'NUA35' AND 'NUA56', HIGH MINERAL RED MOTTLED BEANS

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Two common bean (*Phaseolus vulgaris* L.) germplasm lines with red mottled grain type, NUA35 and NUA56, were bred for high seed mineral content at the International Center for Tropical Agriculture (CIAT). These genotypes are products of an initiative to improve the nutritional quality of common beans through the enhancement of micronutrient content and the reduction in anti-nutritional factors found in bean seeds that is part of the a novel breeding program at CIAT and other CGIAR centers meant to combat micronutrient deficiencies in human populations. The germplasm lines *per se* belong to a series of genotypes bred for Nutritional Improvement of Andean beans useful for production zones in the tropics and subtropics, hence the code NUA. The two germplasm lines were developed to be high in seed iron and zinc content through selection for these two minerals in early generations of a backcross population created by crossing a commercial, red mottled variety as the recurrent parent with a high mineral donor parent. Both lines produce large grain (above 45 g/ 100 seed) and are bush beans. NUA35 has determinate type I growth habit while NUA56 is indeterminate and of type II growth habit.

Origin: NUA35 and NUA56 are both advanced generation $F_{3:5}$ derived breeding lines from the backcross [CAL96 x (CAL96 x G14519)], where 'CAL96' is a type I growth habit, released variety in Uganda (known as 'K132'), that was originally bred at CIAT and that is widely adapted for Eastern and Southern Africa as well as for the Andean region of South America. CAL96 also has red mottled seed type which is appreciated for its dark burgundy color combined with medium red and light cream mottled pattern and is in consideration for variety release in Colombia as well. 'G14519' (Hickman pole bean from the CIAT germplasm bank) is a type IV growth habit, climbing bean germplasm accession with brown seed that is originally from the United States and which was selected from the CIAT core collection due to it high seed mineral content. Both CAL96 and G14519 are adapted to tropical environments and produce well at 1000 to 1800 masl altitude testing sites in Colombia. The development of the NUA35 and NUA56 was carried out at CIAT headquarters (Palmira, Colombia) using hand emasculation to produce the simple cross and subsequent backcross. Pedigree selection was used from the BC_1F_1 to the BC_1F_3 generation when families were derived based on single plant selection and similarity in seed type and seed color to the recurrent parent. The $BC_1F_{3:4}$ seed from individual families was tested for iron and zinc mineral content using atomic absorption spectrophotometry (AAS) and the highest mineral entries with red mottled grain type were selected for further testing in the $BC_1F_{3:5}$ generation. Seed of this generation was tested in Colombia (Darién and Popayán) from 2004 onward, with subsequent generations tested more widely in other locations within Colombia as well as in Bolivia in South America, Guatemala and Mexico in Central and South America and Kenya, Malawi and Zimbabwe in Eastern and Southern Africa. The seed color of the two NUA lines likewise is very acceptable as they have the same deep red color that is noteworthy of CAL96, the recurrent parent.

Description: Nutrition quality evaluations for seed iron and zinc show that the NUA lines produces more than the average amount of iron for common bean which is 55 ppm; and close to the average amount of zinc for the crop which is 35 ppm. NUA56 has somewhat higher average seed iron content (83.3 ppm) than NUA35 (77.9 ppm) across 15 sites (Table 1) where the genotypes have been tested; while the opposite occurs for average seed zinc content where NUA35 (34.1 ppm) and NUA56 (32.5 ppm). Considering that Andean beans usually have lower than average seed zinc content, this amount of zinc can be considered moderate within the gene pool.

NUA35 and NUA56 are being registered as germplasm lines. They are currently being evaluated in regional trials in the Andean region (Bolivia and Colombia) as well as in Central America (Costa Rica and Guatemala) with additional trials in Eastern and Southern Africa (Kenya, Malawi and Zimbabwe) that are ongoing. NUA lines have proven adaptable in several countries and are being considered for variety releases in Bolivia (NUA35 and NUA56), Colombia (NUA35), and Malawi (NUA56). In addition they have been widely tested on-farm in Colombia and in several additional Eastern and Southern African countries. Analysis with the software program Homologue™ predicts adaptation range in regions such as inter-Andean valleys of Colombia and Ecuador, lowlands of Bolivia, and parts of Kenya, Uganda, Malawi and Mozambique.

Table 1. Seed iron and zinc concentration[1] (in ppm) and seed yield (in kg/ha) for NUA35 and NUA56 grown over 15 sites in Latin America.

Location (Deparment, Country)	Seasons	NUA 35				NUA 56			
		Iron (ppm)		Zinc (ppm)		Iron (ppm)		Zinc (ppm)	
		Avg.	CV	Avg.	CV	Avg.	CV	Avg.	CV
A. Ibañez (Santa Cruz,Bolivia)	1	99	-	41	-	95	-	34	-
San Juan (Santa Cruz, Bolivia)	1	101	-	34	-	100	-	30	-
Darién (Valle, Colombia)	6	69	0.16	28	0.12	61	0.18	25	0.15
Palmira (Valle, Colombia)	4	70	0.16	29	0.11	75	0.22	27	0.12
Yotoco (Valle, Colombia)	1	71	-	43	-	-	-	-	-
Vijes (Valle, Colombia)	1	53	-	31	-	-	-	-	-
Sandoná (Nariño, Colombia)	1	83	0.02	33	0	82	0.09	36	0.16
Yacuanquer (Nariño, Colombia)	2	83	0.17	37	0.12	112	0.03	43	0.03
Consacá (Nariño, Colombia)	3	67	0.23	30	0.23	81	0.11	36	0.03
Popayán (Cauca, Colombia)	5	73	0.11	30	0.14	67	0.13	25	0.19
Quilichao (Cauca, Colombia)	3	64	0.23	29	0.18	78	0.12	29	0.19
Caldono (Cauca, Colombia)	2	79	0.14	35	0.04	-	-	-	-
Puriscal (San Jose, Costa Rica)	1	70	-	34	-	84	-	34	-
Quesada (Jutiapa, Guatemala)	1	95	0.08	38	0.13	89	0.09	39	0.14
Chinantenango (Guatemala)	1	92	0.16	39	0.19	75	0.11	32	0.18
Average across sites		76	0.14	34	0.12	81	0.13	33	0.15

1/ Iron and zinc content were determined by atomic absorption spectrophotometry by the CIAT analytical services lab. To avoid variability seed for each experiment was hand harvested and processed to avoid contamination and then shipped to CIAT for analysis where seed mineral content was evaluated by grinding 4 g of grain from each sample into a fine powder using a modified Retsch mill with a teflon capsule chamber and zirconium grinding balls. Powder was transferred to 25 ml plastic tubes and analyzed for both iron and zinc concentration measured in parts per million (ppm) with a wet digestion method.