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Response of Winged Bean to Temperature and Photoperiod at Different Locations Distributed from the Tropics to the Temperate Zone

By Jiro ABE*1, Hiroshi NAKAMURA*2, Toshio HANADA*3, Yoshiya SHIMAMOTO*4 and Daisuke NAKATA*5

*1,2 Okinawa Branch, Tropical Agriculture Research Center
(Ishigaki, Okinawa, 907-01 Japan)
*3 Research Division I, Tropical Agriculture Research Center
(Tsukuba, Ibaraki, 305 Japan)
*4 Faculty of Agriculture, Hokkaido University
(Sapporo, 060 Japan)
*5 Tohoku National Agricultural Experiment Station
(Shimo-kuriyagawa, Morioka, Iwate, 020-01 Japan)

Introduction

As the result of many studies which have been made on the adaptability and yield potential of winged been (*Psophocarpus tetragonolobus* (L.) D.C.) since the 1970's, this crop has come to be regarded as a hopeful legume productive and resistant to pests and diseases in the tropics[6,7]. Therefore, if the winged bean without photoperiod-sensitivity is obtained, it may become a promising summer season vegetable in the subtropical region of Japan. In that region, good quality green vegetables are hardly produced due to serious pests and high temperature, so that green vegetables are imported from the temperature regions. From this viewpoint, the authors developed Ishigaki selections of winged bean less sensitive to photoperiod.

To determine plant response of them to photoperiod and temperature, two series of experiment were carried out. In the series A, the experiment was conducted at four locations distributed from the tropics to the temperate zone, while in the series B, it was done in different growing seasons at a single location[8].

This paper deals with the results of the series A experiment. The study constitutes a part of the TARC's research program "the Winged Bean Introduction".

Present address:
*1 Upland Crop Division, Tohoku National Agricultural Experiment Station (Shimo-kuriyagawa, Morioka, Iwate, 020-01 Japan)
*2 Department of Applied Physiology, National Research Institute of Vegetables, Ornamental Plants and Tea (Ano, Mie, 514-23 Japan)
*3 Okinawa Branch, Tropical Agriculture Research Center (Ishigaki, Okinawa, 907-01 Japan)
*5 Planning Department, Agricultural Structure Improvement Bureau, MAFF (Kasumigaseki, Chiyoda-ku, Tokyo, 100 Japan)

Materials and methods

Table 1 shows four locations. Urizun (Ishigaki-1), Ishigaki-2, Ishigaki-3 and Ishigaki-4 which were selected from M-13-1 (a Malaysian variety), Tpt-9, Tpt-19 and UPS-89, respectively, and other two varieties, UPS-31 and Tpt-2 were used. Four or five of them were planted. UPS and Tpt refer to the accession number of *Psophocarpus* in the University of Papua New Guinea and the International Institute of Tropical Agriculture in Nigeria, respectively. The plants were grown at a density of 1 m between rows and 0.5 m between plants with trellis. Neither agricultural chemicals to control diseases and insect pests nor fertilizer was given. The number of days to germinate and to the first flower was determined when 50% of seeds germinated and 50% of plants showed the first flower, respectively. The photoperiod, otherwise to mention, consists of true day-length and civil twilight in the field conditions.

Results

1) Germination

The number of days to germinate was seven to ten days both in Malaysia and Ishigaki with 26 to 28°C of mean air temperatures, in consistency with the results obtained in the tropics[6,7] (Table 2). In cool climate (20°C) of Morioka, Urizun needed 16 days, two to four days more than other

Table 1. Experiment sites and date of sowing

Site	Institute	Date of sowing
Malaysia	Jalan Kebun Res. Station, MARDI (3°00′N)	May 9, 1983
Ishigaki	Okinawa Branch, TARC (24°22′N)	May 25, 1983
Morioka	Tohoku National Agr. Expt. Station (39°42′N)	June 2, 1984
Sapporo	Hokkaido University (43°03′N)	May 24, 1983

Table 2. Germination and flowering of winged bean varieties

Site	Variety	Germination			1st flower opening		Percent flowering plants
		Days after sowing	Rate (%)	Accuml. temp. after sowing(°C)	Date	Days after germination	
Malaysia							
	Urizun	9	87	246	July 16	59	100
	Ishigaki-2	7	100	191	July 19	63	100
	Ishigaki-4	8	92	218	July 23	66	100
	UPS-31	10	75	273	July 23	65	100
	Tpt-2	9	92	246	July 27	70	100
Ishigaki							
	Urizun	9	92	246	Aug. 7	65	100
	Ishigaki-3	9	100	246	Aug. 18	76	100
	Ishigaki-4	8	100	218	Aug. 20	77	100
	UPS-31	10	96	270	Oct. 13	128	100
	Tpt-2	9	100	246	Oct. 20	138	100
Morioka							
	Urizun	16	100	326	Aug. 28	71	76
	Ishigaki-2	14	90	281	Sept. 6	82	92
	Ishigaki-3	14	93	281	Sept. 29	105	82
	Ishigaki-4	12	90	236	Sept. 24	102	56
Sapporo							
	Urizun	57	60	810	—	—	0
	Ishigaki-2	35	73	451	Aug. 28	61	50
	Ishigaki-3	39	53	512	—	—	0
	Ishigaki-4	—	7	—	—	—	—
	UPS-31	—	40	—	—	—	—

Table 3. Climatic conditions during the assumed flower induction period of Urizun

Site	Induction period	Mean air temp. (°C)	Photoperiod (hr)
Malaysia	June 15—July 5	27.0 (25.6—27.9)	13.1—13.0
Ishigaki	July 4—July 24	30.1 (29.3—30.8)	14.5—14.2
Morioka	July 17—Aug. 6	26.0 (22.7—28.7)	15.8—15.2
Sapporo[1)]	Aug. 17—Sept. 6	20.2 (17.2—24.3)	15.0—13.8
Sapporo[2)]	July 26—Aug. 15	21.2 (17.4—25.6)	16.0—15.0

1): No plant of Urizun flowered.
2): In the case of Ishigaki-2.

varieties. The extent of the varietal difference increased to about 20 days at the inhibitory low temperatures[6)] (<15°C) of Sapporo.

This result indicates that Urizun is very sensitive to temperature as far as its germination is concerned. At the same time, the result offers interesting information that more than 50% of seeds of several varieties could survive in cool, humid soils for one to two months until emergence.

2) Flower induction

The period of three weeks starting from four weeks of age of seedlings was regarded as the flower-inducing period of winged bean, based on Khan's report[6)] that means a period of 3–4 weeks starting from the minimum age of four weeks is needed for flower induction. The mean air temperature and photoperiod during that period are shown in Table 3, and the date of the first flowering is given in Table 2. In three sites, except Sapporo, the varietal difference in the number of days required for germination was only less than four days, so that all varieties tested must be exposed to the same photoperiod during their flower inducing period in each site.

As given in Table 2, Urizun showed the lowest photoperiod sensitivity among the varieties tested, because the increase in number of days to flower due to increased photoperiod expresses a degree of photo-sensitivity, though modification by the temperature factor[10)] is needed. The result also shows that Urizun has the shortest basic vegetative growth. On the other hand, the tropical varieties could not achieve flower induction in Ishigaki at 14.5 hr photoperiod, in consistency with Herath and Ormrod[5)] who demonstrated that UPS-31 did not flower at 14 hr photoperiod even at the optimum temperature in a phytotron.

3) Pod and seed production

Winged bean as a tropical legume could not complete its life cycle from germination to seed production for the next generation in Sapporo, where the number of days showing mean air temperature higher than 20°C was only 26. However, one plant out of five flowered plants of Ishigaki-2 set a pod even in such adverse environment (Plate 1). In Morioka with 73 days showing mean air temperature higher than 20°C, some green pods were produced, but not mature dry seeds (Table 4, Plate 2). For example, Urizun produced about two edible pods on average, with the best plant producing six edible pods and 18 small pods lighter than 5 g. Other varieties flowered too late to get edible pods.

At Ishigaki, Urizun and other Ishigaki selections were able to continue reproductive growth after flowering. However, the combination of higher temperature and longer days than those in Malaysia caused lower seed yield (Table 5). On the other hand, with photoperiod-sensitive Tpt-2 and UPS-31, their flowering was delayed, and hence their seed production took place just at the optimum climatic season for seed ripening, i.e. late October and afterwards. As a result, they showed comparatively high seed yield similar to that obtained in Malaysia.

Urizun, Ishigaki-2 and Ishigaki-4 gave higher yield in Malaysia than that in Ishigaki. Particularly the former two varieties

Table 4. Pod production in Morioka

Variety	Pod-setting plants		Percentage of pods grouped by fresh weight/pod			Mean pod fresh weight	No. of pods/ plant[3]
	(%)[1]	(%)[2]	(≦1 g)	(1−5 g)	(≧5 g)	(g)	
Urizun	57.1	76.2	17	65	18	3.1	11.8
Ishigaki-2	46.1	50.0	80	20	0	0.7	1.7
Ishigaki-3	4.0	5.0	100	0	0	0.3	2.0
Ishigaki-4	25.0	50.0	83	17	0	0.5	15.1

1): Based on the total no. of plants emerged.
2): Based on the flowered plants.
3): Based on the plants which set pods.

Plate 1. Ishigaki-2 showing a green pod in the field of Hokkaido University in Sapporo

Table 5. Seed yield and its components in Malaysia and Ishigaki

Variety	Pod length (cm)		No. of seeds/ pod		100-seed weight (g)		No. of pods/ plant		Seed yield (g/m^2)	
	Mal.	Ish.	Mal.	Ish.	Mal.	Ish.	Mal.	Ish.	Mal.	Ish.
Urizun	18.7	16.6	12.6	8.9	27.9	26.7	54.2	42.8	190	103
Ishigaki-2	14.5	—	9.8	—	34.8	—	58.6	—	200	—
Ishigaki-3	—	16.8	—	6.9	—	31.4	—	34.8	—	76
Ishigaki-4	15.9	15.1	11.5	9.6	30.4	21.7	35.3	33.2	118	70
UPS-31	16.1	18.7	10.3	11.9	37.6	31.5	27.2	29.3	106	108
Tpt-2	27.8	27.3	16.5	15.5	41.6	45.4	12.7	12.1	125	92
Mean[1]	19.6	19.4	12.7	11.5	34.4	31.3	32.4	29.4	125	92

1): Excluding Ishigaki-2 and Ishigaki-3.

Plate 2. Urizun which produced green pods in the field of Tohoku National Agricultural Experiment Station in Morioka

outyielded tropical varieties by about 40 to 80% in Malaysia.

In both sites, Malaysia and Ishigaki, Tpt-2 showed the longest pods containing the greatest number of the largest seeds, while Ishigaki-4 showed small pods with relatively few seeds. The major factor causing yield difference between both sites was the number of pods per plant for Urizun and 100-seed weight for Ishigaki-4, indicating the varietal difference in the response of yield components to different conditions, although the number of pods per plant or per m^2 is considered to be most important[1,2,6].

Discussion

The time of flowering, that is, the earliness of flowering in short-day plants is related to three main factors: (a) the critical photoperiod for flower induction, (b) the optimum photoperiod for flowering after the completion of flower induction, and (c) the basic vegetative growth. The factor (c) may be indicated by the number of days to the first flower opening in the equatorial tropics. From this view point, (c) of Urizun and the Ishigaki selections is shorter than UPS selections, which are known to mature earlier than other tropical varieties[1,3,4,6,7]. The factor (a) of Urizun was not determined, because this variety flowered under 15.5 hr of photoperiod. Urizun showed the lowest photoperiod sensitivity in addition to its high productivity.

This variety produced pods at Shinjo, 38°45′ (S. Konno, personal communication), Tsukuba, 36°02′, (unpublished data) and Osaka, 34°41′ (Shibata[9]), and the pod yield was influenced by temperatures and diseases and insect pests.

Urizun can be cultivated not only as a summer vegetable, but also as a perennial one, when some warming means are adopted, in Ishigaki and other subtropical regions.

Summary

To determine flowering response and productivity of four Ishigaki-selections, which were developed for low photoperiod-sensitivity in Ishigaki, a subtropical island of Japan, these selections were grown at four locations distributed from the tropics to the temperate zone (Malaysia, Ishigaki, Morioka, and Sapporo). For comparison, two tropical varieties were used.

In Sapporo (43°N), three fourths of seeds of Ishigaki-2 germinated 35 days after sowing at the mean air temperature of 21.2° (17.4–25.6°). A half of the emerged plants flowered under 15–16 hr of photoperiod, and one plant produced a pod. Urizun (Ishigaki-1) germinated too late (mid August) and no flowering occurred.

In Morioka (39°42′N), Urizun flowered 71 days after germination, under the photoperiod of 15.5 hr, and produced edible green

pods (each heavier than 5 g). Other selections also flowered, but it was too late to produce edible green pods.

In Ishigaki, Urizun flowered 65 days after germination, under the photoperiod of 14.2–14.5 hr and produced about 43 green pods per plant. Ishigaki-3 and Ishigaki-4 took more than 10 days longer than Urizun for flowering, and less yield. The tropical varieties, Tpt-2 and UPS-31 flowered very late (October), so that they can't be used as a summer vegetable. As their seed ripening proceeded in the cool season, their seed yield was rather high.

In Malaysia, Urizun flowered earlier than any other varieties and its yield was about 40% higher than the tropical varieties, Tpt-2 and UPS-31.

Thus, it was clearly indicated that Urizun has the lowest photoperiod sensitivity with the shortest basic vegetative growth period and high productivity. This variety can well be grown in Ishigaki and other subtropical areas as a summer vegetable.

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(Received for Publication, February 4, 1987)