PN-ABF-773

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THE INSTITUTES FOR APPLIED RESEARCH

BEN-GURION UNIVERSITY
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אוניברסיטת בן־גוריון
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Beer-Sheva, Israel

באר־שבע, ישראל

PN-ABE-173

THE INSTITUTES FOR APPLIED RESEARCH
BEN-GURION UNIVERSITY OF THE NEGEV

C 8-142 BGUN-ARI-7-90

SOUTHERN AFRICAN EDIBLE VEGETABLES: GERMPLASM COLLECTION, EVALUATION AND BREEDING

Annual Report January - December 1989

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Rec'd in SCI APR 5 1990

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Submitted to U.S. Agency for International Development
CDR Program Project C-8142
(File No. 864551)

Beer-Sheva, Israel March 1990

ABSTRACT

Africa contains a wide array of edible indigenous vegetable species which are relatively unknown to African and western scientists. The present program is aimed at determining and characterizing the genetic variations in a number of these species, with emphasis upon members of the Cucurbitaceae and of the genus Amaranthus. During the first year we mounted one major and several minor collecting trips and collected germplasm from other sources. In addition we examined electrophoretic variations in *Cucumis metuliferus* and vegetative and reproductive variations in *Momordica charantia*.

Key words: African vegetables, Cucurbitaceae, genetic variations, germplasm.

ACKNOWLEDGEMENTS

We wish to thank Shoshana Avni and the Staff of the Sha'ar HaNegev Experimental Station for their excellent technical work, as well as Marion Milner for typing the report and Aliza Sen for styling.

INTRODUCTION

The entire agricultural production of the world is based upon a handful of crops. This applies to staple crops (grains, legumes and tubers) as well as to fruits and vegetables. In the case of vegetables, much of the world's research and almost all international trade is confined to those few species that have gained culinary acceptance in Europe and the United States. These include tomato, pepper, cabbage, celery, carrot, brassicas, onion, etc.

In Africa a wide array of edible indigenous vegetable species are grown or are available. These species have been eaten and/or used in other ways by local populations for hundreds if not thousands of years. They are grown almost exclusively as subsistence crops and are gathered from the wild or grown by the family for the family. Each family selects seed from its own fruit or obtains seed from other members of its village for sowing the following growing season. Very few varieties are cultivated, if at all, and the crops grown are effectively landraces. Consequently much genetic variation may be expected within each species, with little genetic exchange occurring from locality to locality.

However, these endemic fruits and vegetables are in danger of disappearing from cultivation in many areas due to processes set in motion during the colonial era (Brucher, 1977) when temperate zone crops and agrotechniques were introduced into tropical Africa. The colonial powers oriented their research efforts towards crops that they could grow and export to Europe or towards those wished to consume themselves. The former category included wheat, corn, plantation and raw material crops. The cultivation of these new crops was often accompanied by the destruction of native forests, exposure and weathering of already poor soils, and the elimination from production or reduction of indigenous crops.
In addition the colonial settlers were interested only in the fruits and vegetables familiar to them from their home country and looked down upon the indigenous crops.

Now that African countries have achieved independence the control of agricultural development is in the hands of their scientists. However, many scientists, including many working in vegetable production, are trained wholly or in part at western

universities and write their theses work on "European" vegetables. When they return to their country, two factors often militate in favor of research in those crops rather than in the endemic species. First, most first-rate international journals are biased toward the "European" crops. Second, the local political elite often encourages research on Western crops because international markets already exist and the politicians must think in terms of the national economy i.e. export earnings.

In the present program we will investigate the genetic variation and economic potential of two groups of vegetables, the first group consisting of endemic species of the Cucurbitaceae and the second of members of the Amaranthus genus. The species that we areinterested in include:

1. **Cucumis metuliferus** - (African jelly melon, kiwano) - This plant is endemic to eastern, central and southern Africa. It is an attractive climbing annual which grows to a length of several yards. The fruit, which is eaten, is shaped like a short stout cucumber with blunt spikes on the outside. Its pulp is brilliant green and very juicy but with a rather bland taste due to low sugar content which, at the moment, limits its appeal. Because of its pleasant appearance, the species is being grown commercially in several countries as a decorative crop. In Kenya and other African countries it is eaten as a fruit or mixed with other fruits in a compote. In some areas it is considered to be a treat.

2. **Cucurbita pepo** - (squashes, marrows, pumpkins) - Pumpkins and squashes are widely grown throughout Kenya. However, little research has been conducted on either or variety testing breeding and agromanagement. That is, nothing is known about genetic variation in Kenya. Farmers normally grow several plants in their garden, harvest the fruit and save some seed for the next planting. Thus no true varieties are widely grown but rather landraces. In addition, relatively little gene flow is believed to have occurred. In addition to the fruit, the seed is consumed by many people.

3. **Luffa acutangula** - (ridge gourd, turia) - This squash-like fruit, often confused with the closely related sponge gourd, is eaten as a curry or prepared like eggplant in some areas of Kenya. It is endemic over much of Africa and southern Asia. It is usually grown either as a climbing vine on huts and tressels or as squashes are on the ground. While varieties exist, none have been bred and the extent of genetic variation in Kenya is unknown.

4. **Luffa cylindrica** - (sponge gourd) - This pantropic species, unlike its close relative turia, is usually not eaten but rather used as a cleaning utensil or as a filter. Nevertheless, it is an important vegetable for many people and is included in our

targeted species. In addition, it has excellent resistance to powdery and downy mildew, a trait needed in turia (Mendlinger, unpublished information).

5. **Momordica charantia** - (bitter gourd, karela) - This annual pubescent vine that climbs by means of tendrils produces a small, oval fruit which is eaten as a curry when still unripe. There exists an extensive international market for the fruit as with *L. acutangula*, varieties were bred for India & China but not for African conditions.

6. **Coccinia sessilifolia** - (wild cucumber) - This wild species is eaten by villagers and nomads. The fruits are cooked and eaten as a vegetable and the large underground storage organs are roasted or boiled. In addition, this species is used in many traditional folk medicines.

7. **Lagernaria siceraria** - (bottle gourd, doodhee) - This species is one of the oldest cultivated by man. Nevertheless, relatively little modern research has been conducted on it and the amount of genetic variation is almost unknown. The fruits are eaten when still unripe. The skin of the ripe fruit is used for storage of liquids and sometimes grain.

8. **Amaranthus sp.** - This genus is eaten principally in Africa as a leafy vegetable. Its importance in many areas is comparable to lettuce or spinach in the United States and Europe. It is a C-4 plant and as such an efficient producer of carbohydrates. Amaranthus is suitable for many crop rotations and is resistant to many soil pests. It is high in vitamin C, iron and protein.

RESULTS

This report will present our work to date in both Kenya and Israel. Because of the necessity of collecting the germplasm before initiating the experimental parts of the program, most of the first year was devoted to collection and not evaluations. However, the Israeli team succeeded in collecting germplasm of some species and conducting some preliminary field studies and electrophoretic analyses. The report will cover:

(i) Kenya- preliminary exploration and mapping
(ii) Kenya- joint collecting trip by Kenyan and Israeli scientists
(iii) Kenya- collecting trips conducted by the Kenyans alone
(iv) Israel- germplasm collection from non-Kenyan sources
(v) Israel- electrophoretic examination of genetic variation in *Cucumis metuliferus*
(vi) Israel- field evaluation of vegetative growth, flowers and fruit quality in six *Momordica charantia* accession lines.

I. KENYA - PRELIMINARY EXPLORATION AND MAPPING

For most of the species targeted for study little or no information is available regarding their distribution in Kenya. Therefore, the two principal investigators (S.M. and J.C.) decided that it would not be worthwhile for the Israeli to come to Kenya to collect seed until more information on species distribution was available.

In much of Kenya the farmers are dependent upon the rains and their crop are harvested in are specific periods, namely May-June, October-November and end of December-January. It was agreed by the PI's that Dr. Chweya would spend the first harvest period conducting exploratory trips in different parts of the country to identify potential collecting sites. Dr. Chweya made two trips each to the eastern and western parts of the country. During the eastern trips he scouted the road from Nairobi to Mombasa, the Shimba hill, and the area between Mombasa and Malindi. During the western trips he scouted the area north of Nakuru toward Tot, the highlands and the Lake Victoria area.

II. KENYA - JOINT COLLECTING TRIP BY KENYAN AND ISRAELI SCIENTISTS

From October 12 to 22 the Israeli scientists Dr. Sam Mendlinger and Ms. Susanne Huyskens went to Kenya to join Dr. James Chweya and Mr. Elizaphone Seme, director of the Kenyan Gene Bank, in this year's major collecting trip. The itinerary

was based upon Dr. Chweya's earlier explorations. It was decided that rather than collect in depth in a few areas, it was more important to gain an understanding and appreciation of the extent of the genetic variation of the targeted species in Kenya. Therefore our aim was to collect over as many different ecological and tribal areas as possible. Our trip was broken into two parts. The first four days were devoted to collecting along the Nairobi - Mombasa highway and north and south of Mombasa, and the second four-day period to collecting in the Rift Valley, the western highlands, and in the central highlands between Mount Kenya and Nairobi.

Oct. 13 - Spent in discussions between Israelis and Kenyans on collecting strategy and other discussions about the direction of the program.

Oct. 14 - The collecting team (Mendlinger, Chweya, Seme and Huyskens) collected germplasm along the Nairobi - Mombasa highway. The sites are listed in Table 1. Our transect included several ecological types including highlands, semi-arid and subtropical, areas and passed through several tribal areas.

Oct. 15 - We collected in the semi-arid and subtropical areas west and north of Mombasa. This area includes a number of tribes plus areas being settled by people from tribes native to the central highlands.

Oct. 16 - We collected south of Mombasa in the Shimba Hills, near the Tanzanian border and along the coast. This area is a major growing area for pumpkins and Luffa.

Oct. 17 - This was mostly a travel day. We returned to Nairobi, deposited our collection at the Kenyan Gene Bank and drove on to Nakuru.

Oct. 18- We collected in the western-northwestern region of Kenya. The Tungen Hills and the Chernangani and Chrpanda Hill country were are primary areas. They are the home of several Bantu tribes whose members are basically farmers plus the semi-nomadic Pokot, Samburu and Turkana tribes whose members combine farming with cattle and goat herding. The ecology is semi-arid throughout, with some of the Bantu people practicing a primitive irrigation cultivation for vegetables.

Oct. 19 - We collected pumpkins and Luffa from town markets in the western highlands.

Oct. 20 - We spent the day in the central highlands where we collected principally pumpkins from local fields and markets.

Oct. 21 - We spent our last working day cataloging our collection and determining our future collecting and evaluation program. The plants were left at the Kenyan Gene Bank for cleaning.

It was decided that the Israeli PI (S.M.) would return twice in 1990 to Kenya to collect together with the Kenyan team in the two harvest periods omitted in 1989, namely July and December-January. These two trips will be spent collecting in areas not visited in 1989, i.e. along the coast north of Mombasa, the Lake Turkana area and the Masai country. In addition, in-depth collection will be carried out in certain areas to be selected in the light of the genetic variation studies performed during the first year of collection.

III. KENYAN COLLECTING TRIPS CONDUCTED BY THE KENYANS ALONE

Following the joint collecting trip Dr. Chweya made two collection expeditions in November by himself. The first was to the Homa Bay area in Lake Victoria, an area which is repurted to have considerable variation in its pumpkins. The second was to the Oyugis area in the south. The results of these collection trips will be presented in subsequent annual reports.

IV. ISRAEL- GERMPLASM COLLECTION FROM NON-KENYAN SOURCES

When the principal investigators were writing the grant proposal it was decided that it would be beneficial toward the aims of the program to integrate the information obtained on the genetic variation of the germplasm collected in Kenya with analyses of preexisting germplasm collections. It was decided that the Israeli team would acquire the non-Kenyan germplasm and then pass it on to the Kenyans. Accordingly we contacted several germplasm collection centers and wrote directly to researchers. The material so collected is described in Table 2.

Within the first few months of the program, we received a number of accession lines of two species, *Cucumis metuliferus* and *Momordica charantia*. We therefore, decided to begin our genetic variation studies in these species.

V. ELECTROPHORETIC EXAMINATION OF GENETIC VARIATION IN *CUCUMIS METULIFERUS*

We examined the genetic variation in our collection of germplasm of *Cucumis metuliferus*, kiwano by comparing the isozyme profiles of the accession lines obtained to date.

Materials and Methods

Eight accession lines of *C. metuliferus* were compared and contrasted. These were: a commercial line obtained from New Zealand, origins unknown; two mutant lines, M-1 and M-2, derived from the commercial line; lines 67868, 67869 and 67870 obtained from a collection in Germany, origin, collection information, etc. unknown: and lines 77151 and 77313, obtained from South Africa, origins and collecting information also unknown.

The electrophoretic protocol adopted was according to Brody and Mendlinger (1979). Horizontal starch gel electrophoresis (13% Sigma starch) was used. Three buffer systems were used:

(i) Poulik - tank buffer- 18.5g boric acid, 2.4g sodium hydroxide, 1 liter water, pH 8.6; gel buffer- 9.2 g Tris, 1.0 g citric acid, 1 liter water - run at 200 V and 100 mA for three hours.
(ii) TM - tank buffer - 12.1 g Tris, 11.6 g maleic acid, 2.7 g EDTA, 2 g magnesium chloride and 1 liter water, pH 7.4; gel buffer- 1:20 dilution of tank buffer:water - run at 100 V and 100 mA for four hours.
(iii) TC - tank buffer - 70 g Tris/liter water, 30.25 g citric acid/liter water with 10 ml of each solution mixed with 330 ml water for the buffer, pH7.7; gel buffer- 18.6 g boric acid, 1 liter water, pH 7.8 adjusted with sodium hydroxide.

Eleven isozyme systems covering 22 loci were used. These were:
(i) PGI, phosphoglucosoisomerase (3 Loci) - 35 ml Tris-HCl 0.2 M pH8.0, 5 ml magnesium chloride 1 M, 20 mg fructose-6-phosphate, 20 units glucose-6-phosphate dehydrogenase, 10 mg NADP, 15mg NBT and 5 mg PMS.
(ii) G.P., Fraction 1,- 1% solution coomasie blue in 10% acetic acid/water.
(iii) ACPH, acid phosphatase-50ml sodium acetate buffer pH 5.0, 200 mg alpha-naphthyl acid phosphate, 50 mg fast black K.
(iv) MDH, malate dehydrogenase (2 loci)- 40 ml Tris/HCl buffer pH8.0, 5 ml malate substrate, 30 mg NAD, 20 mg NBT and 5 mg PMS.
(v) SDH, shikimic acid dehydrogenase- 50 ml Tris/HCl buffer 0.1 M pH 7.5, 50 mg shikimic acid, 7 mg NADP, 10 mg MTT and 2 mg PMS.
(vi) PGM, phosphoglucomutase (3 loci)- 5 ml Tris/HCl 0.2 M pH 8.0, 35 ml water, 85 mg glucose-1-phosphate, 5 ml magnesium chloride 1.0 M, 40 units glucose-6-phosphate dehydrogenase, 5 mg NADP, 5 mg MTT and 2 mgPMS.
(vii) GDH, glutamate dehydrogenase (3 loci, GDH-1 and-2 and unknown-1), 25 ml Tris/HCl 0.2 M pH 8.0, 25 ml water, 1 g sodium glutamate, 15 mg NAD, 10 mg NBT and 3 mg PMS.
(viii) G-6-PDH, glucose-6-phosphate dehydrogenase (2 loci)- 10 ml Tris/HCl 0.5M pH 7.1, 40 ml water, 1 ml magnesium chloride 1 M, 100 g glucose-6-phosphate, 15 mg NADP, 10 mg NBT and 5 mg PMS.
(ix) EST, esterase (3 loci)- 50 ml phosphate buffer 0.1 M pH 6.25, 50 mg fast blue RR and 30 mg alpha-naphthyl acetate in an acetone/water solution.
(x) 6-PGD, 6-phosphogluconate dehydrogenase- 25 ml Tris/HCl 0.2 M pH 8.0, 2 ml magnesium chloride 1 M, 10 mg 6-phosphogluconic acid, 2 mg NADP, 4 mg MTT and 1 mg PMS.
(xi) GOT, glutamate oxalacetic transamerase (2 loci, GOT and unknown-2)- 50 ml Tris/HCl 0.1 M pH 8.5, 50 mg KGA, 100 mg ASA, 5 mg P5P and 75 mg fast blue BB.

Plants were grown to the 2-leaf stage and either the leaf or the cotyledon was used depending upon the isozyme. The sample was hand ground in a mortar with several drops of distilled water and a wick dipped in the resulting juice was inserted in a slot in the gel. The wicks were removed 20 minutes after the start of the run. After the run, each gel was cut horizontally up to 4 times, depending upon the number of slices needed, and stained with the appropriate recipe. After staining, the gels were read, placed overnight into fixative (10% acetic acid), and wrapped in Saran Wrap and stored at 4°C.

Results and Discussion

The results are presented in Table 3. Twenty two loci were compared. Overall, the results indicate relatively little genetic variation. In addition, no heterozygotes were found, which is rather surprizing in an allogamous species. Of the 22 loci, 18 were monomorphic throughout the species. Of the remaining 4, PGI-2 had 3 alleles, 2 of which were unique to the three German lines. Fraction-1 was found to be variable only in the commercial line. PGM-1 had 2 alleles, the only ones that were found to be widespread in the species: they occurred in the commercial line and its mutants as well as in two of the German lines. The fourth, Unknown-2, was found only in the commercial line and Mutant-1. It was absent in the five lines obtained from Germany and South Africa.

The relatively small variation found can be explained by any one of, or a combination of, three possibilities. First, we may be examining accession lines and not populations. The lines obtained are of unknown origin and history, and thus it is possible that the three lines from Germany are descended from the same plant or population (which would account for the unique "s" allele for PGI-2). In addition, most lines are grown out for seed multiplication, usually using a single plant or at most a few plants crossed among themselves. This would lead to fixation of alleles (and the absence of heterozygotes) with a high probability that the primary allele would be fixed. Brody and Mendlinger (1979) found this situation to obtain in the genera *Triticum* and *Aegilops*.

Second, each line may have originated from only one or at most a few fruits from the same or closely related plants. We found that in Kenya plants of this species (or of closely related species) are usually found either isolated or in groups of a few plants. We never saw large populations. This would also lead to fixation in the wild.

Third, it may be that there is little genetic variation in the species. Lewontin (1974) reports several cases of limited genetic variation in plant species.

The Kenyan material will be compared with these accessions during the second year of the program.

VI. ISRAEL- FIELD EVALUATION OF VEGETATIVE GROWTH, FLOWERS AND FRUIT QUALITY IN SIX MOMORDICA CHARANTIA ACCESSION LINES

We obtained six lines of *Momordica charantia*, karela, early in 1989 and decided to examine vegetative growth parameters, flower production and fruit quality in plants grown in the field. These are results preliminary and further examinations are planned.

Materials and Methods

The six lines tested included five accession lines, one obtained from Japan and four from European sources, plus the main commercial line in Kenya. Three to four plants of each line were grown within a larger field of the same species where experiments on agromanagement were being conducted. The beds were two meters wide and prepared as for melon. A single drip line with 2-liter per hour drippers spaced 0.5 meters apart was laid for irrigation and fertilization. A 2.5-meter long section was set aside for each line. A single seed was sown next to each dripper. Percent germination was not uniform but a minimum of three seeds per line germinated. The low seeding number per line was due to the fact that there was not enough time for propagation of our limited seed supply before the next season. The plants were given the normal treatments for melons for the area.

During the growing period the height and number of branches of each plant and the number of male and female flowers were periodically recorded. Fruit were harvested and various fruit quality and biochemical parameters were examined.

Results and Discussion

The number of branches per plant and the plant height over time are presented in Figs. 1. All lines except Kenya produced the same number of branches, about two by day 60. The Kenyan line produced almost 6. The height of the plants increased slowly throughout the growing period in all lines, with very little difference between the lines.

The length and width of the leaves are presented in Figs. 3 and 4 respectively. The Kenyan line has slightly longer leaves than the others. As regards width, no differences were found between the lines.

Figs. 5 and 6 present the mean number of female and male flower respectively produced over six census days and Table 4 gives the total number. There are differences in the number of flowers produced per line. For female flowers, no significant increase in flower production with time or size of plants was found, i.e each plant produced the same number of female flowers per census period throughout the growing season, and no significant correlation was found. The Kenyan and 561 lines produced more female flowers and 562 the fewest. For male flowers, 560, Japan and the Kenyan line exhibited a linear increase in flower production with time. The Kenyan line produced more flowers than the others, as seen in Table 4.

Fig. 7 and 8 present the fruit width and length respectively. Considerable variation is present for these traits and breeding for a desired shape should be possible.

Table 5 presents the fruit quality and biochemistry parameters. Genetic variation was found in all traits, excepting acidity, but including the two parameters for sugar content, TSS and reducing sugars.

Table 6 presents the different mineral levels in the lines. Once again, variation exists and may be exploited for agricultural purposes.

NEXT YEAR'S PROGRAM

The research objectives of the first year were severely limited by the need to collect germplasm, and little joint research was performed between Israel and Kenya. However in 1990 our program will concentrate on field evaluation of our species, together with electrophoretic analyses. The PI's have agreed to grow the collected lines in two localities in both countries and examine the same parameters. One student from Kenya will come to Israel to conduct some of the field research. A second Kenyan student will come to Israel to conduct electrophoretic analyses in turia and karela.

Dr. Mendlinger will make two 17-day trips to Kenya for purposes of collection, discussion and planning. Dr. Chweya may also make a second trip to Israel.

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Table 1. Collecting sites, October 1989: ecology and species collected

Site	Ecology	Species
1. Emali	semi-arid, plain	*Lagernaria, Cucurbita pepo*
2. Makindo farm	semi-arid, river bed	*Citrillus* (feral), *Cococcinia* sp.
3. Makindo market		*Cucurbita pepo*
4. Nthinge	semi-arid	*Cucumis* sp.
5. Mariakani field station	subtropical	*Cucumis sp., Amaranthus* sp.
6. Mombasa suburb	subtropical	*Cucurbita pepo, Luffa acutangula*
7. Miritini	subtropical	*Luffa cylindrica, Amaranthus* sp.
8. Mazeras	subtropical	*Cucurbita pepo*
9. Kiwanja-ndegi	subtropical	*Amaranthus* sp. *Cucurbita pepo,. Cucumis* sp.
10. Kokotoni	subtropical	*Cucurbita pepo, Amaranthus* sp.
11. Mariakani market		*Luffa cylindrica, Lagernaria, Amaranthus* sp., *Cococcinia* sp., *Cucurbita pepo*
12. Mariakani-Kdoleni	open plain	*Amaranthus* sp.,*Cucurbita pepo*
13. Mwamba	open plain	*Cucurbita pepo, Amaranthus*
14. Kaloleni	forest	*Amaranthus* sp., *Cucurbita pepo*
15. Kibaomi	subtropical	*Cucurbita pepo*
16. Matuga research station	subtropical	*Cucurbita pepo. Amaranthus* sp.
17. Shimba Hills	subtropical	*Cucurbita pepo,. Amaranthus* sp. *Luffa cylindrica*
18. Lunja Lunja	open hill country	*Amaranthus sp., Cucurbita pepo*
19. Kidima	subtropical	*Cucurbita pepo*
20. Kisauri-Mombasa	subtropical *charantia*	*Luffa acutangula,Momordica*

Site	Ecology	Species
21. Kabernet Market	upland mountains	*Cucurbita pepo*
22. Escarpment #1	subtropical valley	*Cucurbita pepo, Cococcinia*
23. Escarpment #2	subtropical valley	*Cucumis* sp.
24. Escarpment #3	subtropical valley	*Cucumis* sp
25. Tot	semi-arid valley	*Cucumis* sp.
26. Chesogon-Lomut	semi-arid valley	*Cococcinia*
28. Kakamaja market	Upland, hilly	*Cucurbita pepo*
29. Mbali Marke	Upland, hilly	*Luffa cylindrica, Cucurbita pepo*
30. Kisumu market	subtropical Lake Victoria	*Cucurbita pepo*
31. Nyahururu market	Upland, hilly	*Cucurbita pepo*
32. Mweiga market	Upland	*Cucurbita pepo*

Table 2. Species and number of accessions collected from non-Kenyan sources

Species	Number of accessions
Cucurbita pepo	17
Luffa cylindrica	15
Luffa acutangula	10
Pachyrhizus erosus	4
Lagernaria	61
Cucumis metuliferus	8
Momordica charantia	17

Table 3. Isozyme variation patterns over 22 loci in 8 accession lines of *Cucumis metuliferus*. n=10

Locus	Line							
	Commercial	Mutant-1	Mutant-2	67868	67869	67870	77151	77313
PGI-1	m	m	m	m	m	m	m	m
PGI-2	m	m	m	m,s	m,s	f,m,s	m	m
PGI-3	m	m	m	m	m	m	m	m
Fraction-1	m,s	m	m	m	m	m	m	m
ALPH	m	m	m	m	m	m	m	m
MDH-1	m	m	m	m	m	m	m	m
MDH-2	m	m	m	m	m	m	m	m
SDH	m	m	m	m	m	m	m	m
PGM-1	m,s	m,s	m,s	m	m,s	m,s	m	m
PGM-2	m	m	m	m	m	m	m	m
PGM-3	m	m	m	m	m	m	m	m
GDH-1	m	m	m	m	m	m	m	m
GDH-2	m	m	m	m	m	m	m	m
G-6-PDH-1	m	m	m	m	m	m	m	m
G-6-PDH-2	m	m	m	m	m	m	m	m
Esterase-1	m	m	m	m	m	m	m	m
Esterase-2	m	m	m	m	m	m	m	m
Esterase-3	m	m	m	m	m	m	m	m
6-PGD	m	m	m	m	m	m	m	m
GOT	m	m	m	m	m	m	m	m
Unknown-1	m	m	m	m	m	m	m	m
Unknown-2	m	m	?	n	n	n	n	n

m,s,f = medium, slow and fast alleles respectively

n = null allele

Table 4. Total number of male and female flowers per plant is six lines of *Momordica charantia* over six census periods. n = 3, 4 or 5.

Line	Male		Female	
	N	r	N	r
562	9	0.19	5	0.80
025	61	0.79	18	0.59
560	121	0.97**	24	0.72
561	73	0.69	37	-0.11
Japan	29	0.87*	12	0.20
Kenya	330	0.97**	37	0.49
x^2	633***	133***		

* = $0.01 < p < 0.05$

** = $0.001 < p < 0.01$

*** = $p < 0.001$

Table 5. Fruit constituents of six accession lines of *Momordica charantia*. Values are means ± S.E.

Parameter	Line					
	43560	35025	561	562	Japanese	Kenya
TSS (%)	2.90±0.21[b]	3.74±0.20[a]	2.98±0.10[b]	3.00±0.42[a,b]	3.30±0.12[a,b]	3.37±0.36[a,b]
Weight (g)	145±27.6[a,b]	58±9.4[b]	76±12.3[b]	122±35.2[a,b]	181±41.1[a]	191±36.2[a]
Length (cm)	14.8±1.22[a,b]	10.5±2.12[b,c]	9.0±0.53[c]	14.3±1.82[a,b]	16.7±1.78[a]	17.3±232[a]
Circumference (cm)	17.9±1.28[a,b]	11.3±0.,41[c]	16.6±1.00[a,b]	15.8±2.26[b,c]	18.5±1.59[a,b]	20.0±1.88[a]
Water (%)	94.63±0.30 [a,b]	92.73±0.29[c]	94.05±0.33[a,b]	93.51±0.50[b,c]	94.25±0.30[a,b]	94.77±0.49[a]
pH	5.13±0.17[c]	5.46±0.03[b]	5.51±0.05[b]	5.60±0.02[b]	5.97±0.06[a]	5.48±0.05[b]
EC (mmho/cm)	4.8±0.31[b]	8.1±1.32[a]	5.2±0.40[b]	5.5±0.38[b]	4.8±0.89[b]	5.1±-0.26[b]
Acidity (meq/gfw)	0.02±0.00	0.06±0.00	0.06±0.00	0.06±0.00	0.06±0.01	00.00±0.00
Reducing sugars (µg/gfw)	3.25±0.11[c,d]	5.27±0.68[b,c]	8.60±0.68[a]	2.32±0.83[d]	5.86±1.10[b]	4.21±0.27[b,c]

Table 6. Mineral content of karela fruits grown at Sha'ar HaNegev.
Values are means of 5 fruits ± S.E.

Line	Mineral (mg/g dry w)					
	Mg	Ca	Na	K	Fe	Cl
43560	2.28±0.23[a,b]	2.63±1.58	0.41±0.07[b]	25.83±0.31[a,b]	0.050.00	3.79±0.3
35025	2.05±0.19[b]	0.98±0.27	1.78±0.36[a]	23.33±1.67[b]	0.05±-0.00	5.69±1.0
561	3.28±0.85[a]	1.72±0.39	0.43±0.10[b]	24.58±0.81[b]	0.06±0.01	5.59±0.5
562	1.53±0.15[b]	1.17±0.18	0.35±0.03[b]	26.00±0.50[a,b]	0.05±0.00	3.83±0.3
Japan	2.38±0.32[a,b]	1.16±0.16	0.48±0.09[b]	29.00±1.97[a]	0.05±0.00	4.65±0.3
Kenya	2.06±0.11[b]	1.39±0.15	0.41±0.08[b]	24.58±0.15[b]	0.05±0.00	4.13±0.4

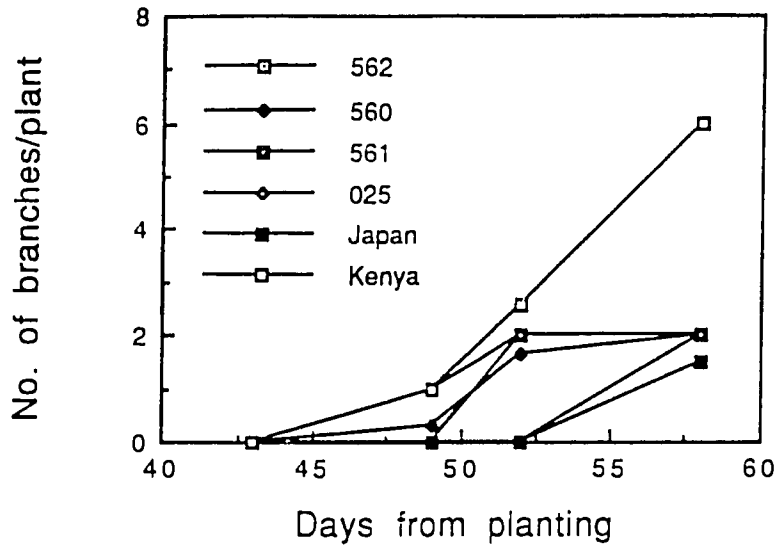

Fig. 1. Number of branches per plant in six accessions of *M. charantia* over 4 census dates

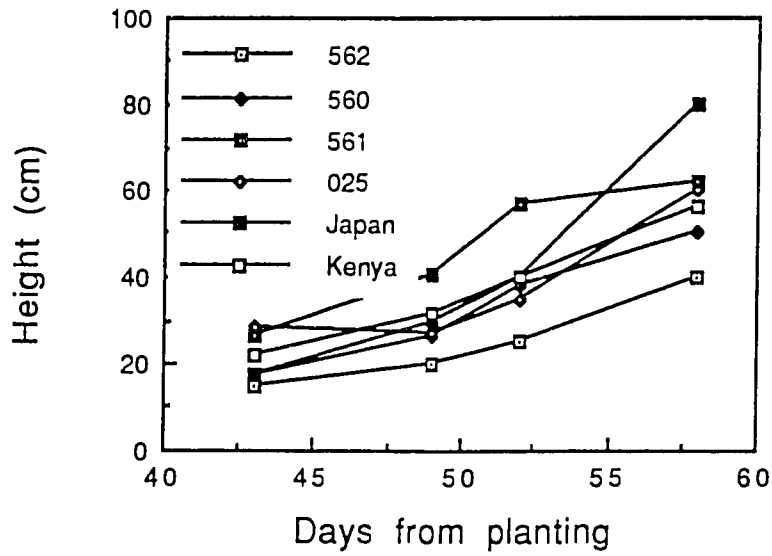

Fig. 2. Height of plants of six accessions of *M. charantia* as a function of time

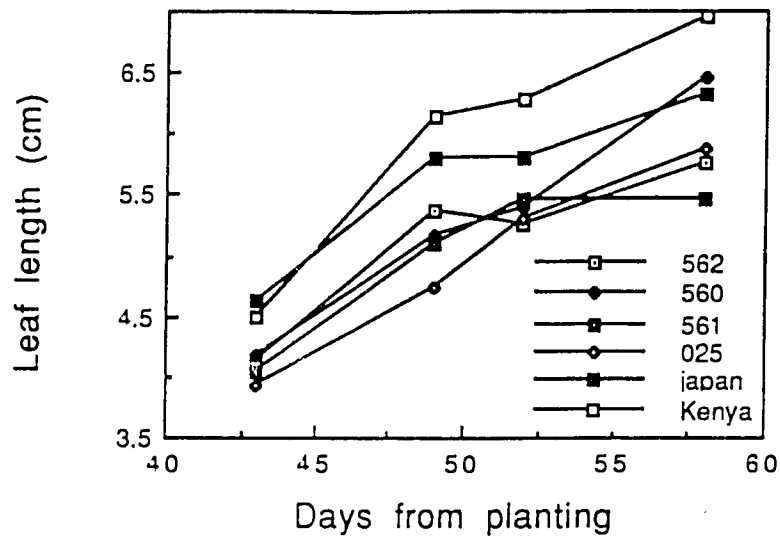

Fig. 3. Leaf length in six accessions of *M. charantia* as a function of time

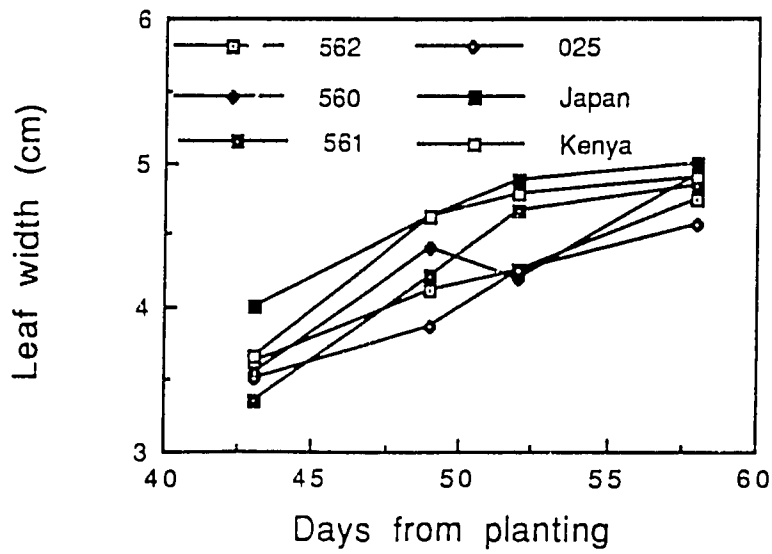

Fig. 4. Leaf width in six accessions of *M. charantia* as a function of time

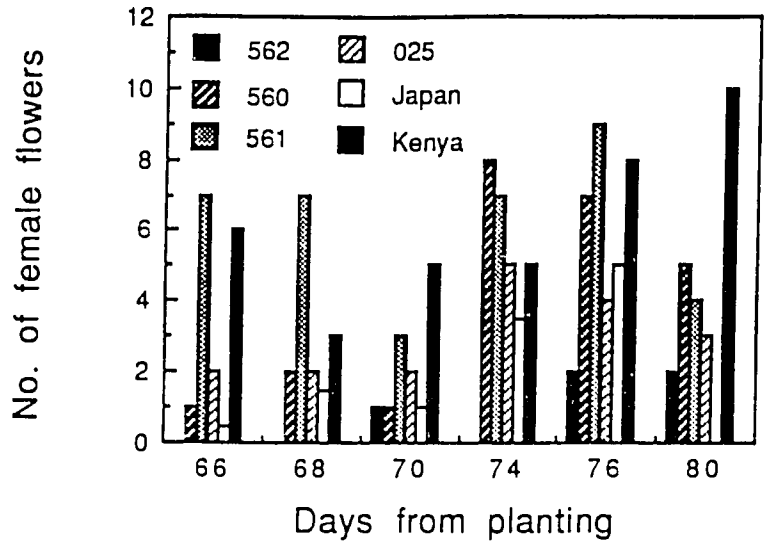

Fig. 5. Number of female flowers per plant in six accessions of *M. charantia* as a function of time

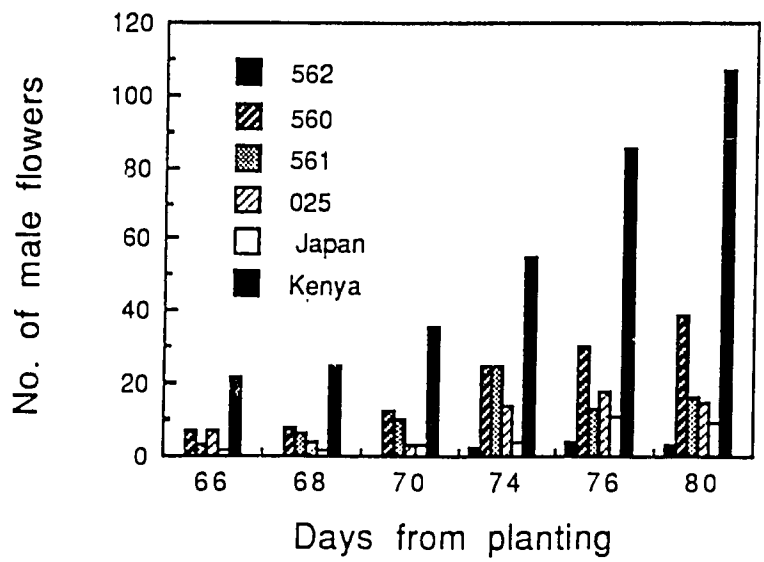

Fig. 6. Number of male flowers per plant in six accessions of *M. charantia* as a function of time

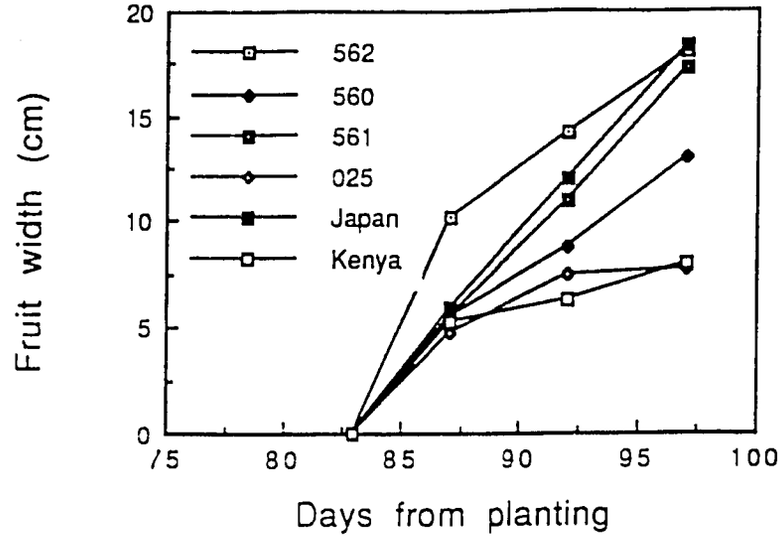

Fig. 7. Fruit length in six accessions of *M. charantia* as a function of time

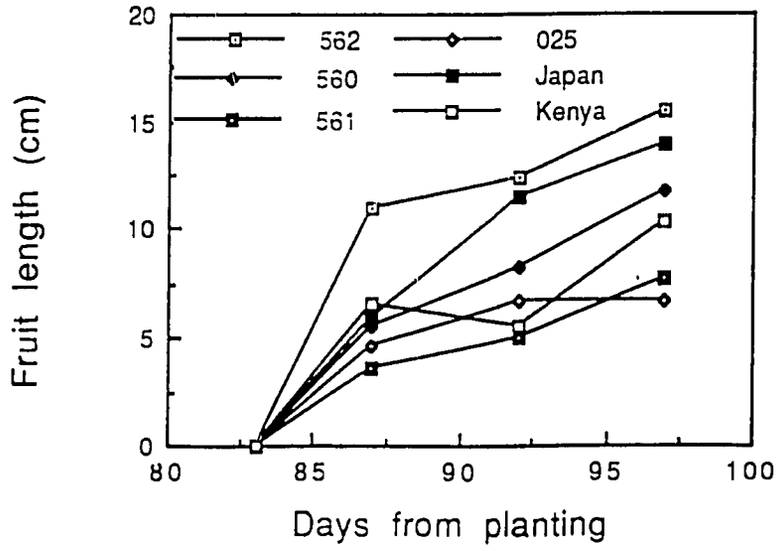

Fig. 8. Fruit width in six accessions of *M. charantia* as a function of time