

Weed Azuki Bean, an Overlooked Representative

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Abstract

Two forms of prostrated and slightly branching Azuki bean (*Phaseolus angularis* W.F. Wight) grow naturally in the ruderal and cultivated fields in central Japan. These have larger leaves and thick stem, like the cultigen, and have easily dehiscent black pods similar to the wild Azuki bean (*P. angularis* var. *nipponensis* Ohwi). Two forms have seeds intermediate in size between the cultigen and wild Azuki beans. The black-seed form shows relatively larger plant stature and is seen in ruderal sites and edges of cultivated fields, and the yellow-green-seed form is found in orchard fields and kitchen gardens as a weed. These overlooked representatives may have an important role in our understandings of the process of domestication and may provide a unique genetic resource in improvement of the cultigen.

Introduction

Wild relatives of crop plant are potential genetic resources in crop improvement^{1,2}). Wild forms of cultivated plant are frequently found in habitats under human disturbance. Harlan and de Wet (1965)³) defined such forms as weed races, and de Wet and Harlan (1975)⁴) pointed out their evolutionary importance in the domestication of crop plants.

The Azuki bean (*Phaseolus angularis* (Willd.) W.F. Wight; syn: *Vigna angularis*) is an economically valuable leguminous crop in Northeast Asia. Though the wild ancestor of the Azuki bean is not yet known, wild Azuki (*P. angularis* var. *nipponensis* (Ohwi) Ohwi) is considered to be one of the native plants of Japan by Japanese taxonomists⁵). In spite of the necessity of agronomical surveys on the wild Azuki bean to understanding the origin of variation in cultigens, there have few studies on variation in wild Azuki bean populations.

During my preliminary exploration of the wild Azuki bean, a semi-wild representative was found in ruderal and cultivated fields at separate places in Japan. The present paper describes this overlooked representative of Azuki bean and estimates its seed and pod size.

Materials and Method

Materials collected in 1988 and several cultivars for control were listed in Table 1. The explored area is restricted to the Kinki district and its surroundings. Cultivar materials for control are samples collected in 1988 and samples cultivated in the college farm in 1988. For convenience, the author refers to each accession or cultivar by a short code, for example J-1 (= Azn/88-J-1) or cv-K-1 in the present paper.

At each site, up to 50 well-developed and matured pods which contained many seeds were randomly sampled. Plants were also collected for herbarium specimens. Observa-

Table 1 Locality and habitat of materials

Accession	Locality	Habitat or cultivar name
<i>Var. nipponensis</i>		
Azn/88-J-8	Torigoe, Ishikawa, Ishikawa	Roadside
Azn/88-J-6	Yoshino, Torigoe, Ishikawa	Riverside
Azn/88-J-7	Kamashimizu, Torigoe, Ishikawa	Roadside
Azn/88-J-9	Tougou, Fukui, Fukui	Roadside waste
Azn/88-J-10	Imajou, Nanjou, Fukui	Edge of vacant fields
Azn/88-J-1	Chinai, Makino, Shiga	Riverside
Azn/88-J-12	Imazu, Imazu, Shiga	Vacant site for housing
Azn/88-J-19	Fukuzumi, Sasayama, Hyougo	River bank
Azn/88-J-22	Ochikata, Nishiki, Hyougo	River bank
Azn/88-J-3	Chihaya, Kawachinagano, Osaka	Railwayside
Azn/88-J-2	Chihaya, Kawachinagano, Osaka	Unpaved-road side
Azn/88-J-4	Chihaya, Kawachinagano, Osaka	Riverside
Azn/88-J-13	Amami, Kawachinagano, Osaka	Railwayside
Weed race-1		
Azn/88-J-5	Shiramine, Ishikawa, Ishikawa	Azuki bean field
Azn/88-J-21	Sakamoto, Nishiki, Hyougo	Tea garden
Azn/88-J-16	Kimitouge, Hashimoto, Wakayama	Railwayside
Azn/88-J-14	Miyukituji, Hashimoto, Wakayama	Edge of parking area
Azn/88-J-23*	Nojiri, Totsukawa, Nara	Roadside
Azn/88-J-15	Mitsu, Mitsu, Okayama	Roadside
Weed race-2		
Azn/88-J-11	Shiotsu, Nishiasai, Shiga	Kitchen garden
Azn/88-J-20	Fukuzumi, Sasayama, Hyougo	Roadside
Azn/88-J-17	Deto, Hashimoto, Wakayama	Kitchen garden
Azn/88-J-18	Deto, Hashimoto, Wakayama	Orchard field
Cultivar for control		
Aza/74-K-1	Tongsanmyon, Kanwon, Korea	“Hwajoen”** race
Aza/74-K-2	Tongsanmyon, Kanwon, Korea	“Hwajoen” race
Aza/87-K-3	Hamdok, Cheju, Korea	Landrace
Aza/88-J-2	Shiramine, Ishikawa, Ishikawa	Landrace
Aza/88-J-1	Shiotsu, Nishiasai, Shiga	Landrace
Aza/88-J-15	Fukuzumi, Sasayama, Hyougo	‘Shiro Azuki’
Aza/88-J-16	Kuroishi, Konda, Hyougo	‘Hachigatsu Azuki’
Aza/88-J-17	Hongou, Nishiki, Hyougo	Landrace ‘Dainagon’

*, supplied by E. Takei; **, Korean type of swidden.

tions were recorded on the pod and herbarium samples. In order to determine the degree of domestication in each accession, seed size and pod traits were evaluated quantitatively. Seed size (length, thickness, and width) was measured on 10 grains per accession; for expressing seed size, the index of seed size (I) was calculated as follows;—

$$I = \sqrt[3]{\text{length} \times \text{thickness} \times \text{width}} \quad (\text{mm})$$

Length and width were measured on 10 pods per accession.

Results and Discussion

Observation and Classification. All the observed plants showed yellow flowers with linear long floral bract, twice as long as the caryx-tube. Their black pods cling to the floral stalk exactly downward, and their seeds all have a flat and striate navel. Based on these traits, it is clear that all the samples belong to *P. angularis*. Collected samples were preliminarily classified into following three categories based on visible traits (i.e., plant type, pod size, and seed color):

Var. nipponensis: Thirteen accessions from the Kinki district have branching thin stems, small thin leaves, black gentle pods and small green-variegated black seeds (Table 2, Plates 1, 4, 5, 6). The plants are distinctly climbers, and occur in ruderal and covering sites near natural vegetation (Plate 1, Table 2).

Weed race-1: Five accessions have relatively large stems and occur in more ruderal sites than those in which var. *nipponensis* occurs (Table 1). This race shows less branching and rather determinate growth habit in ruderals, and sometimes are of an erect-plant type similar to cultigens in an open habitat (Plate 2). This race has relatively large leaves (Plate 4), long black pods (Plate 5, Table 2), and green-variegated black seeds (Plate 6).

Weed race-2: Four accessions have relatively thin stems and show more branching than weed race-1 (Plate 3). This race occurs in arable land as a weed (Table 1) and has intermediate-sized leaves (Plate 4) and greenish yellow (brown) seeds (Table 2, Plate 6). In Deto, Wakayama prefecture, the farmers recognize this race as a weed by the black color and easily dehiscent pods (Plate 5), and they usually remove the plants from the cultivated fields. This race sometimes intensively invades Azuki bean fields, and a "change of seed" has sometimes occurred in cultivated Azuki beans.

Evaluation of seed traits. The seeds of var. *nipponensis* were small (Table 2). The average length, thickness, and width of seed ranged from 3.78 to 4.59 mm, from 2.76 to 3.45 mm, and from 2.37 to 2.87 mm, respectively. The average seed size index ranged from 2.91 to 3.61. The J-12 accession has the smallest seeds, and the J-4 accession the largest seeds in var. *nipponensis*. Two weed-races have seeds intermediate-sized between var. *nipponensis* and cultigen. Average length, thickness, and width of seeds ranged from 4.45 to 5.78 mm, from 3.61 to 3.93 mm, and from 3.03 to 3.39 mm, respectively. Average index of seed size ranged from 3.67 to 4.16 in the weed race. The J-11 accession shows the smallest seed size and the J-20 accession the largest size in the weed race. Cultivars showed rather large seed size with a wide range of variation compared to wild and weed Azuki beans. In cultivars, the average index of seed size ranged from 3.82 to 6.48; and their seed size is distinctly different from that of var. *nipponensis*.

Evaluation of pod traits. Pod size was evaluated on a part of my accessions of wild and weed Azuki beans (Table 3). Pod length and width are shorter in var. *nipponensis* than in the weed race. The number of seeds per pod is not significantly different in wild and weed representatives. Shape, color, and dehiscence of the pod did not show a marked difference in wild and weed Azuki beans. Although pod traits of the cultivar were not evaluated, the pod of the present-day cultivars is longer and thicker than that in wild and weed Azuki beans. Cultivars usually show indehiscent white (or straw color) pods with papiriferous pod-wall.

Although the traits evaluated in the present survey are relatively instable, differences

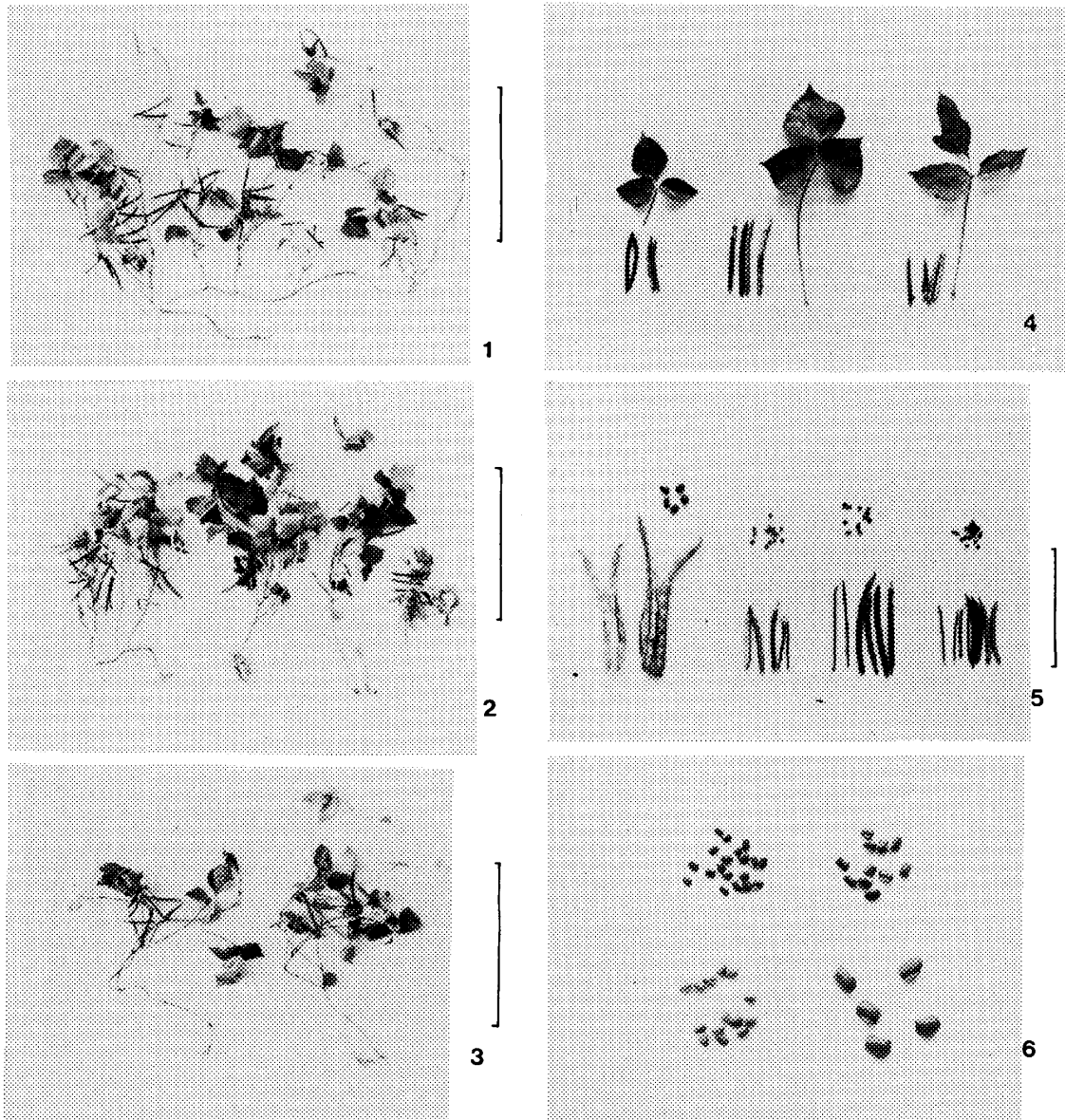


Plate 1 Plant of var. *nipponensis*.
Bar indicates 30 cm.

Plate 2 Plant of weed race-1.
Samples from relatively open habitats. Bar indicates 30 cm.

Plate 3 Plant of weed race-2.
Bar indicates 30 cm.

Plate 4 Ternate leaf and pod.
Left, var. *nipponensis*; center, weed race-1; right, weed race-2.

Plate 5 Pods and seeds.
Left to right, 'Dainagon'; var. *nipponensis*; weed race-1; weed race-2.
Bar indicates 10 cm.

Plate 6 Seeds of wild, weed and cultivated Azuki bean.
Upper left, var. *nipponensis*; upper right, weed race-1; below left, weed race-2;
below right, 'Dainagon'.

Table 2 Variation in seed size (mm) and color in Azuki beans

Accession	Seed length	Seed thickness	Seed width	Size index I (Range)	Color
<i>Var. nipponensis</i>					
J-8	3.87	3.28	2.83	3.30 (3.18–3.40)	Black, variegated
J-6	3.97	3.32	2.66	3.27 (3.00–3.49)	Black, variegated
J-7	4.02	3.24	2.76	3.30 (3.07–3.50)	Black, variegated
J-9	4.22	3.33	2.68	3.35 (3.22–3.51)	Black, variegated
J-10	4.53	3.27	2.72	3.42 (3.26–3.57)	Black, variegated
J-1	3.92	2.94	2.49	3.06 (2.78–3.36)	Black, variegated
J-12	3.78	2.76	2.37	2.91 (2.78–3.03)	Black, variegated
J-19	4.04	3.23	2.87	3.34 (3.07–3.74)	Black, variegated
J-22	4.19	3.20	2.84	3.36 (3.16–3.55)	Black, variegated
J-3	4.03	3.14	2.68	3.23 (3.05–3.70)	Black, variegated
J-2	4.59	3.35	2.77	3.49 (3.28–3.75)	Black, variegated
J-4	4.40	3.45	3.11	3.61 (3.17–3.83)	Black, variegated
J-13	3.89	3.28	2.74	3.27 (3.15–3.35)	Black, variegated
Weed race-1					
J-5	4.65	3.63	3.06	3.72 (3.59–3.83)	Black, variegated
J-21	4.50	3.61	3.21	3.73 (3.56–3.89)	Black, variegated
J-16	5.40	3.89	3.33	4.12 (3.88–4.45)	Black, variegated
J-14	4.72	3.83	3.26	3.89 (3.68–4.07)	Black, variegated
J-23	5.24	3.66	3.39	4.02 (3.71–4.38)	Black, variegated
J-15	4.45	3.86	3.27	3.83 (3.47–4.14)	Black, variegated
Weed race-2					
J-11	4.51	3.63	3.03	3.67 (3.46–3.84)	Green yellow
J-20	5.78	3.93	3.17	4.16 (3.82–4.41)	Green yellow
J-17	4.62	3.71	3.15	3.78 (3.54–4.03)	Green yellow
J-18	4.66	3.83	3.22	3.85 (3.49–4.17)	Green yellow
Cultivar					
cv-K-1	5.45	4.26	3.79	4.45 (4.24–4.61)	Black, variegated
cv-K-2	5.20	3.54	3.03	3.82 (3.54–4.05)	Red
cv-K-3	5.43	4.21	3.96	4.49 (3.99–4.83)	Red
cv-J-2	6.77	5.70	4.77	5.68 (5.20–6.17)	Red
cv-J-1	6.91	5.12	4.83	5.55 (5.05–5.82)	Red
cv-J-15	6.41	4.88	4.74	5.29 (4.84–5.67)	White
cv-J-16	5.93	5.06	4.86	5.26 (4.84–5.56)	Red purple
cv-J-17	7.92	6.05	5.68	6.48 (5.94–7.15)	Red

in seed and pod size among wild, weed, and cultivated Azuki beans are clear (Tables 2 and 3). Based on these traits, pod dehiscence, and growth form, a weed representative is easily distinguishable. In nature the weed race shows variable maturing and growth habits (Plate 2). This implies that its seeds gradually germinate under natural conditions and that the timing of germination determines the growth form and plant type of the weed race. The growth form of cultivated Azuki bean fluctuates with seeding time, planting density, length of day, and climatic factors^{6,7)}. Since agronomic evaluations of cultivated

Table 3 Variation in average pod size and number of seeds per pod

Accession	Pod length (mm)	Pod width (mm)	No. seeds
<i>Var. nipponensis</i>			
J-6	70.06	4.65	10.1
J-7	57.50	4.42	8.9
J-10	71.56	4.95	9.8
J-1	59.73	3.85	9.1
J-12	60.46	3.78	10.0
J-19	65.01	3.90	11.5
J-22	72.11	4.03	11.3
J-3	66.49	4.26	11.1
J-2	67.67	4.55	9.8
J-4	68.20	4.74	10.6
J-13	65.36	4.49	10.0
Weed race-1			
J-21	65.73	4.87	9.7
J-16	72.88	4.77	8.9
J-14	78.34	5.36	10.1
J-23	79.90	4.74	11.6
J-15	76.32	4.96	10.8
Weed race-2			
J-20	77.63	4.80	9.8
J-17	76.18	5.11	11.0
J-18	61.70	5.22	8.0

Azuki bean have mainly been done in the northern part of Japan (Niigata and Hokkaido prefectures)^{8,9)}, comparison between cultivars and weed races is difficult at present.

The cultivars of the Azuki bean show a wide variation in seed size, seed color (white, yellow-green, brown, red and black, with or without variegation; see Table 2) and pod color (straw color, brown, and black), and these characteristics cover the weed-race variation observed by my present rapid evaluation. Relatively determinate growth habits and larger seed size strongly suggest that the two weed races are "run-wild" varieties of cultigens or transitional forms between wild and domesticated forms. In separate places in the Kinki district, farmers said that 40 or 50 years ago, cultivars with easily dehiscent black pods similar to the weed race had been cultivated and sometimes spread outside the agricultural fields. These cultivars tolerate wide environmental conditions and show high pest tolerance. They are said to have an unpleasant taste but have saved men from hunger in a lean year. Weedy races which arose from "run-wild" cultigens or are true-wild varieties are frequently observed in the Japanese archipelago, covering over 85 cultivated plant-species: examples are radishes, carrots, watercress, melons, mints, oats, caw peas etc. (Yamaguchi, unpublished). Therefore the occurrence of weed races in the Azuki bean is not a peculiar phenomenon. The reason the weed Azuki bean has been overlooked is not satisfactorily known; however, separating the weed race from the wild, weedy, and crop categories may result in a better understanding of cultivar classification and infraspecific taxonomy¹⁰⁾. For understanding origin of weed races and observing them taxonomically, further evaluation is necessary on weed and wild races together with

cultivars.

Since present-day cultivated Azuki beans in the Kinki district include several cultivars, as is true throughout Japan, the weed race, by its wide variation (Table 2) and its similar growth form to cultigen, may provide useful genetic resources for saving the cultigen gene pool with its narrow base. Azuki bean has its center of diversity in Central China and a secondary center in Japan¹¹⁾; more extensive exploration for overlooked weed representative in a wide area of East Asia is desired.

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