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A Preliminary Evaluation of Black and Navy Bean Productivity in Virginia

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Abstract

Black and navy beans (*Phaseolus vulgaris* L.) are economically important crops for US Agriculture and provide nutritious food for humans. These crops are predominantly grown in Colorado, Idaho, Michigan, Nebraska, North Dakota, and Washington states. We are interested in introducing these crops in Virginia as alternative summer crops. Four cultivars each of black (Eclipse, T-39, Zenith and Zorro) and navy bean (Alapena, Avalanche, Norstar, and Vista) were grown in the field at Randolph Farm of Virginia State University in Ettrick, Virginia during 2016. We planted these twice (May 26 and June 30) by using two inter-row spacings (37.5 and 75 cm). Results indicated that yields of black bean (1691 kg/ha) didn't differ significantly from that of navy bean (1402 kg/ha). Effects of cultivars and row spacings were not significant. Seed yield for May planting date (883 kg/ha) was significantly lower than that for June planting (2210 kg/ha). Concentrations of protein, P, K, Ca, Mg, S, Al, B, Cu, Fe, Mn, fructose, glucose, sucrose, raffinose, stachyose, verbascose, total sugar, insoluble dietary fiber, and total dietary fiber in black and navy bean seeds were not different. Black bean had significantly higher soluble dietary fiber concentration (4.46%) as compared to navy bean (3.68%). Nutritional quality traits of black and navy bean seed produced in Virginia compared well with values in the literature. Based on desirable seed yield levels and nutritional quality, it was concluded that black and navy bean are potential new/alternate crops for Virginia and adjoining areas in the mid-Atlantic region of United States of America.

Keywords: *Phaseolus vulgaris*, minerals, protein, dietary fiber, crop diversification

1. Introduction

Need for crop diversification is recognized as one of the important factors for production of adequate and nutritious food for the growing human population on a world-wide basis. This is especially true of US agriculture which depends upon a limited number of crops. New crops have been important to American agriculture as most crops currently grown in the United States were imports from different parts of the world. The importance of crop diversification in the success of Australian and Canadian agriculture is well documented. Fletcher (2002) indicated that at least 67% of the increased value of crop production in Australia over the period 1950-1992 was derived from new crops. Blade and Slinkard (2002) cited successful cultivation of many new crops in Canada such as canola, chickpea, field pea, lentil, mustard, canary seed, sunflower, and many spice crops. Sustainable Agriculture Network (SARE, 2004) indicated that we need to diversify crops to enhance profits, to soften impacts of environmental resources, to spread farmer's economic risk, to exploit markets, to create new industries, and to aid the domestic economy. Alternative crops research has been going on at Virginia State University since 1993 (Bhardwaj et al., 1996).

Common bean (*Phaseolus vulgaris* L.; 2n = 2x = 22), a collective term that includes dry bean, is an important economic crop in the US. During 2008, approximately 1.7 million acres of dry and snap beans were planted in the United States. Production of dry beans is primarily located in North Dakota, Michigan, Nebraska, and Colorado (90% of production). Snap beans are grown for the fresh and processing markets on 300,000 acres, primarily in Oregon, Wisconsin, and New York. Collectively, the value of common bean production at the farm gate in 2008 was $1.5 billion whereas the value of production during 2014 and 2015 was approximately 980 million and 866 million dollars, respectively indicating a decline in value of production. During most years, dry bean value exceeds the value of all other vegetable legumes combined (chickpea, lentil, pea, and peanut). US breeders focus on five dry bean classes (pinto, navy, black, Great Northern, kidney) and snap beans for the fresh and processing markets. Each market class is defined by a specific seed size, color, and pattern, traits controlled by many genes (McClean, 2002). ERS (2017) has listed the leading varieties of dry edible beans as: Pinto 42%; Navy 17%; Black 11%; Great Northern 5%; and Garbanzo (large chickpeas) 5%.

Commercial production of dry beans is concentrated in Colorado, Idaho, Michigan, Nebraska, North Dakota, and Washington states as evidenced the following Figure 1 (BeanCAP, 2009). This figure indicates lack of any tangible production in the eastern United States. Even though dry beans (*Phaseolus vulgaris* L.) are not a traditional component of the existing cropping system they have considerable potential as alternative crops in Virginia and adjoining states. These crops have excellent positive effects on human health and consumers are incorporating increasing amounts in their diets.

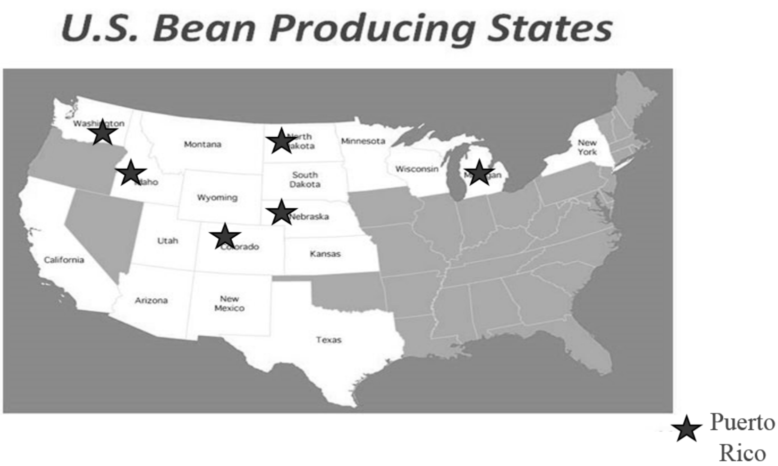

Figure 1. Concentrated areas of commercial production of dry beans

Our objectives were to characterize nutritional quality of black and navy bean in Virginia, compare their nutritional quality to that available in literature, and to make a judgement about the potential of these food legume crops in Virginia and adjoining areas.

2. Materials and Methods

2.1 Plant Material and Production

Four cultivars each of black (Eclipse, T-39, Zenith and Zorro) and navy (Alapena, Avalanche, Norstar, and Vista) bean were grown in the field (Abel sandy loam-Fine Loamy mixed thermic Aquatic Hapridult soil) at Randolph Farm of Virginia State University in Ettrick, Virginia during 2016. We used two planting dates (May 26 and June 30) and two row spacings (37.5 and 75 cm) using a RCBD with four replications. The experiment was designed as a split-plot with planting dates as main plots, cultivars as subplots, and row spacings as sub-subplots. Each plot consisted of four rows spaced either 0.375 or 0.75 m apart with 1.5 m distance between plots. Each experiment consisted of four replications per planting date. The rows were 3.6 m long. About 100 seeds were planted in each row with a tractor-driven research planter. The seed depth was 2 to 3 cm. These plots received 30 kg/ha each of N, P, and K. Experimental area received a preplant incorporated treatment of Trifluralin herbicide at the rate of 1 liter/ha. The plots were manually weeded once. All plots were harvested upon maturity in fall season of 2016.

2.2 Analysis of Seed Composition

We used raw mature seeds of each of the four cultivars of black (Eclipse, T-39, Zenith, and Zorro) and navy bean (Alapena, Avalanche, Norstar, and Vista) grown for these studies. Seed from two replications were used for nutritional quality analyses. Mineral concentrations, including nitrogen (N), in seed were determined according to AOAC methods (AOAC, 2016) by Waypoint Analytical Laboratory (Richmond, Virginia, USA). Total protein concentration was calculated by multiplying N content with protein factor 6.25.

Sugars were extracted from ground sample (1 g) and analyzed by HPLC following methods optimized by Johansen et al. (1996). Sugars in the extracts were identified by comparing their retention times with standard sugars. For quantification, trehalose was used as internal standard and the sugar concentration was expressed as g per 100 g meal (Bhardwaj & Hamama, 2016).

Dietary fiber concentrations (Insoluble, soluble, and total dietary fiber) were determined using AOAC 991.43 method using the ANKOM TDF Dietary Fiber Analyzer in the Common Laboratory of Virginia State University. This method uses Filter Bag Technology to determine the concentrations IDF (insoluble fiber), SDF (soluble fiber) and TDF (total fiber) within a given sample using the weight of the recovered IDF and SDF residue corrected for ash and protein content.

All data were analyzed using version 9.1 of SAS (SAS Institute, Inc., 2014) using ANOVA with 5 percent level of significance. Seed composition traits of black and navy bean produced in this study were compared to those in the literature.

3. Results and Discussion

Effects of cultivars and row spacings on seed yield were generally non-significant (Table 1). Late planting (June 30) resulted in significantly higher seed yield as compared to early planting (May 26), 2210 and 883 kg/ha, respectively. Seed yields of both black and navy bean were statistically similar (1691 and 1402 kg/ha, respectively) even though seed yield of black bean (averaged over four cultivars) was approximately 21% higher than that of navy bean. In our opinion, these differences are expected to be more pronounced after inclusion of a wider array of cultivars of both types in future studies. Based on these results, we conclude that seed yields of both black and navy beans produced in Virginia are acceptable based on average yields of other summer crops such as double-crop soybean. Higher seed yield from late planting indicates that black and navy bean might need higher temperature for successful growth and production. These results indicate that production of black and navy bean in rotation with winter wheat (Generally planted in October-November and harvested in late June-early July) may be possible.

Table 1. Seed yields from bean field experiments during 2016 at Petersburg, Virginia

Type	Cultivar	Seed yield (kg/ha)*
Black bean	Eclipse	1780.4 a
	T-39	1848.8 a
	Zenith	1224.3 a
	Zorro	1911.4 a
Navy bean	Alapena	1467.0 a
	Avalanche	1198.7 a
	Norstar	1322.1 a
	Vista	1620.5 a
Row spacing	15-inch	1697.7 a
	30-inch	1395.6 a
Planting date	May 26, 2016	883.3 b
	June 30, 2016	2210.0 a
Bean type	Black bean	1691.2 a
	Navy bean	1402.1 a

Note. * Means followed by similar letters were not different according to Duncan's Multiple Range Test (5% level).

Differences among four black bean cultivars for nutritional quality traits (Table 2) were non-significant except when Zorro had significantly higher Ca concentration over Zenith. Differences among four navy bean cultivars for nutritional quality traits (Table 2) were non-significant except when Avalanche had significantly higher concentration of Cu, S, P, Zn, Ca, Sucrose, Raffinose total sugar over different cultivars.

Table 2. Comparison of nutritional quality traits of Virginia-grown black and navy bean with literature values

Trait	Black bean[1]	Navy bean[2]	Pinheiro[3]	Duenas[4]	Pedrosa[5]	USDAa[6]	USDAb[7]
Protein (%)	25.0 a*	25.1 a*	21-30	17.8	24.9-26.6	21.6	22.3
P (%)	0.59 a	0.61 a	0.50-0.80			0.35	0.41
K (%)	1.59 a	1.55 a	1.24-2.12			1.48	1.18
Ca (%)	0.18 a	0.18 a	0.07-0.29		0.04-0.16	0.12	0.15
Mg (%)	0.21 a	0.22 a	0.13-0.25		0.10-0.15	0.17	0.17
S (%)	0.24 a	0.24 a					
Al (ppm)	11.4 a	12.7 a					
B (ppm)	10.1 a	10.1 a					
Cu (ppm)	12.4 a	12.4 a	4.7-13.5				
Fe (ppm)	44.4 a	48.4 a	32-88		52-60	50.2	54.9
Mn (ppm)	14.9 a	15.4 a	8-20				
Zn (ppm)	31.9 a	30.2 a	11.5-45.3		21.6-24.0	36.5	36.50
Fructose[8]	0.84 a	0.86 a					
Glucose[8]	0.44 a	0.55 a					
Sucrose[8]	2.29 a	2.44 a			3.1-3.5		
Raffinose[8]	0.39 a	0.48 a			0.12-0.13		
Stachyose[8]	1.80 b	2.31 a			2.72-2.79		
Verbascose[8]	0.00 a	0.01 a					
Total sugars[8]	5.75 b	6.64 a				2.12	3.88
IDF[9]	15.6 a	14.4 a		21.4			
SDF[9]	4.46 a	3.68 b		5.8			
TDF[9]	20.0 a	18.3 a		27.2	32.3-32.7	15.5	15.3

Note. [1] Means based on four cultivars (Eclipse, T-39, Zenith, and Zorro); [2] Means based on four cultivars (Alapena, Avalanche, Norstar, and Vista); [3] Pinheiro et al. (2010); [4] Duenas et al. (2016); [5] Pedrosa et al. (2015); [6] USDA (2018a); [7] USDA (2018b); [8] g/100 g meal; [9] Insoluble, soluble, and total dietary fiber, respectively (%); * Means followed by similar letters were not different according to Duncan's Multiple Range Test (5% level).

As groups, differences between black and navy bean for nutritional quality traits (Table 2) were not significant except for concentrations of total sugar (5.75 vs. 6.64%) and soluble dietary fiber (4.46 vs. 3.68%). Observational comparisons of nutritional quality of Virginia-grown black and navy bean with literature values and the standard reference values maintained by Agricultural Research Service, USDA (USDA, 2018a, USDA, 2018b) revealed that, in general, nutritional quality of black and navy bean produced in Virginia is not different than values reported in the literature.

Results of this preliminary study indicated that both black and navy bean could be developed as alternate food crops for farmers in Virginia and adjoining areas. These results, however, are from only one year's data and should be repeated. Additionally, the results implied that a possibility of producing black and navy bean in rotation with winter wheat exists. This observation, if confirmed by further studies, could result in significant enhancement of farm economies in Virginia and adjoining areas. Dry bean (*Phaseolus vulgaris* L.) are consumed by humans more than any other legume crop. The health benefits from eating beans are numerous and include reducing the cholesterol and sugar levels in blood which prevent or alleviate certain types of cancer, Type 2 diabetes, and cardiovascular diseases. Diets rich in zinc and iron, two micronutrients abundant in dry bean, can delay the onset of AIDS and as such, HIV positive patients are encouraged to include beans in their diets. Recently, research has shown that beans significantly reduce the onset of breast cancer, colon cancer, and biomarkers for heart disease risk (BeanCap, 2009). Current study, demonstrates that production of black and navy bean can be expanded to Virginia and adjoining areas not only to help farm economy but also to provide a source of healthy food for human consumption.

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