Inheritance of tolerance to low soil N stress

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INTRODUCTION

Inadequate soil nitrogen availability has been identified as a major constraint to bean production in Africa with an estimated annual loss of 679,000 tones per year (Wortmann et al, 1998). Resource poor farmers do not normally apply fertilizers to their bean crops because of the prohibitive costs of applied inputs. Consequently the performance of bean crops largely depends on their inherent capabilities to acquire and efficiently utilize the limited and declining soil nitrogen capital and biological fixation. One strategy to improve the genetic adaptation of beans to low N soils is to develop bean genotypes capable of making more efficient use of acquired N. Cultivars that are efficient in uptake and use of available nutrients are needed to improve and stabilize productivity particularly for poor farmers in low potential production environments. A regional effort called Bean Improvement for Low Fertility in Africa (BILFA) was initiated in 1990 to identify genotypes for different soil fertility constraints, including inadequate soil N with moderate fertility (Wortmann et al, 1998; 2000). Forty eight lines out of 200 screened individually for each stress were finally selected for combined tolerance to two or three fertility stresses (low P, low N and low pH complex) in third screening cycle (BILFA III) based on performance at 10 locations. The nature of genetic control for low soil N tolerance of these lines has not been studied. This study was designed to find out the mode of genetic mechanisms involved in the inheritance of low N tolerance as part of breeding programme for cultivars tolerant to major soil-related constraints.

MATERIALS AND METHODS

Elite lines known to be tolerant to low N were crossed with well-adapted popular cultivars, which were susceptible to low N in an 8 x 8 diallel scheme. AFR 708, CIM9314-36 and CAL 143 were selected for low soil N tolerance while E5, E8, GLP-2, SCAM 80cm/15 (KK8) and CAL 96 (K132) were the well-adapted varieties. The 28 F_1 progenies and their parents were planted out in two experimental locations (Kabete and Thika) in a split plot design with three replicates. N levels were the main plots and genotypes, the subplots. N levels were 0 (-N) and 120 kg N ha^{1} (+N). Soil N was 0.19% at Kabete and 0.34% (N-NO_3, trace for NH_4-N) at Thika and therefore deficient (FURP,1994). P deficiency at both sites was corrected by applying 100 kg P ha-^{1} to all plots. Normal cultural practices were carried out. Supplemental irrigation was supplied as needed. Grain yield was used as an indicator for tolerance to low N stress. Analysis of variance and combining ability analyses was done according to Griffins method II, model I using MSTAT-C software. GCA: SCA ratio was calculated according to Baker (1978).

RESULTS AND DISCUSSION

Analysis of variance showed highly significant genotypic differences for grain yield. The mean yield was lower for -N (1119.8 kg ha-^{1}) and higher for +N (1345.6 kg ha-^{1}) at Kabete. At Thika location, the overall mean yield also lower for - N plots (1035.8 kg ha-^{1}) than for +N (1343.6 kg ha-^{1}). This indicated that the most of genotypes probably met their N requirements largely through dinitrogen fixation and more efficient acquisition from the soil under low N stress. SCAM 80-CM/15, CAL 143 and AFR 708 were the best yielding parents under low N stress at Kabete but not at Thika. Table 1 shows that the general combining ability (GCA) were highly significant for all treatments except at Thika under no N stress. Specific combining abilities were important except for Thika under no N stress conditions. The GCA: SCA ratio was greater than 0.75 except at Thika for no N stress plots where it was 0.54. This indicated that tolerance to low stress was largely due to additive gene effects. CAL 143, CIM 9314-36, SCAM 80-CM/15, and CAL 96 were the best general combiner at both locations under low N stress. GCA effects for CAL 143, CIM 9314-36 were significant (Table 2).

Table 1 General and specific combining ability mean squares for grain yield in N stress and no stress conditions at Kabete and Thika.

		Mean squares			
		-N		+N	
Source	df	Kabete	Thika	Kabete	Thika
GCA	7	1949129.2203**	1912288.62**	680890.5533**	525211.494
SCA	28	1131585.783**	1069888.84**	443368.8783**	912393.53**
Error	70	622.8177	1445.08	1491.2044	1079.55
GCA/SCA ratio		0.77	0.78	0.75	0.54
Mean yield kg ha-^{1}		1119.8	1035.8	1345.6	1343.6

Table 2 The general combining ability effects for grain yield under low and high nitrogen fertility for the two locations.

	Nitrogen Fertility level			
	-N		+N	
Parents	Kabete	Thika	Kabete	Thika
E5	-472.697**	-471.238**	203.819**	237.46**
KK8	279.694**	257.592**	-194.427**	-110.538**
K132	61.943**	61.349**	51.993*	-28.761
E8	-87.4**	-99.856**	-236.619**	-182.906**
GLP 2	-196.304**	-186.527**	95.7**	-81.707**
AFR 708	-6.015	-2.246	33.891	22.649
CIM9314-36	295.687**	298.054**	91.696**	39.232*
CAL 143	125.092**	142.872**	140.28**	104.571**

* '** Significantly different from 0 at 0.05 and 0.01 probability levels respectively.
-N= No N fertiliser; +N =N fertilser applied

CONCLUSION

The high GCA: SCA ratio implies that the additive genetic component was predominant in controlling tolerance to low N stress. CAL 143, CIM 9314 and SCAM 80-CM/15 which are medium to large sized, can be useful parents in breeding for tolerance to low soil N. Our earlier efforts to use small seeded parents from BILFA II was frustrated by high incidence of hybrid dwarfism in crosses between small seeded fertility tolerant and the susceptible but popular large seeded parents. These require use of bridging parents.

References

Baker, R. J. 1978. Issues in diallel analysis. Crop Sci. 18:533-536.

FURP.1994. Fertilizer use recommendations. Fertilizer Use recommendation Project(FURP), Vol.1-14, Kenya Agricultural Research Institute, Nairobi, Kenya.

Wortmann, C. S., Chirwa, R., Rachier, G., Lunze, L., Rabary, B., and Nabuhungu, L. 2000. Bean Improvement for Low Fertility Soils in Africa: The BILFA II. BIC 43: 11-12.

Wortmann, C. S., Kirkby, R. A., Eledu, C. A., and Allen, D. J. 1998. An atlas of common bean (*Phaseolus vulgaris* L.) production in Africa. Centro Internacionale de Agricultura Tropical, Cali, Colombia.