

Research Article

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Probing of the genetic components of seedling emergence traits as selection indices, and correlation with grain yield characteristics of some tropical maize varieties<https://doi.org/10.1515/opag-2020-0180>

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Abstract: Ten maize varieties of tropical origin were tested at two different agro-ecological zones during the cropping season of 2007 and 2008 to investigate the genetic components of seedling emergence characteristic and correlate with grain yield and related traits in Nigeria. Heritability values were high for all traits study, indicating reliability and stability of most of the traits across different environments. Variety DMRLSR-Y had highest 300 kernel weight (105.2 g), but least grain yield and second to the least emergence percentage, indicating bigger kernel and highest kernel weight/cob but low plant stands resulted in low grain yield. Genotypic and agronomic correlation analysis revealed positive associations ($p < 0.01$) between grain yield and emergence percentage ($E\%$), and 300 kernel weight; however, interval between pollen shed and silking was negatively correlated with physiological maturity period and 300 kernel weight. Improvement of this variety for higher emergence percentage is therefore predicted for higher grain yield. High values of genotypic and phenotypic coefficient of variation recorded by emergence percentage (41 and 45%) and grain yield (25 and 32%), respectively, revealed the less effects of environmental factors on the aforementioned characters, and it showed the stability and reliability of the two traits. High values of both broad sense heritability and genetic advance recorded by emergence percentage ($E\%$) and 300 kernel weight confirmed that standard selection procedure could be used to identify superior genotypes for the two traits.

Keywords: genetic, emergence, seedling, heritability

1 Introduction

One of the tools for measuring grain yield is the germination percentage and seedling emergence index (Hampton and Tekrony 1995). Testing for seed vigour is one of the advancements that have been made in seed quality control programmes. Similarly, Abdurakhmonov et al. (2008) and Mponda et al. (1997) have reported that seedling vigour is a suitable selection index in crop yield improvement programmes. Seed vigour determines crop stand per unit area, their establishment, and yield. Poor seed quality is a product of maize plant derived from poor seed vigour. Vice versa, good quality maize seeds are expected to produce vigorous maize seedlings across different environments. Researchers have reported that two of the factors causing poor maize grain yield are poor quality seed, coupled with low seed vigour associated with most of the maize planted by most Nigeria farmers. Investigation on maize seed quality and seedling vigour among the maize grown by the tropical farmers is vital for the development of high grain yield of maize varieties grown in the tropics. The establishment of the level of correlation between maize seed and seedling emergence traits also require the estimation of heritability for the improvement of maize for high grain yield in the tropic. Emergence percentage ($E\%$), emergence index (EI), and emergence rate index have been identified as essential components of seedling vigour (Fakorede and Agbana 1983; Fakorede and Ojo 1981). The positive and significant correlations between maize grain yield and emergence characters have been established by Fakorede and Ojo (1981). Fakorede (1985) conducted an experiment to compare maize seed emergence percentage and their resultant grain yield across multiple years. The authors observed that the planting year that recorded the highest seedling emergence percentage and vigour had the highest grain yield. The authors therefore suggested that higher maize grain yield is expected if high seedling emergence percentage and vigour are maintained under favourable genetic and other environmental factors.

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Investigation on the status of the genetic components of variation existing among the seedling emergence traits, the nature, or percentage of their heritability and the correlation that exist among the traits are vital tools that are needed for effective selection in maize grain yield breeding programmes (Fayeun *et al.* 2016). A study carried out by Chukwudi and Agbo (2014) revealed a continuous and significant variation on seedling vigour and seedling emergence rate with the seed sizes. The authors therefore concluded that the presence of genetic variability among seedling traits is essential for its improvement.

Other authors (Opeke and Fakorede 1986) noted that variation in seedling emergence characters within and between crop populations may be determined by the condition from which the seeds were produced, processed, and stored, coupled with the genetic status. High yielding maize lines and the high seedling emergence percentage have also been observed to be characterized by high emergence rate index.

For the attainment of continuous progress in crop improvement programme, establishment of genotypic correlations present in genetically varying populations for the traits to be developed is required. This information is needed by crop breeders especially when targeting the improvement of two or more traits concurrently. Positive correlation indicates that the two traits increase simultaneously, whereas negative correlation indicates inverse proportional relationship among the traits being tested (Opeke and Fakorede 1986). Genetic variability, heritability estimates, correlations, and predicted responses to selection index selection for seedling emergence and yield in three maize populations were investigated by Opeke and Fakorede (1986). The authors observed that selection for high emergence traits resulted in a positive gain in maize grain yield. The authors therefore concluded that substantial progress will be made in maize grain yield improvement programmes by selecting desirable emergence traits. The authors also suggested that selection of both seedling emergence traits and maize grain yield should be done simultaneously.

Probing into the degree of heritability available among desired traits targeted for improvement will assist breeders in identifying the degree of genetic component present for the inheritance of a trait (Chopra 2000). Moreover, high heritability indicates the reliability of a selected trait based on phenotypic variability, which assure its stability across different environments, thus determining the breeder success in the selection programme (Hamdi 1992).

Genetic advance (GA) is another selection tool that is exploited by crop breeder; it is expressed as level of gain resulting from a trait under investigation. High GA with high heritability estimates is desired for effective selection process. It also indicates the presence of additive gene action, which further suggests reliable crop improvement through standard selection process. Selection is more reliable when based on both heritability and GA than estimating either of the two parameters alone.

The experiment was therefore conducted to assess genetic variation and heritability of seedling emergence traits, and association with grain yield characteristics of some tropical maize varieties.

2 Materials and methods

Ten open-pollinated varieties of maize from the International Institute of Tropical Agriculture, Ibadan were used for the study. The maize varieties were developed between years 1979 and 2008. Those maize varieties that were released before year 2000 were classified as Era 1 genotypes, while those released after year 2000 were regarded as Era 2.

The materials were planted in a four-replicate randomized complete block design at two locations IAR & T Sub Station (Orin-Ekiti 7.8316° N, 5.2345° E) and (Iropora-Ekiti 5°9'25" E and 7°45'25" N).

In all evaluations, two row plots were used. Each row was 6 m in length, spaced at 0.75 m between rows 0.25 m within rows with four replications to give a population density of approximately 53,333 plants per hectare. Observed cultural practices included pre-emergence spray of gramazone and primextra for weed control supplemented with hand weeding as necessary during the season. Fertilizer was also split applied using N-P-K 15:15:15 at 10 days after planting (DAP) at the rate of 30 kg N/ha and top dressed with urea 6 weeks after planting at the same rate.

Seedling emergence was recorded at 5, 7, and 9 DAP and used to compute: Emergence percentage (E%), EI, and emergence rate index (ERI), according to the modified formula of Fakorede and Ojo (1981), were calculated as follows:

- (i) $EI = \sum(\text{Plants emerged in a day}) (\text{DAP})$.
- (ii) $E\%$: This was calculated as the percentage of seedling emerged 9 DAP relative to the number of seeds sown per plot.

$$E\% = \frac{\text{Seeding emerged by 9 DAP}}{\text{Number of seeds planted}} \times 100.$$

- (iii) ERI, i.e. speed of emergence was computed by expressing EI as a proportion of $E\%$ as follows:

$$\text{ERI} = \text{EI}/E\%.$$

Other data collected were as follows: days to 50% tasselling, days to 50% anthesis, days to 50% silking, 300 kernel weight, kernel row, and seed weight/cob, and grain yield was converted to tones/hectare (t/ha) at 15% moisture. EI and ERI were estimated from the seed emergence counts. Anthesis-silking interval (ASI) was also estimated as the difference between days to 50% silking and anthesis.

2.1 Estimation of variance components

The variability present in the population was estimated by computing mean, phenotypic and genotypic variance, and coefficient of variation. To estimate the phenotypic and genotypic variance, genotypic and phenotypic coefficients of variation were estimated based on the formula of Syukur et al. (2012) as follows:

$$\sigma^2g = [(MSg) - (MSe)]/r,$$

$$\sigma^2p = [\sigma^2g + (\sigma^2e/r)],$$

where σ^2g = genotypic variance, σ^2p = phenotypic variance, σ^2e = environmental variance (error mean square from the analysis of variance), MSg = mean square of genotypes, MSe = error mean square, and r = number of replications.

2.2 Estimation of broad sense heritability and GA

2.2.1 Broad sense heritability (h^2)

Estimate of each trait was computed according to the procedure outlined by Falconer and Mackay (1996) as:

$$\text{Heritability } (h^2) = \frac{\delta^2g}{\delta^2p}$$

where δ^2g = genotypic variance and δ^2p = phenotypic variance.

$$\text{PCV}(\%) = \frac{\sqrt{\delta^2p}}{x} \times 100$$

The mean values were used for genetic analyses to determine phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV).

$$\text{GCV}(\%) = \frac{\sqrt{\delta^2g}}{x} \times 100,$$

where δ^2g = genotypic variance, δ^2p = phenotypic variance, and x = sample mean.

GCV and PCV values are categorized as low when less than 10%, moderate at 10–20%, and high when greater than 20%.

2.2.2 Genetic advance

The expected GA for the different character under selection was estimated as suggested by Johnson and Robinson (1955).

$$\text{GA} = K(\sigma_p)h^2,$$

where K = the selection differential ($K = 2.06$ at 5% selection intensity), σ_p = the phenotypic standard deviation of the character, and h^2 = broad sense heritability.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

Variations because of the environment were significant for days to physiological maturity and 300 kernel weight, while other measured parameters did not significantly vary with environment (Table 1). It is evident that both physiological maturity and 300 kernel weight can be improved through the manipulation of environmental factors. Genotypic variation was significant for emergence percentage, emergence index, days to physiological maturity, 300 kernel weight, and grain yield at 0.05 level of probability, indicating the existence of sufficient genes in the topical maize population that can be manipulated for the improvement of maize emergence percentage. The level of genetic variation present in crop populations for a trait is a genetic component that is desired by plant breeders for the improvement of crop trait (Idahosa et al. 2010). Variations among Era 1 i.e. older maize varieties were highly significant for $E\%$, while they were not for newer Era i.e. older maize varieties. Genetic diversity within a crop species is an

Table 1: Mean squares from combined ANOVA for grain yield and agronomic traits in 10 maize varieties representing two maize breeding eras in Nigeria evaluated at Orin and Iropora, 2008 and 2009

Sources	Df	Emergence percentage (E%)	Emergence index (EI)	Emergence rate index (ERI)	Anthesis-silking interval (days)	Days to maturity (Days)	300 kernel weight (g)	Kernel weight/cob (g)	Yield (t/ha)
Rep	3	440.60	0.23	0.01	0.41	0.05	219.50	381.0	0.70
Environment (Env)	1	6182.9	2.78	0.08	6.61	108**	32322**	35045	2.92
Genotypes (G)	9	1904.60**	1.65**	0.03	0.53	136**	1042.60**	495.10	3.61**
Entry (Era 1)	4	1612.80**	1.09	0.35	0.53	265.0**	66.70	517.60	1.82
Entry (Era 2)	4	1785.78	1.84	0.02	0.65	2.90	515.80	435.60	6.29**
Era 1 vs Era 2	1	3547.08	3.13	0.026	0.05	154.0	7053.4	643.1	0.05
Genotypes × Env (ge)	9	319.70	0.33	0.34	0.61	9.67	696.80	571.70	1.35
Env × Era 1	4	49.30	0.26	0.02	0.53	17.9**	458.60	100.90	1.60
Env × Era 2	4	633.30**	0.48	0.03	0.48	0.85	748.30	118.70	0.93
Env × (Era 1 vs Era 2)	1	146.9	0.01	0.01	1.45	12.03	1443.2	4266.9	2.03
Pooled error	65	195.80	0.33	0.03	6230	1.36	183.30	570.0	1.10

*** Significant at <0.05 and 0.01 levels of probability respectively.

essential tool needed by breeder for selection procedure in maize grain yield improvement programme. Genotype × environment interaction effects were significant for E% among Era 2 genotypes at 0.05 level of probability, indicating that emergence percentage can also be influenced by environmental factors. Mean value of E% was higher among older maize varieties (Era 1) relative to newer varieties Era 2 (Table 2). The older maize varieties also emerge more rapidly than new ones (Table 2). Variation was significantly higher for grain yield among modern maize varieties, i.e. Era 2 genotypes at 0.05 level of probability. Environment by Era 1 genotypes interaction effect was not significant for all the measured traits except days to physiological maturity, and this indicates that selection based on the phenotype will therefore remain stable in various environments. Moreover, environment by Era 2 genotype interaction effect was only significant for E% at 0.05 level of probability, and this suggests the influence of environmental factors on the expression of E% among Era 2, i.e. modern maize varieties (Table 2). This indicates that selection for emergence percentage among these genotypes is not reliable as it changes with environment.

Mean for E% was highest (80%) for variety TZSR-Y in Era 1, while the least emergence percentage (30.70%) was recorded by variety BR9922DMRSR in Era 2 (Table 2). Highest and least emergence index were obtained by varieties BR9928DMRSR and TZSR-Y, respectively. Varieties TZSR-W and BR9922DMRSR recorded the same value of ERI, i.e. speed of seed emergence relative to the remaining eight varieties. Least ASI was recorded by ACR99TZLCOM4DMRSR, BR9928DMRSR, TZBRELD4CO-W, and TZSR-Y. These four genotypes are therefore good candidates for drought tolerance maize improvement programmes. Highest 300 kernel weight (105.2 g) which was significantly different from other maize varieties was obtained by variety DMRLSR-Y, while the highest grain yield (3.92 t/ha) was recorded by variety BR9943DMRSR. The two maize genotypes (DMRLSR-Y and BR9943DMRSR) can be included in maize grain yield improvement programmes. However, variety DMRLSR-Y that recorded the highest 300 kernel weight (105.2 g) also recorded least grain yield and second to the least E%, indicating that this genotype has bigger kernel and highest kernel weight/cob but low plant stands. It showed the importance of improving seedling E% in quest to breed maize for higher grain yield. Similarly, Kamara *et al.* (2004) attributed the gains in maize grain yield to changes in seedling emergence, early growth characteristics, and other morphophysiological characteristics.

Genotypic variation relative to variation because of phenotype was higher for all the measure traits (Table 4).

Table 2: Means for location and genotypes for grain yield and agronomic traits in 10 varieties representing two maize breeding eras in Nigeria evaluated at Orin and Iropora, 2008 and 2009

Source	Eras (based on year of release)	Emergence percentage (E%)	Emergence index (EI)	Emergence rate index (ERI)	Anthesis- silking interval (Days)	Days to maturity (cm)	300 kernel weight (cm)	Yield (t/ha)
TZSR-W	1	44.50	6.31	0.25	2.00	89.00	92.60	2.62
DMRLSR-Y	1	44.10	6.93	0.19	2.00	90.00	105.20	2.32
DMRLSR-W	1	75.60	6.41	0.18	2.00	77.00	102.8	3.02
TZSR-Y	1	80.70	5.89	0.08	1.00	89.00	97.50	3.57
ACR99TZLCOM4DMRSR	1	62.20	6.40	0.11	1.00	91.00	82.20	2.68
BR9922DMRSR	2	30.70	6.58	0.24	2.00	91.00	94.80	3.60
BR9928DMRSR	2	44.60	7.28	0.17	1.00	91.00	79.20	3.18
BR9943DMRSR	2	66.80	7.23	0.11	2.00	90.00	77.20	3.92
AMATZBR-W	2	64.80	6.70	0.22	2.00	90.00	74.40	3.71
TZBRELD4CO-W	2	53.60	6.13	0.15	1.00	89.00	78.50	3.15
Mean		52.10	6.8	0.20	2.00	90.00	80.8	3.50
Lsd		14.01	0.58	0.19	0.79	1.17	13.55	1.01

Variation is one of the vital tools exploited by crop breeders for standard selection (Tollenaar 1991). Estimation of PCV and GCV is used to determine the component of phenotypic and genotypic variations for different economic traits present in a crop population. Reliability of a breeding programme is to a large extent a product of high magnitude of GCV. This study recorded high GCV and PCV for emergence percentage (41 and 45%) and grain yield (25 and 32%), respectively, indicating that both traits were influenced by genetic factor (Gashaw et al. 2010). Higher percentage of GCV compared to that of PCV suggests that the environmental influence is less on the traits in a study, which is also an indication of progress in breeding programmes. It also reveals that additive gene action is involved in the inheritance of maize seedling emergence percentage and grain yield (Abdurakhmonov et al. 2008). However, GCV% was low for EI,

while PCV% was moderate for the same trait, and this is an evidence of greater influence of environmental than genetic factor on EI. Both GCV% and PCV% were moderate for ASI. High GCV% was recorded for 300 kernel weight compared to PCV% for the same trait. High heritability was recorded for E% (92%), EI (85%), ASI (83%), and physiological maturity period (98%), suggesting that these traits were predominantly controlled by genetic factors. Thus, high heritability is desired by breeders for a standard selection in maize improvement programmes (Tewari 1999; Rai et al. 2000; Rama Kant et al. 2005; Reddy et al. 2013).

GA is another major tool required for effective selection programme. It is among the good indices for predicting the progress that can be expected during selection activities (Reddy et al. 2013). Combination of high heritability and GA is desired for a reliable index of selection

Table 3: Mean, genetic (σ_g^2), genotype \times environment interaction (σ_{ge}^2), phenotypic variance, and heritability estimates (h^2) for emergence and yield traits of 10 maize varieties representing two maize breeding eras in Nigeria evaluated at Orin and Iropora, 2008 and 2009

Parameter	E%	EI	ERI	ASI (days)	MAT (days)	300 KW (g)	GY (t/ha)
Mean	52.10	6.8	0.20	2.00	90.00	80.8	3.50
σ_g^2	455.93	0.38	0.005	0.126	33.90	241.62	0.79
σ_{ge}^2	319.70	0.33	0.34	0.61	9.67	696.80	1.35
σ_p^2	537.26	0.52	0.017	0.152	34.46	317.76	1.25
h^2	92.00	85.00	30.00	83.00	98.00	76.00	63.00
GA	40.48	1.09	0.01	0.66	11.88	27.92	1.45
GCV	41.00	9.00	35.0	18.0	7.00	19.00	25.00
PCV	45.00	11.00	65.0	20.0	7.00	22.00	32.00

E%, emergence percentage; EI, emergence index; ERI, emergence rate index; ASI, anthesis-silking interval; MAT, physiological maturity time; 300 KW, 300 kernel weight; GY, grain yield.

Table 4: Correlation between emergence and grain yield parameters among 10 tropical maize varieties representing two breeding eras evaluated at Iropora and Orin-Ekiti, 2008 and 2009

Parameter	<i>E</i> %	EI	ERI	ASI	MAT	300 KW	GY
<i>E</i> %		−0.329	−0.661*	−0.190	−0.478	−0.035	0.295
EI			0.145	0.305	0.246	−0.295	0.119
ERI				0.641*	0.042	0.173	−0.206
ASI					−0.267	−0.308	0.052
MAT						0.462	0.109
300 KW							0.109
GY							

Significantly different at 0.05 level of probability; *E*%, emergence percentage; EI, emergence index; ERI, emergence rate index, ASI, anthesis-silking interval; MAT, physiological maturity time; 300 KW, 300 kernel weight; GY, grain yield.

(Johnson and Robinson 1955). In the present study, Table 3 shows high GA for *E*% and 300 kernel weight. However, low GA was recorded for the remaining parameters tested under the same environment. High heritability coupled with GA observed for *E*% and 300 kernel weight implied that phenotypic selection could be used to select superior genotypes for these traits (Idahosa *et al.* 2010; Gashaw *et al.* 2010). Similarly, Swamy *et al.* (1971) reported higher percentage of both heritability and GA for grain yield, plant height, and days to silk, and therefore concluded that all the mentioned characters were under the influence of additive genetic action. The author therefore suggested that standard selection protocols would be adequate for the improvement of the traits (Edwards *et al.* 1976).

Table 4 revealed that grain yield had positive but insignificant associations ($p < 0.01$) with *E*% and 300 kernel weight; however, ASI was negatively correlated with physiological maturity period and 300 kernel weight. It is an indication that a reduction in ASI is positively associated with 300 kernel weight and grain yield. This indicates that the synchronization of interval between pollen shed and silking could be used for maize grain yield improvement in moisture stressed areas. Tollenaar (1991), in a similar experiment, observed that higher grain obtained from hybrid maize resulted from, a higher final leaf number, a longer duration from planting to tassel emergence and reduction in ASI.

flowering or short interval between pollen shed and silking is desired for higher 300 kernel weight and grain yield. GCV and PCV were high for *E*% 41 and 45% and grain yield 25 and 32%, respectively, suggesting that these characters are under the influence of genetic control. High heritability and GA recorded by *E*% and 300 kernel weight indicate that phenotypic selection could be used to select superior genotypes for the tested traits.

It was also observed that the same BR9943DMRSR that obtained the highest grain yield per hectare recorded 66% and 77 g of *E*% and 300 kernel weight, respectively. Therefore, the evidence shows that greater grain yield per hectare requires higher seedling emergence percentage and kernel size.

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4 Conclusion

This study revealed that grain yield had positive associations ($p < 0.01$) with *E*% and 300 kernel weight, whereas ASI was negatively correlated with physiological maturity period and 300 kernel weight. It is implied that early

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