IMPROVEMENT OF A STEM BORER RESISTANT MAIZE POPULATION FOR NITROGEN DEFICIENT ENVIRONMENTS

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ABSTRACT

Nitrogen (N) deficiency is a common feature in all maize growing ecologies of West and Central Africa. It is therefore imperative to produce maize varieties that are able to survive in N deficient environments. To determine their potential in improving the population for N deficient environments, S_1 progenies from a stem borer resistant maize population- BR9928DMRSRLNC1 were evaluated under low soil N (30kgN/ha) condition at Mokwa and Zaria, Nigeria in 2013. Furthermore, the original and improved cycle of the population were later evaluated at the same test locations under two additional N fertilizer levels (0kg and 90kgN/ha), to estimate gains from selection. Several traits were evaluated. For most of the traits studied, genetic variability was moderate to low and ears per plant, ear aspect and plant height were significantly correlated with yield. Step-wise multiple regression, identified ears per plant and ear aspect as having high direct effects on grain yield. Expected gains per cycle were lower than observed for most traits except grain yield and plant height. Comparison between the original and improved cycle revealed that in general, selection reduced days to flowering and ear aspect ratings across all N levels. In addition, grain yield increments were observed in all N environments with the most significant change of 15% occurring at 90kgN/ha. Using a weighted index with larger weights assigned to grain yield, ear aspect and ears per plant should increase gain in further selection programs.

Keywords: Nitrogen deficiency; maize; genetic variability; genetic gain; S_1 progeny selection

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INTRODUCTION

Sustainability of agricultural systems in West and Central Africa (WCA) can be addressed by instituting practices that allow efficient utilization of available resources. One such practice involves selecting plants that are resilient and productive in sub-optimal growing conditions. Nitrogen (N) deficiency is a major constraint to maize productivity in the tropics (Gibbon et al., 2007; Coboet al., 2010). N deficiency is caused by several factors such as torrential rainfall which causes leaching of soil N below the root zone, poor weed control in farmers' fields (Lafitte and Edmeades, 1994) which increase competition for available N, and most importantly, the sub-optimal application of soil nutrient amendments which are usually beyond the reach of resource poor farmers (Morris et al., 2007). It is estimated that annual loss of maize yield due to low-N stress alone varies from 10 to 50% (Wolfe et al., 1988).

Low N stress losses are often compounded in environments where high disease incidence, insect pests and parasitic weeds are prevalent. These stress combinations on average, reduce yield further by more than 30% (Shiferaw et al., 2011). Such environments are descriptive of the forest and moist savannah ecologies of WCA. Significant genetic variability exists for N use efficiency in maize (Smith et al., 1995; Banziger et al., 1997; Wang et al., 1999 and Ajala et al., 2012), and breeding for this trait under sub-optimal N conditions is feasible (Dawson et al., 2008). Recurrent selection methods have been effective in the improvement of yield and tolerance or resistance to yield-limiting stresses in several breeding programs (Banzigeret al., 2000; Badu-Apraku et al., 2010; Ajala et al., 2010; Hallauer and Carena, 2012). Breeding efforts at the International Institute of Tropical Agriculture, IITA using selfed progeny recurrent selection techniques have resulted in the breeding and commercialization of stem borer resistant (Ajala et al., 2010), and low N tolerant maize varieties (Ajala et al., 2010, 2012; Badu-Apraku et al., 2012). Since stem borer damage symptoms and disease epiphytotics are more severe on maize plants grown in N deficient soils, there is need to further minimize losses and yet increase productivity of our farming systems. Combining low N tolerance, disease resistance with an appreciable level of stem borer resistance is indeed an incentive for increased maize cultivation especially in the forest ecology, where stem borer infestation could be devastating.

Whole plant traits which are correlated with yield under N stress have been utilized in improving maize targeted for N deficient environments. Such traits show variation, are heritable and can thus be modified by breeding. Information on the variability of such traits within a population will guide on appropriate selection procedure to increase gain in further selection programs (Hallauer et al., 2010). The present study was therefore conducted with the objectives of (i) determining the variability for traits indicative of low N tolerance in a stem borer resistant maize population, (ii) determining the relationships among traits to identify most promising trait/s to improve selection efficiency and (iii) to compare the performance of the improved cycle of selection to the original at 0, 30 and 90kg N/ha N fertilizer levels.

MATERIAL AND METHODS

Test population

An improved population conferring resistance to downy mildew, streak and most recently, combined resistance to both the pink stalk borer *Sesamia calamistis* Hampson(Noctuidae)and the African sugarcane borer, *Eldana saccharina* Walker (Pyralidae) was released and commercialized in Nigeria as BR9928DMRSR (NABGRAB, 2014). Following its commercialisation, it was further improved for low N tolerance resulting in the formation of BR9928DMRSRLN and later BR9928DMRSRLNC1. Bulk seed from BR9928DMRSRLNC1 maize population were sown during the off-season (December 2012 – March, 2013) under irrigation following recommended nursery practices at IITA, Ibadan (7°22' N, 3°58' E). Random plants from the population were self- pollinated to generate S_1 families.Only S_1 ears with sufficient seed were picked. One hundred and eighty-nine (189) S_1s from the population and three checks totalling 192 entries comprised the S1 evaluation trial which was evaluated at the developed low-N screening sites in Mokwa (9°18N, 5°40'Eand 457masl) and Zaria (11°11'N, 7°38'Eand 686 masl). Mokwa has an annual rainfall of 1100mm, an average daily temperature of 27.5°Cand while Zaria has an annual rainfall of 1040 mm, with an average daily temperature of 24.8°C. Both locations are situated in the southern and northern Guinea savannah ecologies of Nigeria.Mokwa. IITA has developed N-screening fields in three demarcated fields in each of the two locations for the different N-levels (0, 30 and 90 kg N/ha) as previously described (Ajala et al., 2010). For the S_1 family evaluation, only the 30kgN/ha fields in each of the two locations was used.Planting of the S1 trial was done at the onset of the rainy season, in June, 2013.

The S1 evaluation trial trials in each location were laid out as randomized complete block design with two replications. Single row plots of 3m length spaced at 0.75m between rows and at 0.25m between hills within the row were used. Hills were double planted but latter thinned to one plant per hill at three weeks after planting to give a density of 53,333 plants per hectare. N, Phosphorous (P) and K (potassium) were applied at planting. (P in the form of triple superphosphate (monocalcium phosphate), and K as muriate of potash (potassium chloride) at the rate of 40 kg/ha). Soil samples were taken from the low N fields at the beginning of the season and only the balance of N (applied as urea) required to make-up the 30N kg/ha treatment was applied. Weeds were controlled by a pre-planting spray of Round-Up ®(N-phosphonomethyl glycine) at three weeks before planting. A mixture of metolachlor plus atrazine and paraquat was applied at planting at the rate of 1.6 and 1.0 kg a.i. ha^{-1} for pre- and post-emergence weed control respectively and supplemented with hand weeding when required during the season. Rainfall amount and distribution during the season (June–October) in 2013 were generally sufficient (>500mm) for optimal maize growth..

Data collection and analysis

Data collected for each of the trials included days from sowing to 50% pollen shed (anthesis) and 50% silk extrusion (silking) and the difference between the two days estimated to give the anthesis-silking interval (ASI). Plant height was estimated at approximately three weeks after silking as the distance from ground level to the flag leaf from five random plants per plot. Thereafter, stay green, often called leaf death score, was determined on a scale of 0-10 where 0 = 0% of all leaves below the ear green and 10 = 100% of all leaves below the ear dead. Total number of plants and ears harvested per plot were counted at harvest and recorded. Ears per plant was estimated as the number of ears harvested divided by the number of plants per plot. Ear aspect was rated on a scale of 1-9 with 1= highly desirable ears having clean, big and uniform ears with good grain filling to 9 = not desirable. All ears harvested per plot were shelled to obtain grain weight and moisture content determined using the DICKEY-johnMini GAC®2500 hand held moisture meter. Grain yield was then obtained as grain weight adjusted to 15% moisture content and expressed in t/ha.

Data were subjected to analysis of variance (ANOVA) considering entries (S_1 families), reps, plots as random effects. ANOVA was pooled across the two locations for yield and other traits. From the combined analysis, variances were partitioned into relevant sources of variation to test for differences among entries/S_1 families and the presence of S_1 family × location interaction using PROC GLM of Statistical Analysis System (SAS Version 9.3, SAS Institute, 2011). Means were obtained on entry basis for each progeny. Standard error (SE) of the means, experimental coefficient of variation (CV) of the traits and phenotypic correlation between traits were calculated to determine relationship among traits, while step-wise multiple regressions were further carried out using grain yield as the dependent variable.

Broad sense heritability (H) of the traits in the population was obtained using the formula $\sigma^2g/\ \sigma^2ph$, (Dabholkar, 1992; Falconer and Mackay, 1996), where; σ^2g = genotypic variance and σ^2ph = phenotypic variance.Ten percent (10%) selection intensity was applied (Ajala et al., 2012) to identify the best progenies for recombination in the populations to generate a new and improved version of the population for future use. For the method, a rank summation index (Mulumba and Mock, 1978) involving ears per plant, ASI, ear aspect, stay green and grain yield under low-N was used to generate the selection index. Selection differential (S) was calculated by subtracting the population mean for all S_1 progeny from the mean of the selected S_1s to be advanced. $S = \mu_{sel} - \mu_0$ where; μ_{sel} is mean of the best 18 selected lines to advance to newer cycle, μ_0 is mean of the original reference population prior to selection of the best low N tolerant lines. Recombination involved ear-to-row planting of the remnant S_1 seed of selected lines and hand pollination using bulk pollen was carried out with one half pollinating the other to ensure random mating.

Predicted responses or gain from selection were calculated as $R = h^2S$ following the breeders equation where h^2 = heritability and S=selection differential.

Evaluation of Selection Cycles

The original and improved population (derived from intermating the selected S1 families), BR9928DMRSRLNC1 and LY-POP28LN were evaluated in completely randomized block design with four replications under 0N, 30N and 90N conditions (0kg, 30kg and 90kgN/ha) in 2015 and 2016 at Mokwa and Zaria experimental stations using the developed low-N screening fields and methods earlier described. Each entry was planted to a two-row plot, but each plot was bordered by a common earlier maturing genotype, thus allowing the harvesting of the two test rows. Each row of the test plot was 5m long, spaced 0.75 between rows and 0.25 m between hills within rows. Hills were also overplanted but later thinned to one plant/hill to give a density of 53,333 plants/ha. All other standard crop management practices, such as application of fertilizers and herbicides for the zero, low and high N trials were followed. Total annual rainfall (data not shown) was above 1000 mm in the two test years at both locations. Comparison of means of cycles of selection was done and gains per cycle compared.

RESULTS

Variability for low N tolerance among S1 families

For most traits, significant mean squares were obtained from the analysis of variance ($p<0.01$ to $p<0.05$) when both locations were pooled. Location effect was also significant for flowering time (days to 50% anthesis and 50% silking), plant height; ears per plant, ear aspect and grain yield while the expression of traits such as stay-green and ASI were relatively stable across location (Table 1). The test locations (Mokwa and Zaria) were able to discriminate among the performance of the S_1 families when means for each location was compared. Grain yield, plant height, stay-green and ears per plant showed significant differences among S_1families. Family x location effects were also significant for ASI, staygreen and ears per plant. Although not statistically significant at 0.01 and 0.05 levels of probability, other traits such as ear aspect and flowering data showed considerable variability among the S_1 families evaluated.

The distribution for grain yield and other traits for the 187 S_1 lines are shown in Table 2. Average value for grain yield was 1464kg/ha ranged from 442kg to 3144 with a CV of 61.4 %. Although large, a CV of 61.4% for grain yield is still reasonable bearing in mind the nature of experimental materials which were S_1 lines and very variable. The standard error (SE) of the mean for all the other traits was small, while the coefficient of variability (CV) which is a relative measure of variation, was reasonable for all the traits except for the ASI (86.6%) which ranged from 0.9 to 2.5 days. Comparing the experimental C.V.s, these figures suggest considerable variability for grain yield, ASI, Ear aspect and ears per plant among traits studied. At harvest, most ears rated below average (<5) for ear aspect with level of desirability increasing with reducing values. Stay-green character clustered around the average with a narrow spread of 3-6.

The rank summation index (RSI) applied to this population gave equal weights to the characters of interest. The means of the S_1 lines selected (μ_{sel}), their index values (RSI) and the population mean (μ_0) and selection differential (S) are presented in Table 3. Among the traits used for selection, grain yield of the selected S_1 lines had the highest selection differential (35.2 %) while stay green the lowest (10.1%). Plant height, although not used in the index had a selection differential of just 4.2 %. With the exception of plant height, none of the progenies selected had values less desirable than the population mean except for grain yield of S_1 line 172. The means of the selected were more desirable than the population mean for all the traits computed in the index implying that the selected were superior to the unselected.

Interrelationships among traits to identify most promising trait/s to improve selection efficiency

Table 4 shows correlation between grain yield and agronomic traits studied. Although weak (0.19), phenotypic correlations were significant ($p<0.05$) between days to silking and stay-green. Among the traits, ears/plant showed highly significant phenotypic correlations ($p<0.01$) with most other traits except days to anthesis and ear aspect. Ears per plant and grain yield had the highest r value (0.46**) suggesting a high correlation between the two traits in this population. Plant height and ear aspect also showed positive correlations with grain yield. On the contrary, ASI and stay-green characters which are often correlated to grain yield in N stressed environments (Ajala et al., 2012) and used in computing indices for drought and low N stressed environments and in selecting progenies in this population showed no significant correlations with yield. Results obtained from stepwise multiple regression of yield on other parameters under low-N revealed that ears per plant was the most important trait contributing to grain yield in the population with R^2 value of 0.49% (Table 5). Ear aspect contributed an additional 3% while plant height although not used in computing the index contributed 6%.

Variances (genetic and phenotypic) were low for ASI, stay-green and ears per plant (Table 6) resulting to the low heritability values obtained. Genotypic variances were large enough for plant height and grain yield for selection to be effective in the two populations. Heritability estimates for all the traits were generally low to moderate. Heritability was moderate for plant height (0.40%), ears per plant (0.33%) and grain yield (0.31%) and low for ASI (0.19%) stay green (0.16%) and ear aspect (0.13%) indicating moderate genetic control.

Comparisons between the original and improved cycle in three N fertilizer levels

Expected gains per cycle for stay green, ear aspect, plant height and ear per plant under 30N were much lower than observed with the exception of grain yield which was similar to observed (Table 6). Comparison of the previous cycle to the newer one formed after evaluation, selection and recombination of remnant seeds of desirable progenies of the population (Table 7) revealed that in general, selection reduced days to flowering, ear aspect and there was also a tendency for stay-green to reduce in 0 and 30N evaluations while, ASI, plant height, ears per plant increased in 30N and 90N evaluation. Plant height also reduced slightly in 0N as well as ASI. Yield gains of 6.07, 9.20 and 14.99% occurred in all N level treatments with the most significant gain occurring under high-N.

DISCUSSION

Developing new maize cultivars conferring resistance to different stresses can help stabilize yields in WCA. However, programmes focusing on resistance to a particular stress often do not improve or test resistance/susceptibility to other yield limiting stresses and this may have unpredictable consequences on crop productivity. In this study, we sought to determine the potential of a stem borer resistant population for further improvement by assaying grain yield and other secondary traits for low N tolerance as well as estimating relative gain that can be made when selecting for such traits.

Results of our study showed that genetic variability was moderate to low for most of the traits studied. The spread in distribution of individuals expressing these traits and the measure of selection differentials of selected families showed substantial variability for effective selection still inherent in the population. Stay green and ASI were the least variable traits and as such little progress can be made in further selection using these two traits. Correlation among traits and with yield although weak to moderate, revealed that ears per plant, ear aspect and plant height showed highly significant correlation with yield, while ASI and stay green again showed no correlation with yield, but were significantly correlated with ears per plant, a determinant of yield. Our findings was in contrast to previous report of Banziger and Lafitte (1997) who identified delayed leaf senescence (stay-green) and shortened ASI as having high correlations with grain yield and being reliable secondary traits for selection of superior genotypes under low N and drought conditions. Ajala et al., (2010) also identified these two traits as being highly correlated with yield in LNTP-W and LNTP-Y maize populations. It is important to note that the stem borer resistant population had previously undergone two cycles of selection for low N tolerance prior to the current study and as such variances and allele frequencies of these traits could have been altered or near fixed. The nature of germplasm and its breeding history could have influenced trait associations resulting in deviations from the expected as seen in drought and low N tolerant genotypes. In addition, the evaluation environments were (Mokwa and Zaria) which are in the southern and northern guinea savannah ecologies. Stem borer resistant materials are often bred and cultivated in the forest ecologies where stem borers are endemic and as such may be less suited to the savanna ecologies.

Step-wise multiple regression identified three traits, namely ears per plant, plant height and ear aspect as having high direct effects on grain yield while the direct contribution of other variables were not significant in this population, suggesting that gains from selection for yield was related mainly to changes in these traits. Ajala et al., (in press) using the S_1 recurrent selection scheme also identified ear aspect and plant height to have high direct contribution to yield in LNTP-W and LNTP-Y maize populations implying that the two traits namely ear aspect and plant height could be contributory to grain yield under low-N stress.

Broad sense heritability estimates for all the traits were generally low to moderate. Johnson et al. (1955) rated heritability values low (<30.00%), moderate (30-60%) and high (>60.00%).For traits with low heritability in this study such as ASI, stay green and ear aspect, direct selection for these traits may not be very effective. Nonetheless, predicted/expected gains per cycle for stay green, ear aspect, plant height and ear per plant were much lower than observed suggesting the limitations of basing predictions on broad sense heritability estimates alone. A possible reason for these differences is an underestimation of heritability in the S_1 progeny trial. A reduction in genetic variance is often observed under stressed conditions. At low N-input, Bertin and Gallais (2000) have shown that genetic variance in N use efficiency (NUE) was reduced one year and increased in another year. The genetic, phenotypic, and environmental and genotype x environmental variances determine the heritability estimates. The high magnitude between phenotypic and genotypic variances reported in this study implies greater environmental influence. Another reason for the dissimilarity between predicted and realized gain is the possibility of the genotype x environment interactions experienced in the selection environments to not be representative of environmental interactions that occurred in the multi-year original and newer cycle evaluation trials (Comstock and Moll, 1963).

Many workers have reported a poor correspondence between predicted and observed responses using S_1family selection (Burton et al., 1971; Muleba and Paulsen, 1983). Bradshaw (1983) suggested that the use of total genetic variance or its additive portion in predicting progress for S_1 selection is not appropriate and thus proposed that use of covariance between S_1 and S_1testcross families. Simultaneous consideration of estimates of heritability and genetic gain/advance in predicting the value of selection is proven to be more dependable than predictions based on heritability alone (Johnson et al., 1955).

Genetic gain represents the advancement in the mean of an improved population over the original population. The estimates of genetic gain as per cent of mean were categorized as high (>20), moderate (10-20) and low (<10). Ears per plant, plant height and grain yield had the highest heritability values of 0.33, 0.40 and 0.31 and consistent genetic gain across N fertilizer levels compared with other traits showing minor or no commensurate gains in the desired direction.

The increase in ASI in the newer cycle under 30 and 90N conditions although inconsistent with expectation as selection for low N tolerance usually shortens the ASI, was indeed still favourable as days to anthesis and days to silking actually reduced in both N test conditions, and with that a slight reduction in maturity which is indeed desirable. Significant increments in plant height were reported in the Maksimir 3 Synthetic (M3S) population as a result of S_1 progeny selection for grain yield (Sarcevic et al., 2004).

A reduction in fecundity often accompanies the S_1 progeny method due to the effect of inbreeding often leading to a reduction in yield of the population evaluated. Other undesirable effects are an increase in number of days to flowering, reduced plant height and a reduction in number of ears produced. Flowering time is an important feature determining yield and seed quality in maize. A change in flowering time is a strategy used to survive in stressed environments. Among abiotic stresses, drought, heat and

low N can increase anthesis-silking intervals (ASI), resulting in negative effects on maize yield as evidenced in a wider ASI under 0N evaluation in this study.
Anthesis date and plant height are often included in computing indices or truncating undesirable individuals to ensure that the selected fraction of the population does not become later, earlier, or taller than the original, unselected population. Increased plant height is often correlated with grain yield as taller plants are more likely to yield better especially in a population of inbred individuals or when evaluating in stressed environments. Increased plant height though advantageous in stressed environments (Talabi et al., 2016) can lead to increased lodging in optimum environments (Banziger et al., 2001) especially in environments where storms are frequent. Comparing the mean of the selected fraction with the mean of all genotypes being evaluated can help to prevent undesirable changes in the germplasm (Ajala et al., 2009). The progenies selected for recombination differed slightly in height from the population mean ($\mu_{sel} = 4.2$) implying that modifications for adaptation to low N tolerance can be made in this population without any significant alteration in plant height. Talabi et al., (2016) also identified ears per plant and ear aspect as among the most important traits contributing to grain yield in low N environments. It is generally accepted that a combination of heritability and genetic advance gives increases precision in predicting the selection value for a trait (Olayiwola and Soremi, 2014). The high gain and heritability for ears per plant indicates that this trait may be the most ideal for improving performance of this population in future low N selection programs. Banziger et al., (2000) weighted ears per plant as the second most important trait for improvement of low N tolerance in maize following grain yield. For further improvement of this population for N deficient environments, emphasis should be on grain yield contributing traits such as ear aspect, ears per plant and with caution plant height to select for better performing progenies before recombination. Weights should be assigned based on the relative economic value of each trait or its relative value of each trait as an indicator of low N tolerance.
Many traits have been modified by selection for adaptation to various environments (e. g. cold and drought tolerances, disease and insect resistances, lodging resistance, stay-green, duration of the grain filling) which are expected to confer an advantage across fertility levels. As expected, modern cultivars generally outperform older ones across a range of fertility and N levels (Gallais and Coque, 2005). Comparison of the previous cycle to the new ones formed in this population revealed an increase of 6.06, 9.20 and 15.0% respectively in all N levels suggesting that favourable changes in gene frequencies for N use efficiency had occurred in the population despite the fact that selection was done with an index using grain yield with other traits under low-N alone presents an opportunity to rapidly identify N use efficient genotypes in this population.
Fakorede (1977) postulated that, in developing countries where N may not be readily available to the farmer, breeders can develop high yielding genotypes by selecting under intermediate levels of N. Stem borer resistant materials are routinely bred and evaluated under intermediate (60kgN/ha) nitrogen levels. As such, inadvertent selection for improved nitrogen use efficiency does occur in breeding cycles. In addition to providing needed protection in stem borer endemic environments, stem borer resistant populations can be ideal source germplasm for improving yield in low N environments. Since its formation, LYPOP28LN has been evaluated in the National and International Trials at IITA. Its performance has been laudable in multi-locational trials in both low N stressed and optimum environments. In addition, it still performs optimally in stem borer endemic areas combining low N stress with stem borer resistance. . Although it may be too early to generalize, further investigation is required to assess the suitability of stem borer resistant germplasm for low N stress tolerance breeding.

CONCLUSIONS

Ample genetic variability observed among the S_1 progenies confirms that potential for improvement for N deficient environments still exists in BR9928DMRSRLNC1 maize population. However, low variances and heritability estimates, predicted and observed gains for some traits limit their use for continued improvement. Plant height, ear aspect and ears per plant were identified as important secondary traits. Using a weighted index with larger weights assigned to grain yield, ear aspect and ears per plant should increase gain in further selection programs. Stem borer resistant source populations could be candidate genotypes for improving maize for sustainable maize production in West and Central Africa.

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TABLE 1: *Mean squares of agronomic traits of the 189 S_1 families from BR9928DMRSRLNC1 maize population and three checks evaluated under low N conditions (30kgN/ha) at Mokwa and Zaria, Nigeria in 2013.*

Source of variation	df	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height	Stay-green	Ear aspect	Ears per plant	Grain yield
		(------------days-------------)			(cm)	(0-10)	(1 - 9)	(no)	(kg/ha)
		($x10^2$)	($x10^2$)		($x10^2$)				($x10^4$)
Location (L)	1	165.88**	64.86**	1.55ns	4428.76**	0.77ns	472.06**	33.42**	43166.46**
Rep (L)	2	0.94ns	5.80ns	0.52ns	68.63**	1.05ns	23.50**	0.93**	338.41*
Family (F)	191	0.50ns	1.57ns	1.00**	7.31*	0.72**	2.44ns	0.11**	121.98**
L x F	191	0.57ns	1.72ns	0.81*	4.11ns	0.66**	2.14ns	0.08*	87.72ns
Error	360	0.61	1.98	0.62	5.88	0.49	2.58	0.07	84.38
R-Square		0.63	0.5	0.61	0.76	0.6	0.6	0.75	0.73

*, **: significant at 0.05, 0.01 probability levels, respectively; ns: not significant

TABLE 2: *Summary of results obtained from evaluation of 189 S_1 progenies from BR9928DMRSRLNC1 under low N (30kgN/ha) condition at Mokwa and Zaria, Nigeria in 2013.*

Trait	Mean ± SEM	Range Min	Range Max	CV (%)
Days to 50% Silking	68.6±6.7	49.5	76	20.5
Days to 50% anthesis	69.5±4.0	51.3	74	11.7
ASI (anthesis-silking interval)	0.9± 0.4	-0.8	2.5	86.6
Plant Height (cm)	156.9± 10.4	89.3	185.8	15.4
Stay green (0-10)	4.7±0.4	3	5.5	15.1
Ears/Plant	0.7± 0.1	0.4	1.3	34.4
Ear Aspect (1-9)	4±0.7	1	6	39.1
Grain Yield (t/ha)	1464±367	442	3144	61.4

TABLE 3: *Agronomic traits and Rank Summation Index (RSI) values of the selected (best 18 based on index)S_1 progenies of BR9928DMRSRLNC1 maize population (n=189).*

Entry	Grain Yield (kg/ha)	Plant height (cm)	Stay Green (0-10)	Ear Aspect (1-9)	ASI (days)	Ears/Plant (no)	RSI
32	2636	173	4	4	0.8	1	125
115	2115	163	5	3	0.5	1.1	190
125	1849	153	4	3	0.8	0.8	212
44	3144	186	5	3	1	1.1	214
172	1313	157	4	3	0.5	0.9	214
29	1902	164	4	4	0.8	0.7	221
91	2452	162	5	4	0.5	0.8	233
142	1742	151	4	2	0.3	0.6	234
161	1994	157	5	3	1	0.9	241
105	2238	154	5	4	0.8	0.8	248
123	1760	174	4	4	1	0.9	257
14	1837	164	5	3	0.8	0.9	260
39	1537	178	4	4	0.8	0.8	266
65	1658	153	4	4	0.3	0.6	289
72	1809	158	4	4	1	0.8	291
46	2114	173	6	4	0.5	0.9	298
151	1656	160	5	4	1	0.9	314
106	1879	167	6	4	0.5	0.9	319
Mean Selected	1979.6	163.6	4.5	3.4	0.7	0.8	
Mean Population	1464.0	157.0	5.0	4.0	0.9	0.7	
Seldif (%)	35.2	4.2	-10.6	-14.9	-22.8	21.1	

TABLE 4: *Phenotypic correlation coefficients obtained between pairs of measured agronomic traits from the evaluation of 189 S1 lines from BR9928DMRSRLNC1 maize population under low-N (30kgN/ha) in Mokwa and Zaria, Nigeria in 2013.*

Traits	Days to Silking	ASI	Plant height (cm)	Stay green (0-100%)	Ear Aspect (1-9)	Ears/plant	Grain yield (t/ha)
Days to Anthesis	0.45**	-0.10NS	0.26NS	0.32**	0.16NS	-0.09NS	-0.03NS
Days to Silking		-0.02NS	0.25**	0.19*	0.24**	-0.25**	0.08NS
ASI			-0.02NS	-0.08NS	-0.05NS	-0.31**	-0.09NS
Plant height (cm)				0.31**	0.02NS	0.29**	0.37**
Stay green (0-100%)					0.05NS	0.20**	-0.14NS
Ear aspect (1-9)						-0.01NS	-0.27**
Ears/plant							0.46**

P ≤ 0.05, ** P ≤ 0.01, ns = not significant, respectively.

TABLE 5 Regression coefficient (b-values), coefficients of determination (R2) and
R2 change (ΔR2) from stepwise multiple regression of yield on other parameters obtained
from the evaluation of 189S1 lines from BR9928DMRSRLNC1 maize population under
low-N (30kg N/ha) in Mokwa and Zaria in Nigeria in 2013.

Trait	*b-value*	R^2	ΔR^2
Ears per plant	1396.78±118.13**	0.49	0.49
Plant height	11.82±1.19**	0.55	0.06
Ear aspect	93.7±20.11**	0.58	0.03

TABLE 6: *Estimate of genetic (σ^2g), phenotypic variances (σ^2ph) and broad sense heritability (H) estimates obtained from the evaluation of S_1 lines from BR9928DMRSRLNC1 maize populations under low-N (30kgN/ha) in Mokwa and Zaria in Nigeria in 2013.*

Traits	σ^2g	σ^2ph	h^2	S	Predicted Gain (h^2S)	Gain/cycle (%)
ASI	0.05	0.25	0.19	22.8	4.33	22.22
Plant height (cm)	70.49	178.13	0.4	4.2	1.68	0.12
Stay green (0-100%)	0.03	0.19	0.16	-10.6	-1.7	-2.38
Ear aspect (1-9)	0.14	0.62	0.23	-14.9	-3.36	-6.25
Ears/plant	0.01	0.03	0.33	21.1	7.03	15.39
Grain yield (t/ha)	60.09	194.79	0.31	35.2	10.91	9.2

TABLE 7: *Mean values of agronomic parameters and grain yield obtained from the evaluation of BR9928DMRSRLNC1 and its improved version, LY-POP28LNSYN under 0, 30kg N/ha and 90 kg N/ha in Mokwa and Zaria Nigeria in 2015 and 2016.*

	Traits							
	Days to anthesis	Days to silking	ASI	Plant height	Stay green	Ear Aspect	Ears/plant	Grain yield
Populations				0-N				
BR9928DMRSRLNC1	67	68.5	1.84	142	4.3	4.8	0.44	881.12
LY-POP28LNSYN	66.6	67.5	0.9	134	4.5	4.6	0.42	934.49
*Gain (%)	-0.6	-1.46	-51.09	-5.63	4.65	-4.17	-4.55	6.06
				30-N				
BR9928DMRSRLNC1	65	65.8	0.9	173.9	4.2	4.8	0.65	2271
LY-POP28LNSYN	64.2	65.3	1.1	174.1	4.1	4.5	0.75	2480
Gain (%)	-1.23	-0.76	22.22	0.12	-2.38	-6.25	15.39	9.2
				90-N				
BR9928DMRSRLNC1	64.1	65	0.9	180		4.6	0.9	2848
LY-POP28LNSYN	63.6	64.7	1.1	184		4.3	1.1	3275
Gain (%)	-0.78	-0.46	22.22	2.22	0	-6.52	22.22	14.99

*= Gain (%) represents change in value expressed as proportion of the previous cycle of selections

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