Navy and Black Beans Evaluated for Biological Nitrogen Fixation Ability and Under Organic Production

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Introduction

Organic dry bean (*Phaseolus vulgaris* L.) acreage in Michigan accounted for 38% of the U.S. total organic dry bean acreage in 2008. Historically, navy beans were the leading market class in the state. More recently black beans have overtaken navy beans.

Dry beans have the ability to form an association with *Rhizobium* spp. which provides nitrogen fixed from the atmosphere to the bean plant. Dry beans are generally considered poor nitrogen fixers and nitrogen is applied to achieve good yield. Variability exists, however, in the ability of different genotypes to fix N.

To investigate the ability of 36 elite breeding navy and black bean lines and checks to fix nitrogen the lines were grown in growth pouches to study early nodule formation and development. Lines were also studied in a greenhouse using a no nitrogen system to determine nitrogen fixation ability at flowering. These three methods, growth pouch, greenhouse, and field, allow evaluation of the early, mid, and late stage nitrogen fixation ability of dry bean genotypes, respectively.

Materials and Methods

For the growth pouch study seeds were sterilized and then germinated for 3 d on water agar (9 g agar in 1 L water) in an incubator at 29° C. Seedlings were dipped in a 3 d old liquid broth culture of *Rhizobium tropici* strain CIAT899 and placed into growth pouches. Plants were watered N free Broughton and Dilworth nutrient solution (Broughton and Dilworth, 1971). Nodules were counted on day 10.

To study BNF at flowering, the 36 genotypes studied in the growth pouch experiment were planted 4 per pot in a 2:1 perlite/ vermiculite potting mix. Pots were inoculated with *Rhizobium* strain CIAT899 and plants were watered with B&D solution.

At opening of the first flower, plants were harvested. Roots were evaluated for nodule development by rating on a scale of 0 to 6. Shoot and root biomass was determined after plants had dried for 7 d at 70° C followed by grinding for total nitrogen analysis (A&L Great Lakes, Fort Wayne, IN).

Certified organic ground and transition ground were used to evaluate the 36 genotypes under organic conditions in Tuscola county on a farmer's field and at the SVREC. Planting occurred in June 2011 and harvest was by the end of September 2011. Weeds were controlled with cultivation and hand hoeing and pulling.

Table 1. Yield of select black and navy dry bean genotypes grown at Sattelberg Farms on certified organic ground in Unionville, MI and on transitional ground in Frankenmuth, Michigan, at the Saginaw Valley Research and Extension Center (SVREC), in 2011.

Genotype	Seed Type	Geometric Mean, Yield kg ha^{-1}	Yield kg ha^{-1} Sattelberg Farm	Yield kg ha^{-1} SVREC	100 Seed Wt g Sattelberg Farm	100 Seed Wt g SVREC
Zorro	Black	2019	2428	1678	21.1	20.8
B09175	Black	1921	2187	1687	26.6	26.4
B09199	Black	1758	1883	1642	24.4	22.3
N09174	Navy	1739	1937	1562	25.1	24.5
Black Velvet	Black	1670	2017	1383	25.0	23.7
B10202	Black	1660	1678	1642	25.1	22.9
Vista	Navy	1624	1919	1374	20.4	19.4
Medalist	Navy	1358	1187	1553	20.1	19.1
N09055	Navy	1334	1500	1187	20.0	18.4
N09034	Navy	1315	1562	1107	22.0	20.2
N10101	Navy	1315	1562	1107	15.9	15.0
N09178	Navy	1279	1348	1214	20.2	18.0
R99	No-Nod, Navy	669	946	473	20.3	17.2
Mean			1839	1366	20.9	20.2
LSD.05			348	250	1.2	2.8
CV			13.6	12.8	4.0	4.7

Figure 1. Nodule number by seed class of 36 genotypes evaluated for early nodulation in growth pouches.

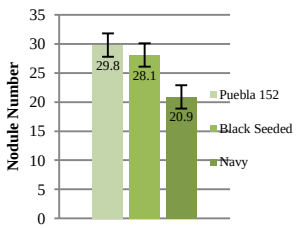

Figure 2. 10 d old roots of black dry bean elite breeding line B10201.. Roots inoculated with *Rhizobium tropici* UMR899.

Table 2. Nitrogen yield, biomass, and nodule rating, and 10 d nodule number of a selection of dry bean genotypes evaluated in the greenhouse at Michigan State University, East Lansing, MI, and in growth pouches in 2011.

Genotype	Seed Type	N yield mg plant^{-1}	Biomass g plant^{-1}	Nodule Rating[2]	Nodules
Black Velvet	Black	107.5	2.9	6.0	23
Puebla 152	High N Fixer	77.9	2.3	6.0	30
B09175	Black	68.6	2.1	5.5	30
B09135	Black	65.5	1.8	4.5	34
B09204	Black	54.8	1.4	4.0	23
B09035	Black	54.3	1.8	4.0	14
B10202	Black	51.4	1.5	4.0	36
Zorro	Black	39.9	1.3	3.5	27
Medalist	Navy	31.6	0.9	4.5	15
Vista	Navy	31.2	0.9	2.5	25
N09104	Navy	23.2	0.53	4.0	30
B09041	Black	23.0	0.8	3.5	14
N09056	Navy	16.5	0.5	2.0	21
N07007	Navy	12.8	0.4	2.0	18
B09128	Black	12.4	0.4	2.5	23
R99	No-Nod, Navy	5.5	0.2	0.0	0
Mean		39.6	1.2	3.5	25
LSD.05			1.1		

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Results

The commercial variety 'Zorro' and elite breeding line B09175 were the highest yielding genotypes studied under organic field conditions (Table 1). Black bean genotypes tended to populate the top of the list for yield while navy beans tended to be lower yielding. The navy bean breeding line N09174 is promising and may be suitable for organic production yielding significantly higher than average.

Black bean genotypes tended to develop more nodules than navy bean genotypes (Figure 1). There were no significant differences between black and navy beans for days to visible nodules , root length., or root growth.

Under greenhouse conditions the commercial black bean 'Black Velvet' yielded greater biomass and nitrogen than the high BNF check Puebla 152 (Table 2). Following trends seen in the field and growth pouches, black bean genotypes tended to yield greater biomass and nitrogen than the navy bean genotypes.

Discussion

Black beans may be better suited to production systems with limited N input than navy beans. Navy bean varieties may require a larger amount of nitrogen input to be competitive with black bean varieties for yield.

The navy bean breeding line N09174 is promising in that it yielded as well as black bean lines. Black beans Zorro and B09175 demonstrate yield stability over multiple environments

BNF ability may be a contributing factor to the improved yields seen in black beans compared to navy beans. It would seem possible to develop navy beans which are competitive with black beans.

Hungria and Phillips (1993) reported a reduction in nodule number in a white seeded genotype when compared to a black seeded line. Also, levels of anthocyanins were reduced in white seeded lines studied. Anthocyanins are responsible for the dark color in black beans and are essential for establishing symbiosis between bean plant and *Rhizobium*.

Literature Cited

Broughton, W.J., and M.J. Dilworth. 1971. Control of leghaemoglobin synthesis in snake beans. Biochem J 125: 1075–1080

Hungria, M., and D. A. Phillips. 1993. Effects of a Seed Color Mutation on Rhizobial nod-Gene-Inducing Flavonoids and Nodulation in Common Bean. Molecular Plant-Microbe Interactions. 6(4):418-422.