TARC Repot

Growth and Yields of Winged Bean Grown in Different Seasons in Okinawa

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Introduction

We have tried to introduce winged bean (*Psophocarpus tetragonolobus* (L.) DC.) as a summer vegetable in the subtropics of Japan.

Winged bean varieties collected from eight countries were examined for two years to detect early maturing plants, which are less sensitive to long days[2]. We obtained four selections, Ishigaki-1 (cv. Urizun), -2, -3 and -4, in the first year of the trial[3,14]. Then we carried out two kinds of experiments to determine their adaptability to photoperiod and temperature of the subtropics of Japan together with productivity. The first experiment was conducted at different sites distributed from the tropics to the temperate zone[3]. The second experiment was conducted in Ishigaki Island, Okinawa, to know the growth and yields of the winged bean planted in different seasons, for the purpose of making clear the sensitivity of winged bean to climatic factors of Ishigaki Island. The result is presented in this paper.

This is the last paper of the TARC's research program "the Winged Bean Introduction". To this program, biochemists[1], entomologists[17] and agronomists[3] belonging to other institutes than TARC have joined. The authors wish to acknowledge their cooperation.

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Materials and methods

Experiment 1: Effect of sowing dates on growth and seed production.

Six winged bean varieties were sown five times bimonthly from late January to late September 1983 in the field of Okinawa Branch (24°N lat.) of TARC (Table 1). For each variety, a plot comprised eight plants spaced 0.5 m between plants and 1 m between rows. The layout of the plots was of randomized block design with three replications. Plastic poles (each 2.25 m long and bent like an arch) were fixed across each row with their both ends inserted into the soil with 1 m distance between both ends. Winged bean plants were allowed to twine around the plastic poles (a plant to a pole).

Experiment 2: Pod and seed development with time.

UPS-31 and Tpt-2 were sown on July 11, 1983 with spacing of 1 m × 1 m. Plastic supporters were used. No fertilizer nor pesticide was applied. Each flower was tagged on the day of its bloom in the period of November 1 to 18 for the study of seed and pod growth.

Experiment 3: Varietal difference in green pod production.

Urizun and UPS-31 were sown on July 2,

Table 1. Effect of sowing time on growth and seed production (Expt. 1)

Date of sowing and variety	Germination		Flowering			No. of dry pods/m² [5]					Seed yield (g/m²)
	Days[1]	%	Date[2]	Days[3]	Rate[4]	—Aug	Sept. —Oct.	Nov. —Dec.	Jan. —Feb.	Total	
January 28											
Urizun	17	92	Apr. 30	75	100	21.4	15.6	20.6	14.0	71.6	124
Ishigaki-2	15	67	May 14	91	95	6.8	9.6	32.4	13.6	62.4	75
Ishigaki-3	15	92	June 2	110	95	7.0	10.2	16.4	12.2	45.8	64
Ishigaki-4	15	75	May 9	86	89	1.0	2.0	20.0	2.2	25.2	47
UPS-31	16	67	Oct. 9	238	4	0	0	24.2	18.2	42.4	105
Tpt-2	15	79	Oct. 17	247	0	0	0	3.0	14.0	17.0	56
March 30											
Urizun	15	92	June 12	59	82	3.6	6.8	17.6	25.0	53.0	112
Ishigaki-2	12	88	June 8	58	59	0.4	2.0	17.6	27.8	47.8	92
Ishigaki-3	12	96	June 16	66	57	0	1.2	16.5	25.8	43.5	84
Ishigaki-4	12	100	June 8	58	79	0	4.8	31.4	4.0	40.2	47
UPS-31	12	92	Oct. 13	185	5	0	0	7.0	26.6	33.6	86
Tpt-2	12	100	Oct. 17	189	0	0	0	3.2	22.0	25.2	109
May 25											
Urizun	9	92	Aug. 7	65	100	0	16.8	63.8	5.0	85.6	205
Ishigaki-3	9	100	Aug. 18	76	100	0	7.4	46.8	15.8	70.0	182
Ishigaki-4	8	100	Aug. 20	79	100	0	6.0	45.2	15.2	66.4	140
UPS-31	10	96	Oct. 13	131	100	0	0	15.4	43.2	58.6	215
Tpt-2	9	100	Oct. 20	139	100	0	0	0.4	23.8	24.2	184
July 26											
Urizun	11	79	Sept. 26	51	100	0	0	31.0	8.8	39.8	75
Ishigaki-2	10	83	Sept. 23	49	100	0	0	3.8	39.0	42.8	74
Ishigaki-3	8	100	Oct. 16	74	100	0	0	3.8	31.6	35.4	80
Ishigaki-4	10	100	Oct. 5	61	100	0	0	11.4	42.6	54.0	96
UPS-31	9	92	Oct. 16	73	100	0	0	13.8	25.2	39.0	96
Tpt-2	8	92	Oct. 24	82	95	0	0	0	20.2	20.2	108
September 28											
Urizun	13	100	Dec. 5	55	100	0	0	0	0	0	0
Ishigaki-2	13	88	Dec. 8	58	79	0	0	0	0	0	0
Ishigaki-3	11	96	Dec. 14	66	84	0	0	0	0	0	0
Ishigaki-4	11	100	Dec. 2	54	100	0	0	0	0.4	0.4	—
UPS-31	15	92	Dec. 9	57	94	0	0	0	0.2	0.2	—
Tpt-2	9	100	Dec. 14	68	95	0	0	0	0	0	0

1) : Number of days from sowing to the day when 50% of the seeds germinated.
2) : Date of observation.
3) : Number of days from germination to the first flowering (bloom of the first flower).
4) : Percentage of plants that flowered during four months after germination.
5) : Observation period.

1983 with spacing of 1 m × 1 m, in the farmers field (very fertile porous soil of coral origin) in Ishigaki Island. The plastic poles described above were used to support winged bean plants. However, in this case each plant was allowed to twine up the pole alternately in the opposite direction. The farmer harvested marketable green pods every three days from Octboer to early December and recorded the total number of harvested pods each time.

Results

1) Seed germination

It took 8 to 9 days even at the optimum mean temperature, 27°C (Table 1). In late January with mean temperature of 18°C (the lowest during the experiment) it took 15 to 17 days. Urizun required two or three days more as compared with other varieties also in

Table 2. Climatic factors in relation to flower induction

		Date of sowing				
		Jan. 28	Mar. 30	May 25	July 26	Sept. 28
Mean temp. (℃)	Juv.	18.9	26.0	28.4	29.4	26.0
	F. I.	21.2	26.2	30.0	29.6	21.1
Rainfall (mm)	Juv.	251	152	39	249	335
	F. I.	247	205	6	27	75
Sunshine (hr/day)	Juv.	1.3	6.2	7.7	7.6	5.4
	F. I.	2.2	4.5	8.7	9.7	3.7
Photoperiod (hr)	F. I.	12.7	14.1	14.5	13.3	12.0
		−13.2	−14.4	−14.2	−12.8	−11.6
Accumulated temperature in the period from germination to the first flowering (×100 degree-days)						
Urizun		16.7	15.6	18.8	14.5	12.8
Ishigaki-2		20.5	15.2	—	14.3	13.4
Ishigaki-3		25.5	17.6	22.1	21.4	15.2
Ishigaki-4		19.2	15.2	22.9	17.8	12.8
UPS-31		*	*	*	21.1	13.6
Tpt-2		*	*	*	23.6	15.7

Juv.: Juvenile stage.
F.I. : Flower induction period.
* No flower primordia induced during the assumed flower induction period (a period of three weeks starting from four weeks of age of seedlings).

this trial[3]. It indicates the need to develop varietal capability of faster germination or methods to hasten germination by means of chemical or physical treatments[4,14,15].

2) *Flower induction*

As shown in Table 1, Urizun and Ishigaki selections flowered whenever air temperatures rose above 20°C, that is, any time except January and February[14]. UPS-31 and Tpt-2 did not flower until October in spite of growing under such a short day condition as about 13 hr of photoperiod* during their assumed flower induction period, i.e., three weeks starting from four weeks of age of seedlings (juvenile stage)[3,10], when sown in late January (Tables 1 and 2). The reason is that the flower primordia induced by short days were transformed its leaf buds by the succeeded long days[18].

The sowing at late September showed the least accumulated air temperature during the period from germination to flowering. In this case, the daylength was shorter than 12 hr. This daylength is shorter than the critical daylength for cultivars grown in the tropics[9]. Under such a condition, the flowering earliness of the cultivars tested was Tpt-2, Ishigaki-3<UPS-31, Ishigaki-2<Urizun, Ishigaki-4. This result, except that of Ishigaki-4, was consistent with the result of our previous experiment[3] conducted in Malaysia.

3) *Seed production*

Urizun, which showed the lowest sensitivity to long days among the varieties tested, gave the highest seed yield among the varieties when sown in January and March (Table 1). Throughout the experiment 1, the highest yield (205 g/m²) was obtained from Urizun sown in May. Simple extrapolation of this yield gives 2 t/ha of seed yield, which seems to be fairly high when we consider the growing season shorter than six months[9,11]. The seed yield of Urizun sown in January and March decreased despite the longer growing season, because day-length continued to increase after flowering and which caused adverse effects on reproductive growth.

The seed yield of Urizun and other varieties

* Photoperiod in this paper expresses true day-length + civil twilight at the field condition.

Table 3. Varietal differences in yield components (average of the plants sown in January, March, May and July)

Variety	Dry pod			No. of seeds per pod	100-seed weight (g)	Shelling percentage
	Length (cm)	Width (cm)	Weight (g)			
Urizun	15.8	0.85	5.2	10.6	24.8	50.5
Ishigaki-2	13.2	0.72	4.6	8.3	25.5	46.0
Ishigaki-3	18.2	0.84	6.5	8.5	38.3	50.1
Ishigaki-4	13.9	0.68	4.1	9.4	28.8	64.2
UPS-31	17.1	0.76	6.0	10.7	29.6	52.8
Tpt-2	25.1	1.00	12.4	14.1	43.9	50.0

sown after May continued to decrease because lowering temperature prevented the seed production of winged bean, a tropical plant, although the number of days to flowering was decreased due to shorter day-length. Thus, the plants sown in late September did not produce mature seeds.

The peak of seed harvest occurred in November, showing that the flowering began in late September followed by the seed development period of 50 to 60 days[5]. Particularly, UPS-31 and Tpt-2 began to produce mature seeds from November, regardless of sowing time.

The varietal differences in yield components except the number of pods per plant are given in Table 3. Tpt-2 showed the highest value for the length and width of pods, number of seeds per pod and 100-seed weight, but the least in the number of pods per plant. On the contrary, Ishigaki-2 and -4 showed the smallest pods, with their pod length and width being half and one third of those of Tpt-2, respectively. Shelling percentage ranged from 46 to 64%. Most varieties showed around 50%, which is very low compared with other grain legumes[11].

4) Pod and seed development with time

Development with time of a pod and a seed was compared between Tpt-2 and UPS-31 which show a great contrast in their size of the pod and seed. Their growth curve of the pod and seed resembles each other (Fig. 1). The length and width attained the full size 30 days after flowering. Fresh weight of a pod composed of pericarp (pod wall) and seeds reached maximum weight, 60 g for Tpt-2 and 30 g for UPS-31, showing that the winged bean is one of the largest edible legumes[6]. On the other hand, pod dry weight continued to increase until the last sampling time (55 days after flowering) due to the increase in seed dry weight. The seed became visible with the naked eye one week after flowering, but its dry weight increased very slowly during four weeks of early seed development, and after that increased rapidly. The growth pattern of pod shown above is different from that reported by Data & Pratt[5] (pods of Tpt-2 reached the full size 23 days after flowering). This may be due to climatic difference between the tropics and the subtropics.

Moisture content of green pods of both varieties increased to 90 to 92% at 20 days after flowering, and then turned to decrease. On the other hand, seed moisture content was about 88% at the initial stage, and it decreased gradually.

5) Green pod production of Urizun

Pods were carefully harvested before the suture became fibrous 12 to 15 days after flowering, because they were sold to a restaurant on a contract. Harvesting ended on December 10 when air temperatures lowered to slightly below 20°C.

The dry weather with the total of 31 mm rainfall continued for 40 days after sowing, and high temperature continued till a typhoon attack in late August. In addition, the dry weather prevailed again in September until

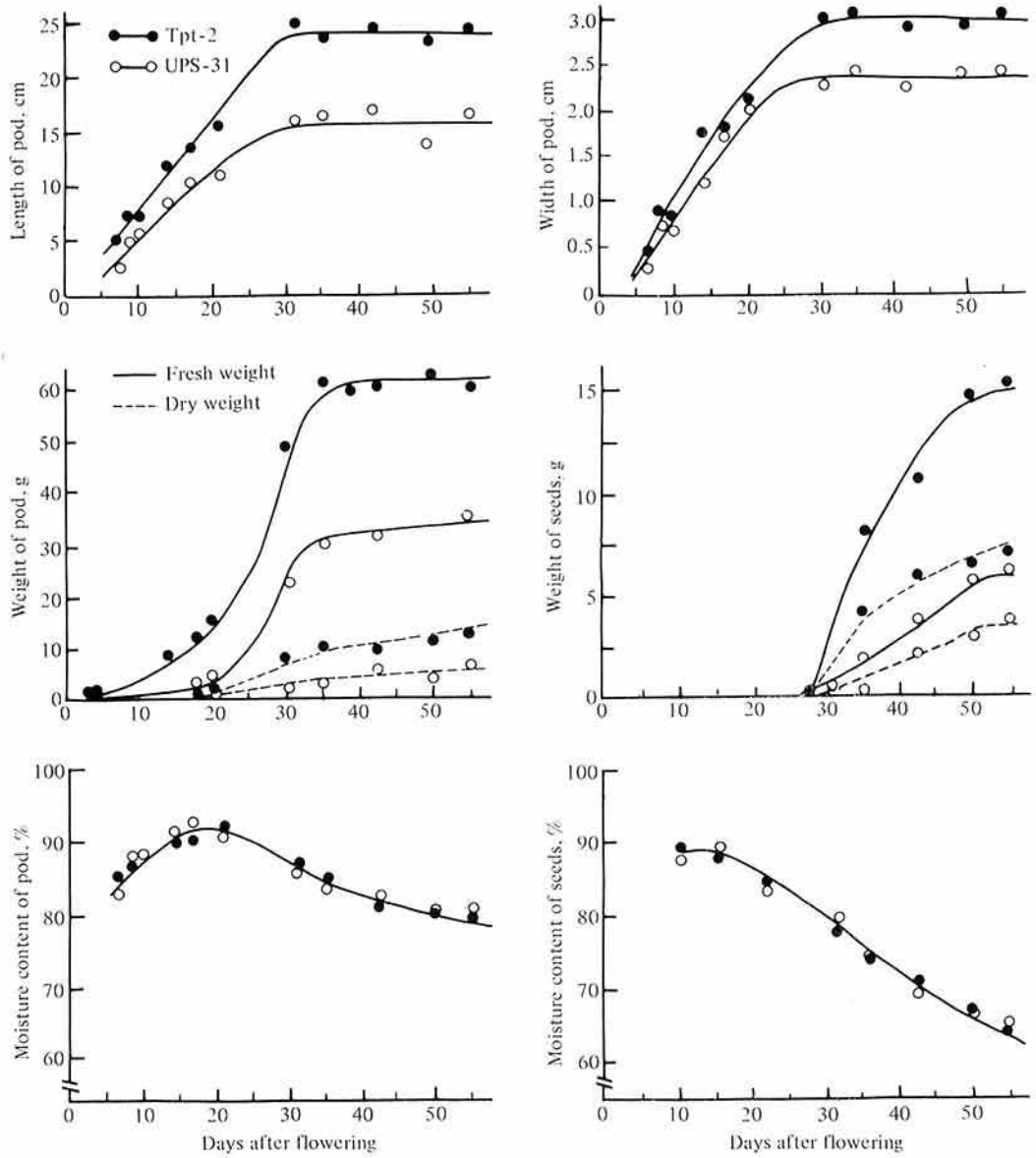

Fig. 1. Growth of pods and seeds

the next typhoon on September 25. As a result, the onset of flowering was much delayed. A single plant of Urizun gave first one pod and ten cumulative pods on October 12 (100 days after sowing) and on October 27, respectively. The corresponding dates for UPS-31 were October 27 and November 9. Thus Urizun matured two weeks earlier than UPS-31. During the favorable season for pod production from November to early December a single plant of Urizun and UPS-31 produced daily 3.5 pods and 1 pod, respectively. This large varietal difference*

* The number of pods produced by the two varieties sown in July in the usual field without fertilizer (Expt. 1) was ca. 40 for each (Table 1).

indicates that Urizun is adapted to intensive green pod production. In general, winged bean grown in fertile soil hardly gives high yields, due to excessive vegetative growth occurring at the sacrifice of yield. However, Urizun has the property of hardly making excessive vegetative growth. Although this particular property is not always manifested, it can be said that the extent of reproductive growth suppression caused by fertile soils is less with Urizun. Namely, fertile soils favor reproductive growth in Urizun and frequent harvesting of green pods stimulates flowering and pod-setting in Urizun more than in UPS-31.

It was reported earlier that the optimum stage for harvesting green pods ranged from 12 to 19 days after flowering in Nigeria[13], from 14 to 20 days in Ghana[16], and from 15 to 20 days in the Philippines[5], showing that the harvesting terminated 20 days after flowering when pericarp begins to become fibrous but keeps still the maximum moisture content as shown in Fig. 1. The harvesting time in our experiment was very short ranging from 12 to 15 days after flowering when sutures were not yet fibrous. This difference in harvesting stage between the result in the tropical countries and our result depends mainly on whether fibrous sutures are permissible or not to consumers. The harvest of green pods ended in mid December when the mean temperature lowered to below 20°C. At this temperature pod growth was so slow that the pods of the same size as those harvested in the optimum season became more fibrous.

Discussion

Winged bean has adapted to the tropical climate with short days and high temperature[11], and is distributed in the tropics. Therefore, to grow winged bean in other regions than the tropics, genetic improvement is required, like the case of rice, maize, etc.

We have succeeded in breeding a new variety 'Urizun' that produces green pods even in the summer season of the subtropics of Japan[14,15], where tropical varieties can produce green pods only in a short period from October to December. Urizun, however, is not completely neutral to day-length. Namely, we observed that the number of flowers significantly decreased under long days. Another feature of Urizun is the existence of time lag in setting first pods. The first pod setting occurred one to two weeks behind the bloom of the first flower in May and June (sown in January and March).

Noguchi et al.[14] stated that mean air temperature of 20°C is critical to green pod production. It is consistent with our results. On the other hand, high temperature, 30 to 36°C, was detrimental according to Khan[11], but the mean temperature in Okinawa does not exceed 30°C in the monthly average even in the summer due to the oceanic climate. In western parts of the mainland of Japan the interruption of flowering due to high temperatures is observed (personal communication of Dr. H. Shibata). Thus, the tolerance to higher or lower temperature is required not only to extend the harvesting period in the subtropics but also to spread winged bean culture to higher latitude.

In spite of some shortcomings as above mentioned, the development of Urizun with excellent characters will certainly make winged bean a popular summer vegetable in the subtropics of Japan[14,15].

Summary

Three different experiments were carried out to evaluate a new variety of winged bean, 'Urizun', developed in Okinawa, regarding seed and pod production, flowering behavior, and growth pattern of seed and pod at Ishigaki Island (24°N lat.).

Experiment 1: Effect of sowing dates on growth and seed production.

Six varieties including Urizun were sown bimonthly from January to September. Urizun showed the slowest seed germination, but the earliest maturity. Its seed yield was higher than any other varieties tested, when sown in January, March and May. Urizun produced pods whenever mean temperature was

higher than 20°C, while tropical varieties, UPS-31 and, Tpt-2, set pods during three months after October.

Experiment 2: Pod and seed development with time.

Two contrasting tropical varieties, Tpt-2 and UPS-31, were used to investigate pod and seed development. Both varieties attained maximum values of pod and seed size, 30 days after flowering (DAF), and fresh weight of pods 30 to 35 DAF, but dry weight continued to increase till the last sampling time (55 DAF). Maximum moisture content of about 90% was kept till 20 DAF.

Experiment 3: Green pod production of Urizun.

The experiment was conducted in a farmer's field with fertile soil. The pods were harvested 12 to 15 DAF just before the suture began to become fibrous. The daily pod production of a single plant of Urizun and UPS-31 was 3.5 pods and one pod, respectively, during the optimum harvest season (from early November to early December).

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