INHERITANCE OF SEED-ZN ACCUMULATION IN NAVY BEAN

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Navy bean (*Phaseolus vulgaris* L.) genotypes vary in their susceptibility to Zn deficiency. Zinc-deficiency problems have plagued commercial navy bean production since the 1960s. Zinc deficiency was first documented in 'Sanilac', a bush-type (CIAT Type I) navy bean produced from X-ray mutagenesis of 'Michelite' (Down and Andersen, 1956). Researchers have historically used foliar deficiency symptoms to determine the inheritance of tolerance to low soil Zn. Polson (1968) investigated the genetics of the Zn-efficiency trait in a population derived from a hybridization of Sanilac (Zn-inefficient) and 'Saginaw' (Zn-efficient). He found dominant genes controlled tolerance to low soil Zn and that a two-gene complimentary interaction resulted in a 9:7 ratio in the F_2. Polson eventually concluded that the 9:7 ratio was extremely close, but not absolutely correct because the F_3 was more tolerant to Zn than expected. Seed-Zn concentration has recently been identified as a means to identify Zn-efficient genotypes. Moraghan and Grafton (1999) found that Zn-efficient genotypes possessed a greater concentration of seed-Zn than Zn-inefficient genotypes. The objective of this study was to determine the inheritance of high seed-Zn accumulation in a population derived from 'Albion' (Zn-inefficient) and 'Voyager' (Zn-efficient).

Voyager (P_1) and Albion (P_2) plants and F_1, F_2, F_1BC_{P1}, and F_1BC_{P2} lines were grown under field condition at sites near Erie, ND in 1999 and 2000. Individual plants were hand-harvested from each row at maturity and seed from individual plants was bulked. Seed was counted, washed with de-ionized water containing detergent, and rinsed with de-ionized water. Samples were dried at 70C for 48 h, weighed, and ground in an agate mortar with an agate pestle to pass a 0.25-mm mesh sieve. Sub-samples of the ground seed were digested on an aluminum block with 4 mL HNO_3 and 2 mL $HClO_4$. The acid digests were analyzed for Zn by atomic absorption spectroscopy. Standard Reference Material 1572 or 1515 from the National Institute of Standards and Technology, Gaithersburg, MD, was digested and analyzed concurrently with samples.

The number of Zn-efficient genes segregating was estimated by comparing the proportion of parental Zn-efficient phenotypes observed in the F_2 generation to the proportion of Zn-inefficient phenotypes observed in the F_2 generation based on seed-Zn concentrations. Genetic models containing one or two genes were evaluated. A chi-square test was used to measure goodness of fit to a 9:7 and 3:1 ratio of distribution of F_2 lines for seed-Zn accumulation. Lines within two standard deviations above the seed-Zn concentration for Albion were classified Zn-inefficient. The genetic model with the smallest and non-significant chi-square value ($P < 0.05$) was adopted.

The DTPA-soil Zn was 2.4 and 1.0 mg kg^{-1} in 1999 and 2000, respectively. In 1999, the soil pH was 5.8, while in 2000 the soil was more calcareous having a pH of 7.2. In 1999, the seed-Zn concentration of Voyager averaged 33.2 mg kg^{-1} (Table 2). In 2000, the average seed-Zn concentration of Voyager was 21.7 mg kg^{-1} (Table 1). Albion seed-Zn concentration averaged 20.9 and 14.4 mg kg^{-1} in 1999 and 2000, respectively. The soil DTPA-Zn and pH may explain the differences in seed-Zn concentrations between years. Because of the differences in seed-Zn concentrations between parents, data from 1999 and 2000 were not combined. The distribution of F_2 lines for seed-Zn concentration was tested for a goodness of fit to a 3:1 ratio. In 1999, the distribution of 41 inefficient to 139 efficient resulted in a chi-square value of 0.47, a good fit. In 2000, the distribution of 16 inefficient to 77 efficient resulted in a chi-square value of 3.01, a good fit. F_3 progeny testing could not be conducted because of the destructive nature of seed-Zn testing.

The hypothesis of a two-gene complimentary interaction in the F_2 proposed by Polson was rejected. Based on the results in 1999 and 2000, these data collected from a segregating F_2 and backcross population indicate that one dominant gene is responsible for seed-Zn accumulation. Due to the transgressive segregation observed in the F_2, a minor gene(s) also may play a role in seed-Zn accumulation.

Table 1. Seed-Zn concentration of populations grown near Erie, ND in 2000.

Genotype	no.	Seed Zn Mean	s	Range	CV
		-------------- mg kg^{-1} --------------			
Voyager	36	21.7	1.75	19.0 - 27.8	8.06
Albion	36	14.4	0.89	13.3 - 17.1	6.18
A / V (F_1)	24	23.1	1.98	19.8 - 29.6	8.57
A / V (F_2)	93	22.6	4.43	12.4 - 34.2	19.6
A / V // A	27	16.6	2.36	13.5 - 20.9	14.2
A / V // V	21	19.8	1.67	17.2 - 23.7	8.43

Table 2. Seed-Zn concentrations of populations grown near Erie, ND in 1999.

Genotype	no.	Seed Zn Mean	s	Range	CV
		-------------- mg kg^{-1} --------------			
Voyager	7	33.2	1.5	31.0 - 35.3	4.52
Albion	7	20.9	2.54	18.1 - 23.3	12.15
A / V (F_1)	28	30.6	1.83	26.7 - 35.6	5.98
A / V (F_2)	180	28.9	5.67	15.9 - 42.7	19.62
A / V // A	27	27.3	5.17	17.8 - 37.2	18.9
A / V // V	21	33.3	2.45	28.2 - 38.4	7.36

References

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