J. BIOL. ENVIRON. SCI.,
2019, 13(38), 79-84

Review Article

Adzuki beans (*Vigna angularis*), a Traditional Chinese Legume for Sustainable Agriculture and Food Production

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Received: 28.05.2019; Accepted: 12.06.2019; Published Online: 31.10.2019

ABSTRACT

Adzuki bean (*Vigna angularis*) is a traditional legume crop that plays a crucial role in the sustainability of both agricultural systems and in the food protein supply. As adzuki bean has been used for thousands of years in China as traditional Chinese medicine and foods, it has a great potential to be drug candidate or functional food materials. Adzuki is a good source of essential fatty acids, fiber, minerals and phytochemicals such as polyphenols and phytates. Legumes are nitrogen-fixing systems that have long been used for biological nitrogen fixation in agriculture. Biologically fixed nitrogen of adzuki beans can be yielded so that the hazards of the chemical fertilizers can be reduced. Because of the growing requests for plant production, especially protein and oils and also decrease the economic and environmental pressure on agro-eco systems, it emerges that grain legumes, adzuki bean included would play a major role in future cropping systems and sustainable agriculture. Legumes, especially those which have various medicinal effects can help to restore soil organic matter and reduce pests and diseases problems, and they may lead to more soil fertility. Adzuki beans have considerable potential globally to be a functional food for health promotion and diseases prevention in not only Asian countries, but also other parts of the world.

Keywords: Traditional Chinese Medicine, Adzuki Bean, Soil Fertility, Super-food, Nitrogen Fixation

INTRODUCTION

Adzuki, a unique traditional Chinese food for sustainable agriculture

Among the species of medicinal plants, some are mainly confined to folk medicine and some are used as occasional or local substitutes for the main species listed in the Materia Medica (Ogbaji *et al.* 2017, Ogbaji *et al.* 2018, Shahrajabian *et al.* 2018, Soleymani *et al.* 2018, Shahrajabian *et al.* 2019a,b,c,d). Hu Shiuying (1980) listed 60 genera of legumes, with nearly 100 species in her extensive book An Enumeration of Chinese Materia Medica. Grain legumes are known for their nutritional richness especially protein and amino acids, which are largely lacking in human diets leading to malnutrition (Soleymani *et al.*, 2011a). The economic and environmental importance of legume crops is largely due to their ability to fix atmospheric dinitrogen in symbiosis with rhizobia (Soleymani *et al.* 2011b, Soleyman and Shahrajabian 2012a, b, Soleymani *et al.* 2012, Shahrajabian *et al.* 2017, Yong and Shahrajabian 2017, Young *et al.* 2017a, Yong *et al.* 2018). Adzuki bean (*Vigna angularis*) is a small bean that has an inherently sweet, nutty taste and it is one of the 12 most important grain legume crops in the world (Kumar *et al.* 2012, Reddy *et al.* 2017, Tazawa *et al.* 2018). In China, they call it Xiaodou, Hondou and Chidou. Adzuki bean sprouts are consumed as food and herb medicine in Chinese folk (Li *et al.* 2011). Globally China ranks number one in azuki bean production and exports. The major production regions are located in north east China, Huabei, and Huanghe River and Haihe River valley including Heilongjiang, Inner Mongolia, Jilin, Liaonin, Hebei, Shaanxi, Shanxi, and Jiangsu provinces. As an herbal medicine, adzuki bean has been practiced since the Tang Dynasty of China to maintain health and control weight (Liu *et al.* 2017). The chief countries of Adzuki bean production are China, Japan, Taiwan, and South Korean. Adzuki beans were most likely developed in China and introduced into Japan around A.D. 1000 (Yousif *et al.* 2007). Adzuki beans cultivars showed different antioxidant activities and cytoprotective effects according to the concentration and composition of phenolic compounds. Gohara *et al.* (2016) found that all adzuki bean cultivars showed polyunsatured fatty acids prevalence and nutritional indices and ratios considered adequate for biological system maintenance of a healthy organism.

Table 1. Province of origin and frequency of accessions of adzuki bean from each province in China (Redden *et al.* 2009).

Province (region)	Frequency	Percentage	Province no.
Shanxi	64	27.7	8
Hebei	34	14.7	7
Henan	27	11.7	11
Jilin	21	9.0	3
Shandong	17	7.4	9

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Heilongjiang	15	6.5	2
Shaanxi	11	4.8	10
Hubei	9	3.9	15
Liaoning	8	3.5	4
Beijing	7	3.0	5
Anhui	6	2.6	12
Neimenggu (North)	4	1.7	1
Sichuan	2	0.9	14
Jiangsu	2	0.9	13
Taiwan (Coast)	1	0.4	18
Tianjin	1	0.4	6
Guizhou	1	0.4	17
Yunnan	1	0.4	16
Total	231	100.0	

Table 2. A list of elite varieties of Adzuki bean in China (Li *et al.* 2017).

Jihongxiaodou 2
Jihongxiaodou 4
Jihnog 9218
Jibaohongxiaodou 2
Bao 876-16
Zhonghong 2
Baochong 947
Baihong 2
Baihong 3
Jihong 6
Jingnong 5
Jingnong 8
Liaoxiaodou 1
Jinlinghongdou
Ehongxiaodou 1

Table 3. Chemical composition of whole adzuki bean (Yousif *et al.* 2007).

Moisture	Ash*	Protein*	Lipid*	Fiber*	Carbohydrate*
8.2-12.0	4.0	24.5	0.5	-	71.0
11.0	3.8	22.1	0.4	4.3	56.7
11.9	3.2	21.4	1.6	4.3	57.6
-	3.7	21.9	1.8	3.3	69.3
11.1	4.4	22.7	2.1	-	70.8

*dry basis.

Table 4. Essential amino acid content of adzuki bean.

Amino acid	Content (g/16 g N)
Isoleucine	4.5
Leucine	7.8
Lysine	7.0
Methionine	1.8
Cystine	1.1
Phenylalanine	5.4
Tyrosine	3.4
Threonine	3.8
Valine	5.4

Table 5. Flavonoids and saponins contents in extracts from Adzuki Bean.

Peak no.	Compounds	Contents (mg/g ABTE)	Contents (mg/g ABF)	Contents (mg/g ABS)
2	Catechin	12.37	49.39	ND
7	Quercetin-3-O-rutinoside	225.99	404.73	ND
8	Quercetin-3-)-glucoside	21.37	90.08	ND
9	Vitexin-4$^{//}$-O-	36.66	74.60	ND

	glucoside			
10	Azukisaponin IV	6.63	ND	11.40
11	Azukisaponin VI	20.04	ND	206.35
12	Azukisaponin V	165.99	ND	283.21
13	Azukisaponin II	186.99	ND	389.73
14	Azukisaponin I	8.90	ND	5.42
15	Azukisaponin III	79.03	ND	27.58

ABTE adzuki bean total extract, *ABF* adzuki bean flavonoids, *ABS* adzuki bean saponins, *ND* not detected (Liu *et al.*, 2017).

Table 6. Health benefits of Adzuki bean.

Cholesterol-free
Good source of folate
Easy to cook with
Incredible delicious
Good for weight loss
Slow down the blood sugar and protect against diabetes
Easy to digest
A good source of Magnesium, Potassium, Phosphorous, Managanese and Iron
Fantastic source of protein
Good source of fiber

Adzuki cropping in different parts of China

Adzuki cropping pattern in South of China

The lowland regions of Southern provinces are not major production areas for adzuki bean, with complex terrain and various cropping system including intercropping, relay intercropping, and multiple cropping (Li *et al.*, 2017).

There are rice + adzuki bean multiple cropping systems, and maize + adzuki bean relay intercropping systems.

Adzuki cropping pattern for spring-sown areas

These areas are distributed in Inner Mongolia and the north part of Hebei, Shanxi, and Shaanxi with the main cropping patterns (one crop per year) as follows:

1) Adzuki bean- maize (sorghum) –millet
2) Adzuki bean- maize- sorghum
3) Adzuki bean- spring wheat- maize (flax)- maize
4) Adzuki bean- wheat- wheat
5) Adzuki bean- millet- maize- wheat

Northern cropping patterns for summer-sown areas

These areas are distributed in Shandong, Henen and South part of Hebei (Li *et al.* 2017). The main cropping patterns (with two crops per year) are as follows:

1) Winter wheat (barley)- adzuki bean- winter wheat (barley)- adzuki
2) Winter wheat (barley)- adzuki bean- cotton (maize, sorghum or millet)
3) Winter wheat (barley) –summer maize intercropping with adzuki bean- spring maize intercropped with soybean.
4) Spring wheat- millet (broomcorn millet)- adzuki bean
5) Winter wheat (barley)- maize intercropped with adzuki bean- winter wheat (barley)- maize intercropped with adzuki

Adzuki Bean and Nitrogen Fixation

Kimura *et al.* (2004) reported that adzuki bean has a remarkable peak of N accumulation in the early reproductive stage. And this is mainly due to N_2 fixation, though the soil nitrate level is high. They have concluded that adzuki bean absorbed N mainly for a short period and depended more on symbiotically fixed N_2 and, in contrast to common bean, left a high level of NO_3-N remaining in the soil after cropping. Delic *et al.* (2010) reported that strains of *B. japonicum* showed high potential of N_2 fixation, particularly 525 and 542. *B. japonicum* strains resulted 65-71% shoot dry weight and 99-138% total N content uninoculated control with full

N content (100%). No significant difference was found between the plants inoculated with *Bradyrhizobium spp*. strains and uninoculated control plants without N (40-42 and 42% shoot dry weight, respectively), which indicated symbiotic N_2 fixation inactivity of the *Bradyrhizobium spp*. strains. Knj strain had the middle position (56% shoot dry weight). These data showed that *B. Japonicum* 525 and 542 strains could be used in further investigations in order to apply them as inoculants in microbiological N fertilizers. Da silva *et al.* (2016) indicated that inoculation with Rhizobium strains and Molybdenum supply effectively contributed to biological nitrogen fixation and improving grain production. Abd-Alla (2011) noticed that isoflavonoid analysis from root extracts of grafted plants showed that NOD1-3 shoots had markedly higher root isoflavonoid concentrations in root of both NOD1-3 and common bean cv. Adzuki compared with self-grafts of common bean Adzuki. Exogenous application of daidzein, genistein, coumestrol, glycitein and in combination at concentration of 10 µmol to the nutrient solution significantly increased the nodule numbers of common bean cv. Adzuki. Kimura *et al.* (2004) concluded that adzuki bean absorbed N mainly for a short period and depended more on symbiotically fixed N_2 and, in contrast to common bean, left a high level of NO_3-N remaining in the soil after cropping.

Table 7. Various sources of nitrogen fixation (Dashora 2011).

No.	Source of N fixation	Nitrogen fixed (10^6 tons per year)
1	Land	153
2	Legume	39
3	Non-legume	10
4	Others	104
5	Sea	40
6	Total biological	193
7	Lightning	9
8	Industry	85
9	Total non-biological	94

Table 8. Average shoot dry weight, total and fixed N content of nodulated adzuki bean, *Vigna angularis* indicating to potential nitrogen fixation activity of *Bradyrhizobium* strains.

Treatment inoculated and [1]uninoculated	Shoot dry weight mg plant^{-1}	Symbiotic effectively (%)	%N	Shoot total n content mg plant^{-1}	Symbiotic effectively (%)	Shoot fixed N content mg plant^{-1}	[2]Actove groups of strains
525	320b	71	1.77	5.73ab	122	4.90ab	
532	310bc	69	1.68	5.37bc	114	4.54bc	
542	300bc	67	2.16	6.52a	138	5.71a	I
526	290bc	65	1.27	4.64bc	99	3.81c	
Knj	250cd	56	1.27	3.17d	67	2.34d	II
2001	210de	47	0.67	1.40e	30	0.63e	
2801	190e	42	0.56	1.08e	23	0.32e	III
5388	180e	40	0.71	1.26e	27	0.46e	
NΘ	450a	100	1.04	4.71bc	100	/	Controls
Θ	190e	42	0.45	0.83e	18	/	
LSD 0.05	47.9			0.870		0.867	
0.01	63.0			1.150		1.147	

[1] uninoculated controls: NΘ-with N and Θ-without N; [2] I-*B. japonicum*, II-Knj and III- *B. spp*. a-e: Means in a column followed by the same letter are not significantly different by Duncan ·s multipme range test at the 5% level (p≤0.05).

Table 9. Average nodule number, nodule dry weight, shoot and root length, root dry weight and total root N content nodulated adzuki bean, *Vigna angularis*.

Treatments inoculated and [1]uninoculated	Nodule N° plant^{-1}	Nodule dry weight mg plant^{-1}	Shoot length (cm)	Root length (cm)	Root dry weight mg plant^{-1}	Root total N content mg plant^{-1}
525	23.0b	55.20c	23.63b	31.06a	179a	2.72ab
532	24.6b	68.88a	23.64b	27.02abc	180a	2.59b
542	21.1c	44.31d	22.74bc	28.72ab	180a	3.42a
526	31.4a	62.17b	22.80bc	30.93a	160abc	1.58c
Knj	38.8a	43.20d	22.40bc	22.75bcd	170ab	1.70c
2001	6.5d	21.45e	22.12bc	24.85abc	140bcd	0.81d
2801	6.0d	5.40f	22.10bc	26.58abc	120d	0.62d

5388	7.0d	2.80f	20.97c	18.32d	130cd	0.74d
NΘ	/	/	27.16a	23.79bcd	170ab	1.70c
Θ	/	/	21.13c	20.96cd	120d	0.54d
LSD 0.05	3.5	6.08	1.55	4.57	26	0.67
0.01	6.0	7.98	2.05	6.03	34	0.82

[1] uninoculated controls: NΘ-with N and Θ-without N; [2] I-*B. japonicum*, II-Knj and III- *B. spp*. a-e: Means in a column followed by the same letter are not significantly different by Duncan ׳s multipme range test at the 5% level (p≤0.05).

Table 10. Nodulation and nitrogenase activity of adzuki inoculated with *Rhizobium legumiosarum* biovar *phaseoli* strain RCR 3622 and TAL 1383 (Abd-All 2011).

Plant species	Bacterial strain	Nodule number/plant	μmol C_2H_4/plant/h
Adzuki	RCR 3622	19	0.92
	TAL 1384	15	0.71

Means followed by the same letter in each column were not significantly different at the 5% level using LSD test.

CONCLUSIONS

Legumes help build soil fertility, their nitrogen fixation has other advantages in agro-ecosystem, including improved soil structure, deep rooting, erosion protection and contributing to greater biological activity and sustainability. Growing of leguminous plants can also benefits both the plants and soils by yielding nitrogen in the compound form. Adzuki beans fix atmospheric nitrogen by working symbiotically with special bacteria, rhizobia, which live in the root nodules. Rhizobia infect root hairs of the leguminous plants and produce the nodules. Adzuki beans are consumed in so many Asian countries such as China, Japan, Korea, Taiwan, Singapore, Indonesia, Malaysia, Thailand, Vietnam, India and Philippines. In both China and Japan, they are consumed daily as a dessert or snack especially in traditional Chinese festivals like Chinese New year. Adzuki beans are a rich source of carbohydrates, protein, vitamins, minerals, fiber and also contain anti-nutritional factors. Adzuki bean owns various pharmacological activities due to different extracts or individual compound. One of the most important role of Adzuki bean is balancing yield, which gives economic return, with the environmental and agronomic benefits.

REFERENCES

Abd-Alla, M. H. (2011). Nodulation and nitrogen fixation in iterspecies graft of soybean and common bean is controlled by isoflavonoid signal molecules translocated from shoot. Plant Soil Environ. 57(10):453-458.

Da Silva, A., Franzini, V. I., Piccolla, C. D., and Muraoka, T. (2016). Molybdenum supply and biological fixation of nitrogen by two Brazilian common bean cultivars. Revista Brasileira de Engenharia Agricola e Ambiental. 21(2):100-105.

Dashora, K. (2011). Nitrogen yielding plants: the pioneers of agriculture with a multipurpose. American-Eurasian Journal of Agronomy. 4(2):34-37.

Delic, D., Stajkovic, O., Rasulic, N., Kuzmanovic, D., Josic, D., and Milicic, B. (2010). Nodulation and N2 fixation effectiveness of *Bradyrhizobium* strains in symbiosis with adzuki bean, *Vigna angularis*. Brazilian Archives of Biology and Technology. 53(2) DOI: 10.1590/S1516-89132010000200007

Gphara, A. K., Souza, A. H. P. D., Gomes, S. T. M., Souza, N. E. S., Visentainer, J. V., and Matsushita, M. (2016). Nutritional and bioactive compounds of adzuki bean cultivars using chemometric approach. Ciencia e Agrotechnologia. 40(1):104-113.

Hu, S. (1980). An Enumeration of Chinese Materia Medica. Chinese University Press, Hong Kong.

Kimura, S. D., Schmidtke, K., Tajima, R., Yoshida, K., Nakashima, H., and Rauber, R. (2004). Seasonal N uptake and N_2 fixation by common and adzuki bean at various spacings. Plant and Soil. 258(1):91-101.

Kumar, R., Mittal, R. K., and Pandey, D. P. (2012). Genetic variability for yield and growth attricutes in adzuki. Research on Crops. 13(2):562-565.

Li, L., Liu, B., and Zheng, X. (2011). Bioactive ingredients in adzuki bean sprouts. Journal of Medicinal Plant Research. 5(24):5894-5898.

Li, L., Yang, T., Liu, R., Redden, B., Maalouf, F., and Zong, X. (2017). Food legume production in China. The Crop Journal. 5:115-126.

Liu, R., Zheng, Y., Cai, Z., and Xu, B. (2017). Saponins and flavonoids from Adzuki bean (*Vigna angularis L.*) amerliorate high-fat diet-induced obesity in ICR mice. Frontiers in Pharmacology. Volume 8. Article 687.

Liu, R., Cai, Z., Xu, B. (2017). Characterization and quantification of flavonoids and saponins in adzuki bean (*Vigan angularis L.*) by HPLC-DAD-ESI-MS^n analysis. Chemistry Central Journal, 11, 93.

Ogbaji, P. O., Li, J., Xue, X., Shahrajabian, M. H., and Egrinya, E. A. (2017). Survey yield components of Spinach under influence of biofertilizer and nutrient solution in soils of Chengdu, Hunan, Shannxi and Xiaotanshan, China. Research on Crop Ecophysiology. 12(1):1-8.

Ogbaji, P. O., Li, J., Xue, X., Shahrajabian, M. H., and Egrinya, E. A. (2018). Impact of bio-fertilizer or nutrient solution on Spinach (*Spinacea Oleracea*) growth and yield in some province soils of P. R. China. Cercetari Agronomic in Moldova. 2(174): 43-52.

Redden, R. J., Basford, K. E., Kroonenberg, P. M., Amirul Islam, F. M., Ellis, R., Wang, S., Cao, Y., Zong, X., and Wang, X. (2009). Variation in adzuki bean (*Vigna angularis*) germplasm grown in China. Crop Science. 49:771-782.

Reddy, C. K., Luan, F., and Xu, B. (2017). Morphology, crystallinity, pasting, thermal and quality characteristics of starches adzuki bean (*Vigna angularis L.*) and edible kudzu (*Pueraria thomsonii Benth*). International Journal of Biological Macromolecules. 105:354-362.

Shahrajabian, M. H., Soleymani, A., and Khoshkharam, M. (2017). Influence of green manuring from different cover crops and farm yard manures on quantitative and qualitative characteristics of forage corn in low input farming. Research on Crop Ecophysiology. 12(2):62-68.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2018). A review of goji berry (*Lycium barbarum*) in traditional Chinese medicine as a promising organic superfood and superfruit in modern industry. Academia Journal of Medicinal Plants. 6(12):437-445.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019a). The power of natural Chinese medicine, ginger and ginseng root in an organic life. Middle-East Journal of Scientific Research. 27(1):64-71.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019b). Clinical aspects and health benefits of ginger (*Zingiber officinale*) in both traditional Chinese medicine and modern industry. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science. 1-11.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019c). Traditional Chinese medicine and agriculture; organic life and sustainability for future. GSC Biological and Pharmaceutical Sciences. 7(1):91-95.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019d). A review of ginseng species in different regions as a multipurpose herb in traditional Chinese medicine, modern herbology and pharmacological science. Journal of Medicinal Plants Research. 13(10): 213-226.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011a). The responses of qualitative characteristics and solar radiation absorption of berseem clover cultivars to various nitrogen fertilizer levels. Journal of Food, Agriculture and Environment. 9(2):319-321.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011b). Changes in qualitative characteristics and yield of three cultivars of berseem clover intercropped with forage corn in low input farming system. Journal of Food, Agriculture and Environment. 9(1):345-347.

Soleymani A., and Shahrajabian, M. H. (2012a). Forage yield and quality in intercropping of forage corn with different cultivars of berseem clover in different levels of nitrogen fertilizer. Journal of Food, Agriculture and Environment. 10(1 part 2):602-604.

Soleymani, A., and Shahrajabian, M. H. (2012b). Influence of nitrogen fertilizer on ash, organic carbon, phosphorus, potassium and fiber of forage corn intercropped by three cultivars of berseem clover as cover crops. International Journal of Biology. 4(3):38.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2012). Evaluation the benefits of different berseem clover cultivars and forage corn intercropping in different levels of nitrogen fertilizer. Journal of Food, Agriculture & Environment. 10(1 part 2):599-601.

Soleymani, A., and Shahrajabian, M. H. (2018). Changes in germination and seedling growth of different cultivars of cumin to drought stress. Cercetari Agronomice in Moldova. 1(173):91-100.

Tazawa, H., Kano, H., Matsumoto, N., and Murakami, M. (2018). Aroma compounds contributing to the flavor of Adzuki bean jam used for Dorayaki sweets. Journal of the Integrated Study of Dietary Habits. 29(1):45-52.

Yong, Y., and Shahrajabian, M. H. (2017). Evaluation of the benefits of oat-soybean and oat-groundnut intercropping in Jilin province, China. Research on Crop Ecophysiology. 12(1):98-106.

Yong, Y., Hu, Y., Shahrajabian, M. H., Ren, C., Guo, L., Wang, C., and Zeng, Z. (2017). Organic matter, protein percentage, yield competition and economics of oat-soybean and oat-groundnut intercropping systems in Northern China. Cercetari Agronomic in Moldova. 3(171):25-35.

Yong, A., Hu, Y., Shahrajabian, M. H., Ren, C., Guo, L., Wang, C., and Zeng, Z. (2018). Changes in dry matter, protein percentage and organic matter of soybean-oat and groundnut-oat intercropping in different growth stages in Jilin province, China. Acta Agriculturae Slovenica. 111(1):1-7.

Yousif, A. M., Kato, J., and Deeth, H. C. (2007). Effect of storage on the biochemical structure and processing quality of Adzuki bean (*Vigna angularis*). Food Reviews International. 23:1-33.