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The Potential for Breeding Heat Tolerant Vegetables for the Tropics

Robert F. Chandler, Jr.[1]

Considered as a group, vegetable crops constitute man's richest source of vitamins, minerals, and plant proteins. Yet the yield of most vegetable crops in the tropics is less than one-third that of the same crops when grown in temperate zones. Although poor cultural practices and high incidence of insect and disease attack are significant factors in accounting for the low yields, certain important vegetable crops perform poorly in the tropics simply because of prevailing high temperatures. In the past this constraint has limited the production of such crops to high altitudes or to the winter months. In recent years, however, considerable progress has been made in breeding varieties that produce well during the hot season in the tropics, with some approaching the yield potential of the same crops grown in cool climates.

To demonstrate the possibilities for breeding heat tolerant vegetable varieties, recent advances with three important crops are presented briefly in this paper. Chosen for review are the tomato (*Lycopersicon esculentum* Mill.), the white potato (*Solanum tuberosum* L.), and the heading type of Chinese cabbage (*Brassica campestris* L. ssp *pekinensis* [Lour] Olsson).

Tomato

In 1944, Went (25) showed that tomatoes set fruit best when night temperatures range between 15° and 20° C, but that poor

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set is obtained at either higher or lower temperatures. Since then this fact has been corroborated many times by various research workers. Kuo et al (20) give an excellent review of the subject. Villareal (24), working at the Asian Vegetable Research and Development Center (AVRDC) with the largest varietal collection of tomatoes anywhere in the tropics, reported that from among over 4,600 varieties tested only 39 had the capacity to set enough fruit for a commercial crop when night temperature exceeded 22° C. The heat tolerant varieties identified from these tests were then used as parents in a breeding program to develop cultivars that were tolerant to both high temperatures and disease attack.

Studies (1,11,18,19,20,21,23, for example) have shown that the physiological basis for heat tolerance varies among cultivars. Favorable characteristics include high pollen and ovule viability, abundant pollen production, and a lack of stigma exertion. Plant breeders at AVRDC have attempted to combine all of these attributes into one genotype.

Although the tomato will not survive in the humid tropics without a degree of resistance to bacterial wilt (Pseudomonas solanacearum), essential also is the capacity to set a good crop of fruit under high temperatures and wet conditions. The genetic lines originating from AVRDC's tomato breeding program, which have been tested in many countries in the humid tropics, usually possess both heat tolerance and resistance to bacterial wilt. Therefore, the yield data obtained reflect both heat tolerance and disease resistance. Nevertheless, without the ability to set a crop under high temperature conditions, yields would be extremely low or nil. Thus, valid comparisons can be made between the performance of the heat tolerant modern varieties and the traditional ones.

The annual reports from AVRDC (3,4,5,6,7,8,9,10) contain yield data from comparisons on the Center's experimental fields as well as from tests in many other tropical areas of the world. Selected findings from several sources are shown in Table 1. As indicated in the data, the heat tolerant varieties outyielded the local varieties in the same locations by a factor of nearly three to one.

AVRDC has frequently reported the success of its varieties in national tests around the world, but in many instances exact yields have not been given. In 1980 the Center announced outstanding yield advantages for its genetic lines in the following locations (in addition to those listed in Table 1): Guam, Indonesia, the Philippines, Upper Volta, Honduras, the Virgin Islands, Sri Lanka, and Togo. Several countries have given local varietal names to the AVRDC lines they have tested.[2]

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[2] Editor's note - AVRDC heat tolerant tomato selections have been released to farmers in Fiji, Guam, Indonesia, Malaysia, Panama, Papua New Guinea, the Seychelle Islands, Singapore, Sri Lanka, Taiwan, Tanzania, and Thailand.

Table 1. Yield comparisons of heat tolerant tomato lines from AVRDC and traditional varieties (checks) at different locations* and years in the humid tropics.

Location and year of test	Improved AVRDC selection	Yield (t/ha)	Traditional check variety	Yield (t/ha)
Taiwan, 1976	143-0-48-1-0	12	Green Skin	7
Taiwan, 1976	143-0-10-3-0	15	TK 70	9
India, 1977	CL-33d-0-22	43	CO-1	30
Malaysia, 1977	CL-502-F5-20	25	Banting	0
Taiwan, 1978	9d-0-3-6	18	White Skin	2
Taiwan, 1978	9-0-0-1	17	VC 48-1	7
Brazil, 1979	143-0-10-3	73	Highest yielding local check	11
Caroline Islands, 1979	143-0-6-9	14	Local check	0
Bangladesh, 1980	Average of 10 AVRDC selections	36	Local check	26
Zambia, 1980	4 AVRDC lines	26	Local check	13
Mean yields		27.9		10.5

* All tests were conducted during the hot summer months at low elevations.

White Potato

The white potato (Solanum tuberosum) is a cool climate crop and has never been grown commercially in the lowland tropics during the hot summer season. However, both AVRDC and the International Potato Center (CIP) have conducted research to develop potato varieties that will give commercial yields under tropical conditions. This is an important line of research because the potato can provide an excellent source of energy and high quality protein to tropical populations in which malnutrition is often prevalent. As CIP points out (13), the development of a heat tolerant potato could move the commodity from a luxury item to a common staple food in the tropics.

AVRDC collected germplasm of potato tubers as well as true seed from 1972 through 1978 (the Center discontinued research on the white potato in 1979). A few selected data from the experimental trials conducted by AVRDC between 1974 and 1978 are shown in Table 2.

Table 2. Selected yield data of heat tolerant and heat sensitive lines of potatoes when tested on AVRDC's experimental field.

Selection number and year of test	Marketable tubers (no. per hill)	Weight of marketable tubers (g/hill)	Calculated marketable yield (t/ha)
1512-1 (1974)	5.0	320	17 *
Average of 5 best heat tolerant selections (1976)	4.2	464	24 *
1282-19 (1978)	2.5	250	7.6
Nohrin 1 (check-1976)	1.0	80	1.5*
S 510 (check-1978)	0	0	0
S 18	0	0	0

* Indicates that the figure was derived by assuming the same number of hills per hectare as in 1978 experiments.

In its 1978 Progress Report (8) AVRDC stresses the superior qualities of selection 1282-19 because it is both heat tolerant and resistant to bacterial wilt (Pseudomonas solanacearum). This may seem surprising when the relatively low yield of 7.6 t/ha of marketable tubers is considered (Table 2). However, it should be pointed out that the soils on AVRDC's experimental field are heavily textured and drain imperfectly for good tuberization. To prove this point, AVRDC scientists in 1974 (3) tested a heat sensitive variety, Nohrin 1, in clay pots with varying soil. The results showed that when the potatoes were grown in a mixture of soil, sand, and compost, tuber production was 340% higher than in the control pots (soil only).

Another factor causing low yields in the two main 1978 experiments involving selection 1282-19 was a poor stand at harvest time due to excessive rain. The first experiment had a stand of 70% and the second only 62%. In a separate experiment that year, marketable yield of No. 1282-19 more than doubled (14 t/ha) when stands were improved to 100% by transplanting pregerminated tubers. Direct-planted tubers of this clone had a 64% stand and a marketable yield of only 6 t/ha.

As with the tomato, AVRDC arranged for cooperative trials in other locations. For example, in the Philippines in 1976 (6) the best AVRDC selection (1284-19) yielded 10 t/ha while the local check (Fina) produced only 1 t/ha. In tests conducted in 1978 (8) by the Philippine Packing Corporation in Bukidnon (450 m elevation), four AVRDC varieties were among the top ten and yielded between 16 and 38 t/ha. Included in the four was selection 1282-19.

As shown in Table 2, two of the heat sensitive check varieties produced no marketable tubers, and one (Nohrin 1) produced only a single marketable tuber per hill compared with a calculated yield of 24 t/ha for heat tolerant selections. AVRDC has therefore proved that it is possible to develop white potato varieties that are heat tolerant and disease resistant, and that under favorable soil conditions will yield over 20 t/ha.

CIP started its program to develop heat tolerant potato varieties in 1974, placing tests at San Ramon, Peru at an elevation of 800 m. Since that location was not really representative of the lowland tropics, CIP established a second test station in 1975 at Yurimaguas, located in the Amazon jungle 175 m above sea level. Minimum temperatures are never below 19° C, and day temperatures may reach 36°.

CIP reported that at Yurimaguas in 1975 (12) several clones yielded 500 g/hill which is equivalent to 15 t/ha at the planting distance used at that site.

In tests conducted by CIP at Yurimaguas in 1977 (14) three selections yielded between 12.5 and 17.4 t/ha, whereas the unadapted selections produced yields between 0.06 and 4 t/ha.

CIP reported that in 1979 (15), among 1,500 selected clones evaluated at San Ramon and at Yurimaguas, 200 produced yields between 0.5 and 2.5 kg/plant. In 1980 (16) the fifth cycle population for the lowland tropics contained two selections that produced yields of 32 and 35 t/ha at the Yurimaguas station.

CIP has an extensive international regional research and training program. It has placed representatives in seven locations throughout the world. Part of the work at most of these locations is to test heat tolerant potato varieties or genetic lines. The results reported in 1981 (17) vary considerably from site to site. In the Philippines, low elevation tests in the Cagayan de Oro valley gave a total yield of 33 t/ha and a marketable yield of 21 t/ha on sandy soil. In the same general location on a heavier textured soil, only 10.5 t/ha of marketable tubers were produced. This corroborates the AVRDC findings that in the hot humid tropics potatoes yield much better on light-textured soils.

The potato research programs of CIP, both in Peru and elsewhere, include research on soil and crop management to develop methods for lowering soil temperature through the use of mulches, reflectors, and partial shade. In addition, of course, the programs include attempts through plant breeding to combine heat tolerance with disease resistance.

During recent years much work has been done on the use of

true seed in potato production in order to save transportation costs, to reduce storage problems, and especially to eliminate the transmission of disease-carrying organisms. When this method of propagation is perfected, it will greatly enhance the multiplication and distribution of potato varieties in the tropics.

Although much research remains to be done, it seems clear that as greater disease resistance is combined with heat tolerance, the potato can become an important food crop in many tropical regions where it is not now grown and will thereby contribute substantially to human nutrition.

Chinese Cabbage

Traditionally, Chinese cabbage (heading type) was considered a cool season crop, and production in the tropics was confined to the highlands. In Taiwan, for example, the quantities produced in the cooler areas were inadequate to supply the summer market, and, as a consequence, prices were exceptionally high from May to September.

AVRDC decided from the outset (2) to try to develop heat tolerant Chinese cabbage to increase the supply of this nutritious vegetable during the hot season in the tropics.

In 1973 (2) AVRDC collected 303 varieties of Chinese cabbage, mainly from Taiwan, Korea, and Japan. The collection was screened for heat tolerance by growing all the accessions during the hot months. Only a few of the varieties produced heads, and their weight was much less than that of the common varieties grown during the winter months. The mean weight of the heads of the heat tolerant varieties was only 0.34 kg, whereas the varieties used in the winter trials averaged 2.28 kg. The so-called heat tolerant varieties were not only unable to produce marketable heads during the hot months but were highly susceptible to diseases. Hence, it became evident at the start of AVRDC's Chinese cabbage breeding program that it would be difficult to produce heat tolerant varieties that could be grown successfully at any season of the year in the lowland tropics. Nevertheless, encouraged by the Japanese success a few years earlier in breeding common cabbage (*Brassica oleracea*) varieties that can be grown in the tropics, the Center decided to make a major effort to develop heat tolerant, disease resistant Chinese cabbage cultivars. Judging from the literature, AVRDC is the only institution that has made a serious attempt to achieve this objective.

By 1974 (3) AVRDC's scientists had acquired a total of 449 heading types of Chinese cabbage and announced that when screened for heat tolerance one accession had a mean head weight of 729 g and another of 944 g. The breeding program, consisting mainly of crossing heat tolerant selections with disease resistant ones, in 1974 produced for the first time one set of progeny in which the heat tolerant segregants had heads three times the size

of the heat tolerant parents.

In 1975 and 1976 much of AVRDC's research effort with Chinese cabbage was devoted to genetic studies, the development of rapid screening methods for heat tolerance, and ways of propagating selected genotypes vegetatively. These were important projects and helped to advance the rate of progress in the breeding program. In those two years many crosses were made between heat tolerant selections and those that had some resistance to soft rot, downy mildew, and turnip mosaic virus - the three most serious diseases of Chinese cabbage in the tropics.

In 1978 (8) AVRDC plant breeders evaluated six open-pollinated populations and found one, 77 M(3)27, that had high resistance to soft rot and downy mildew, along with heat tolerance. In a late summer yield trial at the Center it produced a calculated yield of 26.5 t/ha with an average head weight of 799 g. A local heat tolerant check variety (Yuan Pao No. 2) yielded 20.1 t/ha and had a mean head weight of 677 g.

R. T. Opeña, who leads the Chinese cabbage breeding program at AVRDC, was dissatisfied with the progress that he and his colleagues were making in developing heat tolerant varieties that would produce sizable heads during the hot months. In 1978 (8) the AVRDC breeders decided to explore the possibility of making greater strides by using heterosis breeding rather than exploiting interpopulation variability.

Previous studies had shown that the gene pool for heat tolerance was narrow, which of course reduced the chance of making substantial progress through heterosis breeding. AVRDC, however, decided that the most promising approach would be to widen the genetic base by intercultivar crosses between heat tolerant and heat sensitive winter types. In this way not only would genetic diversity be introduced into the heat tolerant gene pool, but additional beneficial genes for disease resistance would be derived from the winter varieties.

The results of this breeding program were the most promising yet obtained at AVRDC (22). The best hybrid (No. 59) yielded over three times that of B189, the local check. The actual yields were 29.3 t/ha (head weight 972 g) for the hybrid and 9.0 t/ha (head weight 321 g) for the check variety.

AVRDC places its more promising lines in yield trials in other countries. In 1980 (10) it reported that its selections were performing better than local entries in Indonesia, Malaysia, Thailand, and the Philippines, as well as in Taiwan in locations away from AVRDC.

Opeña and Lo (22) conclude, "The initial key to achieving high yield in heat tolerant cultivars, therefore, appears to be dependent upon broadening the genetic base for this trait in order to enhance hybrid vigor."

With this more recent approach to breeding heat tolerant Chinese cabbage, high yielding, heat tolerant, and disease resistant cultivars have been developed that can be successfully

grown in the lowland tropics[3]. Yields undoubtedly will still be lower than those obtained in cooler climates, but harvests of 30 t/ha will make the crop economically profitable and also reduce the price to the consumer.

Summary

This paper presents evidence that substantial progress has been made during the past decade in breeding varieties of tomatoes, potatoes, and Chinese cabbage that are tolerant to high temperatures and produce satisfactory yields in the humid lowland tropics. As greater resistance to insect and disease attack is bred into the heat tolerant varieties, higher and more stable yields no doubt will be obtained in the years ahead.

Success with the three vegetable crops cited would indicate that similar progress can be made with other crops if the magnitude of the research effort is sufficiently large. Onions, for example, are extensively grown during the winter months in Taiwan, the Philippines, and India as well as in other tropical and subtropical countries. However, the large onions in demand in urban markets will not produce seed in the tropics unless given a special cold temperature treatment that is impractical for most growers. Therefore, seed must be imported annually. It is probable that a large, truly tropical onion could be developed by crossing the more sizable varieties from the U.S.A., Korea, or Japan with such tropical varieties as Dingras Red Globe from the Philippines. The latter onion produces seed in the tropics but the bulbs are too small to compete on the market with varieties grown from imported seed. Crossing the local tropical varieties with those from temperate zones should result in cultivars that produce both seed and large bulbs under tropical conditions.

Vegetable crops now confined to cool climates include broccoli, cauliflower, head lettuce, green peas, and spinach. Moreover, many vegetable crops now grown in the tropics yield much less than when grown in temperate zones. Thus there is scope for breeding varieties of many vegetable crops better adapted to the high temperatures and humidity of the tropics and more resistant to attack by insects and diseases.

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[3] Editor's note - An AVRDC hybrid has been officially released in Taiwan and adaptations of the Center's lines are being grown in Korea during the summer season. Two open-pollinated, heat tolerant AVRDC lines have also been released in the Philippines.

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