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Cultivar, Planting Date, and Row Spacing Effects on Mungbean Seed Composition

Harbans L. Bhardwaj[1] & Anwar A. Hamama[1]

[1] Agricultural Research Station, Virginia State University, Petersburg, USA

Correspondence: Harbans L. Bhardwaj, Agricultural Research Station, Virginia State University, Petersburg, Virginia 23806, USA. Tel: 804-524-6723. E-mail: hbhardwaj@vsu.edu

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Abstract

Mungbean [(*Vigna radiata* (L.) R. Wilczek, Fabaceae] is becoming an important food crop in the United States of America. This crop has previously been produced in the US states of Texas and Oklahoma but this production is currently not significant. Recent efforts have established that mungbean can be easily produced in Virginia, located in the mid-Atlantic region of the United States of America. However, there is a complete lack of information related to nutritional quality of mungbean produced in this region. We grew mungbean during 2012 and 2013 using two cultivars (Berken and TexSprout), two planting dates (early and late July), and two row spacings (0.375 and 0.75 m) to characterize composition of mungbean seed produced in Virginia. Mungbean seeds produced in this study averaged 1.59, 24.3, and 4.91% oil, protein, and sugars, respectively. These mungbean seeds also contained 38.8, 61.2, 5.79, and 55.1% in saturated, unsaturated, mono-unsaturated, and poly-unsaturated fatty acids, respectively. Predominant fatty acids in the mungbean seed were C16:0 (26.1%), C18:0 (6.11%), C18:2 (36.8%), and C18:3 (18.3%). Iron and zinc contents of the mungbean seed were 8.42 and 3.88 mg·100 g^{-1}. Concentrations of fructose, glucose, sucrose, raffinose, stachyose, and verbascose sugars in mungbean seed were 0.45, 0.30, 0.70, 0.24, 0.84, and 2.37%, respectively. Effects of cultivars, planting dates, and row spacings on mungbean seed composition were, generally, not significant. Overall, mungbean seed compared well with nutritional quality of kidney bean, pinto bean, navy bean, and tepary bean.

Keywords: *Vigna radiata*, food legumes, fatty acids, minerals, sugars

1. Introduction

Mungbean [(*Vigna radiata* (L.) R. Wilczek], a member of the Fabaceae family (also known as the Leguminosae family) along with the common pea, chickpea, soybean, alfalfa, and other crops, is a native of India-Burma (Myanmar) region of Asia and is grown principally for its protein-rich edible seeds for use as food or livestock feed. This plant and its production strategy are very similar to soybean. The seeds have potential as human food (cooked beans or sprouts) and livestock feed. The plant, being a legume, can fix atmospheric N via Symbiotic N Fixation and also can also be used as forage or hay (Oplinger et al., 1990).

Mungbean is one of the most important food legume crops in the Asia. It is also gaining importance in other parts of the world, such as Australia and Canada. The United States imported 12,731, 13,474, and 13,672 Mg of mungbean, respectively during 2012, 2013, and 2014, respectively (ERS, 2015). Although previous research indicated that mungbean has potential as a short-duration summer crop in the mid-Atlantic region of the United States (Bhardwaj & Hamama, 2015; Bhardwaj et al., 1999), there is a lack of information about nutritional quality of mungbean produced in this region. In a previous study (Bhardwaj & Hamama, 2015), we observed that cultivar and planting date effects were not significant for seed yield, however, narrow row spacing resulted in significantly higher seed yield and protein concentration over wide row spacing (1.76 vs. 0.86 Mg ha^{-1} yield and 24.9 vs. 23.7% protein, respectively for 0.375 and 0.75 m row spacings). We also observed that average values for mungbean seed yield, seed size, and concentrations of protein, sugars, and oil were 1.31 Mg ha^{-1}, 7.08 g $seed^{-100}$, 24.3%, 4.91%, and 1.59%, respectively.

The objective of the current study was to characterize seed composition of mungbean seed produced in experiments conducted during 2012 and 2013 in Virginia (Bhardwaj & Hamama, 2015).

2. Materials and Methods

2.1. Plant Material and Production

Seeds of two mungbean cultivars (Berken and TexSprout) were used in this study. Berken (PI-662958) is a small seeded cultivar whereas TexSprout (PI-536545) is a large seeded cultivar. These cultivars were grown during 2012 and 2013 (Bhardwaj & Hamama, 2015) by planting on July 7 and July 27 during 2012 and July 8 and July 23 during 2013 and by using two inter-row spacings (0.375 m and 0.75 m) at Randolph Farm at Virginia State University (37°15′N, 77°31′W). The experiment during each year 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 0.02 to 0.03 m. These plots received 30 $kg \cdot h^{-1}$ of NPK. The soil type was Abel sandy loam (fine-loamy, mixed, thermic Aquatic Hapludult). Experimental area received a preplant incorporated treatment of Trifluralin herbicide at the rate of 1 $L \cdot ha^{-1}$. The plots were manually weeded once. All plots were harvested on 24 Oct. during 2012 and on 31 Oct. during 2013.

2.2 Analysis of Seed Composition

Mineral contents, including nitrogen (N), in mungbean seed were determined according to AOAC methods (AOAC, 1995) by A&L Eastern Agricultural Laboratory, Richmond, Virginia. Total protein was calculated by multiplying N content with protein factor 6.25. The concentration of minerals was expressed as $mg \cdot 100^{-1}$ g.

The oil was extracted from ground seeds (2 g) three times at room temperature by homogenization with hexane/isopropanol (3:2, v/v) as described by Hamama et al. (2005). The oil percentage ($g \cdot 100^{-1}$ g dry basis) was determined gravimetrically (Bhardwaj et al., 2004) after drying in a vacuum oven at 40 °C and stored under N_2 at -10 °C until analyzed.

The fatty acid methyl esters (FAME) of the oil were prepared by acid-catalyzed transesterification technique as previously described (AOAC, 1995). Analyses of FAME were carried out as described by Hamama et al. (2005) in a SupelcoWax 10 capillary column (25 m × 0.25 mm i.d. and 0.25 µm film thickness (Supelco, Inc., Bellefonte, PA) in a Varian Model Vista 6000 Gas Chromatograph equipped with a flame ionization detector and a Spectra Physics Model 4290 integrator. Helium was used as a carrier gas at 25 $cm \cdot s^{-1}$, with a split ratio of 1:100. The column temperature was isothermal at 210 °C. The injector and detector temperatures were 250 and 260 °C, respectively. Fatty acids were identified by reference to the retention of FAME standards and quantitated by the aid of heptadecanoic acid (17:0) as an internal standard. The concentration of each FA was calculated as the percentage (w/w) of the total fatty acids.

Sugars were extracted from ground sample (1 g) and analyzed by HPLC following the 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 $g \cdot 100\ g^{-1}$ oil-free meal.

Seed composition traits of mungbean produced in this study were compared to those in the literature for kidney bean, pinto bean, navy bean, and tepary bean for evaluating the nutritional quality of mungbean.

All data were analyzed using version 9.1 of SAS (SAS, 2014) using ANOVA with 5 percent level of significance.

Table 1. Cultivar effects on concentrations of fatty acids, minerals, and sugars in Mungbean seed produced in Virginia during 2012 and 2013

	Berken	TexSprout	LSD (0.05)
Oil (%)	1.59*	1.60*	ns
Protein (%)	24.7	23.9	ns
Total Sugars (%)	4.92	4.90	ns
Fatty acids (%)			
C14:0	0.256	0.266	ns
C16:0	26.015	26.247	ns
C18:0	6.010	6.113	ns
C18:1	5.713	4.785	ns
C18:2	36.680	36.999	ns
C18:3	18.214	18.336	ns
C20:0	1.855	1.921	ns
C20:1	0.374	0.333	0.039
C22:0	2.935	2.950	ns
C24:0	1.417	1.486	ns
Minerals (mg/100g)			
P	479	484	ns
K	1349	1356	ns
S	206	210	ns
Ca	144	146	ns
Mg	182	186	ns
Na	12.3	12.3	ns
Fe	8.43	8.42	ns
Al	1.56	1.69	ns
Mn	1.78	2.10	ns
Cu	1.20	1.20	ns
Zn	3.81	3.94	ns
B	1.32	1.32	ns
Sugars (%)			
Fructose	0.450	0.456	ns
Glucose	0.294	0.306	ns
Sucrose	0.632	0.765	ns
Raffinose	0.273	0.217	ns
Stachyose	0.844	0.835	ns
Verbascose	2.423	2.324	ns

Note. * Means over two years, two planting dates, two inter-row spacings, and two replications.

3. Results and Discussion

Concentrations of various constituents of mungbean seed were, generally, not significantly affected by cultivars, planting dates, and inter-row spacings (Tables 1, 2, and 3). However, the small-seeded cultivar Berken had significantly higher concentration of C20:1 fatty acid (0.37% of oil) as compared to the large-seeded cultivar TexSprout (0.33% of oil) (Table 1). We believe that this lack of significance resulted from inclusion of only two cultivars in this study, due to limited availability of mungbean cultivars, and expect that significant differences would be observed among cultivars if a large number of cultivars were evaluated. Similar results were observed from a previous study with a limited number of white lupin cultivars (Bhardwaj & Hamama, 2013). Effects of planting dates were significant for concentrations of C16:0, C22:0, and C24:0 fatty acids (Table 2). Earlier planting resulted in significantly lower concentrations of these three fatty acids (26.0 vs. 26.3% C16:0, 2.87 vs. 3.02% C22:0, and 1.32 vs. 1.59% C24:0) in mungbean seeds. Narrow inter-row spacing of 0.375 m resulted in significantly lower concentration of sulfur (204 mg·100 g^{-1}) as compared to the 0.75 m row spacing of (212 mg·100 g^{-1}) (Table 3). As previously reported (Bhardwaj & Hamama, 2015), narrow inter-row spacing resulted in significantly higher concentration of protein (24.9 vs. 23.7%), while early planting resulted in significantly lower concentrations of sugar (4.38 vs. 5.51%) and oil (1.24 vs. 1.99%) in mungbean seeds produced in Virginia.

These results demonstrate that, in general, mungbean seed composition was not affected by agronomic factors in our limited studies in mid-Atlantic region of USA. However, our results establish a baseline for mungbean nutritional quality for comparison with future studies.

Table 2. Planting date effects on concentrations of fatty acids, minerals, and sugars in mungbean seed produced in Virginia during 2012 and 2013

	Early July	Late July	$LSD_{0.05}$
Oil (%)	1.24*	1.99*	0.001
Protein (%)	24.2	24.4	ns
Total Sugars (%)	4.38	5.51	0.001
Fatty acids (%)			
C14:0	0.252	0.272	ns
C16:0	26.0	26.3	0.015
C18:0	6.40	5.78	ns
C18:1	5.58	4.87	ns
C18:2	36.3	37.5	ns
C18:3	18.3	18.2	ns
C20:0	1.97	1.79	ns
C20:1	0.352	0.356	ns
C22:0	2.87	3.02	0.019
C24:0	1.32	1.59	0.002
Minerals (mg/100g)			
P	468	497	ns
K	1321	1388	ns
S	209	207	ns
Ca	149	140	ns
Mg	184	183	ns
Na	12.4	12.2	ns
Fe	8.35	8.50	ns
Al	1.78	1.45	ns
Mn	1.94	1.93	ns
Cu	1.24	1.16	ns
Zn	3.92	3.82	ns
B	1.32	1.31	ns
Sugars (%)			
Fructose	0.450	0.456	ns
Glucose	0.294	0.306	ns
Sucrose	0.632	0.765	ns
Raffinose	0.273	0.217	ns
Stachyose	0.844	0.835	ns
Verbascose	2.423	2.324	ns

* Means over two years, two cultivars, two inter-row spacings, and two replications.

Table 3. Inter-row spacing effects on concentrations of fatty acids, minerals, and sugars in mungbean seed produced in Virginia during 2012 and 2013

	0.375 m	0.75 m	$LSD_{0.05}$
Oil (%)	1.55*	1.64*	ns
Protein (%)	24.9	23.7	0.001
Total Sugars (%)	4.90	4.92	ns
Fatty acids (%)			
C14:0	0.261	0.262	ns
C16:0	26.207	26.056	ns
C18:0	6.109	6.104	ns
C18:1	4.767	5.731	ns
C18:2	37.152	36.526	ns
C18:3	18.557	17.993	ns
C20:0	1.847	1.929	ns
C20:1	0.354	0.353	ns
C22:0	2.982	2.902	ns
C24:0	1.484	1.419	ns
Minerals (mg/100g)			
P	474	489	ns
K	1360	1346	ns
S	204	212	0.007
Ca	149	140	ns
Mg	183	185	ns
Na	11.8	12.8	ns
Fe	8.23	8.62	ns
Al	1.62	1.63	ns
Mn	1.84	2.04	ns
Cu	1.16	1.24	ns
Zn	3.89	3.86	ns
B	1.31	1.33	ns
Sugars (%)			
Fructose	0.385	0.521	ns
Glucose	0.265	0.334	ns
Sucrose	0.752	0.646	ns
Raffinose	0.214	0.276	ns
Stachyose	0.852	0.828	ns
Verbascose	2.434	2.313	ns

Note. * Means over two years, two cultivars, two planting dates, and two replications.

3.1 Seed Composition of Mungbean and Other Food Legumes

We compared the seed composition of mungbean with that of literature values for kidney bean, pinto bean, navy bean, and Tepary bean (Table 4). Comparisons of mungbean seed composition values to those available for other food legumes (USDA, 2015; Bhardwaj & Hamama, 2004, 2005) indicated that concentrations of C16:0, C18:0, C18:2, C20:1, saturated, and poly-unsaturated fatty acids were, generally, higher in mungbean seeds whereas concentrations of C18:1, unsaturated, and mono-unsaturated fatty acids were lower in mungbean seeds. Concentration of C18:3 (The Omega-3 fatty acid) in mungbean seeds was lower than that in seeds of kidney bean, pinto bean, and navy bean but higher than that in the seeds of Tepary bean. Overall, these results indicate that nutritional quality of mungbean produced in mid-Atlantic region of USA is quite similar to that of other food legumes and is acceptable.

Table 4. Seed composition traits of mungbean compared to literature values for kidney bean, pinto bean, navy bean, and tepary bean

	Mungbean		Kidney bean[3]	Pinto bean[3]	Navy bean[3]	Tepary bean[3]
	Virginia grown[1]	Literature[2]				
Oil (%)	1.59	1.15	1.1	1.1	1.3	1.8
Protein (%)	24.3	23.9	22.5	20.9	22.3	23.9
Total Sugars (%)	4.91	6.60	2.23	2.11	3.88	n/a
Fatty acids (%)						
C14:0	0.26	n/a	n/a	n/a	n/a	n/a
C16:0	26.1	n/a	12.8	20.3	24.2	23.3
C18:0	6.11	n/a	1.7	0.4	1.6	6.1
C18:1	5.25	n/a	7.7	20.3	8.7	22.2
C18:2	36.8	n/a	21.5	15.0	23.5	31.5
C18:3	18.3	n/a	33.8	21.0	19.7	10.9
C20:0	1.89	n/a	n/a	n/a	n/a	1.5
C20:1	0.35	n/a	0.00	0.00	n/a	0.8
C22:0	2.94	n/a	n/a	n/a	n/a	1.0
C24:0	1.45	n/a	n/a	n/a	n/a	1.4
Saturated	38.8	34.8	14.5	20.8	25.9	33.4
Unsaturated	60.9	65.2	85.5	79.2	74.1	66.6
MUFA	5.79	1.61	7.7	20.3	8.7	24.2
PUFA	55.1	38.4	55.3	36.0	43.1	42.3
Minerals (mg/100g)						
P	481	367	406	418	443	451
K	1353	1246	1359	1328	1140	1531
S	208	n/a	n/a	n/a	n/a	311
Ca	145	132	83	121	155	184
Mg	184	189	138	159	173	192
Na	12.3	15	n/a	n/a	n/a	n/a
Fe	8.42	6.74	6.7	5.9	6.4	11
Al	1.62	n/a	n/a	n/a	n/a	n/a
Mn	1.94	n/a	1.1	1.1	1.3	2.8
Cu	1.20	n/a	0.7	0.8	0.9	1.2
Zn	3.88	2.68	2.8	2.5	2.5	4.3
B	1.32	n/a	n/a	n/a	n/a	1.2
Sugars (%)						
Fructose	0.45	n/a	n/a	n/a	n/a	n/a
Glucose	0.30	n/a	n/a	n/a	n/a	n/a
Sucrose	0.70	n/a	n/a	n/a	n/a	n/a
Raffinose	0.24	n/a	n/a	n/a	n/a	n/a
Stachyose	0.84	n/a	n/a	n/a	n/a	n/a
Verbascose	2.37	n/a	n/a	n/a	n/a	n/a

Note. [1]: Means over two years, two planting dates, two spacings, and two cultivars grown during 2012 and 2013 at Petersburg, Virginia.

[2]: Adapted from: US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28. Version Current: September 2015. Internet: http://www.ars.usda.gov/ba/bhnrc/ndl

[3]: Adapted from: Bhardwaj and Hamama (2004, 2005).

4. Conclusions

Results of experiments conducted over two years indicate that mungbean can be easily produced in the United States of America especially the mid-Atlantic region. The nutritional quality of mungbean produced in this region was acceptable in comparison with that of other food legumes such as kidney bean, pinto bean, navy bean, and Tepary bean.

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