050
Stomatal conductance	-0.094	-0.004	**0.291**	-0.047
Chlorophyll content	0.065	-0.011	0.084	**-0.161**

The environmental variance had a high ratio than phenotypic and genotypic variance (PCV and GCV) in all the traits measured (Table 4). Stomatal conductance had heritability of 30% followed by canopy temperature (20%). The heritability was low for leaf temperature (2.7%) and chlorophyll content (10%). Stomatal conductance had a PCV of 21.6. Generally, the GCV and PCV were low. The low heritability, PCV and GCV can be attributed to the high environmental variance observed which is partly due to low rainfall observed during the period of experimentation.

Table 4: Variance components, heritability, genotypic and phenotypic coefficient of some physiological traits of maize

	δ^2e	δ^2g	δ^2p	H^2	PCV	GCV	GA	GAM
Canopy temperature	1.88	-0.3	1.6	20	4.4	1.9	-0.49	-1.72
Leaf temperature	0.35	0.0	0.4	2.7	1.8	0.3	0.03	0.10
Stomatal conductance	286112	-72902.8	213209.2	30	21.6	12.6	-325.24	-15.20
Chlorophyll content	27.01	2.4	29.4	10	11.9	3.4	0.90	1.98
Yield	235376	-37821.7	197554.3	20	22.7	9.9	-175.29	-8.96

δ^2e = environmental variance, δ^2g = genotypic variance, δ^2p = phenotypic variance, H^2= heritability, PCV = phenotypic coefficient of variation, GCV = genotypic coefficient of variation, GA= genetic advance, GAM = GA as percentage of mean

Table 5: Genotypic and phenotypic (bold) correlation of some physiological traits of maize

	Days to anthesis	Days to silking	Anthesis silking interval	Canopy temperature	Leaf temperature	Stomatal conductance	Chlorophyll content	Grain yield
Days to anthesis	1.00	0.86	-0.14	0.94	-0.16	-0.71	0.44	0.89
Days to silking	**0.75**	1.00	0.39	0.16	0.33	-0.07	-0.78	0.64
Anthesis silking interval	**-0.23**	**0.48**	1.00	0.03	0.66	0.20	-0.38	-0.36
Canopy temperature	**0.18**	**0.26**	**0.14**	1.00	-0.47	0.70	-0.12	-0.82
Leaf temperature	**0.26**	**0.36**	**0.19**	**-0.16**	1.00	-0.38	-0.37	0.59
Stomatal conductance	**-0.34**	**-0.28**	**0.05**	**-0.11**	**0.04**	1.00	0.63	0.46
Chlorophyll content	**-0.07**	**-0.36**	**-0.43**	**-0.53**	**-0.32**	**0.16**	1.00	-0.23
Grain yield	**-0.07**	**-0.36**	**-0.43**	**-0.24**	**-0.17**	**0.21**	**0.05**	1.00

The genotypic and phenotypic correlation are presented in Table 5. A positive genotypic (0.46) and phenotypic (0.21) correlation exist between grain yield and stomatal conductance. Also a positive genotypic and phenotypic correlation was observed between chlorophyll content and stomatal conductance. Measuring chlorophyll content, as a proxy for the entire photosynthetic complex, indicates photosynthetic potential. Loss of chlorophyll content, i.e., chlorosis, is indicative of stress induced by heat, drought, salinity, nutrient deficiency, ageing, etc., and reflects a loss of photosynthetic potential. (Mullan and Mullan, 2012). Meanwhile the discussion among plant scientist was whether photosynthesisdecline is due to stomatal closure ordue to metabolism destruction(Lawson *et al.*, 2003; Anjum*et al.*,2003).A negative genotypic (-0.82) and phenotypic (-0.24) correlation exist between canopy temperature and grain yield. Canopy temperature and stomatal conductance are traits that are linked by the need of plants to transpire water to fix carbon. Canopy temperature has had widespread application in stress breeding, as it readily integrates the effect of many plants within a crop canopy and hence reduces error associated with plant-to-plant and leaf-to-leaf variation. Cooler canopy temperature is positively associated with yield under heat and drought stress (Pask*et al.*, 2012).

Studies have also shown that canopy temperature is correlated with many physiological factors: stomatal conductance, transpiration rate, plant water status, water use, leaf area index and crop yield. Genotypes with cooler canopy temperature can be used to indicate a better hydration status. It is used routinely, particularly for stress diagnostic and breeding selection of stress adapted genotypes: (i) under drought conditions it is related to the capacity to extract water from deeper soil profile and/or agronomic water use efficiency(WUE); (ii) under irrigated conditions it may indicate photosynthetic capacity, sink strength, and/or vascular capacity-depending on the genetic background and environment and developmental stage; and (iii) under heat stress conditions is related to vascular capacity, cooling mechanism and heat adaptation (Pietragalla, 2012).

The physiological traits studied can be manipulated to develop drought tolerant maize varieties. Stomatal conductance was more associated to grain yield and had a moderate heritability. Canopy temperature should be considered more than leaf temperature because it had a direct effect on grain yield while leaf temperature had a low direct effect but a high indirect effect through canopy temperature on grain yield.

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