CULTIVATION OF TEMPERATE VEGETABLES IN THE TROPICS

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ABSTRACT

Temperate vegetable consumption in the tropical countries has been increasing recently, and technologies for stable production must be developed to meet the domestic demand and supply.

The climatic conditions are the main constraints on temperate vegetable production in the tropics. Therefore, experiments were carried out in Malaysia to investigate the growth response of temperate vegetables in relation to the climatic conditions in the tropics. Experiments on onion and cauliflower in the highlands suggested that constant temperature and daylength throughout the year prevented the cultivation of high quality products. Experiments on shading in the lowlands showed that this method could be effective in the stabilization of temperate vegetable production.

Consumption of temperate vegetables in Malaysia

Annual consumption of whole vegetables in Peninsular Malaysia was estimated to be 622,000 tons (1985 by FAMA). Vegetable consumption per capita a year can thus be estimated at 47.8 kg, when the total consumption is divided by the population of 13 million.

Vegetables are often classified into two categories, i.e. tropical and temperate vegetables, although this definition is arbitrary. The tropics usually refer to the zone within the latitude of 30°N and 30°S, where the average annual temperature exceeds 20°C. Vegetables originating from this zone (countries between Mexico and Brazil in America, between India and Central Australia in Asia and between Egypt and Madagascar in Africa) may be classified as tropical vegetables. They include cucumber, brinjal, lady's finger, long bean, yam, amaranthus leaves, etc. Temperate vegetables are those originating from the temperate zone such as the Mediterranean region, Europe, China, etc. However, vegetables originating from the tropical highlands like potato and tomato should also be defined as temperate vegetables in terms of their temperature requirements.

By classifying vegetables according to their origin, 47% of the vegetables consumed in Malaysia were found to be temperate vegetables (Table 1).

Temperate vegetable production in Malaysia

Malaysian dishes are prepared using mainly tropical vegetables. However, the consumption of temperate vegetables, such as asparagus and broccoli, has been increasing recently and the number of farmers trying to grow them is also increasing.

At present, temperate vegetable production in Malaysia is not adequate to meet the domestic demand. Even though there are some temperate vegetables which have acquired a heat tolerance and are widely cultivated (e. g. mustard leaves), most of them are difficult to grow successfully in the tropics. Potato, onion, garlic, carrot, cauliflower and broccoli found in the market are mostly imported ones.

The quantity of imported vegetables in Peninsular Malaysia amounted to 157,000 tons

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Table 1 Vegetable consumption in Malaysia[a]

Temperate vegetables	(amount 1000 tons)	Tropical vegetables	(amount 1000 tons)
Mustard leaves	(51)	Long bean	(43)
English cabbage	(36)	Cucumber	(42)
Irish potato	(36)	Chilli	(40)
Onion	(28)	Brinjal	(32)
Tomato	(26)	Bayam	(24)
Shallot	(21)	Kangkong	(23)
Garlic	(10)	Sweet potato	(21)
Carrot	(9)	French bean	(17)
Chinese cabbage	(8)	Lady's finger	(14)
White mustard	(7)	Angled luffa	(13)
Lettuce	(6)	Bitter gourd	(12)
Chinese chive	(6)	Pumpkin	(9)
Watercress	(5)	Ginger	(7)
Cauliflower	(4)	Yam bean	(6)
Others	(23)	Others	(10)
Total	276	Total	313

[a] Excluding the amount of bean sprouts.

in 1980 and 148,000 tons in 1981, which indicates that Malaysia still depends on foreign supply for 1/4 to 1/3 of her vegetable consumption.

Characteristics of the climatic conditions in Malaysia

Although high temperature is a common feature, the climate in the tropics is diversified. Some areas have little precipitation, some have a rainy and dry season, and some have ample rainfall throughout the year.

Malaysia which is located near the equator belongs to the tropical rain forest in terms of natural vegetation. Annual precipitation exceeds 2,000 mm without obvious dry season. However from the standpoint of temperate vegetable production, the most distinctive characteristics of the climatic conditions in Malaysia are constant daylength and constant temperature throughout the year (Fig. 1). These climatic conditions may sometimes become a limiting factor for temperate vegetable production.

Constant daylength in the tropics, a constraint on onion production

Malaysia is importing onion mainly from India and the value reached M$ 59,865,000 in 1983. Sorensen *et al.* (1974) reported that high-yielding varieties of onion in Cameron Highlands produced many split bulbs (average 2.3-2.6 bulbs/plant) and Ding *et al.* (1985) reported that bulb formation of shallot under Malaysian lowland conditions deteriorated significantly when compared with imported seed-bulbs. These facts indicate that the climatic conditions prevalent in Peninsular Malaysia are not favorable for onion bulb formation.

1 Cultivation of onion under different daylength conditions

Experiment on onion was carried out at MARDI Cameron Highlands using 20 varieties. After two months at the nursery, the onions were transplanted into the field and subjected to different daylength treatments until the last harvest (from September 10 to December 31, 1984).

Natural daylength (12 hr) decreased slowly from 12:14 hr in September to 11 : 51 hr in December during the experimental period. Long daylength treatment (13 hr) was

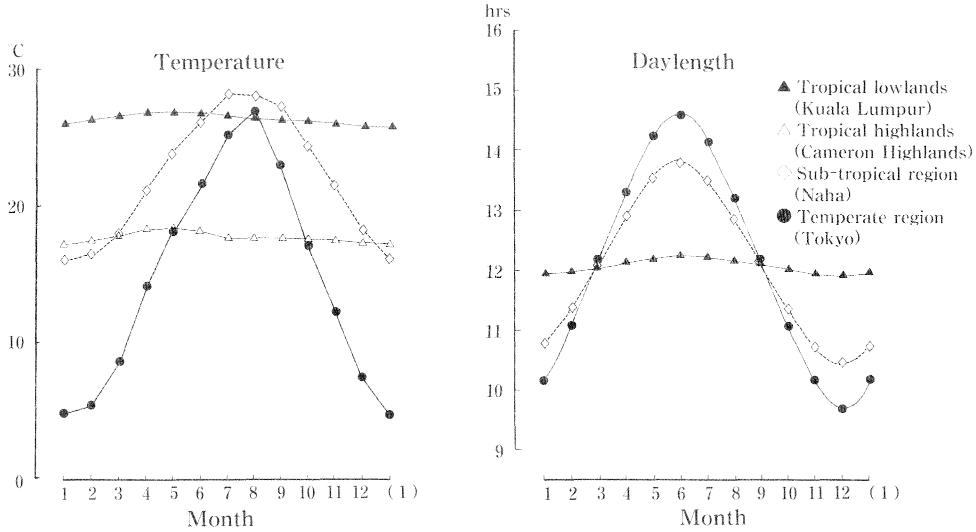

Fig. 1 Mean monthly temperature and daylength at different stations in the temperate, sub-tropical and tropical regions

carried out by putting a 60 W light bulb on for 1 hour before dawn (from 5 : 30 a.m. to 6 : 30 a.m.). Short daylength treatment (11 hr) was conducted by covering the bed with silver plastic film for 1 hour in the morning (from 8 : 00 a.m. to 9 : 00 a.m.) to prevent the penetration of sunlight.

Results of the experiment are shown in Table 2.

Initial harvest : Under natural daylength conditions, harvesting was initiated from three and half months after transplantation. However under long daylength conditions, it was two to two and half months after transplantation and initial harvest was shortened by as many as 43 days.

Bulb formation : Under natural daylength conditions in Cameron Highlands (12 hr), none of the varieties tested showed complete bulb formation. The highest percentage of bulb formation was 91% in White Granex, followed by 79% in O. A. Yellow and 71% in Hayate. In addition, almost half of harvested onions were split into 2-4 small bulbs. By putting the light on for 1 hour at night, bulb formation became complete and the incidence of split bulbs was decreased : 100% bulb formation without any split bulbs was obtained for 8 varieties under long daylength conditions (13 hr). On the other hand, short daylength treatment reduced the percentage of bulb formation. Eight varieties which formed bulbs under natural daylength conditions ceased to form bulbs completely under short daylength conditions (11 hr).

Bulb weight : Bulb weight was the heaviest under natural daylength conditions. It decreased under long daylength conditions as a result of the short maturing period and absence of split bulbs. The bulb weight also became lighter under short daylength conditions due to poor bulb performance.

Growth of onion : Growth of onion under different daylength treatments is shown in Table 3 (variety ; O. A. Yellow). The shorter the daylength, the more pronounced the vegetative growth. Number of leaves and leaf length increased significantly and the leaf color remained green under natural and short daylength conditions. Plant weight also increased due to additional growth of shoots derived from split bulbs.

Table 2 Bulb formation of onion varieties under different daylength treatments

Items	Harvest after sowing (days)			Bulb formation (%)			Bulb weight (g)		
Daylength treatment	Long (13hr)	Natural (12hr)	Short (11hr)	Long (13hr)	Natural (12hr)	Short (11hr)	Long (13hr)	Natural (12hr)	Short (11hr)
Name of variety									
◎ Japanese varieties									
Youzui(Sakata)	135	178	169	100(0)	45(40)	12(100)[a]	42	114	60
Hayate(Takii)	138	180	185	100(0)	71(50)	13(33)	45	113	89
Marushino(Kaneko)	139	169	174	100(2)	61(29)	26(7)	54	89	72
O. A. Yellow(Takii)	144	180	185	100(9)	79(62)	16(20)	99	153	87
Sakigake Y.(Sakata)	144	173	169	100(0)	63(40)	6(100)	51	119	105
Hikari Y.(Marutane)	146	184	185	100(10)	30(86)	5(100)	50	90	80
Kinkyu(Kaneko)	146	185	—	100(0)	38(63)	0	52	76	—
Super Early Y.(Takayama)	151	184	185	100(17)	19(47)	1(0)	94	137	50
One-K(Kobayashi)	152	185	—	100(8)	11(40)	0	59	55	—
Suzuhiro(Kaneko)	161	185	—	100(28)	7(100)	0	57	96	—
Yellow No. 2(Takayama)	168	185	—	80(9)	3(100)	0	63	130	—
Two-K(Kobayashi)	174	—	—	67(16)	0	0	24	—	—
◎ Other imported varieties									
White Granex(Royals Luis)	168	177	179	100(0)	91(45)	73(13)	57	103	63
Pompei(Keystone)	176	185	—	100(33)	50(66)	0	88	123	—
Excel(Keystone)	178	185	—	100(0)	50(50)	0	76	52	—
Yellow Granex(Royals Luis)	181	185	—	100(0)	33(0)	0	55	15	—
Appolo(World Vision)	185	—	—	50(20)	0	0	76	—	—
Hybrid Tule(Keystone)	—	—	—	0	0	0	—	—	—
◎ Varieties available in Malaysia									
Texas Yellow Granex 502	171	185	—	100(0)	75(33)	0	59	107	—
Red Creole	173	180	185	100(24)	57(58)	21(33)	55	60	69

[a] Bracket indicates the percentage of split bulbs in total harvest.

Table 3 Growth of onion under different daylength treatments

Daylength treatment	Formation of bulb	Number of plants harvested	Number of leaves	Longest leaf length (cm)	Plant weight (g)	Bulb weight (g)	Bulb weight / Plant weight	Bulb diameter (cm)
Long (13hr)	Normal	43	5.0	41	108	98	0.91	6.5
	Split	4	7.3	46	137	111	0.81	6.2
	None	0	—	—	—	—	—	—
Natural (12hr)	Normal	14	9.1	51	149	112	0.75	6.3
	Split	23	13.9	49	228	178	0.78	6.5
	None	10	18.9	62	160	—	—	—
Short (11hr)	Normal	5	10.8	69	141	85	0.60	3.7
	Split	1	13.5	65	184	91	0.49	4.5
	None	37	16.2	70	123	—	—	—

Variety : O. A. Yellow

However under long daylength conditions, the leaves dried up after maturation of bulb. Bulb weight accounted for most of the plant weight (90%) and the shape of the onion was more flat (bulb height/bulb diameter was 0.6) without the formation of split bulbs (92% was normal).

2 Conclusion

In Cameron Highlands, the temperature is sufficient (more than 15°C) but the daylength is not long enough for bulb formation of onion. The minimum daylength requirement for initiation of bulb formation is normally known to range between 12 and 14.5 hr, depending on the varieties of onion.

In this experiment, it was revealed that early maturing varieties of onion formed bulb partly, resulting in 2-4 small split bulbs and medium to late maturing varieties of onion did not form bulbs at all under natural daylength conditions in Cameron Highlands. Bulb formation became complete only when daylength was extended by 1 hour.

Selection of super-early maturing types of onion whose critical daylength is below 12 hr seemed to lead to the successful onion production in Malaysia. But this way not. Among the varieties tested in the experiment, daylength requirement of White Granex was the least (estimated to be below 12 hr), which formed bulb under natural and even under short daylength conditions (11 hr) in a high percentage. However it was also observed that some plants of this variety had completed bulb formation at the nursery stage (small bulbs were formed within 2 months after sowing) by being too sensitive to short daylength.

As natural daylength in Peninsular Malaysia is almost constant throughout the year, the effect of bulb forming stimulation by extension of daylength was too weak, resulting in split bulbs or continuous vegetative growth. Therefore, it seems difficult to produce high quality onions under constant daylength conditions in the tropics.

Constant temperature in the tropics, a constraint on cauliflower production

Although higher retail price in the market is a strong incentive for vegetable farmers, cauliflower production in Peninsular Malaysia is restricted at present. Cultivation of cauliflower in Cameron Highlands has been recorded as early as the 1940s (Allen, 1950 ; Berwick *et al.*, 1950) and recently the cultivation has expanded in the lowlands by using heat-tolerant varieties.

However, cauliflowers produced in Peninsular Malaysia are inferior in quality as most of the head curd harvested is small, loose and yellowish in color. Consumers still prefer white, big and compact head curd of cauliflowers which are imported mainly from Australia.

For the production of high quality cauliflower, constant temperature in Malaysia was considered to be one of the limiting factors.

1 Cultivation of cauliflower at different altitudes and selection of high-yielding varieties in highlands and lowlands

To analyze the response of cauliflower to temperature, three locations at different altitudes in Peninsular Malaysia were selected for the experiment.

1) MARDI Station in Cameron Highlands (1,430 m above M. S. L)
2) Bertam Valley in Cameron Highlands (980 m above M. S. L)
3) MARDI Jalan Kebun Station in Kelang (3 m above M. S. L.)

Cultivation of cauliflower was carried out from April 18 to August 16, 1983, using the same 13 varieties at the three locations.

Temperature during the period of the experiment was

1) Abs. Max. 25.4°C, Abs. Min. 14.2°C, Mean Min. 15.7°C at MARDI Cameron Highlands
2) Abs. Max. 35.3°C, Abs. Min. 21.6°C, Mean Min. 23.7°C at MARDI Jalan Kebun

No data were available at Bertam Valley in Cameron Highlands. However taking the altitude into account, the temperature was considered to be about 5°C lower than at MARDI Jalan Kebun.

Results of the experiment are shown in Table 4.

Formation of curd : At MARDI Jalan Kebun, only 4 varieties out of 13, which belong to the super-early maturing type formed head curd. The other 9 varieties did not form curd at all and showed only vegetative growth even after 100 days after transplantation. Temperature in the lowlands was too high for the coolness requirement in these varieties to change the growth phase from vegetative to reproductive.

Table 4 Curd formation of cauliflower at different altitudes in Peninsular Malaysia

Items	Harvest after sowing (days)			Curd weight (g)			Curd weight/Plant weight (%)		
Location	C. H.	B. V.	J. K.	C. H.	B. V.	J. K.	C. H.	B. V.	J. K.[z]
Name of variety									
Meigetsu (Mikado)	61	87	101	28(233)	86(238)	93(255)[y]	15	22	26
Summer White (Musashino)	74	79	100	42(180)	80(537)	25(57)	10	18	9
Hakushu (Sakata)	54	82	108	12(59)	111(362)	61(155)	15	32	20
White Corona (Sakata)	57	81	108	20(104)	52(99)	79(125)	19	21	19
Snow King (Takii)	88	86	—	139(450)	91(175)	—	30	19	—
White Coral (Kaneko)	98	96	—	226(710)	122(195)	—	32	17	—
Snow Crown (Takii)	97	99	—	198(800)	123(160)	—	26	19	—
Hayabusa (Musashino)	100	94	—	165(587)	154(300)	—	30	28	—
Early White (Mikado)	98	—	—	76(310)	—	—	30	—	—
Akizuki (Sakata)	103	—	—	82(340)	—	—	22	—	—
Hakuraku (Sakata)	111	—	—	86(145)	—	—	20	—	—
Rami F1 (Local)	100	—	—	192(315)	—	—	23	—	—
Mont Blanc (Local)	100	—	—	204(490)	—	—	26	—	—

[z] C. H. indicates MARDI Cameron Highlands (1,430 m above M. S. L.), B. V. indicates Bertam Valley in Cameron Highlands (980 m above M. S. L.) and J. K. indicates MARDI Jalan Kebun (3 m above M. S. L.).
[y] Bracket shows maximum curd weight obtained.

At Bertam Valley in Cameron Highlands, 8 varieties (including the early maturing type) formed curd. At MARDI Cameron Highlands, all 13 varieties formed curd.

Quality : In Cameron Highlands, the curd of these 4 varieties which belong to the super-early maturing type was abnormal, showing small buttoning or horn-like shape. This is because these varieties formed buds at the early stage of growth, being too sensitive to cool temperature. Other early to medium maturing types of cauliflower formed normal curd. However in general, the quality and yield of cauliflower were very low in this experiment due to boron deficiency in the nursery soil.

Selection of high-yielding varieties for the highlands and the lowlands : Subsequently, two experiments were carried out to ensure the maximum yield of cauliflower both in the highlands and in the lowlands. Results are shown in Table 5 and Table 6.

Early to medium maturing types of cauliflower were evaluated in Cameron Highlands. Average curd weight was the heaviest in Rami F1 (342 g), followed by Snow Crown (329 g) and Snow King (271 g). Maximum curd weight was 813 g in Snow King.

In the lowlands, 15 varieties from super-early to early maturing types of cauliflower were evaluated. Four varieties out of 15 did not form curd at all, showing only vegetative growth. Two varieties gave a very low percentage (about 10%) of curd formation. Among the varieties tested, average curd weight was the heaviest in Sunny Top (216 g), followed by Summer White (187 g) and Hakushu (185 g). Maximum curd weight was 390 g in Sunny Top. Quality was not the best but acceptable for marketing both in the highlands

Table 5 Evaluation of cauliflower varieties at MARDI Cameron Highlands

Name of variety	Harvest after sowing (days)	Number of leaves	Curd weight (g)	Curd weight / Plant weight (%)	Color of curd: White (%)	Yellow (%)	Purple (%)	Rotten (%)
White Coral (Kaneko)	72	20	122(19-355)[z]	26	17	32	7	44
Hayabusa (Musashino)	74	21	159(20-400)	27	38	26	4	32
Snow King (Takii)	79	22	271(43-813)	38	70	15	15	0
Sakigake 80 (Mikado)	79	23	174(45-385)	28	30	30	16	24
Snow Crown (Takii)	92	23	329(89-740)	46	21	47	30	2
Rami F1 (Local)	88	26	342(74-697)	37	63	21	4	12

[z] Bracket shows minimum and maximum curd weight.

Table 6 Evaluation of cauliflower varieties at MARDI Bertam in the lowlands

Name of variety	Harvest after sowing (days)	Number of leaves	Curd weight (g)	Curd weight / Plant weight (%)	Harvesting percentage (%)	Yield (t/ha)
Sunny Top (Watanabe)	88	31	216(100-390)[a]	50	60	11.2
Hakushu (Sakata)	95	34	185(90-310)	37	70	11.1
Summer White (Musashino)	91	30	187(80-370)	49	66	10.6
Fengshan Extra Early (Known-you)	94	29	143(60-220)	44	57	6.5
Farmer's Extra Early (Known-you)	92	26	122(60-180)	51	50	5.2
Meigetsu (Mikado)	93	34	140(60-290)	44	37	4.4
Hayabusa (Musashino)	113	36	137(90-170)	31	33	3.9
Tropical 45 (Mikado)	92	29	125(65-215)	52	33	3.5
Snow King 65 (Takii)	108	36	146(110-190)	27	27	3.3

Unsuitable varieties in the lowlands : Harvesting percentage was very low (about 10%) in Snow Crown (Takii) and Snow King (Takii). No data were collected as curd did not form at all in Farmer's Early, Farmer's Early No. 2 and Farmer's Early No. 3 (Known-you) and Snow Mountain (Takii).

[a] Bracket shows minimum and maximum curd weight.

and in the lowlands.

2 Conclusion

As the curd of cauliflower consists of an aggregate of flower buds, a change of growth from vegetative to reproductive is necessary for harvest and cool temperature stimulates this condition. If the temperature exceeds the critical range, harvest cannot be achieved and plant shows only vegetative growth. On the contrary, if the temperature is too low from the early stage of growth, harvested curd will be small and of poor quality (like buttoning).

Maximum curd weight obtained in the experiment on cauliflower in Malaysia was 800 g in the highlands and 400 g in the lowlands at most.

To obtain a large curd, the plant must complete a certain period of vegetative growth prior to flower bud formation. In temperate countries, cauliflower is normally cultivated from summer to winter, when the temperature cools down slowly. Plant which has grown enough before the temperatiure decreases below the critical level can produce a large curd.

However due to constant temperature, both the reproductive and the vegetative growth of cauliflower proceed simultaneously in Malaysia. Poor quality of cauliflower was ascribed to this phenomenon.

Attenuation of climatic conditions in the tropics, effect of shading treatment on the growth of vegetables

High temperature is the main constraint on temperate vegetable production in the tropical lowlands. There are two approaches to overcome this problem.

One is the selection of heat-tolerant varieties. The other is the attenuation of the climatic conditions by artificial measures. Experiment on shading treatment was carried out to make the environment in the tropical lowlands more suitable for vegetable cultivation.

1 Cultivation of vegetables under shading house

Sixteen wooden frame houses (3 m×4 m×2.3 m) were set up and eight levels of shading intensity, i. e. 0, 20, 37, 48, 50, 72, 87, 98%, were provided by covering with shading materials (cheesecloth and net) for the experiment. Six kinds of vegetables (Kangkong, radish, cucumber, tomato, French bean and sweetcorn) were cultivated inside the shading houses during the period between Feb. 1986 and Mar. 1987.

Difference of temperature with and without shading : Cooling effect of shading treatment on air temperature (1 m above surface) and soil temperature (10 cm below surface) is shown in Table 7. Little difference was observed in the air temperature (less than 1°C) with and without shading treatment. However, the soil temperature decreased significantly as the shading intensity increased. The difference in the soil temperature reached 5-6°C in the afternoon at the high shading intensity treatments.

Profiles of the highest and lowest soil temperature in relation to the soil depth at 0% and 50% shading intensities are shown in Fig. 2. Although cooling effect by shading treatment was obvious near the surface, diurnal fluctuation in the soil temperature became less conspicuous as the soil depth increased.

Growth of vegetables : Shading intensity which gives the maximum figure of growth parameters in six kinds of vegetables is shown in Table 8. Vegetables showed etiolated or reduced growth under the high shading intensity treatments. Plant height was the maximum at shading intensities between 37 and 87%. Number and weight of leaves was the maximum at shading intensities between 20 and 48%. However, weight of root (radish) was the maximum at 0% shading intensity (without shading).

As for fruits, the maximum weight of fruits in French bean and cucumber was obtained at the shading intensity of 20 and 37% respectively. However, shading was not effective for increasing fruit weight in tomato and sweetcorn.

Yield increase by shading treatment : Yield of vegetables in relation to the shading intensities is shown in Fig. 3. As it is indicated in Table 8, shading provided a favorable environment for the growth of leaves and stem. Therefore, yield increase was observed in leafy vegetables (kangkong) and fruit vegetables which bear fruits on auxiliary shoots as well as main stem (cucumber and French bean). On the other hand, shading was not effective in promoting the growth of roots and increasing the weight of a fruit. Therefore, no yield increase was observed in radish and fruit vegetables which bear a limited number of fruits on the main stem (tomato and sweetcorn).

2 Conclusion

Shading treatment was found to be an effective measure for increasing the yield of leafy vegetables and fruit vegetables such as cucumber. Eze (1987) also reported that the maximum growth of amaranthus leaves in Nigeria was obtained at a light intensity of 70% out of 5 levels of daylight intensities (100, 70, 50, 20 and 6%). Shading practice with the shading intensity between 20 and 40% seems commonly a beneficial and stabilizing measure for leafy vegetable production in the tropics.

Shading treatment was not successful for increasing the yield of radish and fruit vegetables such as tomato. However, it was conspicuously effective for the quality

Table 7 Difference of air and soil temperature between open field and shading treatments at night (4 a.m.) and in the afternoon (4 p.m.)

Shading treatment	None	Shading						
Shading intensity	0%	20	37	48	50	72	87	98%
Air temperature (1 m above surface)								
4 a.m.	23.6±0.9°C	−0.3	−0.1	−0.1	−0.2	−0.3	−0.5	−0.2°C
4 p.m.	32.4±1.0°C	−0.1	0	+0.6	−0.1	−0.2	−0.5	−0.8°C
Soil temperature (10 cm below surface)								
4 a.m.	28.9±0.8°C	−1.9	−0.9	−1.2	−1.2	−2.2	−2.3	−2.3°C
4 p.m.	32.7±1.1°C	−0.9	−2.2	−3.0	−3.5	−4.8	−5.5	−5.8°C

Averaged data of the measurement from June 25 to July 1, 1986

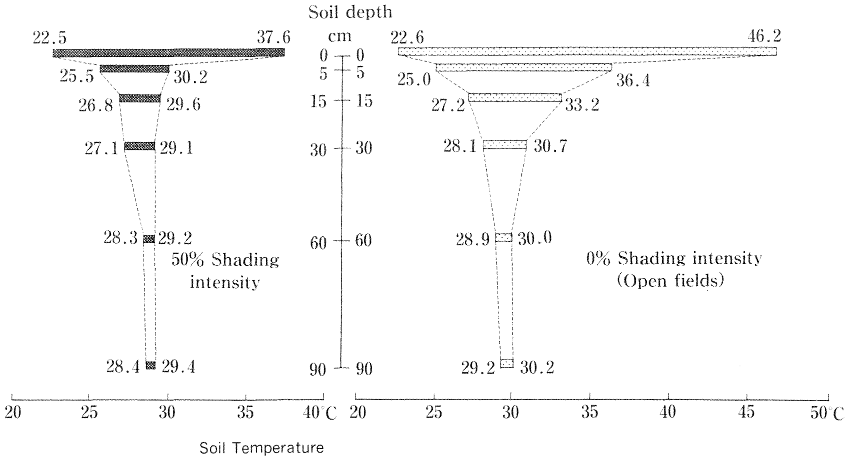

Fig. 2 Profiles of the highest and lowest soil temperature in relation to soil depth at 0% and 50% shading intensities

Table 8 Shading intensity which gives the maximum figure of growth parameters in six kinds of vegetables

Kind of vegetables	Plant height	Number of leaves	Weight of leaves	Weight of root	Weight of fruits
◎ Leafy vegetables					
Kangkong	37%	48%	20%	—	—
◎ Root crops					
Radish	48	37	37	0 %	—
◎ Fruit vegetables					
Cucumber	87	—	48	—	37%
Tomato	72	—	—	—	0
French bean	50	—	—	—	20
Sweetcorn	48	20	20	—	0

improvement. Attacks of insects on radish (mainly flea beetle and diamond back moth) were few and scars on the root surface were scarcely observed by shading. Cracking percentage of the harvested tomato fruits ranged between 33 and 67% in shading houses, while it was 83% in open field.

By decreasing the soil temperature, preserving the soil moisture and preventing insect attacks, shading provided a favorable environment for vegetable production, which contributed to quality improvement as well as yield increase. This practice could be an effective measure for stabilizing temperate vegetable production by attenuating the climatic conditions in the tropics.

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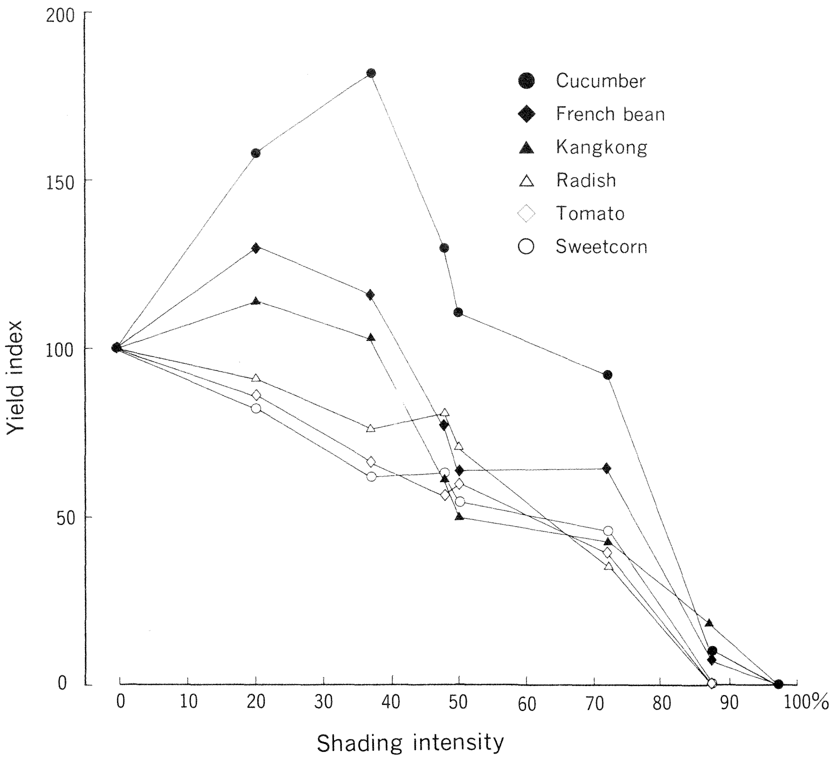

Fig. 3 Yield index of vegetables in relation to shading intensity

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