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SHORT COMMUNICATION

Adaptation of New Adzuki Bean Variety for Organic Production System in Bhutan

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ABSTRACT

Adzuki bean (Vigna angularis Willd.) is a native legume that is cultivated by subsistence Bhutanese farmers as one of the many other pulses for household food security. Several scientific literatures have revealed that many Bhutanese Adzuki bean germplasm has been assessed for genetic variability confirming that Adzuki bean is native to Bhutan. The cultivation of Adzuki bean currently is confined to small areas as a marginal crop for household consumption. The drive towards a certified organic production system in Bhutan has called for an urgent need to adapt, release and promote organic technologies, particularly on organic pests and diseases, and sustainable soil fertility management. Adaptation of high-yielding Adzuki bean varieties and their commercialization as a health food, high-value crop for export, and a good source of nitrogen for sustainable soil fertility management was studied. One new Japanese variety Erimo was rapidly evaluated in the researcher-managed and farmer-managed trials under the organic production system at different locations. The seed yield in the researcher-managed trial was significantly different over locations ($P<0.05$) and ranged from 540 to 1215 kg ac^{-1} with a mean yield of 907.50 kg ac^{-1}. Under the farmer-managed trials in the 2020 season, seed yield ranged from 150 to1080 kg ac^{-1} with a mean of 431.40 kg ac^{-1}. The days to crop maturity ranged from 104 to 126 days which fits well into the farmers' existing cropping system. The 23rd Variety Release Committee (VRC) of the DoA endorsed the release of this variety Erimo with the local name Yusi-Adzuki. This variety will be promoted for commercial cultivation for export to Japan, and as a sustainable soil fertility management technology in the organic production system.

Keywords: *Adzuki bean; Legume; Organic system; Yield; Variety release*

1. Introduction

Adzuki bean (*Vigna angularis* Willd.*)* commonly known as adzuki bean, red bean, and red mung bean is an annual legume that belongs to the Fabaceae family (Sindhu & Manickavasagan, 2020). The scientific community has established that the Adzuki bean was domesticated in China 12,000 years ago and it is currently cultivated in more than 30 countries,

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especially in the East Asia region. In Bhutan, the Adzuki bean is traditionally cultivated by subsistence farmers as one of the many pulses for household food security. However, it has largely remained as a marginal crop that is cultivated in a small area for household consumption because of its low economic value. Several scientific literatures mention the assessment of Bhutanese Adzuki bean germplasm for genetic variability which indicates that Adzuki bean is native to the Bhutanese agriculture systems. A study conducted by Isemura et al. (2001) has reported the use of 43 Bhutanese Adzuki bean strains which demonstrated region-specific traits and distinct differences in morphological characters. In another study on geographical distribution and evolutionary relationships between cultivated and wild Adzuki bean, cultivated Adzuki bean germplasm from Bhutan and Nepal have been used indicating that Adzuki bean is indigenous to Bhutan (Xu-xiao et al., 2003). These studies confirm the cultivation of Adzuki bean in Bhutan and its role in the Bhutanese food system.

Adzuki bean is a traditional legume crop that plays an important role as a source of protein and a versatile nitrogen-fixing legume that has been used for biological nitrogen fixation for sustainable soil fertility management in agriculture (Sun, Shahrajabian, & Cheng, 2019). Further, Adzuki bean is considered to be highly nutritious that is rich in protein, minerals, carbohydrates, and fibre, and is used in various forms such as extract and paste (Kimura et al., 2004; Sindhu & Manickavasagan, 2020). According to Shahrajabian et al. (2019), Adzuki bean has considerable potential to be a global functional food for health, nutrition, and prevention of many lifestyle diseases. It has broad adaptability, high tolerance to poor soil fertility, and is a high-value rotation legume crop that contributes to the improvement of soil through nitrogen fixation under organic farming systems (Kharwal, Singh, & Bhardwaj, 2020). It has been concluded by Kimura et al. (2004), that Adzuki bean adds a significant level of nitrogen in the form of nitrate-nitrogen (NO_3-N) in the soil after its cropping cycle. The root system of Adzuki beans has a high ability for symbiotic nitrogen fixation and the crop has the special ability to accumulate nitrogen in the early reproductive stage. In an organic production system, maintaining and sustaining soil fertility remains a practical challenge since the use of synthetic fertilizers is prohibited. Amongst many other approaches for maintaining soil fertility, the cultivation of legumes for biological nitrogen fixation through suitable crop rotations and intercropping practices is a feasible option recommended to farmers (Forster et al., 2012). The other advantages of legume cultivation, apart from food security, include huge benefits to soil by way of reducing its compaction, and erosion, improving its structure, enhancing organic matter and soil microbial activity, and nitrogen content through nitrogen fixation (Kocira et al.,

2020). Further, Wyngaarden, Gaudin, Deen, and Martin (2015), have concluded that the inclusion of a suitable legume as cover crops in a cropping system increases agro-ecological resilience and crop productivity through nitrogen fixation, soil temperature, and moisture regulation; reduction of erosion, runoff, and leaching; suppresses weeds and disrupts the cycle of established pests and diseases. Adzuki bean could also be promoted as a cover crop to improve both soil fertility and productivity in the organic system.

Bhutanese agriculture represents a traditional mountain farming system that is integrated into sustaining livelihood, the health of soils, ecological processes, biodiversity, and nutrient cycle with only 37% of the farmers using agrochemicals in 19% of the cultivable land. This situation provides a strong basis to adopt organic farming (MoAF, 2018). Through the National Organic Flagship Program (NOFP), several potential landscapes have been supported for rapid conversion from natural farming to a certified organic production system. This drive and focus towards a certified organic production system have created a pressing necessity to adapt, release and promote organic technologies, particularly on organic pests and diseases, and sustainable soil fertility management.

Grain legumes are an important component of Bhutanese agriculture production systems and are popularly grown as pulses, vegetables, and fodder for household food security, animal feeds, and for sale in cases of small surpluses. The role of legumes as a contributor to soil nutrient management is poorly understood and rarely exploited by farmers. However, any crop in subsistence smallholder systems has to first contribute to household food security and income generation. The national drive to transition to Organic production systems thus provides an enormous opportunity for the integration of potential legumes that serve as a source of food, income, and soil nutrient management. In the warm temperate agroecosystem (1800 -2600 masl), apart from Peas (*Pisum sativum*), there are no suitable legumes with high market value resulting in limited diversity of legume crops, particularly for the organic production system. The introduction and adaptation of new high-yielding varieties of Adzuki bean which is a nutritious and healthy food with a very good market potential in Japan, and high nitrogen fixation ability provides Bhutanese farmers with a new opportunity. The four underlying complimentary benefits of including pulses in the food systems are food security, health, sustainable agriculture, and adaptation to climate change emanating from its large genetic diversity and climate-resilient varieties (Calles., 2016). In a study to assess the effects of large-scale conversion to organic farming in Bhutan, Feuerbacher et al. (2018) have recommended the adoption of nitrogen-fixing crops, improved animal husbandry systems to enhance animal

manure production, and access to markets with a price premium for organic products as some of the suitable adaptation strategies to bridge the average yield gap of 24% between organic and conventional production systems.

The work on the adaptation of the Japanese Adzuki bean variety *Erimo* was initially started in 2013 at the National Centre for Organic Agriculture (NCOA), Yusipang which was declared an organic farm in 2004 by the Department of Agriculture (DoA). However, the work was discontinued because the desired volume required by the Japanese entrepreneur for export could not be met by the farmers. In 2020, NCOA, Yusipang was again assigned to coordinate and undertake the fast-track evaluation and release of Adzuki bean variety with the reintroduction of the Japanese variety *Erimo*. Accordingly, NCOA Yusipang initiated the evaluation of this variety through researcher-managed trials and on-farm trials under farmers' management under an organic production system. *Erimo* variety is used to prepare bean paste and is the most preferred variety for Japanese consumers. This variety bred for the Japanese market is considered superior to Blood Wood, another high-yielding and early maturing variety highly popular in the Japanese market (Motley, McCaffery, & Lachlan 2004).

The three underlying objectives of this study were to rapidly assess the adaptability of the new Japanese Adzuki bean variety *Erimo* under an organic production system in the warm temperate agro-ecology in Bhutan; to release a new high yielding variety with a good yield potential that is acceptable for export to Japan; and to recommend and upscale the commercial cultivation of Adzuki bean as a new alternative high-value legume for food security, income, and sustainable soil fertility management under the organic production system in Bhutan.

2. Materials and Method

In the 2020 cropping season, the researcher-managed trials and on-farm trials adaptation were conducted under the organic production system. The researcher-managed trials were conducted under the direct supervision of researchers at three organic sites: Yusipang and Khariphu in Thimphu, and Khatoe in Gasa (Table 1). Adzuki beans variety *"Erimo"* supplied by the Japanese company SUN SMILE Co., Ltd. was evaluated in large observation plots. At Yusipang and Khariphu, the crop was established on the 14th and 15th of May 2020, respectively while at Khatoe the crop was planted on the 2nd of July, 2020. Seeds were sown in line with a row-to-row distance maintained at 0.65 m and plant-to-plant spacing of 0.20 m. At least three to four seeds were sown on each hill without the preparation of any raised beds. The seed rate used was 20 kg ac^{-1}. Locally produced Farm Yard Manure (FYM), vermicompost, and chicken

manure were applied in sufficient quantity during the field preparation. Being an organic production system no in-organic fertilizers and pesticides were applied. Crops were grown under rain-fed conditions. At least four times manual weeding was done to keep the crop free of weed competition.

On-farm adaptation trials managed by farmers were conducted under the organic production system in five locations (Table 3). In the on-farm trials, seed sowing started in May and continued till the end of July depending on the altitude of the location. In higher elevations, early planting was started by the first week of May and continued till mid-June. In all the trial sites, seed sowing was demonstrated by the field crops researchers from the NCOA and Agriculture Research and Development Centre (ARDC), Wengkhar, Mongar.

For both types of trials, data were collected by the researchers from NCOA, Yusipang, and ARDC, Wengkhar with assistance from the dzongkhag agriculture extension officers. At each site, three standard plots (Department of Agriculture [DoA], 2020) each measuring 6 m^2 were randomly marked for collecting the data on yield parameters. Data on morphological characteristics were collected as per the International Union for Protection of New Varieties of Plants (UPOV) guidelines for the conduct of tests for distinctness, uniformity, and stability in Adzuki bean (UPOV, 2015). Both qualitative and quantitative data were collected to evaluate its performance. Data was compiled and computed in MS Excel which was then analyzed using SPSS Version 22.

3. Results and Discussion

The rapid assessment of this new Japanese variety under the organic production system in 2020 and further adaptation in some new locations in 2021 have shown promising results. Results from the researcher-managed trials and on-farm farmer-managed trials are discussed.

3.1 Evaluation under researcher managed trial in three sites under organic production system

In 2020, the researcher-managed trials were conducted in five locations under the organic production system (Table 1). The seed yield was significantly different over locations ($P<0.05$). The seed yield ranged from 540 to 1215 kg ac^{-1} with a mean yield of 907.50 kg ac^{-1}. The seed yield at different locations differed significantly and the difference among the sites could be underpinned by various factors such as soil fertility, water availability, and crop management. The higher mean seed yield at Yusipang and Khariphu is attributable to a higher number of pods per plant as compared to in Khariphu. Further, the crop at Yusipang was given

supplementary irrigation and optimum weed management as compared to two other sites due to distance. Researchers at the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in India who have evaluated 15 genotypes of Adzuki bean under inorganic and organic production systems have reported the mean seed yield of 100.36 and 284.08 kg ac^{-1}, respectively (Kharwal et al., 2020). The mean seed yield of Adzuki bean in China which is considered the centre of origin of this crop is 638 kg ac^{-1} or 1595 kg ha^{-1} (Li et al., 2017). In a yield trial of 231 Chinese germplasm evaluated in Australia, a mean seed yield of 824.00 kg ac^{-1} (2,060 kg ha^{-1}) has been reported by Wang et al. (2001). The mean seed yield of Japanese varieties *Erimo* and *Bloodwood* which were included as checks in this trial was 656 kg ac^{-1} (1,640 t ha^{-1}) and 640 kg ac^{-1}(1,600 t ha^{-1}), respectively.

Table 7. Seed yield and other agronomic traits in three locations, 2020

Locations	Plant height (cm)	Length of pod (cm)	Number of pods/plant	Number of seeds/pod	Seed yield kg ac^{-1}
Yusipang	67.93	11.56	60	6	1215.00
Khatoe	37.47	9.90	34	6	540.00
Khariphu	67.89	10.57	61	7	967.50
Mean	57.76	10.68	52	6	907.50
P value	<0.001	<0.001	<0.05	<0.001	<0.05
Std. Dev (±)	17.57	0.84	15	0.58	341.48

Adzuki as a new crop has to be accepted by the Bhutanese farmers and it has to fit into their established cropping system. The days to maturity of any crop are very critical to recommend and fit this crop in the farmer's existing system. The days to maturity of Adzuki bean in three researcher-managed trial sites ranged from 104 to 126 days with a mean value of 116 days (Table 2).

Table 8. Crop maturity (days) in three locations, 2020

Sites	Date of sowing	Date of Final harvest	Days to 50 % Flowering	Days to maturity
Yusipang	14.5.2020	17.9.2020	65	126
Khariphu	15.5.2020	11.9.2020	70	119
Khatoe	2.7.2020	13.10.2020	70	104
Mean			68	116

3.2 On-Farm evaluation in five sites under organic production system

In the farmer-managed on-farm trials under organic production system in five sites in the 2020 cropping season, the seed yield ranged from 150 to1080 kg ac^{-1} with a mean of 431.40 kg ac^{-1} (Table 3). In the 2021 cropping season, Adzuki bean was again evaluated in more sites under the organic production system. The seed yield recorded in 2021 ranged from 200 to 782.61 kg

ac^{-1} with a mean yield of 427.20 kg ac^{-1} (Table 4). The seed yield recorded under farmers' management in both years is comparable to yields obtained in other countries although the mean yield is comparatively low. One of the critical yield-limiting factors observed in the farmer's field was heavy weed pressure. In the warm temperate areas, Adzuki season falls in the summer season which favours high weed competition. Yield loss from weed infestation is a major production impediment in Adzuki beans (Soltani, Brown, & Sikkema, 2020). The package of practices for Adzuki bean production needs to evaluate and recommend suitable weed control measures as the shortage of farm labour is a major constraint in Bhutan.

Table 9. Seed yield of Adzuki bean, under organic system under farmers management, 2020

Dzongkhag	Gewog	Village	Altitude (masl)	Seed yield kg ac^{-1} at 14% MC
Thimphu	Mewang	Khariphu	2280	1080
Paro	Luni	Chimkha	2700	150
Haa	Samar	Nobgang	2600	150
Gasa	Khatoe	Jabisa	2500	540
Mongar	Mongar	Mongar	640-2100	237
Mean yield kg ac^{-1}				431.40
Std. Dev (±)				396.43

Table 10. Seed yield of Adzuki bean under organic system, 2021

Dzongkhag	Gewog	Village	Seed yield kg ac^{-1} at 14% MC
Chhukha	Bongo	Boeri	782.61
Chhukha	Geling	Chanachen	225.00
Paro	Luni	Chimakha	200.00
Thimphu	Chang	Yusipang	501.20
Mean yield kg ac^{-1}			427.20
Std. Dev (±)			273.43

The time for the maturity of Adzuki beans in warm temperate zones ranged from 104 to 126 days. This result also indicates that adzuki can very well fit as a second crop in the warm temperate agro-ecology after the early harvest of potato, the first crop of vegetables, and winter wheat or barley. The most suitable rotations for Adzuki bean in the warm temperate region (1800 -2600 masl) are Adzuki bean – winter wheat; Adzuki bean-barley; Adzuki bean-vegetables (peas, carrot, radish, cole crops); potato- Adzuki bean; vegetables (cole crops)-Adzuki bean; and Adzuki bean- mustard. In the wet and dry sub-tropical region (600-1800 masl) Adzuki bean can fit into several rotations but the most suitable ones are maize- Adzuki bean; winter wheat/barley- Adzuki bean; potato- Adzuki bean; and vegetables- Adzuki bean.

In the lower elevations below 600 masl, Adzuki bean can be grown as a winter crop after harvesting maize.

3.3 Phenotypic characteristics

It is important to study the crop phenotypic appearances of new crops. The basic phenotypic characteristics based on the UPOV DUS scale observed in the warm-temperate agroecology in Bhutan are presented in Table 5. The adzuki bean variety is an indeterminate type with sequential flowering and at least three harvests have to be done.

Table 11. Phenotypic characteristics of Adzuki bean variety Erimo as expressed under the Warm- temperate agroecology in Bhutan, 2020

No	Characters	Phenotypic descriptions (UPOV DUS Scale)	Observations
1	Days to flowering	50% Flowering	68
2	Plant growth type	Dwarf, climbing	Dwarf
3	Leaf colour	Very light, light, medium, dark. very dark	Light-medium green
4	Leaf shape	Triangular, circular, rhombic, triangular or rhombic, circular or rhombic	Rhombic
5	Flower bracts	Small, medium, large.	Medium
6	Flower colour	White, pinkish-white, pink, violet	Light yellow
7	Pod colour (mature)	Yellow, green, violet, brown	Brown
8	Pod shape	Concave, S-shaped, convex, cylindrical	Cylindrical
9	Seed shape	Circular, circular to elliptical, elliptic, cylindrical, kidney-shaped, rectangular	Cylindrical

4. Conclusion

NCOA Yusipang has adapted Adzuki bean as a potential legume crop for the organic production system with a high nutritional and commercial value and with an assured export market in Japan. Adzuki bean is a versatile pulse that can be successfully cultivated from humid sub-tropical (150-600 masl) to warm temperate (1800 -2600 masl) agroecology in Bhutan. Appreciable seed yields have been obtained even under farmers' management. Private entrepreneurs have shown keen interest to export Adzuki beans to Japan and have already offered a farm gate price of Nu. 250 per kg. However, production at the required scale for the export market with high-quality beans needs to be achieved. Several studies elsewhere have recommended that the inclusion of a suitable legume in the organic production system is considered one of the most sustainable options to improve and enhance soil fertility. Adzuki bean fixes atmospheric nitrogen symbiotically with special bacteria (rhizobia) that thrive in the root nodules. The promotion of Adzuki bean as a commercial pulse under the organic

production systems will have two far-reaching benefits - income generation and sustainable soil fertility improvement. Competition from weeds has been observed as one of the major yield-limiting factors in Adzuki beans. It is therefore very important to evaluate and recommend suitable weed control methods as the shortage of farm labour is a major issue in Bhutan. With the endorsement of the release of the new variety *Yusi-Adzuki* by the 23rd VRC of the DoA, and assured export market, seed production and rapid promotion of this crop need to be taken up in the organic landscapes across the country. Further, the commercial cultivation of Adzuki beans as new organic technology will contribute to household food security, income generation and serve as a pragmatic option for sustainable soil fertility management under the organic production system in Bhutan.

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