DOLORES ARCHAEOLOGICAL PROGRAM TECHNICAL REPORTS

Report Number: DAP-062

Preliminary Report, Demonstration and Experimental Garden Studies 1979 and 1980

by

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Prepared for
Cultural Resources Mitigation Program: Dolores Project
Bureau of Reclamation, Upper Colorado Region
Contract No. 8-07-40-S0562

Under the supervision of
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Final Submission

3 August 1983

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Table 8. Cucurbit data

Variety	Garden site	No. of plants 19 Jul	No. of plants 9 Aug	Tendrils appear	Runners appear	Buds appear	Male inf open	Female inf open	Average vine length 17 Aug (cm)	Average max leaf diam. 17 Aug (cm)	Average plant dimensions (m)	26 Sept fruit
C. Pepo 1971	upper	14	10	9 Aug	9 Aug	9 Aug			108	33	6.2 by 5.4	-
Schroeder	lower	12	8	9 Aug	9 Aug	17 Aug			89	30	3.0 by 3.5	+
C. Pepo 1978	upper	13	10	9 Aug	9 Aug	9 Aug	12 Aug		55	21	3.1 by 1.6	+
H. Johnson	lower	15	9	9 Aug	9 Aug	9 Aug	13 Aug		148	31	5.2 by 4.6	+
C. Pepo 1961	upper	8	7	9 Aug	17 Aug	17 Aug			42	24	2.4 by 1.5	-
Oaxaca	lower	14	8	9 Aug	17 Aug	17 Aug			105	32	4.6 by 4.5	-
C. Pepo 1966	upper	10	9	9 Aug	...	9 Aug	21 Aug		25	21	1.6 by .8	-
Semilla de Agua	lower	12	7	9 Aug	9 Aug	17 Aug			99	35	5.1 by 3.8	-
C. Pepo 1970	upper	11	8	9 Aug	...	9 Aug			34	18	1.8 by .6	-
Chapingo	lower	9	4	9 Aug	17 Aug	...			65	31	4.1 by 3.4	-
C. mixta	upper	9	6	9 Aug	...	9 Aug	27 Aug		17	17	1.5 by .9	+
	lower	5	5	9 Aug	17 Aug	9 Aug	27 Aug		54	24	4.1 by 2.3	+
C. moschata 1975	upper	5	5	9 Aug	9 Aug	9 Aug			60	18	3.1 by 1.7	-
Seminole Greenhaw	lower	12	7	9 Aug	...	9 Aug			15	15	1.4 by 1.3	-
C. moschata 1970	upper	2	2	9 Aug	9 Aug	9 Aug			62	16	3.2 by 3.0	-
San Cristobal	lower	11	8	9 Aug	17 Aug	...			44	16	2.5 by 2.3	-
C. moschata 1968	upper	7	7	9 Aug	9 Aug	9 Aug			60	18	1.6 by 1.3	-
Cordoba	lower	14	8	9 Aug	17 Aug	17 Aug			41	19	3.1 by 2.4	-
C. moschata 1968	upper	9	7	17 Aug	...	...			11	13	1.2 by .6	-
Tehecuan	lower	6	6	9 Aug	17 Aug	...			20	17	2.8 by 1.6	-

Table 8. Cucurbit data--Continued

Variety	Garden site	No. of plants 19 Jul	9 Aug	Tendrils appear	Runners appear	Buds appear	Male inf open	Female inf open	Average vine lenght 17 Aug (cm)	Average max leaf diam. 17 Aug (cm)	Average plant dimensions (m)	26 Sept fruit
C. moschata 1962	upper	10	8	17 Aug	...	...			9	13	1.3 by .8	-
	lower	5	5	17 Aug	...	...			48	21	1.5 by 1.4	-
Lagenaria 1978	upper	8	6	9 Aug	9 Aug	17 Aug		21 Aug	116	25	3.4 by 3.3	+
Schroeder	lower	12	8	9 Aug	17 Aug	17 Aug			56	24	3.7 by 2.3	+

NOTES: Numbers after plant names assigned by Thomas Whitaker who collected the seeds.

inf - infloresence.
... - information not available.

Table 9. Cucurbit botanical specimens

Taxa	Source or variety	BT No.
Cucurbita pepo	Schroeder	1046, 1404
Cucurbita pepo	H. Johnson	1028, 1044, 1402, 1413
Cucurbita pepo	Oaxaca	1033, 1042, 1410
Cucurbita pepo	Semilla de Agua	1031, 1037, 1409
Cucurbita pepo	Chapingo	1032, 1047, 1408
Cucurbita pepo	Charles Mikstachek	1029, 1412
Cucurbita pepo	Seminole	1045, 1407
Cucurbita pepo	San Cristobal	1038, 1406
Cucurbita pepo	Cordoba	1039, 1411
Cucurbita pepo	Tehecuan	1034, 1041, 1424
Cucurbita pepo	Thomas Whitaker	1035, 1040, 1423
Lagenaria siceraria	Tarahumara	1038, 1043, 1405

NOTE: BT - Botanical specimen, these specimens are preserved at the University of Colorado Laboratory of Ethnobotany.

a height of 25 cm (table 10), and they could be planted much closer together than the 1 m spacing allowed for this year. The teparies flowered abundantly but did not set many beans; none was available for harvest due to destruction caused by the rabbits. The Hopi pole beans (P. vulgaris) grew well and would have grown quite large had the cows not trimmed them (table 11). Many flowers developed into beans but the cows destroyed all the plants before they could be harvested.

Other crops

Amaranthus hypochondriacus (grain amaranth) plants started well in the greenhouse, but seemed to suffer from the cool weather early in the

PREFACE

This report combines the results of the 1979 and 1980 experimental gardens. The experimental garden program was designed to study the various factors affecting the growth of cultivated plants under modern conditions. Although many of the plants were chosen because they were similar to prehistoric cultigens, the intent was not to entirely replicate prehistoric gardening techniques. Therefore, plots used for these gardens were plowed and the crops were watered on occassion.

The ensuing report includes discussions on methods, types of crops, yields, weather, and problems encountered. However, final conclusive statements about the garden program are not included since the program was discontinued soon after the 1980 harvest. More information about the gardens can be found in Shuster's unpublished masters thesis, _Factors affecting productivity in subsistence agriculture_ on file in the Department of Biology at the University of Colorado, Boulder.

ACKNOWLEDGMENTS

The following people supplied seeds for the 1979 gardens and their help and support is acknowledged: Mr. Bob Gallegos of Bueno Foods for the Hopi blue corn; Dr. Stephens and Dr. Kohel for the Hopi cotton; Dr. Thomas Whitaker for the cucurbits; Mr. Gary Nabhan for the tobacco, beans and Devil's claw; and Dr. Robert Bye for the Tarahumaran corn varieties.

ABSTRACT

Remains of corn, beans and squash recovered from prehistoric sites excavated in the Dolores Project area indicate that the Anasazi were successfully farming the area. To help answer questions about prehistoric farming practices, experimental gardens were planted in the project area in 1979 and 1980. These gardens were closely monitored and various experiments with different crops were conducted. Resultant yields from the gardens indicate that despite problems of low rainfall, insects, and a short growing season, farming in this area can be quite productive.

INTRODUCTION

Two experimental gardens were established by the DAP (Dolores Archaeological Program) in 1979. A variety of crops was planted and observed throughout the summer season, and preliminary information on soil properties and weather patterns was gathered. Even though the growing season was especially short, cool, and dry, most crops neared maturity and many were harvestable in the early fall.

PART I

EXPERIMENTAL GARDENS
1979

GARDEN SITE FACTORS

Location

Two sites were chosen for the 1979 experimental gardens, in accordance with the Bureau of Reclamation guidelines. The site referred to as the upper garden is located on property formerly owned by James H. Cline. This garden is in a clearing that was used for sheep grazing in the previous decade. The clearing is surrounded by a pinyon-juniper-oak woodland and by sagebrush, and is at an elevation of 2207 m. The other site, referred to as the lower garden, is located on property along the Dolores River. This property was formerly owned by Fred G. Cline. The lower garden is in the flood plain where a heavy growth of perennial grasses and herbs is separated from the river by a stand of willow and cottonwood. This garden is at an elevation of 2073 m.

In the future it would be interesting to test a wider range of sites for their agricultural potential. Critical factors to consider in site choice are soil type, relation to drainages, character of present vegetation, and microclimate. Careful study of vegetation and soils maps, in combination with topographic maps, might help indicate areas to consider. During the 1979 field season, small areas that might be optimal choices for gardens on the basis of one or more of these factors were detected. Throughout the project area various microelevational and physiographic factors create temperature differences between adjacent areas. These differences apparently influence the growth of plants and should be considered when choosing future garden sites. Such factors might have influenced choice of prehistoric garden sites.

Maps

Figures 1 and 2 indicate the original layouts for the two gardens. Each garden was approximately .25 ha (.62 ac), and was arranged in a grid layout of 4- by 4-m planting units. As the season progressed, the effective size of the upper garden was reduced by poor germination of the corn, and the size of the lower garden was reduced by damage from cattle. Figures 3 and 4 show the garden layouts as they appeared at the end of the season. The map of the upper garden (fig. 3) shows contour lines at each .25 m drop in elevation from the high point in the center of the field, and the location of various plantings within the field. The map of the lower garden (fig. 4) does not include contours since the field is relatively flat.

Soil Tests

Although it would be desirable to conduct various soil tests before committing to specific sites and planting in those locations, only pH tests were conducted. Results of the pH tests show that the soil at both sites is neutral or slightly alkaline. Plant growth throughout the summer was normal and no signs of nutrient deficiency were noted. Frank Leonhardy (DAP geological consultant in 1979) characterized the soil in the lower garden as a fine sandy loam, developed in sandy alluvium which overlies fluvial sand and gravel; it is a deep soil but it tends to be poorly drained due to the high water table. The soil in the upper garden is a deep, well-drained soil of the Witt series (Leonhardy and Clay 1982), developed in silty calcareous loess. The lower garden has a deeper surface horizon due to slope wash accumulation, subsequently it supports a more vigorous plant growth.

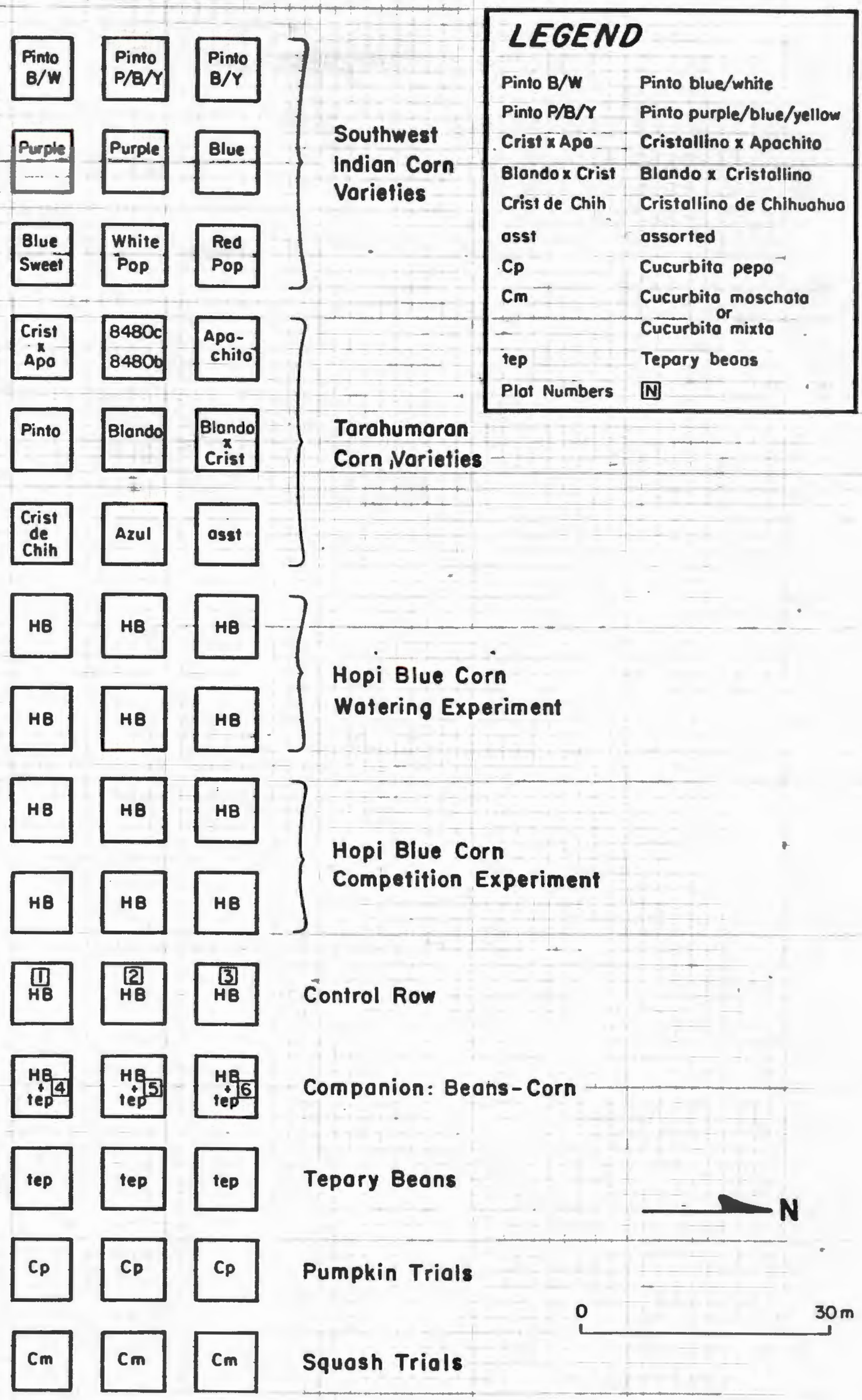

Figure 1. Planting layout for the upper garden, 1979.

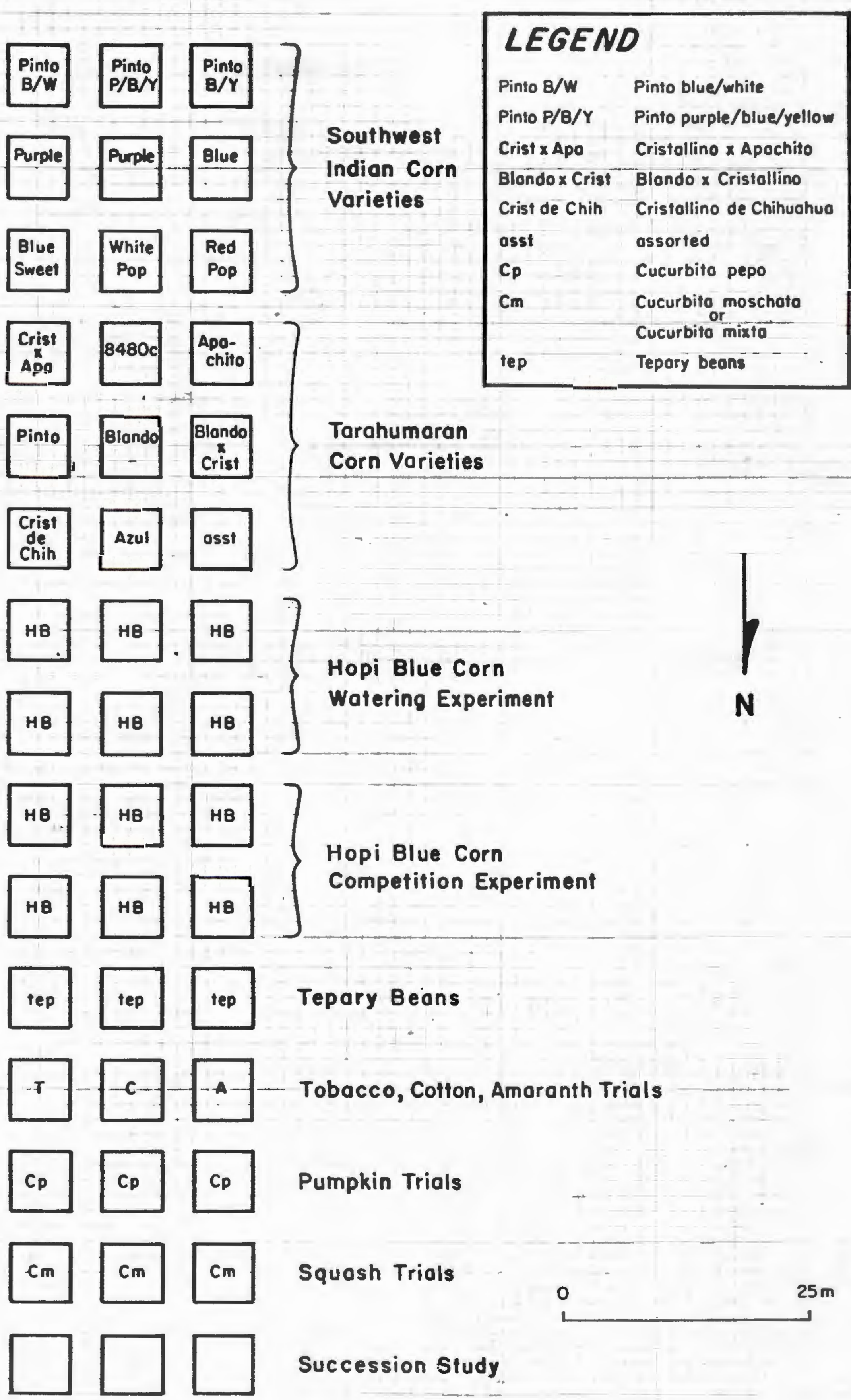

Figure 2. Planting layout for the lower garden, 1979.

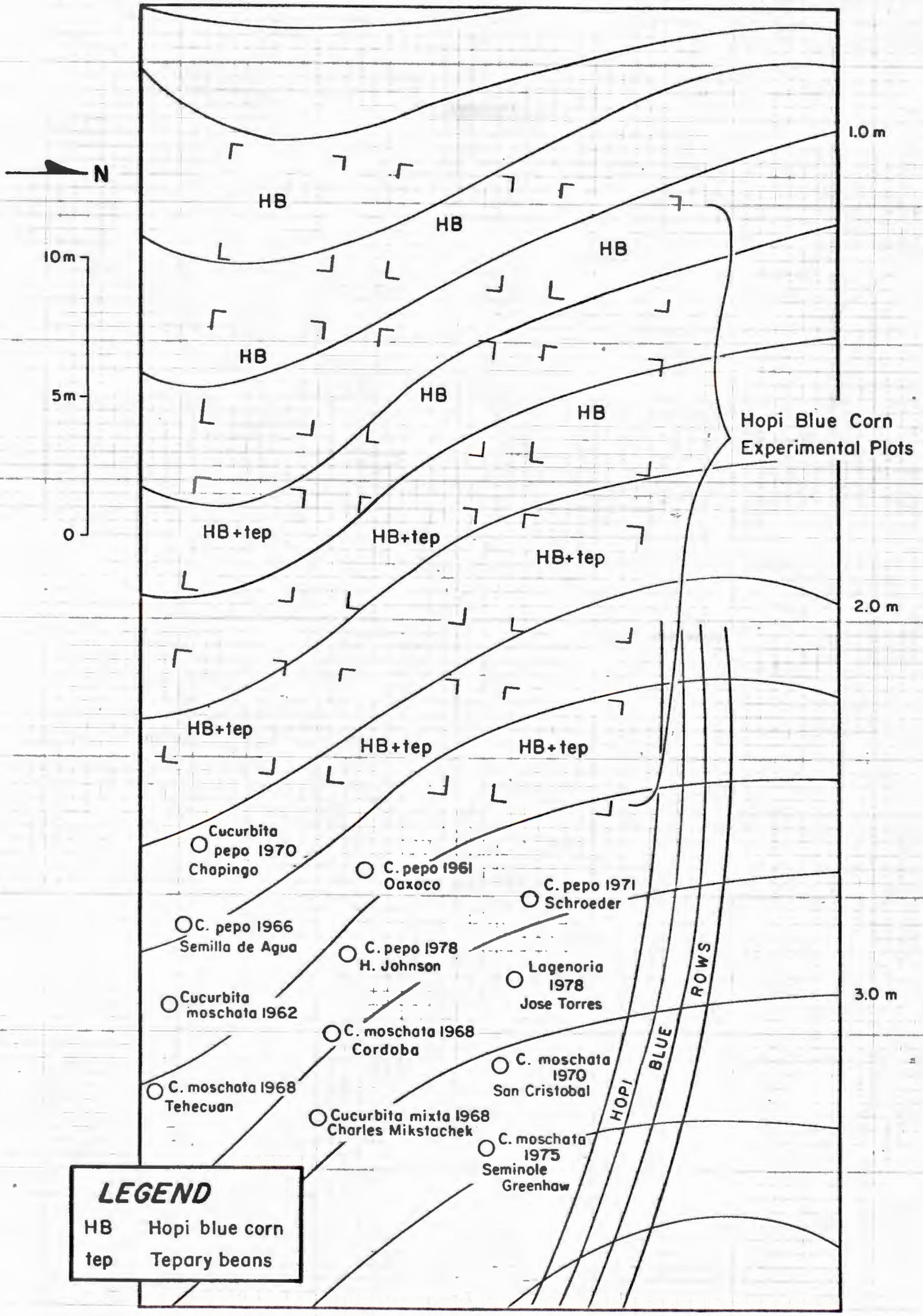

Figure 3. Upper garden layout at end of season, 1979.

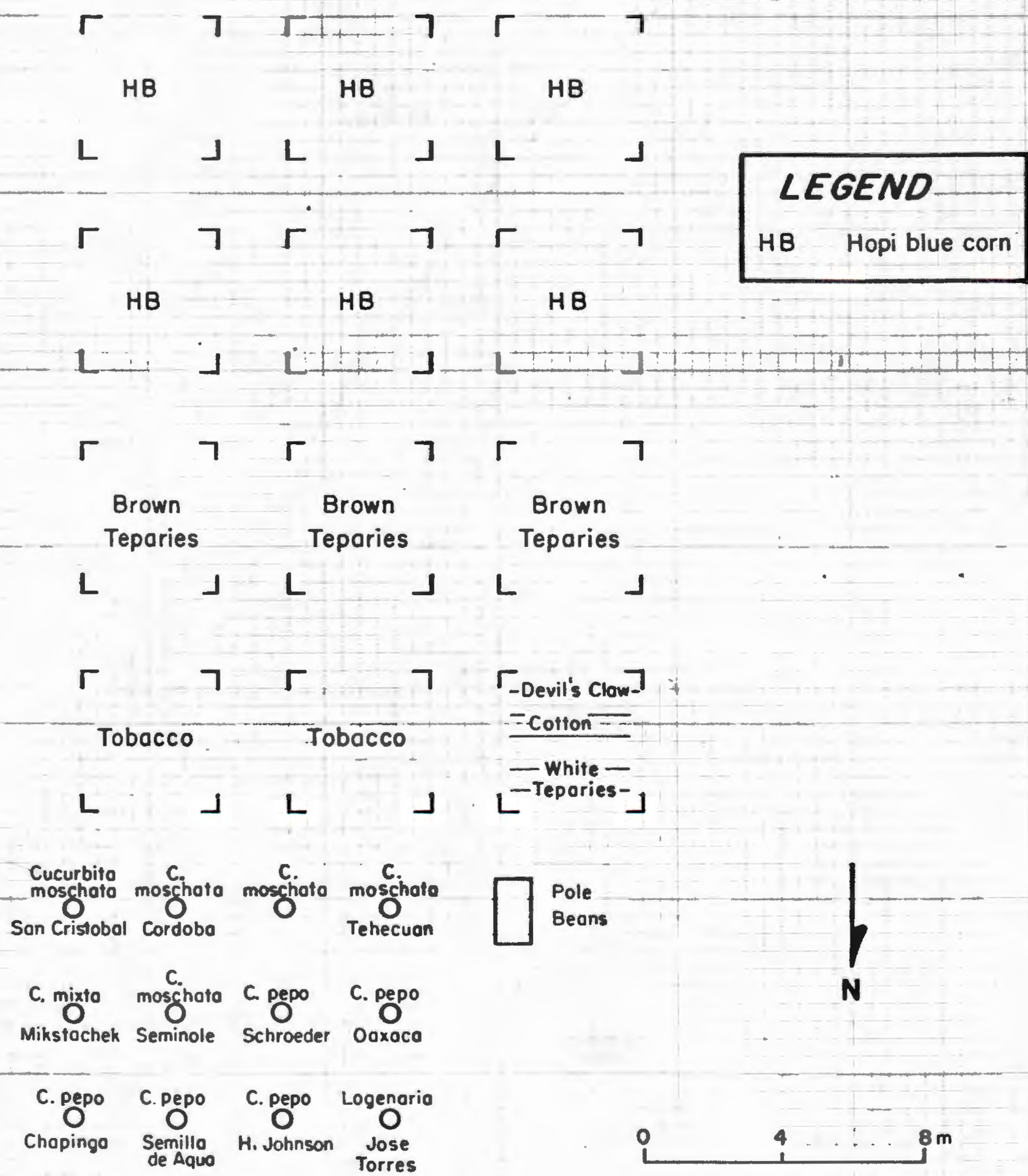

Figure 4. Lower garden layout at end of season, 1979.

Soil moisture is available within a shovel's depth of the surface in the lower garden, and test pits dug by the backhoe reached standing water at a depth of approximately 1.5 m. Although the soils at the upper garden seemed much drier, a series of samples taken at a depth of 25 cm on 10 August showed an average of 12 percent moisture content, which was determined from wet and dry weights of the soil samples. This amount of moisture is sufficient for plant growth.

Weather

Four weather stations were installed at various locations in the project area to record daily maximum and minimum temperatures and rainfall. Unfortunately one thermometer was defective and one rain gauge was stolen, so the records from these stations are incomplete. Weather data from June, July, and August are presented in tables 1, 2, and 3. Total rainfall for the period reported was 23.3 mm in the lower garden and 13.7 mm in the upper garden. A hailstorm on 18 August is not recorded in the tables. Hard frosts were recorded across the project area on 16 and 17 June, and temperatures in the third week of August neared the freezing point.

There were two major problems related to recording weather data. One was that data were not recorded on the weekends because no personnel were available to make such recordings. The second was that data were recorded at different times of the days at different stations. It would be helpful in the future to stress the importance of consistent and careful recordings at each station. It would be even more helpful to install recording rather than maximum-minimum thermometers, since the duration of different temperature regimes is quite variable from one site to another, although the extremes may be the same. For example, the upper garden warmed up earlier in the morning and stayed warmer later in the evening than the lower garden, yet there was little difference between the extremes recorded at the two sites. Microclimatic effects, such as temperature variation between adjacent or close sites, are important in determining the rate of plant growth and were probably observed by prehistoric farmers as they are noticed by farmers today.

Table 1. Weather Data from June, 1979

	DATE 19	20	21	22	23	24	25	26	27	28	29	30
Low temp. (°C)												
Lower garden	...	...	3	8	7	9	11	10	7	8	10	10
House Creek	3	3	3	5	3	...	...	9	6	8	8	...
Grass Mesa	-2	0	2	4	...	...	6	7	5	6	6	...
High temp. (°C)												
Lower garden	...	...	30	32	34	33	33	30	32	34	35	29
House Creek	19	25	27	27	31	...	...	31	30	32	32	...
Grass Mesa	20	26	28	28	...	...	31	31	31	33	33	...
Precipitation (mm)												
Lower garden	0	0	0	0	0	0	0	0	0	0	0	1.2
House creek	0	0	0	0	0	0	0	0	0	0	0	...
Grass Mesa	0	0	0	0	0	0	0	0	0	0	0	...
Upper garden	0	0	0	0	0	0	0	0	0	0	0	tr

NOTE: tr - trace.
... - information not available.

Table 2. Weather data from July, 1979

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Low temp (°C)																															
Lower garden	...	9	7	7	7	11	...	7	...	7	8	9	9	12	11	12	10	11	8	8	10	...	8	11	9	10	10	11	7	...	11
House Creek	...	...	8	6	5	...	...	...	6	7	8	7	8	9	10	9	10	10	11	11	10	11	7	9	9	11	11	11	12	8	12
Grass Mesa	...	6	5	4	4	...	5	4	4	5	5	6	6	...	...	8	9	10	6	8	...	...	5	9	8	9	9	...	6	6	10
High temp (°C)																															
Lower garden	...	25	23	28	31	31	31	...	33	33	32	34	33	34	32	30	32	30	29	29	...	...	29	32	34	33	33	...	33	35	36
House Creek	...	24	23	25	29	...	...	...	30	31	31	33	33	33	34	33	30	30	28	29	27	30	30	30	31	34	33	30	34	31	29
Grass Mesa	...	24	21	28	...	...	32	29	32	32	32	33	33	...	...	32	32	30	28	29	29	28	30	30	32	34	33	...	33	32	30
Precipitation (mm)																															
Lower garden	4.4	0	0	tr	0	tr	0	0	0	0	0	0	0	0	tr	tr	0	5.6	0	tr	tr	0	0	0	0	0	0	tr	0	0	0
House Creek	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	2	0	0	0	0	0	0	0	0	tr	0	0	0
Grass Mesa	6.6	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper garden	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.6	0	0	0	0	0	0	0	0	tr	0	0	0

NOTE: tr - trace.
... - information not available.

Table 3. Weather data from August, 1979

	DATE																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Low temp. (°C)																								
Lower garden	10	11	13	12	...	11	11	11	12	11	13	...	13	...	10	11	6	...	5	6	8	7	8	7
House Creek	8	10	10	9	...	...	11	10	11	11	11	...	11	...	9	11	5	...	...	6	5	...	...	...
Grass Mesa	6	8	7	6	...	...	9	10	8	10	7	...	...	9	7	9	3	3	...	...	2	4	...	...
High temp. (°C)																								
Lower garden	31	33	34	34	33	31	30	31	31	...	31	...	26	...	18	29	22	...	22	23	26	29	30	29
House Creek	31	32	32	34	...	...	30	30	29	30	30	...	30	...	27	19	22	...	...	23	22	...	...	...
Grass Mesa	32	34	33	34	...	...	32	32	31	30	...	...	32	21	19	20	22	24	...	24	27	30	...	...
Precipitation (mm)																								
Lower garden	0	0	0	0	0	0	0.4	0.4	0.6	0	0	0	0	1	1	4	0	3	0	0	0	0	0	0
House Creek	0	0	0	0	0	0	tr	tr	tr	0	0	0	0	tr	tr	tr	0	2	0	0	0	0	0	0
Grass Mesa	0	0	0	0	0	0	0	0	4	0	0	0	0	tr	0	tr	3.3	0	0.3	0.3	0	0	0	0
Upper garden	0	0	0	0	0	0	4.3	0	0	0	0	0	tr	tr	tr	3	0	2	2	0.8	0	0	0	0

NOTE: tr - trace.
... - information not available.

Irrigation

Because of the unusually low rainfall during the summer of 1979, a battery-operated pump was used to distribute water brought in a tank from Dolores to the garden sites. Plants were watered twice a week; amounts varied from 4-5 L per hill for corn to 10 L per hill for squash. This additional water was especially important in the early stages of plant germination and establishment. Watering was discontinued at the lower garden in early August after the plants had developed roots reaching into the soil moisture zone, but was continued on a weekly basis at the upper garden until the end of August.

Predators

Many deer, porcupines, crows, and other potential predators were sighted in the vicinity of the gardens, but these animals did little apparent damage. However, rabbits nibbled the tepary beans at the upper garden on 3 July, 24 July, and 21 August, and attacked the teparies at the lower garden on 22 August. The plants showed varying degrees of recovery depending on the severity of the attack. Tepary beans interplanted with corn seemed somewhat less prone to predation than those planted separately.

By far the major damage to the gardens was done by cattle, which repeatedly escaped from a neighboring range. In the period between 20 July and 3 August, before the lower garden was fenced, the cattle destroyed nearly all of the corn, most of the beans, and damaged other crops by trampling them.

Weeds

One of the research goals for the garden was to determine the effects of weed competition on the corn crop. Unfortunately, due to the nature of the existing vegetation and the lack of available historic accounts of land use of the two sites, this research was impossible. Very few of the weeds commonly associated with agricultural sites, such as *Amaranthus* and *Chenopodium*, were present in the 1979 gardens. Such weeds might appear in future years, as they are present in the project area and do well in old gardens and fields. If there are no plants of these common weedy genera during 1980 at these two garden sites, it would be informative to plant a garden at one of the many locations with established weed populations. This would allow an assessment of the effects of weeds as crop competitors and as potential food resources.

Weeds that appeared in the 1979 gardens are listed in table 4. There was no problem with weeds at the upper garden site until mid-August, when an abundance of lupine sprouts warranted a morning of hoeing. At the lower garden, however, removing sprouts of the perennial herbs required a major and continual expenditure of labor. The *Apocynum* and *Glycyrrhiza* were particularly tenacious and repeatedly produced sprouts. *Equisetum*, *Cirsium*, *Convolvulus*, and grasses were also a problem. Unless regularly eliminated, these sprouts would quickly overtake areas of the garden where their roots were established, and the sprouts would then dominate the crop plants. Deeper plowing, fall plowing, or repeated mechanical cultivation might help to eliminate this problem.

Table 4. Wild plants observed at both gardens, 1979

Taxa	Common name	BT No.
Upper Garden:		
Amaranthus graecizans	Prostrate pigweed	1414
Eriogonum racemosum	Redroot eriogonum	not collected
Lupinus aduncus	Lupine	1012
Lupinus aduncus	Lupine	1013
Lupinus kingii	King's lupine	1014
Sphaeralcea coccinea	Scarlet globemallow	1006
Salsola iberica	Russian thistle	not collected
Xanthium strumarium	Common cocklebur	1415
Lower Garden:		
Achillea millefolium	Western yarrow	1076
Amaranthus retroflexus	Redroot amaranth	1056
Apocynum cannabinum var. suksdorfii	Hemp dogbane	1075
Cirsium arvense	Canada thistle	1063
Convolvulus arvensis	Bindweed	1078
Equisetum arvense	Field horsetail	1079
Glycyrrhiza lepidota	Wild liquorice	1074
Helianthus annuus	Common sunflower	1071, 1089
Melilotus officinalis	Yellow sweet clover	1073
Plantago lanceolata	Plantain	1057, 1067, 1088
Rosa woodsii	Wood's rose	1077
Salix exigua	Willow	1061
Tragopogon dubius	Western salsify	1068
Dactylis glomerata	Orchard grass	1058
Bromopsis inermis	Smooth brome	1059
Agrostis gigantea	Bentgrass	1085
Festuca pratensis	Fescue	1086

NOTE: BT - Botanical specimen. These specimens are preserved in the University of Colorado Laboratory of Ethnobotany.

LABOR REQUIREMENTS

Preparation and Planting

A local farmer was contracted to spend 10 hours plowing and cultivating the land prior to planting. Initial planting was done from 13 June to 23 June. Planting was delayed due to logistical problems with the Bureau of Reclamation. Over 100 person-hours were spent for the initial gridding and planting of the 2 gardens. Later in the season on 4 July, 30 man hours were spent replanting the 12 squares of Hopi blue corn grown for experimental manipulation. About 25 hours were spent planting and tending the plants of tobacco, cotton, amaranth, and Devil's claw, which were planted into the garden after being germinated in the CU (University of Colorado) greenhouse.

Maintenance

During a typical week in late June, July, or August, 10-20 hours were spent watering, mostly in the upper garden; 10-15 hours were spent weeding, mostly in the lower garden; and 1-5 hours were spent hoeing, raking, or doing other chores. With more rainfall, the time spent watering would be considerably reduced, but the time spent weeding might then be increased.

Observations and Records

From 5-15 hours a week were spent recording observations on plant growth. These observations included time of germination, rates of establishment and growth, initiation of flowering and fruit set, weather events and records, and special events such as predation.

Photography

Photographs were taken on a regular basis to record the progress of the gardens. Photographs were also taken during harvest.

CROPS

Varieties Planted

Corn was the main crop planted: a Hopi blue corn was used for experimental manipulation; 12 varieties of corn grown by the Tarahumaran Indians in Chihuahua, Mexico were grown for their response to a sudden shift in latitude; and 9 varieties of corn from Southwest Indian sources were tested to observe their growth responses.

Specialists across the country cooperated in supplying seeds of primitive varieties of several other crops including 3 varieties of beans; 12 varieties of squash, pumpkins, and gourds; Hopi cotton; tobacco; Devil's claw; and amaranth. All of these crop varieties have been reported in the Southwest achaeological record.

Corn

The *Zea mays* varieties planted in both gardens are listed in table 5. Due to insufficient moisture for germination, only a small percentage of the corn planted grew at all, and because of cattle damage most of the corn in the lower garden was lost (table 6). Despite these disappointments, the yield was good from the plants that survived. The patch of approximately 100 hills of Hopi blue corn that grew in the northeast corner of the upper garden is convincing evidence that corn can develop and mature in this climate.

Corn seeds were soaked for 24 hours before planting; for some seeds this proved insufficient to initiate immediate germination and growth. Seeds were not watered at planting time, which also seems to have affected germination. Seeds that had not germinated promptly might have responded to added moisture late in the season if hills containing these seeds had been marked so that hand watering would have been possible. But, since the individual hills had not been marked for hand watering and since there was never sufficient rainfall, many seeds that did not germinate immediately were unable to initiate the growth process.

Table 5. Zea mays varieties planted in both gardens, 1979

Varieties	Number of hills at lower garden on 18 July*
Tarahumaran	
Cristallino de Chihuahua	16
Azul	21
Apachito	5
Pinto	8
Blando	19
Blando X Cristallino	0
Cristallino X Apachito	21
8480c	0
8480b	4
Asst. (8480a, 5905b, 5906)	17
Southwest	
Pinto blue/white	2
Pinto purple/blue/yellow	3
Pinto blue/yellow	0
Purple 1	0
Purple 2	6
Blue	0
Blue sweet	0
White pop	0
Red pop	0
Hopi blue	...

* For all varieties, except Hopi blue and 8480b, 25 hills were planted initially. For Hopi blue, 300 hills were planted initially; for 8480b, 12 hills were planted initially.

NOTES: Numbered varieties were obtained from R.A. Bye, University of Colorado.

8480a - Shoepeg white corn.
8480b - Red dent corn.
8480c - Yellow flint corn.
5905b - Red pop corn.
... - Information not available.

Table 6. Zea mays crop information

Date	Event
	Hopi blue corn
13-14 Jun	Planted upper and lower garden plots and borders
24 Jun	Germination at NE corner of upper garden
28 Jun	Germination at lower garden
3 Jul	Plants 10-12 cm tall at both plots
4-5 Jul	Replanted six plots for experimental purposes at each site
10-14 Jul	Germination from second planting at both sites
19 Jul	Experiments begun on second planting at upper garden
22-23 Jul	Cows destroyed corn at the lower garden
22 Jul	Corn at upper garden 60 cm tall
8-9 Aug	Tassels appeared on corn at upper garden, plants now 160 cm tall
25 Aug	Silks appeared on corn at upper garden, plants now 210 cm tall
	Other varieties
13-14 Jun	Planted upper and lower garden plots
28 Jun	Germination across many plots at lower garden, not at upper garden
22 Jul	All varieties destroyed by cows at lower garden
27 Aug	The sole Apachito plant at upper garden developed a tassel

Optimal planting depth for the corn seeds seems to be 5-8 cm. Seeds planted deeper than 10 cm have difficulty emerging, and seeds planted less deep develop plants with shallow root systems that cannot withstand wind stress.

Squash

Seeds of Cucurbita mixta, C. moschata, C. pepo, and Lagenaria sinceraria were planted at both gardens (tables 7, 8, and 9). Cool weather delayed the planting of cucurbits until late June. Once established all the plants grew well, especially responding to favorable moisture and soil conditions. Although all plants had developed buds by the end of August, there were few male and no female flowers (except one Lagenaria). However, several plants developed female flowers later in the season and several fruits were harvested. If the plants had been started earlier in the season it is very possible that more fruits would have developed. Blossoms of cucurbits were pressed for comparative pollen studies.

Table 7. Cucurbita and Lagenaria crop information

Date	Event
19 Jun	Upper garden cucurbits planted
20 Jun	Lower garden curcubits planted
27-30 Jun	Germination at both gardens
9-17 Aug	Runners, tendrils, and buds appear on most varieties
12 Aug	First male flower open (C. pepo H. Johnson)

Beans

Seeds of Phaseolus acutifolius and P. vulgaris were planted at both gardens. Tepary beans (P. acutifolius), both the brown and white varieties, germinated erratically without irrigation and grew into small shrubby plants. Even without rabbit predation, these plants only reached season (table 12). After being planted into the garden they made little growth progress and were destroyed by cattle early in the season.

Table 10. Phaseolus acutifolius (tepary beans) crop information

Date	Event
	Phaseolus acutifolius, brown tepary bean
14 Jun	Seeds planted at upper and lower garden
27 Jun	Germination poor at lower garden, none at upper garden; replanted at upper garden
3 Jul	Germination at upper site, but rabbits nibbled off tops
13 Jul	Plants at lower garden developing compound leaves; plants 8-12 cm tall
2 Aug	Plants up to 22 cm tall, with buds; eaten by cows at lower garden
9 Aug	Plants at both gardens 20-25 cm tall; with buds
12 Aug	First bean pod at upper garden
17 Aug	37 hills at lower site, average height 16.5 cm; 3-4 plants per hill; 5-30 flowers per plants, some bean pods
21 Aug	Extensive rabbit damage at upper site
22 Aug	Extensive rabbit damage at lower site
	Phaseolus acutifolius, white tepary bean
21 Jun	Planted 2 rows at lower garden, watered well
13 Jul	Plants 8 cm tall; developing compound leaves
22 Jul	Some rabbit predation at upper garden
2 Aug	Cattle removed all foliage and flower buds from plants in lower garden
24 Aug	Lower garden plants not recovered from grazing, only sticklike stems remain

Table 11. *Phaseolus vulgaris* (Hopi pole bean) crop information, lower garden

Date	Event
21 Jun	30 seeds planted in lower garden
26 Jun	Good germination
13 Jul	Plants developing mature leaves
31 Jul	Flower buds; plants 30-35 cm tall, developing runners
2 Aug	Cow damage in lower garden
9 Aug	Some recovery, buds appear again
17 Aug	Flowers open, runners average 54 cm long
24 Aug	Bean pods are 7-8 cm long, average 3 beans per pod

Table 12. *Amaranthus hypochondriacus* (grain amaranth) crop information

Date	Event
18 May	Seeds sown at CU greenhouse
22 May	Very good germination
9 Jun	Transplanted half of crop to 2 cm spacing in trays
11 Jun	Seedlings planted on 9 June died from damping off
15 Jun	Transplanted remaining seedlings
28 Jun	Remaining seedlings 3-4 cm tall; weak
11 Jul	Transplanted 20 plants to lower garden; plants 4-5 cm tall
18 Jul	Plants have good color and are healthy
22 Jul	Cows trampled plants; remaining 12 plants preserved as botanical specimens

Gossypium hirsutum var. *punctatum* (Hopi cotton) plants had a bad start due to damping-off and to insect problems in the greenhouse. After transplanting them to the garden, growth continued to be poor due to cool temperatures. In August the plants improved and developed buds (table 13). Three plants were collected and replanted in the greenhouse, and cuttings were taken from them for propagation. If these propagated plants can be maintained, seeds for next year might be obtained from them.

Nicotiana rustica (Indian tobacco) plants were a great success. From the time of germination the plants were healthy and vigorous. Most plants had flowered abundantly by the end of the season, and many seeds were produced (table 14). The large plants were harvested and were dried and cured. Due to the stickiness of the foliage and succulence of the stems, the plants dried slowly. If harvested intact and then hung to dry, these plants continue to produce flowers for a period of several weeks. The ease of growing this crop suggests that it might have been popular and widely grown shortly after its introduction in the Anasazi area. Of all the crops in the gardens, visitors were always most impressed by the attractive, luxuriant tobacco plants, and surprised at their success in this climate.

Proboscidea parviflora (Devil's claw) seeds did not germinate well in the greenhouse and only five plants were available to plant in the gardens (table 15). Over the course of the summer, however, all five developed into large plants, flowered regularly, and produced fruits (table 16). The foliage of these plants is especially viscous and seems quite resistant to predators.

Table 13. Gossypium hirsutum var. punctatum (Hopi cotton) crop information

Date	Event
8 May	25 seeds scarified with razor blade, planted in dark at 30°C in CU greenhouse
12 May	All seeds germinated but 13 damped-off immediately; embryonic leaves had difficulty emerging from seedcoat
19 May	Plants have aphids and whiteflies
9 Jun	Transplanted 12 plants to 7.5 cm pots
21 Jun	Transplanted 12 plants to lower garden; plants have 3-4 leaves and are less than 8 cm tall
13 Jul	11 surviving plants still less than 8 cm tall, but have some mature lobe-shaped leaves
2 Aug	2 plants destroyed by cows, one pressed as BT 1050
9 Aug	Buds present on all plants, but very small within bracts
17 Aug	Buds still very small, average of 3 per plant; plants average 26 cm tall
29 Aug	3 plants taken to CU greenhouse, cuttings made to propagate others; all have buds
26 Sep	Plants have many bracts
21 Oct	All plants harvested
29 Oct	3 plants in CU greenhouse doing fine

NOTE: BT - Botanical specimen.

Experimental Results

Because of the limited germination and the loss to cattle, only two experiments were pursued, both on plots in the upper garden and both on Hopi blue corn. One experiment measured the effect of different densities of plants within a hill. For this experiment 25 hills of corn were used and all plants were watered at regular intervals. Group 1 hills were thinned to 2 plants per hill; group 2 hills were thinned to 4 plants per hill. Group 1 averaged 1.8 suckers per stalk compared with only 0.6

suckers per stalk in group 2 (table 17). Group 1 grew to an average height of 77.1 cm whereas group 2 plants averaged 68.5 cm in height; the standard deviations within each group were so high that this difference is insignificant (table 17).

Table 14. *Nicotiana rustica* (Indian tobacco) crop information

Date	Event
27 Apr	Seeds sown in CU greenhouse
30 Apr	Germination very good
11 May	Transplanted 80 plants to 5 cm pots
9 Jun	All 80 plants very healthy, began hardening-off outside
21 Jun	Transplanted 70 plants to lower garden, watered well, and protected with sagebrush twigs; plants 8-10 cm tall
21 Jul	First bud appeared
23 Jul	First flower open
2 Aug	16 of 70 plants in bloom, average height 34 cm, average number of leaves 26 (n = 10)
17 Aug	22 of 65 plants have blooms, all have buds; 5 tallest plants in bloom 1 m tall, average 100 buds, blooms and fruits; largest leaves average 18 by 21 cm
27 Aug	Harvest and drying of inflorescences, fruits, leaves, and whole plants

The other experiment varied the amount of water applied to each group of 25 hills. The control sample, group 1, received a total of only 15 mm of rainfall. Group 2 was watered with a sprinkler for approximately 10 minutes, once or twice a week. Group 3 was watered with a hose, applying approximately 5 L per hill directly at the roots, once or twice a week. None of the groups was watered at planting time. In this experiment, neither the number of suckers per plant nor the height varied significantly among the groups (table 17). It might be that none of the groups received enough water to make a significant difference in the growth environment of plants, or that the watering was not continued over a sufficient period of time, or that the difference was in the root system, which was not observed.

Table 15. Proboscidea parviflora (Devil's claw) crop information

Date	Event
27 Apr	Planted about 50 seeds in CU greenhouse, planted in dark
8 May	Damping-off or failure to germinate left only 5 seedlings
21 Jun	Planted 5 plants in garden
21 Oct	All plants harvested

Table 16. Proboscidea parviflora, individual plant data

Plant No.	1	2	3	4	5
Sown in greenhouse	27 Apr	27 Apr	27 Apr	27 Apr	8 May
Planted in garden	21 Jun	21 Jun	21 Jun	21 Jun	21 Jun
1st flower	28 Jun	18 Jun	2 Aug	9 Aug	28 Jun
1st pod	9 Aug	14 Jul	9 Aug	17 Aug	6 Aug
Plant dimensions 17 Aug (cm)	89 by 94	82 by 90	87 by 67	82 by 75	113 by 125
No. of flowers and buds 17 Aug	14	7	9	5	21
No. of pods 17 Aug	4	5	2	2	8
No. of pods 26 Sep					
large	11	14	10	10	31
small	5	5	1	5	8

Table 17. Hopi blue corn experimental results

Group	Average number of stalks per hill	Average number of suckers per stalk	Average height (cm)
		Effect of different density on growth	
1	2.0	1.8	77.1 ± 2.4
2	3.9	0.6	68.5 ± 3.6
		Effect of different watering schedules on growth†	
1	3.8	0.3	64.7 ± 2.2
2	3.9	0.2	61.6 ± 2.9
3	3.9	0.4	61.2 ± 4.8

NOTE: Experiments began on 19 July; measurements were made on 22 August.

This sort of experiment should be repeated in future gardens to gain quântitative information on plant growth. Additional experiments should include a variety of tests, such as the effects of different spacings between hills; the effects of various durations of weed competition if a suitable weed population develops; and the effects of temperature variation.

Harvest

Observation and maintenence of the gardens stopped at the end of August but two trips were made to the gardens in the fall to harvest the crops. One trip to the gardens was made in late September to take final growth measurements and to harvest the crops that had developed. The following discussion is a summary of observations made during that visit.

September harvest

The gardens were visited on 25-27 September to check the status of the crops and to make harvest plans. Since last observed on 28 August the corn and the squash particularly, had grown well. There had been a light frost on 15 September which had burnt the foliage of the squash, but in general, the vigor of the crops at the time of the visit was impressive.

Beans. The tepary beans had been repeatedly grazed by rabbits and only some tough stems remained; thus, any potential production of beans by these plants was lost. The pole beans had been pulled out by cattle and all foliage had been consumed.

Cotton. The 5 remaining cotton plants in the lower garden each had an average of 30 buds; one had an open bloom. Perhaps this prolific bud production was related to the short days, since cotton is a short-day plant (Jones 1936). These plants had suffered a series of setbacks during the summer but were doing well and showed surprising potential for productivity of cotton. It was too late to expect any bolls to mature before winter, but if growth could be forced earlier in the season, it might be possible to produce Hopi cotton at Dolores.

Devil's claw. The Devil's claw plants were quite large and had produced many claws. There were 114 pods of all sizes on the 5 plants which were well over 1 m in diameter.

Tobacco. All the tobacco plants were in bloom and averaged over 1.5 m in height. During this visit, 10 plants were harvested and hung to air dry. Another 10 plants were bagged and taken to CU for biomass-allocation analysis. Average weight for these 10 plants was 140 g; of this, 72 percent was in the leaves, petioles, and stems, with 17 percent in the leaf-blade portion which is suitable for smoking. The inflorescence, including the main axis, peduncles, fruit capsules, and seeds, represented 22 percent of the total biomass. The extractable roots represented only 6 percent of the biomass. The residual stem and infructescence material for a comparative collection are stored at CU as well as 128 g of mature cleaned seeds and 236 g of processed leaves.

Cucurbits. Many of the cucurbit varieties had produced massive plants by late September. All varieties of *C. pepo* and five of the six *C. moschata* varieties had male blossoms, but only *C. pepo* H. Johnson, *C. pepo* Schroeder, *C. mixta*, and *Lagenaria siceraria* had female flowers. All four of these had also produced fruits. The *C. moschata* varieties showed more frost damage than the *C. pepo* varieties, but all were recovering with the development of axillary shoots.

Corn. The cattle had returned to the lower garden and eradicated all the remaining corn. At the upper garden, however, the corn crop was very encouraging. Even the plants of Hopi blue that had never been watered had produced tassels and small ears. The one hill of Apachito had a plant with an ear on it. The experimental treatment plots from the 4 July planting had all produced tassels, and tiny ears were present on some. Best of all, the patch of about 90 hills in the northeastern corner of the upper garden was doing very well. Stalks with tassels averaged 1.6 m in height with individual plants up to 2.3 m. A count of 50 hills showed an average of 7.2 tassels and 5.1 main stalks per hill (the extra tassels were on sucker stalks). These hills had an average of 6.2 ears; some stalks had several ears.

Several sample plants were harvested for eventual biomass-allocation analysis, and a few ears of corn were picked to show to the DAP staff and the Bureau of Reclamation administration.

In late September, 105 days after planting, the corn was in the milk stage and highly desirable as "sweet corn". Most contemporary hybrid sweet corn varieties are said to mature in 70-90 days. The corn had only started to turn blue at the time and was still white kerneled.

Final harvest

Due to a combination of increasingly muddy roads, predation from deer, and vandalism from hunters, a decision was made to do final harvest work in the gardens on 21 October; this work was done by Lisa Floyd and Deb Gardner, DAP employees. All plants were photographed and crop material was collected. Most of this material was returned to CU and was processed for storage.

Beans. No beans were harvested.

Cotton. Four cotton plants were dried in paper bags for comparative material. Three plants were taken to the CU greenhouse to continue growing and to produce plants for the 1980 gardens.

Devil's claw. The large pods were harvested from each plant. Over 75 pods were stored as comparative material. Many contain ripe seeds that can be planted in the future.

Tobacco. Remaining tobacco plants were hung to dry and were not returned to CU.

Squash. Six large fruits of *C. pepo* and one small fruit each of *Lagenaria siceraria* and *C. mixta* were returned to CU; all suffered some fungal infection but the seeds should be salvagable. Three fruits from the 26 September harvest yellowed and matured nicely and will be used for photographs and comparative material.

Corn. The crop of Hopi blue corn was returned to CU on 21 November. Unfortunately, many of the cobs were seriously infected with fungal organisms, which indicates that more care should have been given to husking the ears and spreading them out to dry promptly after harvest.

After a few days of cleaning and drying the cobs however, the damage was arrested and the corn was boxed for storage.

Total yield from the 90-hill patch of Hopi blue corn was 450 mature ears, unfilled cobs, and nubbins, which weighed a total of 28.7 kg. This would be an estimated yield of 2570 lbs or 40 bushels per acre (table 18). At 3 lbs/person/day, this amount could feed 2 1/2 people for one year. Reports on agriculture in the American Southwest at the turn of the century mention yields of less than 10 bushels/acre (Parsons 1936). Modern Midwestern corn growers, however, expect yields of 100-200 bushels/acre.

However, it should be noted that this estimate does not take into account the area of the garden that was planted to corn but did not produce any fruits. If the total area planted to corn was used in the calculations the estimate of bushels per acre would be lower.

Table 18. Yield statistics for *Zea mays*, Hopi blue corn, upper garden, 1979

Number of Ears Produced

26 September, direct count of 52 hills:
Average of 6.2 small and large ears per hill, 7.2 tassels per hill, and 5.1 main stalks per hill

21 October, direct count of 8 hills:
Average of 7.3 ears and unfilled cobs per hill

21 October, total yield of patch (approximately 90 hills):
Average 5.0 ears and unfilled cobs per hill

Total crop yield,
310 mature ears, 126 cobs and nubbins. By conservative estimate, 20 mature ears were lost to early harvest, predation, and vandalism

Weight of Corn Produced

Total weight of husked, dried corn on the cob produced
28,700 g or 63.8 lbs (includes mature ears and cobs)

The average weight is 320 g per hill for 90 hills

Potential Productivity

This patch included 90 hills spaced 1 m apart. Allowing for missing hills, assume patch size to be 100 m^2

From this trial, the extrapolated yield is:
2870 kg/hectare = 3570 lbs/acre = 40 bushels/acre

SUMMARY

Achievements

1. A major achievement of the 1979 field season gardens is that several crops were raised successfully to maturity, and that many ripe ears of corn were harvested. Those crops that did not mature are expected to do so in the future if they are planted earlier in the season. Success with the tobacco plants is especially interesting.

2. The one year experience of gardening in the DAP area has given a better understanding of the soil, the climate, the predators and weeds, and the labor requirements for such a project; the information gained will guide future efforts.

3. Interest in the gardens was aroused by contacting local authorities in various agencies, both involved with the project and unrelated to it. Tom King and Rip Radcliffe from the Bureau of Reclamation visited the gardens, the Western Audiovisual crew filmed them, and the garden has been discussed with Adrian Fisher of the Colorado State University Experimental Station and Marilyn Colyer of Mesa Verde National Park.

Recommendations

1. A wider variety of garden sites should be tested, although each can be much smaller than these first two gardens. It would be worthwhile to plow transect lines across fields and plant a few row of corn, to see if corn height and growth are correlated with drainage pattern and surface contour of the land.

2. Weather stations with built-in recording thermometers would give better microclimatic data than is presently available.

3. The garden manager should be hired to start work in early May, so that the gardens could be prepared and planted by late May. An early start risks damage from a late frost, but could yield more fruits at harvest time.

4. With more cooperation and additional labor at planting time, plots can be laid out more uniformly and accurately and hills can be individually marked. Watering each hill at planting time would greatly increase germination of corn.

5. If fencing is to be installed it should be put up early in the season. Traps of different sizes would help to record the herbivore predation and also to eliminate some of the crop damage problems that were encountered during this first season.

Summary

In view of the pioneer nature of the 1979 experimental gardens, the information gathered, insights gained, and crops produced are especially rewarding. Future gardens should provide information that will supplement the archaeological mitigation program in reconstructing a picture of Anasazi life in the Dolores area.

PART II

EXPERIMENTAL GARDENS
1980

INTRODUCTION

Abundant supplies of corn, occasional beans, and fragments of squashes have been recovered from sites excavated by the DAP. With this indication that the Anasazi were successfully farming the area, it is important to address questions concerning their agricultural system, the agronomy of their major crops and the productive potential of local agricultural sites.

Thus, a program of demonstration and experimental garden studies was begun by the DAP in 1979. The first year's results confirmed the potential for producing corn, beans, and squashes under present-day conditions within the project area and indicated critical factors for future study. The program was continued in 1980 to investigate these factors.

Objectives for the 1980 garden studies include:

1. Continue a series of climatic records at the two garden sites, including daily temperature patterns, frost-free season, and rainfall.

2. Replicate the results of the 1979 garden studies by again demonstrating the successful growth and potential yield of the major crops.

3. Establish a comparative collection of cultivated plant materials, including various parts of the plants collected throughout the season as well as at final harvest.

4. Compare different varieties of corn, beans, and squash for their various growth and yield characteristics.

5. Compare the problems and assets of the upper and lower garden sites.

6. Estimate potential yield of the different crops at both sites, and variability of potential yield as a result of different experimental treatments within the sites.

7. Conduct experiments with Hopi blue corn on the effects of planting density, and competition with weeds.

8. Observe and record successional patterns of wild plants on disturbed ground, with particular emphasis on weedy annuals such as Amaranthus that can serve as an additional food resource.

9. Estimate relative labor expenditure for the different crops.

MATERIALS AND METHODS

Sites

The lower garden was located on the Dolores River flood plain at the same site used in 1979. The upper garden was extended 50 m east of the 1979 site, moving it slightly downhill into a drainage basin. It is at an elevation of 2207 m in the uplands west of the Dolores River. Each garden measured approximately 100 by 25 m, or about .25 ha (0.62 ac) in area.

Rainfall (table 19) and daily minimum and maximum temperatures (figs. 5, 6, 7, and 8) were recorded in weather stations established at both gardens from 25 May to 24 August, when the weather station at the lower garden was stolen. Soil temperatures were also recorded. Observations continued at the upper garden until 30 September. In addition, a recording thermometer at the upper garden graphed temperatures on a 24-hour basis.

Seeds

Seeds for the 1980 gardens were obtained from various sources and a botanical specimen (BT) of each kind was preserved (appendix A). An attempt was made to find plant varieties which resemble those that were used by the Anasazi in the Four Corners area, as indicated by examination of archaeological plant specimens in the University of Colorado Museum, the Denver Museum of Natural History, and the Mesa Verde National Park Museum. Other varieties were included to test the growth and yield potential of types introduced from different latitudes and climates when grown in this area. Some modern cultivars were planted for comparison with the primitive varieties. Samples of all seeds planted have been preserved as botanical

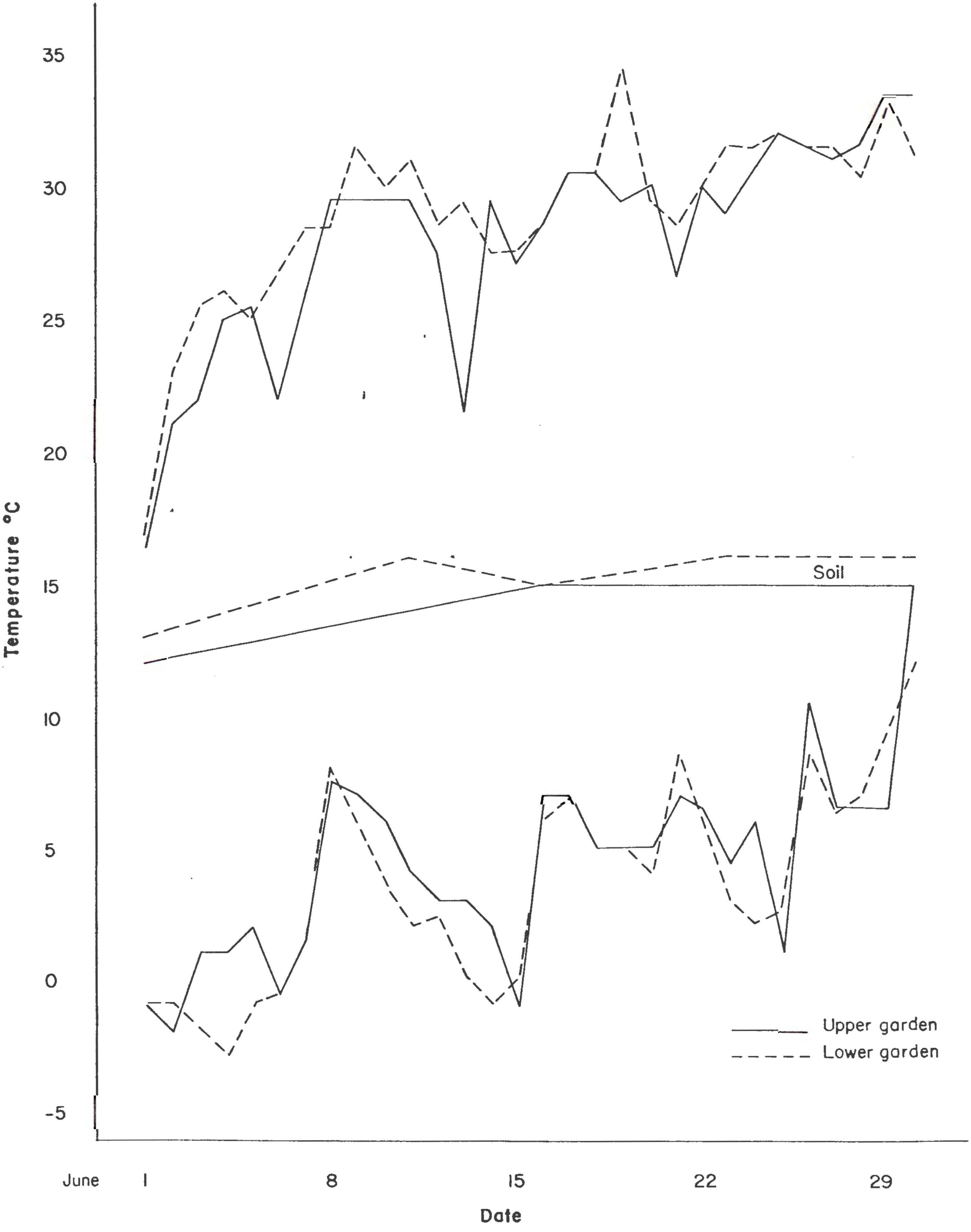

Figure 5. Daily temperatures for June--minimum and maximum (°C).

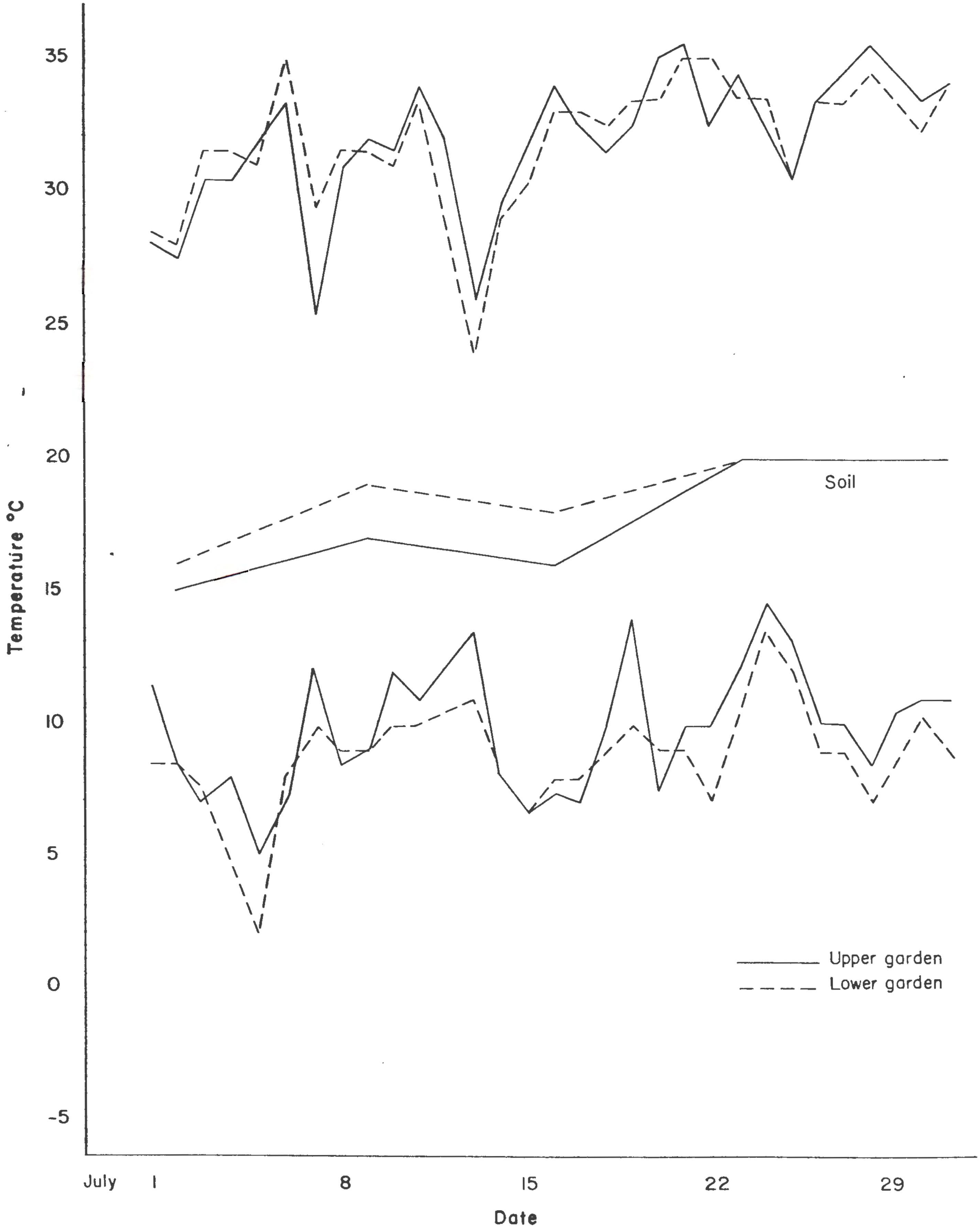

Figure 6. Daily temperatures for July--minimum and maximum (°C).

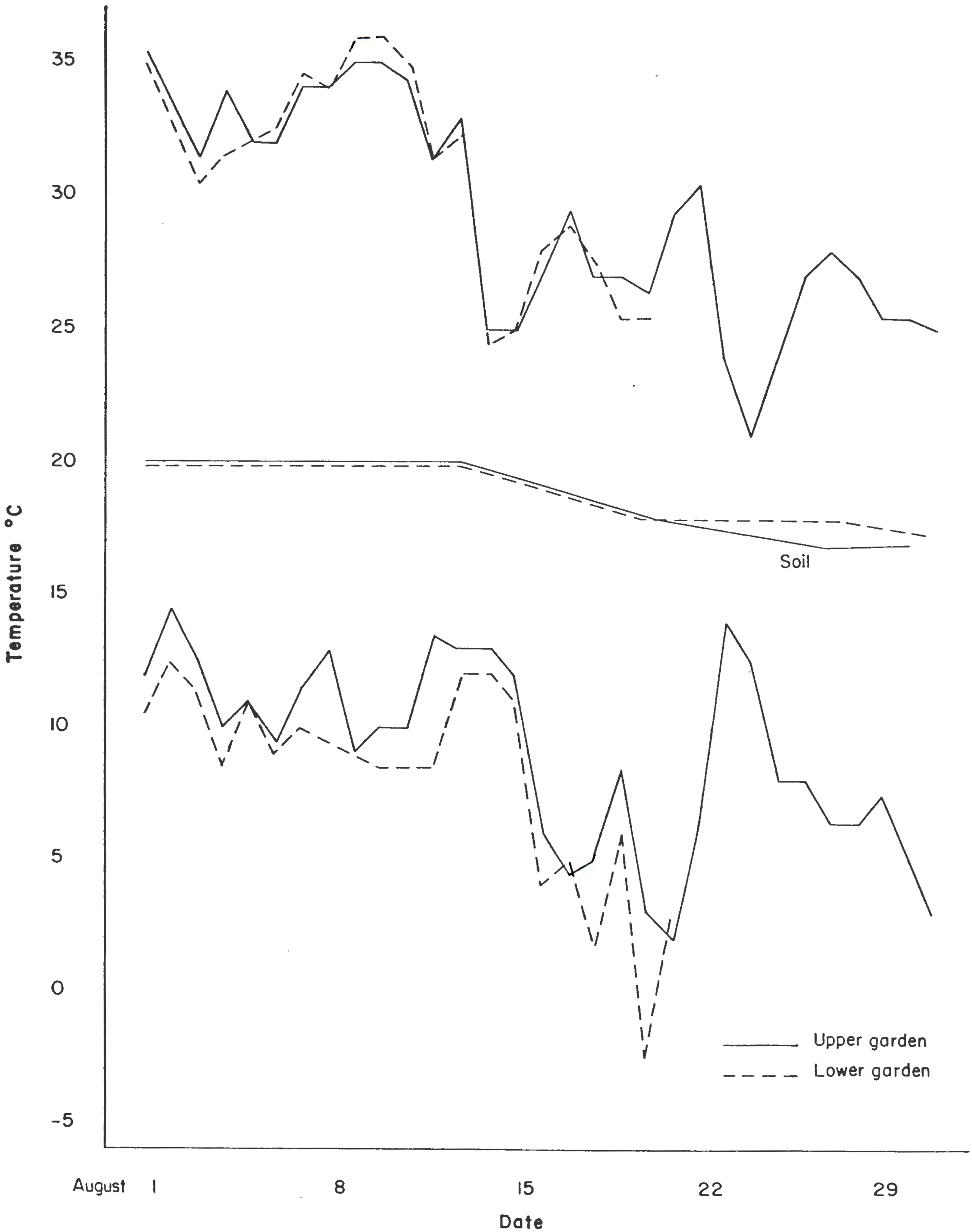

Figure 7. Daily temperatures for August--minimum and maximum (°C).

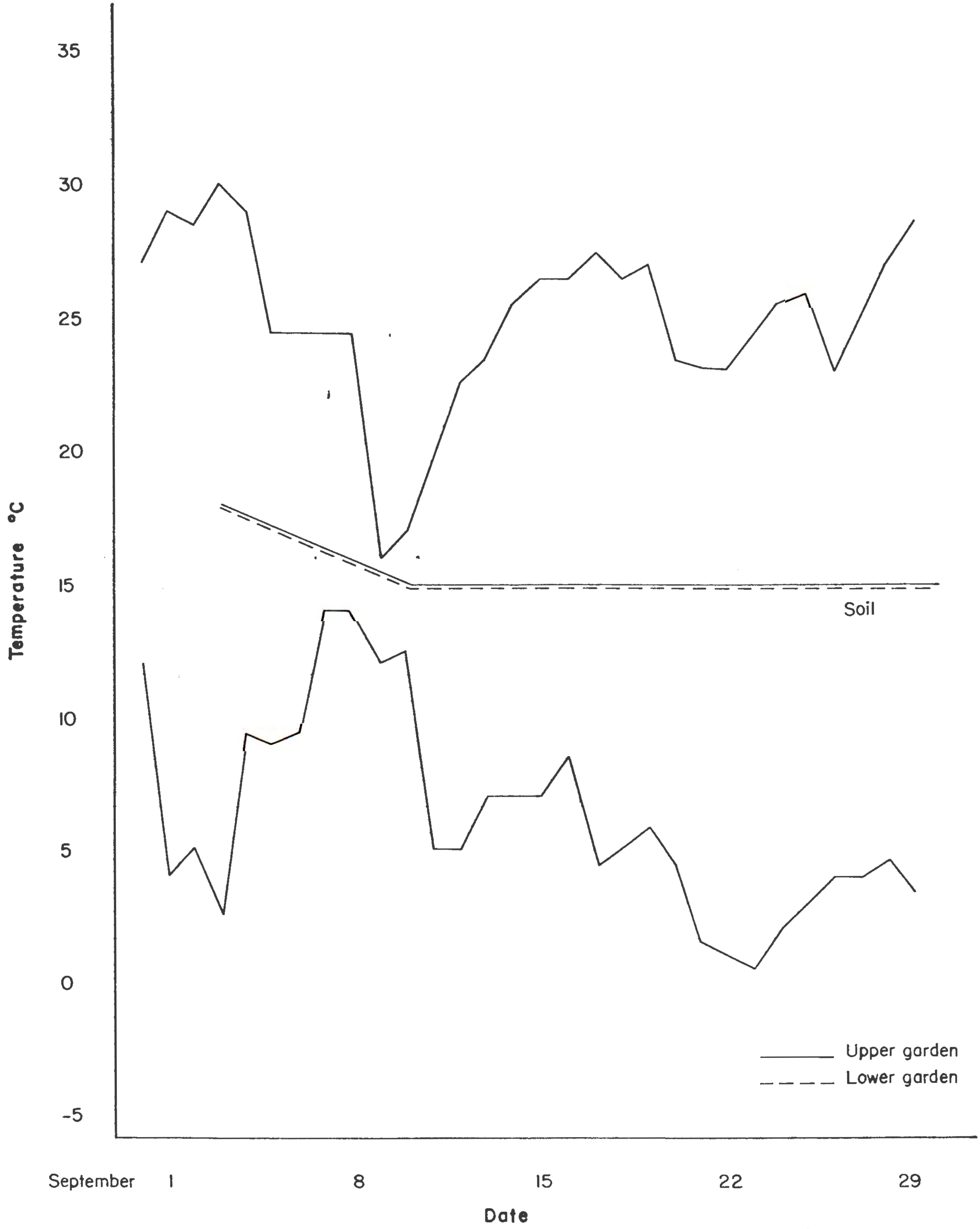

Figure 8. Daily temperatures for September--minimum and maximum (°C).

specimens (table 20). Table 21 gives a brief summary of the crops planted in 1980. Not all types listed in appendix A were planted.

Table 19. Rainfall summary 1980, upper and lower gardens

Date	Upper garden Amt (mm)	Upper garden Cum (mm)	Lower garden Amt (mm)	Lower garden Cum (mm)
Jun	No measureable precipitation			
2 Jul	1.2	1.2	1.6	1.6
6 Jul	tr	1.2	tr	1.6
7 Jul	0.2	1.4	0.2	1.8
8 Jul	1.2	2.6	0.4	2.2
13 Jul	1.0	3.6	1.0	3.2
25 Jul	4.2	7.8	4.0	7.2
29 Jul	3.0	10.8	1.4	8.6
5 Aug	0.6	11.4	0.2	8.8
12 Aug	1.2	12.6	1.2	10.0
13 Aug	0.2	12.8	0.2	10.2
14 Aug	4.6	17.4	4.2	14.4
23 Aug	1.4	18.8	1.4	15.8
24 Aug	15.6	34.4	15.6	31.4
5 Sep	5.4	39.8	Rain gauge stolen	
6 Sep	2.6	42.4	...	...
8 Sep	4.4	46.8	...	...
9 Sep	3.0	49.8	...	...
10 Sep	11.8	60.6	...	...
27 Sep	0.4	61.0	...	...

NOTES: Records began on 25 May; no cumulative data for that month.

... - Information not available.
tr - Trace.
Amt - Amount.
Cum - Cumulative.

Table 20. Botanical specimens collected from cultivated plants, 1980

BT No.	Taxa	Common name or race name	Comments
2442	*Zea mays*	Hopi blue corn	
2443	*Phaseolus vulgaris*	Wren's Egg pole bean	
2444	*Cucurbita pepo*	Squash	Seeds obtained from DAP 1979 gardens
2445	*Cucurbita pepo ovifera*	Yellow flowered gourd	
2446	*Cucurbita mixta*	Squash	Seeds obtained from DAP 1979 gardens
2447	*Cucurbita maxima*	Hubbard squash	
2448	*Citrullis vulgaris*	Arikara watermelon	
2456	*Zea mays*	Papago corn	
2436	*Pisum sativum*	Pea	Seeds obtained from Tarahumàra Indians
2438	*Phaseolus coccineus*	Scarlet runner beans	Seeds obtained from Hudson Seeds
2629	*Citrullis vulgaris*	Arikara watermelon	
2630	*Cucurbita maxima*	Buttercup squash	
2631	*Cucurbita ficifolia*	Chilicoyote	
2632	*Cucurbita mixta*	Zapotec squash	
2633	*Cucurbita pepo*	Squash	Seeds obtained from R.A. Bye Bye 9515
2634	*Lagenaria siceraria*	Bottle gourd	
2635	*Proboscidea parviflora*	Devil's claw	
2636	*Capsicum annuum*	Chile	Seeds obtained from Tarahumara Indians
2637	*Capsicum annuum*	Chimayo chile	
2638	*Nicotiana rustica*	Indian tobacco	
2639	*Vigna unguiculata*	Cowpeas	
2637	*Phaseolus acutifolius*	Brown tepary bean	
2638	*Phaseolus lunatus*	Lima bean	
2642	*Phaseolus vulgaris*	Bean	Seeds obtained from Tarahumara Indians
2643	*Phaseolus vulgaris*	Boleta bean	
2644	*Phaseolus vulgaris*	Bean	Seeds obtained from R.A. Bye Bye 8409
2645	*Phaseolus vulgaris*	Zapotec black bean	
2646	*Phaseolus vulgaris*	Hidatsa red bean	

NOTE: BT - Botanical specimen. These specimens are preserved at the University of Colorado Herbarium.

Table 20. Botanical specimens collected from cultivated plants, 1980

BT No.	Taxa	Common name or race name	Comments
2647	*Phaseolus coccineus*	Scarlet runner bean	Seeds obtained from R.A. Bye Bye 9633
2669	*Phaseolus vulgaris*	Wren's Egg pole bean	
2670	*Phaseolus vulgaris*	Jacob's Cattle bean	
2671	*Phaseolus lunatus*	Southern Running sieva bean	
2672	*Phaseolus lunatus*	Christmas lima bean	
2673	*Phaseolus coccineus*	Scarlet runner bean	Seeds obtained from Hudson Seeds
2674	*Laganeria siceraria*	Bottle gourd	
2675	*Cucurbita moschata*	Butternut squash	
2676	*Cicer auranticum*	Chick pea	

Table 21. Crops grown in the 1980 DAP gardens

Scientific name	Common name(s)	No. of varieties
Amaranthus hypochondriacus	Grain amaranth	1
Capsicum annuum	Chile	2
Citrullis vulgaris	Watermelon	1
Cicer auranticum	Chick peas	1
Cucurbita ficifolia	Squash, chilicoyote	1
Cucurbita maxima	Squash	2
Cucurbita mixta	Squash	5
Cucurbita moschata	Squash	1
Cucurbita pepo	Squash, pumpkin, gourd	6
Gossypium hirsutum	Hopi cotton	1
Nicotiana rustica	Indian tobacco	1
Phaseolus acutifolius	Tepary bean	2
Phaseolus coccineus	Scarlet runner bean	3
Phaseolus lunatus	Lima bean	3
Phaseolus vulgaris	Common bean	17
Pisum sativum	Pea	3
Lagenaria siceraria	Bottle gourd	1
Proboscidea parviflora	Devil's claw	1
Vicia faba	Faba beans	1
Zea mays	Corn	28

Planting and Cultivation

Both gardens were disked by a local farmer on 30 May to turn under existing vegetation and to loosen the soil. Planting began in early June and continued through the month. Beans were planted 2 to 8 cm apart in rows that were 0.75 m apart. Between two and eight squash seeds were planted in hills that were spaced 3 m apart. Between two and six corn seeds were planted in hills that were spaced 1 m apart and 15 corn seeds were planted in hills that were spaced 3 m apart. Figures 9 and 10 show the

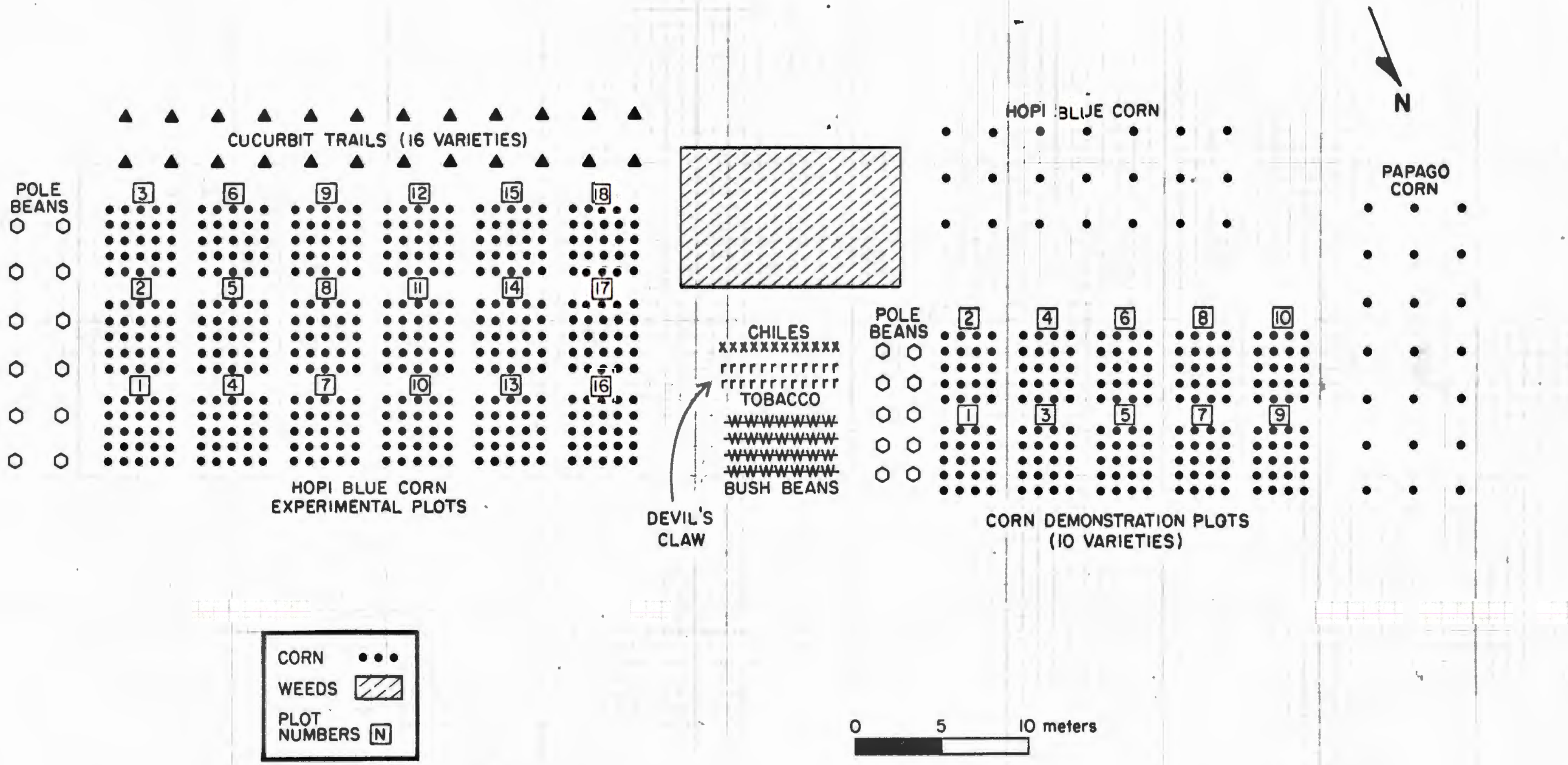

Figure 9. Planting layout for the upper garden, 1980.

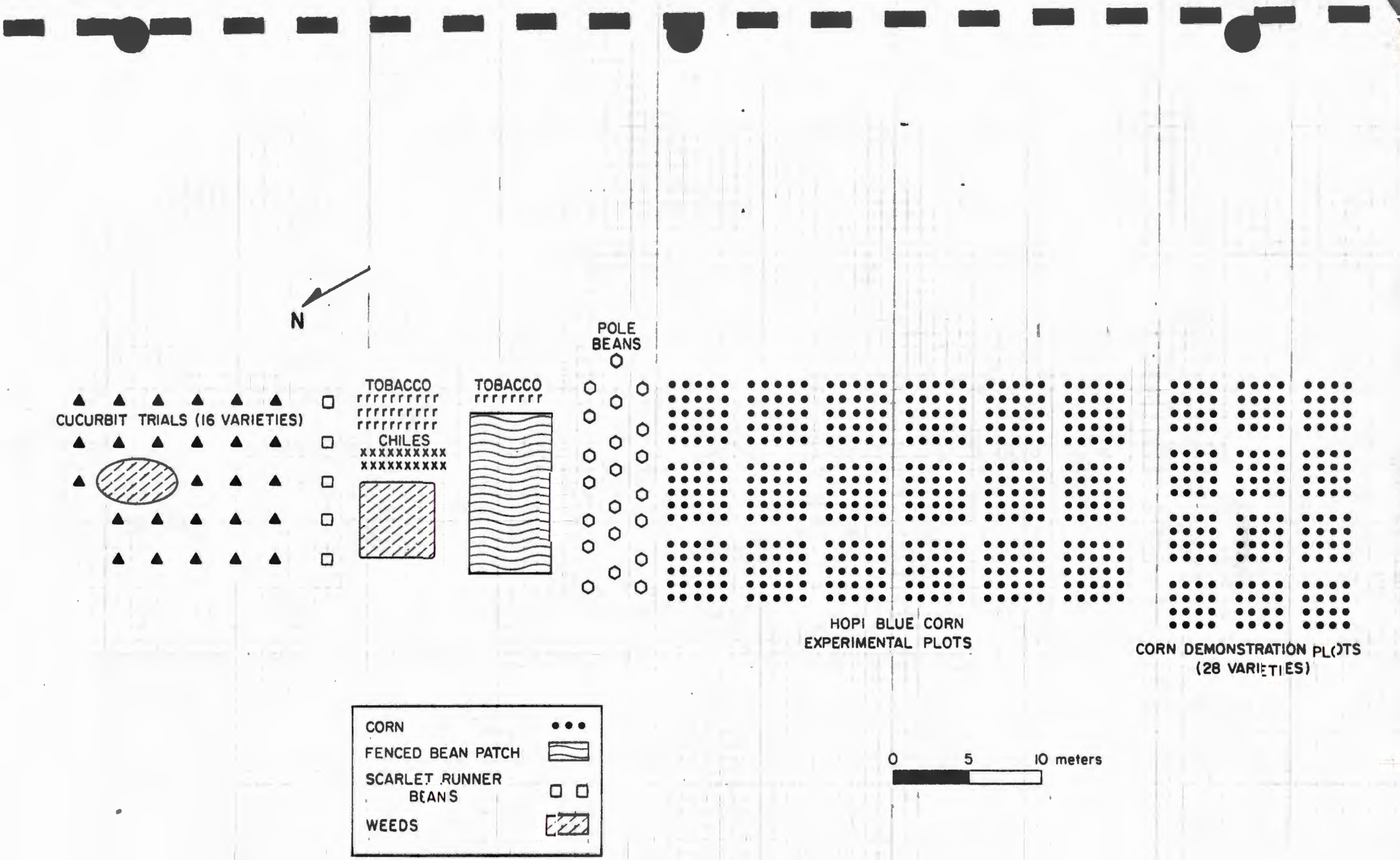

Figure 10. Planting layout for the lower garden, 1980.

planting layouts for the upper and lower gardens, respectively. All seeds were soaked overnight before planting. Corn seeds were covered with 10 cm of dirt in the bottom of holes that were dug to 25 cm deep. This was done to place the seeds lower in the soil where moisture levels were higher. All seeds were watered when planted; corn hills received approximately 4 L each. Plants at the upper garden only were watered a second time in late June after germination. Transplants of chiles, tobacco, and Devil's claw were planted and watered in late June.

Throughout the growing season, an attempt was made to keep weeds removed from both gardens, except in certain experimental and control plots. This was difficult because the dominant weeds continually produced new shoots from their deep perennial rhizomes. All weeds were hoed or hand pulled from the gardens at least once every week. Cultivation of beans, squash, and other plants, and hilling-up around corn plants were carried out as needed throughout July and August.

Observations and Records

Systematic observations and measurements were made of all crops, and photographs were taken to document both normal and unusual growth phenomena. Vigor and extent of vegetative growth, drought tolerance, susceptibility to predators and diseases, onset of flowering, and the development of fruits were the main characteristics noted. More detailed observations and measurements were made on specific crops when time allowed, following techniques established by authorities on those crops (cf. Whitaker and Bohn 1950; Kaplan 1980).

Harvest

Final harvest of mature fruits and other plant parts took place throughout September. Because frost came earlier to the lower garden, plants there were harvested first. Most plants were air-dried or artifically-dried to assure safe storage. Hopi blue corn at the upper garden was placed in shocks to finish maturing and to dry until it could be harvested in late October. All collected materials were numbered and preserved as botanical and ethnobotanical specimens.

Other Work

Botanical work related to the gardens included collecting specimens of the wild flora adjacent to, and present in, both sites (tables 22 and 23). Specimens were also collected from old fields and gardens throughout the project area that were in different stages of succession. Vegetation adjacent to the gardens, in unweeded portions of the gardens, and in places where the 1979 gardens were not replowed was sampled for species composition and biomass production using random throws of the Daubenmire square to establish quadrats (Mueller-Dombois and Ellenberg 1974).

Seeds of *Amaranthus retroflexus* and *Helianthus annuus* were collected from populations in 1 m^2 plots adjacent to the gardens and at other locations in the project area to obtain a measurement of the seed production. Insects were noted when observed and were collected from the gardens and adjacent areas in August.

Table 22. Wild plants collected at the upper garden, 1980

BT No.	Taxa	BT No.	Taxa
2319	Lithophragma tenella	2244	Orthocarpus luteus
2923	Pseudocymopterus montanus	2245	Chenopodiaceae
2320	Ceratocephala testiculata	2246	Physalis sp.
2925	Senecio sp.	2247	Helianthus annuus
2323	Claytonia sp.	2248	Asclepias subverticillata
2324	Quercus gambellii	2249	Eriogonum racemosum
2204	Amaranthus graecizans	2250	Epilobium paniculatum
2205	Portulaca oleracea	2251	Heliomeris multiflora
2206	Chenopodium	2252	Orthocarpus luteus
2207	Lupinus sp.	2253	Bromus japonicus
2208	Lappula echinata	2254	Madia glomerata
2209	Lappula redowskii	2255	Artemisia frigida
2210	Iva xanthifolia	2449	Portulaca retusa
2211	Helianthus annuus	2450	Physalis virginiana
2212	Orthocarpus purpureo-albus	2451	Helianthus annuus
2213	Sonchus oleraceus	2452	Xanthocephalum sarothrae
2214	Sisymbrium altissimum	2453	Iva xanthifolia
2215	Polygonum sawatchense	2454	Moldavica parviflora
2216	Polygonum aviculare	2455	Conyza canadensis
2217	Agropyron smithii	2457	Aster sp.
2218	Epilobium paniculatum	2458	Amaranthus retroflexus
2219	Salsola iberica	2648	Verbascum thapsus
2220	Sphaeralcea coccinea	2649	Lactuca serriola
2221	Oenothera coronopifolia	2650	Sisymbrium altissimum
2222	Carduus nutans	2651	Rhus aromatica
2223	Asclepias subverticillata	2652	Amelanchier utahensis
2224	Achillea millefolium	2653	Chrysothamnus nauseosus
2225	Lotus wrightii	2654	Chrysothamnus nauseosus
2226	Erigeron divergens	2655	Heliomeris multiflora
2227	Bromus tectorum	2256	Helianthus annuus
2228	Eriogonum racemosum	2257	Machaeranthera bigalowii
2229	Tragopogon dubius	2258	Cordylanthus wrightii
2230	Heterotheca villosa	2259	Iva xanthifolia
2231	Verbena bracteata	2260	Salsola iberica
2232	Melilotus officinalis	2261	Lupinus sp.
2233	Convolvulus arvensis	2262	Polygonum sawatchense
2234	Lupinus kingii	2263	Erigeron sp.
2235	Polygonum sawatchense	2264	Chenopodium
2236	Heliomeris multiflora	2265	Polygonum sawatchense
2237	Artemisia frigida	2266	Bouteloua hirsuta
2238	Artemisia tridentata		
2239	Chrysothamnus sp.		
2240	Xanthocephalum sarothrae		
2241	Ceratocephala testiculata		
2242	Rosa sp.		
2243	Penstemon sp.		

NOTE: BT - Botanical specimen. These specimens are preserved at the University of Colorado Herbarium.

Table 23. Wild plants collected at the lower garden, 1980

BT No.	Taxa
2949	Dactylis glomerata
2950	Bromopsis inermis
2951	Brassica rapa
2952	Plantago lanceolata
2953	Leucanthemum vulgare
2954	Trifolium sp.
1967	Calystegia sepium ssp. americana
1968	Convolvulus arvensis
1969	Lappula redowskii
1970	Brassica sp.
1971	Lappula echinata
1972	Apocynum androsaemifolium
1973	Glycyrrhiza lepidota
1974	Cirsium arvense
1975	Asclepias syriaca
1976	Gramineae
1977	Agropyron sp.
1978	Bromopsis inermis
1979	Equisetum arvense
1980	Phleum pratense
1981	Bromopsis inermis
1982	Hordeum jubatum
1983	Agropyron sp.
2432	Aster sp.
2433	Physalis virginiana
2434	Helianthus annuus
2435	Xanthium strumarium
2437	Glycyrrhiza lepidota
2439	Chenopodium sp.
2440	Chamaesyce sp.
2441	Lactuca serriola
2677	Aster sp.
2678	Aster sp.
2679	Iva xanthifolia
2680	Compositae
2681	Compositae

NOTE: BT - Botanical specimen. These specimens are preserved at the University of Colorado Herbarium.

RESULTS AND DISCUSSION

Weather

Dates for the frost-free periods at the upper and lower gardens are given in table 24. At the lower garden this period was only 67 days; at the upper garden it was 98 days. Average daily minimum and maximum temperatures, as presented in table 25, were close to normal.

Table 24. Frost-free season

	Cortez, Co. 1883 m 1951 to 1975	DAP gardens 2207 m, 2073 m 1979	Upper site 2207 m 1980	Lower site 2073 m 1980
Last 0°C. night	May 21	Jun 20	Jun 15	Jun 14
First 0°C. night	Sep 30	Sep 15	Sep 21	Aug 20
Total frost-free days	131	87	98	67

Table 25. Average daily minimum and maximum temperatures

		Cortez, Co.* °C (°F)	Upper garden °C (°F)	Lower garden °C (°F)
Jun	Lo	8.5 (47)	4.5 (40)	3.5 (38)
	Hi	28.5 (83)	28.0 (82)	29.0 (84)
Jul	Lo	13.0 (55)	9.0 (48)	8.5 (47)
	Hi	32.0 (89)	31.0 (87)	32.0 (89)
Aug	Lo	12.0 (53)	8.0 (46)	7.0 (45)
	Hi	30.0 (85)	31.0 (87)	29.0 (84)
Sep	Lo	7.0 (45)	6.0 (43)	... ...
	Hi	26.0 (79)	25.0 (77)	... ...

* Cortez data based on records for 1951 to 1975 and used as basis for comparison. These data are not available for Dolores.

NOTE: ... - Information not available.

Precipitation was well below normal for the growing season, with most of the rainfall coming from two major storms in late August and early

September (table 26, fig. 11). Soil moisture content declined from early June to mid-August causing moderate to severe drought stress in many plants, but soil moisture was restored by the late summer storms (fig. 12).

Table 26. Precipitation during the growing season

	Cortez, Co.* (mm)	Upper garden (mm)	Lower garden (mm)
Jun	11.4	0.0	0.0
Jul	28.7	10.8	8.6
Aug	42.4	23.6	22.8
Sep	29.0	26.2	26.2
Total	111.5	60.6	57.6

* Cortez data based on records for 1951 to 1975 and used as basis for comparison. This data is not available for Dolores.

This weather pattern was widespread across the area and local farmers and gardeners reported below average yields for many crops because of the extended drought. The Montezuma County Sentinel ran feature articles on the extent and effects of the drought during June, July, and August.

Crops

Corn

At the lower garden, 18 experimental squares of 25 hills each were planted with Hopi blue corn, and 16 squares of 16 hills each were planted with 28 other varieties of corn. Germination was 60 to 80 percent in most squares but cutworms killed many seedlings and the resulting stand was uneven, with very low populations in some squares. Throughout June and July the drought slowed plant growth. Even though soil moisture was

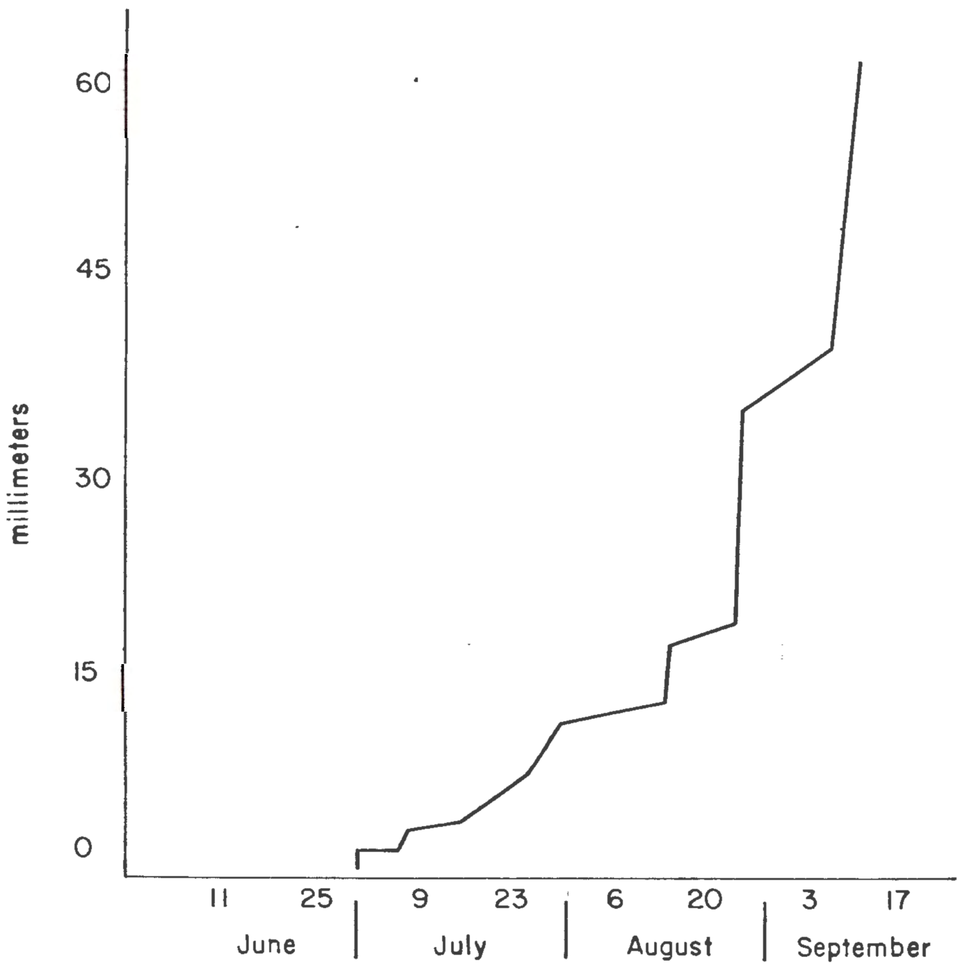

Figure 11. Cumulative rainfall at the upper garden, 1980.

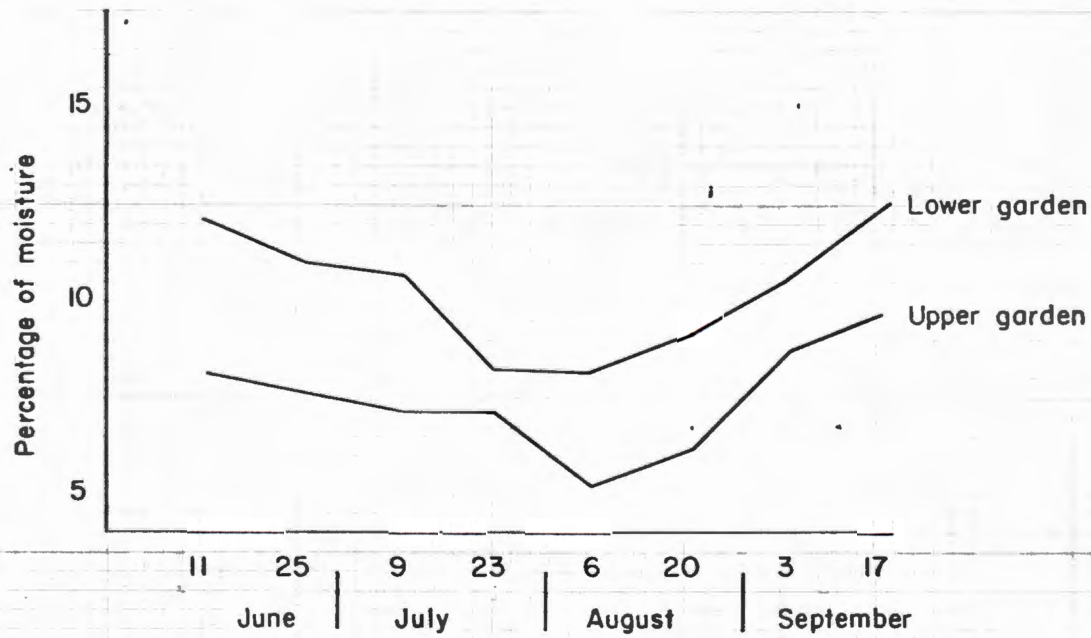

Figure 12. Soil moisture content at both gardens, 1980.

available, high afternoon temperatures and gusty winds increased transpiration. Intense competition from the perennial weeds Apocynum androsaemifolium, Cirsium arvense, Convolvulus arvensis, and Glycyrrhiza lepidota inhibited corn growth despite efforts to keep the weeds removed. Grasshopper predation reduced foliage surface area in August and September. Grasshoppers also ate the silks on the developing ears, thus preventing pollination. Untimely frost on 20 August whitened the tassels and leaves of the corn and essentially stopped growth and development.

Due to all of these factors, corn yield at the lower garden was poor. None of the demonstration varieties produced any ears of corn, and many died without even tasselling. The Hopi blue corn produced a total of less then one bushel of ears, and of these, few had well-developed kernels.

A comparison of Hopi Blue corn grown under different conditions at the lower garden (table 27, fig. 13) shows that competition with weeds throughout the growing season significantly reduced growth of stalks and yield of ears. Where weeds were present, plants in squares with more then 60 corn plants were shorter and produced fewer ears than those in squares with fewer then 30 corn plants. With weeds removed, the effects due to the density of the corn population were not significant. Further analysis will evaluate total aboveground biomass production under the different conditions.

At the upper garden, 18 experimental squares of 25 hills each were planted with Hopi blue corn, and 10 demonstration squares of 20 hills each were planted with 10 other different varieties of corn. Between 60 and 80 percent of all corn germinated, and cutworm damage was less severe than at the lower garden so many stands matured at the desired densities. Many varieties were affected by drought stress in June and July but were relieved by the late summer rains. Grasshopper predation and weed

Table 27. Comparison of corn grown under different conditions, lower garden, 1980

Plot No.	No. of plants (1)	No. of leaves (2)	Ht of leaves (3)	Ht to Tassel (4)	Percentage with tassel (5)	No. of tillers per plant (6)	Percentage of sterile tillers (7)	No. of ears (8)	Total No. of female units (9)
Weeds present in plot throughout the growing season									
4	33	17.5 ± 0.2	125.4 ± 7.1	81.3 ± 7.5	100	1.3 ± 0.4	72	0.0 ± 0.0	1.3 ± 0.3
7	23	14.2 ± 0.8	73.6 ± 4.6	35.9 ± 4.1	55	0.3 ± 0.1	100	0.0 ± 0.0	0.2 ± 0.1
1	66	14.7 ± 0.5	86.4 ± 4.2	33.2 ± 2.6	60	0.2 ± 0.1	100	0.0 ± 0.0	0.0 ± 0.0
3	62	14.5 ± 0.5	96.4 ± 2.5	38.5 ± 1.5	72	0.1 ± 0.1	100	0.0 ± 0.0	0.0 ± 0.0
Weeds removed from plot throughout the growing season									
13	22	16.5 ± 0.3	161.9 ± 4.6	124.6 ± 4.4	100	1.8 ± 0.4	38	1.2 ± 0.3	2.7 ± 0.4
18	21	16.8 ± 0.2	151.2 ± 4.9	110.0 ± 5.9	100	1.7 ± 0.6	47	0.9 ± 0.2	2.3 ± 0.3
8	60	17.5 ± 0.3	160.7 ± 5.8	124.6 ± 6.6	100	0.9 ± 0.3	89	1.0 ± 0.0	2.0 ± 0.2
16	69	17.2 ± 0.2	180.4 ± 3.4	131.4 ± 3.0	100	1.2 ± 0.4	75	0.6 ± 0.2	1.1 ± 0.2

NOTES:
1 - Total plants per 4- by 4-m plot.
2 - Total leaves per primary stalk.
3 - Height (cm) with leaves extended skyward.
4 - Height (cm) to first branch at base of tassel.
5 - Tassels on primary stalks.
6 - Includes all tillers arising from main stalk.
7 - Tillers without tassel or ear development.
8 - Ears at milk stage of maturity or greater maturity.
9 - All ears regardless of maturity level.

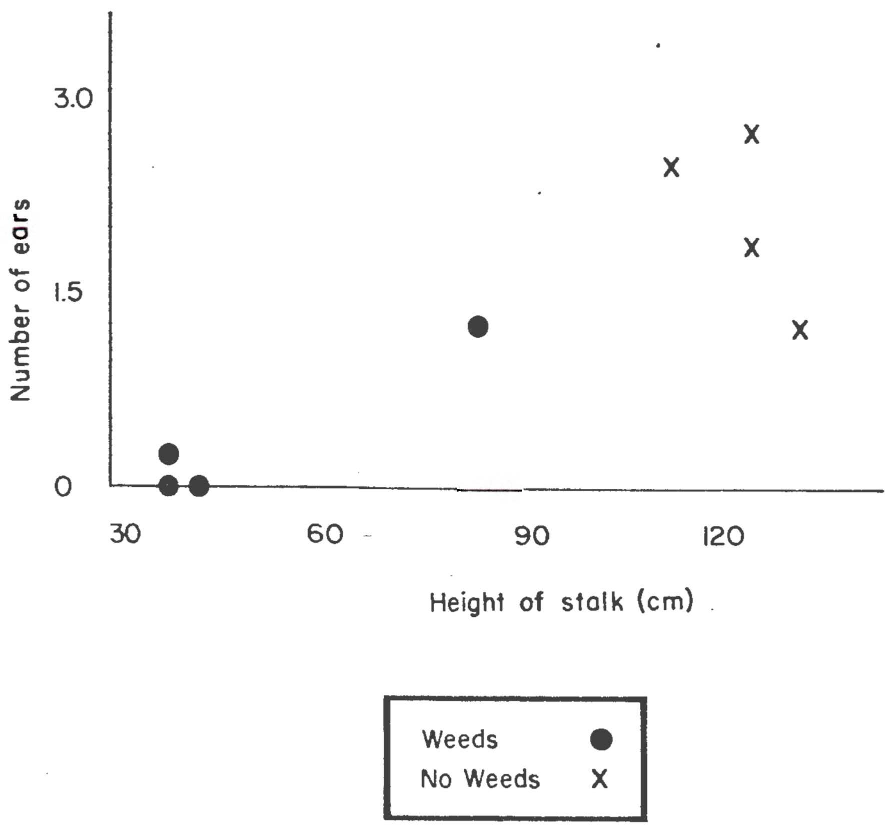

Figure 13. Effects of weed competition on corn, lower garden.

competition were less intense at the upper garden than at the lower garden.

Observations of the different varieties of corn grown at the upper garden are presented in table 28. Regular measurements of stalk height, number of leaves, and number of tillers were made. The measurements of stalk height are presented in table 29, as an expression of growth rates for the different varieties. During the stages of establishment and vegetative growth, height increase is a linear function and different varieties show nearly equal rates of growth. After tasselling and silking, there is little further increase in height and the growth curve levels out at the mature height (fig. 14).

Some varieties in the upper garden produced mature ears and these were harvested. Unfortunately, earworms were present under the husks of many ears. Preliminary yield data are presented in table 30. Detailed measurements were made on sampled plants of all varieties and will be analyzed in combination with measurements made on the tassels and ears after the field season.

Plants in experimental squares of Hopi blue corn showed great variation in height and leaf color throughout the growing season. This may have been due to soil differences on a very local scale or to differences in moisture level in the soil at the time when the plants were most sensitive: during and after germination of the seed. Since much variation occurred within any given square, the differences could not be explained by applied treatments of controlled weeding or by plant density. However, nearly all stalks bore ears and final measurements and analysis should illuminate the situation. Mature ears are needed for analysis but the kernels were still milky in late September; since the plants had not yet

Table 28. Comparison of corn varieties grown, upper garden, 1980

Variety	Tassles	Silking	Green corn	Number of tillers	Drought stress	Height (cm)	Comments
Hopi blue	10 Aug	25 Aug	15 Sep	2-3	Low	184	
Chapalote	28 Aug	25 Sep		0-1	Low	165	Will not mature in time
Papago	8 Aug	15 Aug	15 Sep	0-1	Low	166	Refer to "Results and Discussion" section
Apachito	8 Aug	20 Aug	15 Sep	1-2	Medium	191	Pigmented stalks and tassels
Azul	8 Aug	20 Aug	15 Sep	3-4	Very high	188	Suffered badly from drought
Blanco	8 Aug	20 Aug	15 Sep	1-3	Medium	225	Very tall stalks
Cristallino	8 Aug	20 Aug	15 Sep	1-3	Medium	210	Subject to lodging
Blando	20 Aug	10 Sep		0-2	Medium	238	Will not mature in time
WJL sweet*	28 Jul	8 Aug	30 Aug	0-3	Low	114	Very early and productive
Red pop	20 Aug	5 Sep	25 Sep	1-3	High	130	Will not mature in time
Teosinte				10-15	Low	prostrate	Uncharacteristic growth

*WJL - William J. Litzinger

NOTES: These comparisons are based on corn plots at the upper garden. Seeds were planted 8-9 June 1980. The plants were watered only once, on 22 June. Dates of tasseling and silking indicate when one-half of the plants were at that stage. Height is to the top of the leaves when extended straight upwards.

Additional information on vegetative characteristics of these varieties and on yield of mature grain is in preparation but not available at this time.

Similar plots of these and other varieties were planted at the lower garden, but growth of corn there was severely limited by insect predation, weed competition, and early frosts. Thus measurements on plants in those plots are incomplete.

Table 29. Weekly growth rates of 10 varieties of corn, upper garden, 1980

Variety	1 Jul	9 Jul	16 Jul	23 Jul	31 Jul	7 Aug	15 Aug	22 Aug	29 Aug
Hopi blue	30	40	75	110	120 T	155 S	170	180	180
Chapalote	30	60	70	95	110	130	145	150 T	165
Papago	30	45	80	110	140 T	170 S	195	200	200
Apachito	30	60	80	115	130 T	160 S	190	205	210
Azul	35	60	85	120	140 T	175 S	200	205	205
Blanco	30	60	90	115	145 T	185	210 S	225	230
Cristallino	35	60	80	125	150 T	200	215 S	230	230
Blando	35	65	90	120	140	165	200 T	210	225 S
WJL sweet*	20	45	75	90 T	100 S	105	110 T	110	110
Red pop	15	30	50	70	80	95	100 T	110	120 S

* WJL - William J. Litzinger

NOTES: Values are height in centimeters measured to the top of the upstretched leaves, based on weekly measurements of five plants per variety.

Letters T and S refer to the occurrence of tasseling and silking, respectively, in at least 25 percent of the plants of that variety.

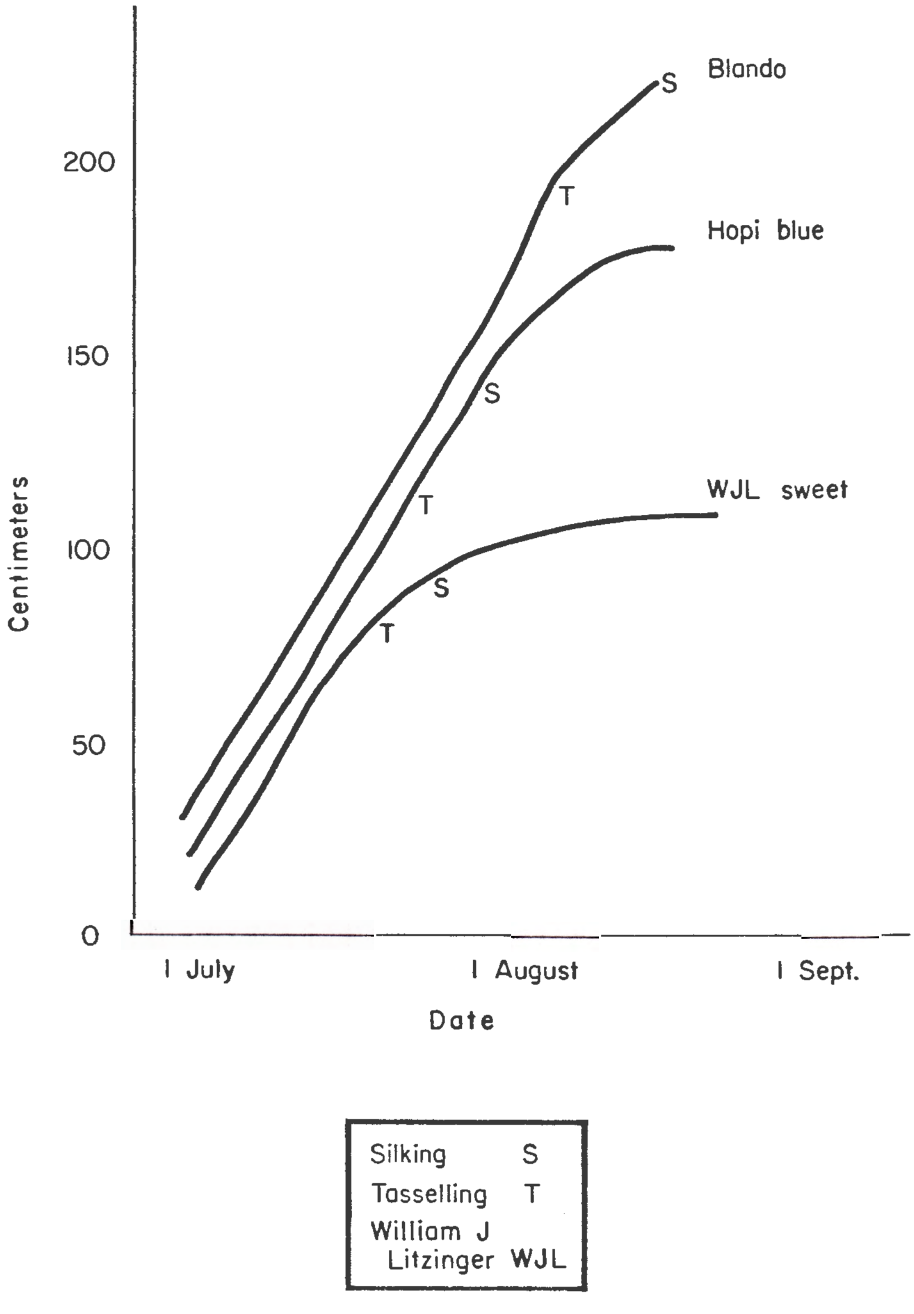

Figure 14. Growth rates of corn.

frozen, all hills were labeled and the stalks were assembled into shocks for protection from predators and from extreme weather until the ears could be harvested in October.

Table 30. Preliminary data on yields of different corn varieties, upper garden, 1980

Variety	Number of plants	----- Number of Ears -----				Ear size
		Mature	Immature	Incipient	Total	
Hopi blue	65	61	30	19	110	Large, thick
Papago	68	109	14	0	123	Medium
Apachito	60	72	27	5	104	Medium
Azul	68	75	25	15	115	Medium
Blanco	63	63	81	25	169	Medium, long
Cristallino	41	67	13	16	96	Long, thin
Blando	64	55	49	23	127	Long, very thin
WJL sweet*	18	40	19	9	68	Short

* WJL - William J. Litzinger.

Preliminary measurements on Hopi blue corn at the upper garden are presented in table 31. These data suggest that weed competition reduces both the stalk height and potential yield of plants within a square. Where weeds were present, stalk height and potential yield were also reduced by higher densities of corn plants within a square, but when weeds are removed the effects of corn plant density are not significant. This parallels the preliminary results at the lower garden.

Other analyses to be carried out on the Hopi blue corn from the upper garden include a comparison of stalk height, tillering, and yield of ears from plants from hills with one, two, three, or four plants within 16 m plots of the same overall density. Another approach will be the measurement of biomass allocation for plants within different size classes (from very short to very tall) and a comparison of the number of ears from those plants.

Plants of Hopi blue corn from the large hills of 10 to 15 plants showed fewer signs of drought stress than those in the smaller, more closely spaced hills, but are similar in stalk height and number of ears set. However, ears matured somewhat earlier on plants in the large hills. Further analysis based on yield of mature ears might indicate an advantage to one or the other planting method.

Table 31. Preliminary measurements on Hopi blue corn, upper garden, 1980

Plot No.	Corn density	Average Ht to tassel base (cm)	Average No. of female units
Weeds present in plot throughout the growing season			
2	30	113	2.1
6	30	99	2.0
7	30	94	1.7
3	60	100	1.1
4	60	86	1.5
8	60	101	1.3
1	90	52	0.6
5	90	94	0.8
9	90	78	1.0
Weeds removed from plot throughout the growing season			
11	53	100	1.4
12	55	82	0.9
14	55	95	1.2
18	55	90	1.4
10	65	106	1.1
15	65	87	1.1
16	65	110	1.2
14	73	128	1.2
17	75	100	1.4

NOTES: Number of female units includes mature and immature ears on main stalks and tillers.

Based on measurements made 11 September.

Plans to study the effect of competition with annual weeds on the growth and yield of corn were upset when no annual weeds germinated in the corn plots in either garden after the soil dried out in May. The effect of competition with the perennial weeds on corn vigor was therefore studied as a problem characteristic of the sites employed for the gardens. However, an opportunity arose to study the effects of competition of corn with Amaranthus retroflexus (pigweed) in a cornfield on Road 25 north of Cortez; this was an irrigated field of modern hybrid corn. Weeds had grown up to the height of the corn since it was last cultivated in early July. Weeds were abundant in some parts of the field but missing in others; the corn population was rather uniform throughout. Table 32 presents a comparison of plants growing under these two conditions, based on measurements made in the field on 23 September. All values are averages based 10 samples from areas with pigweed and 10 from areas without pigweed. Each sample area was a 3 m length along a row of corn. Corn rows were 1 m apart.

Table 32. Comparison of corn growing with and without pigweed competition

	Mean No. of pigweed plants per plot	Mean No. of corn plants per plot	Mean No. of ears per plot	Mean Ht to tassel per plot (cm)
Sample plots with pigweed	13	8.3	11.4	125
Sample plots without pigweed	0	9.7	16.7	137

This data suggests that pigweed competition reduces height and yield of ears in corn. However, the food potential of pigweed itself is not unrecognized. When questioned why he hadn't tried to eliminate the pigweed from his field, the farmer, Mr. Tozer, replied, "Oh, I'm just going to turn my cows into that cornfield anyway and they like the pigweed as well as the corn!"

Beans

Four species of beans of the genus Phaseolus were planted at both gardens. Bush beans were planted at a density of approximately 15 per meter in rows 75 cm apart, for an overall density of 20 plants per m^2. At these low population densities the leaf canopy was never closed and bare soil was always visible between the rows. This unshaded soil reached surface temperatures as high as 54° C (130° F) in late afternoons during July. This probably prevented superficial root development and also increased leaf transpiration. Although no plants showed wilting as a sign of drought stress, it is likely that growth was reduced. However, plants of all species responded to the late summer rains with a flush of vegetative growth and flowering.

Many factors acted to limit growth and productivity of bean plants. Although no vertebrate predators caused damage in 1980, as the rabbits did in 1979, many insects attacked both foliage and developing pods. Predation by insects was very intense at the lower garden and many varieties were repeatedly defoliated and gradually died. Different varieties showed a range of susceptibility to predation. All varieties of Phaseolus coccineus (scarlet runner beans) were attacked first by aphids, then by grasshoppers. Phaseolus vulgaris Wren's Egg, P. vulgaris Jacob's Cattle, and P. lunatus Southern Running sieva, were also quite vulnerable to both insect pests. During late July and in August when most varieties were in bloom, grasshoppers ate nearly all the developing bean pods at the lower garden despite applications of the insecticide Carbaryl (Sevin). During this period predation was less intense at the upper garden and about one-half of the bean pods initiated were able to develop to maturity. Table 33 shows the contrast between lower and upper garden insect populations in August.

Table 33. Insect populations at the lower and upper garden*

	Lower Adjacent	Lower Within	Upper Adjacent	Upper Within
Total No. insects netted	324	31	134	14
Total taxa represented	16	6	12	2

* Based on samples collected 21 August 1980.

Diseases were also responsible for limiting the growth of some varieties. *Phaseolus vulgaris* cv. Jacob's Cattle was susceptible to a root infection that caused the plants to gradually yellow and die. *Phaseolus acutifolius*, (white tepary beans) showed signs of a viral infection (perhaps transmitted by aphids) that caused tightly curled foliage and a proliferation of terminal branching. Affected plants produced no bean pods.

Only plants of the species *P. acutifolius* and *P. coccineus* had well-developed root nodules at the end of the season, indicating the presence of rhizobial symbionts. The suitable bacteria may not have been present in the soil to innoculate *P. vulgaris* or *P. lunatus*, or their root nodules may have been inconspicuous. The absence of this interaction should be limiting to bean plant growth but apparently this was not the case in the many varieties of both species that grew well.

Many varieties of *P. vulgaris* introduced from Mexico did not flower during the growing season, probably due to a short-day requirement i.e., many beans require short-day conditions to initiate flowering (Kaplan 1980). This could have effectively prevented the successful introduction of primitive bean varieties from Mexico northward. Modern varieties have been selected for day-neutral behavior and most of the varieties of beans planted in 1980 did flower in time to develop fruits before frost.

Figure 15 graphically represents the hours of daylight during the growing season.

Bean plants with well-filled pods were pulled up and dried to hasten ripening of the seeds. The pods were then picked and bagged for storage. Yield was very low at the lower garden and only moderate at the upper garden. Local bean farmers also had a disappointing yield in 1980. No mature pods or seeds were produced on plants of Phaseolus coccineus at either garden. Phaseolus acutifolius (brown and white tepary beans) produced less than .25 L of dry beans per 50 plants at either garden. Phaseolus vulgaris (boleta beans) and P. vulgaris Jacob's Cattle produced about .25 L of dry beans per 50 plants at the upper garden but much less at the lower garden. No other variety of any species produced as many beans as seeds were sown.

Despite the reputation of Montezuma County as a bean growing area, two years of experience at the DAP gardens show beans to be a difficult crop: demanding of labor and attention, susceptible to insects and disease, and unreliable in yield. Their main advantage is drought hardiness. Table 34 summarizes the comparison of bean varieties grown in 1980.

By contrast, all three varieties of Pisum sativum (peas) grew vigorously, tolerated drought and frost, resisted insect predation and disease, and produced over a long season. Their performance in the DAP gardens makes an interesting comparison with the sister legume, beans. Peas, however, are an old-world domesticate and were not available to the Anasazi.

Squash

Seeds of 16 varieties of 6 species of cucurbits (Cucurbita and Lagenaria) were planted at both gardens in hills 3 m apart. Rate and extent of vegetative growth were dependent on variety, soil type, soil moisture

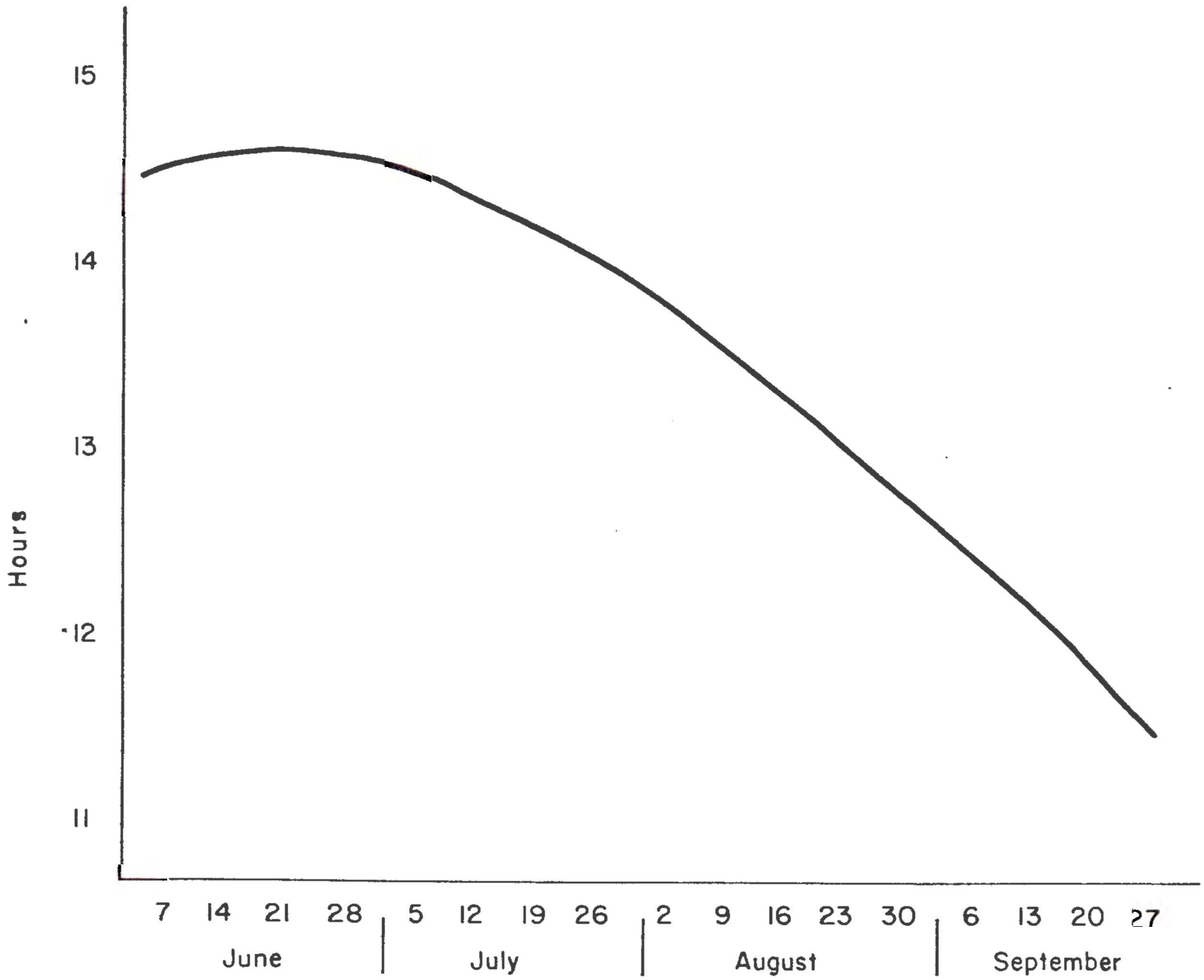

Figure 15. Hours of daylight during the growing season.

Table 34. Comparison of bean varieties grown in upper and lower gardens, 1980

Variety	Flowers open	Green beans	Dry beans	Predation stress	Diseases	Presence of root nodules	Frost sensitivity
Phaseolus acutifolius							
Brown tepary	28 Jul	30 Aug	20 Sep	Low-medium	Leaf curl	Yes	Medium
White tepary	28 Jul	30 Aug	20 Sep	Low-medium	None	Yes	Medium
Phaseolus lunatus							
Henderson's bush lima	28 Aug	none	none	Very low	None	No	Hardy
Christmas lima	3 Aug	21 Sep	none	Very low	None	No	Hardy
Southern Running sieva	20 Aug	none	none	Medium	None	No	Hardy
Phaseolus coccineus							
Hudson's scarlet	17 Jul	19 Sep	none	Very high	Yellowing	Yes	Medium
Bye 8410	23 Jul	none	none	Very high	None	Yes	Medium
Bye 9633	23 Jul	none	none	Very high	None	Yes	Medium
Phaseolus vulgaris							
Jacob's Cattle	22 Jul	31 Jul	5 Sep	Very high	Yellowing	No	High
Boleta	31 Jul	2 Sep	20 Sep	High	None	No	High
Hidatsa red	31 Jul	27 Aug	15 Sep	Medium	None	No	Medium
Zapotec black	31 Jul	27 Aug	15 Sep	Medium	None	No	Medium
Tarahumara (assorted)	none	none	none	medium	None	No	Medium

NOTES: All beans were planted 11-12 June 1980. Average germination for most varieties was 50 percent.

In general, predation stress was much higher at the lower garden due to a higher population of insects. Aphids, grasshoppers, and root worms were the most common predators. No damage from rabbits or other mammals was observed in 1980.

supply, and temperature. Cucurbita pepo and C. ficifolia at the lower garden produced the largest plants, with vines up to 4.5 m long. Identical plantings of one variety of C. pepo were made in four different soil types at the upper and lower gardens, and produced plants that ranged from stunted and yellowish to vigorous and deep green.

Squash plants require considerable moisture to develop well and presumably the higher soil moisture content at the lower garden was responsible for the more lush growth shown there by all species of cucurbits in both 1979 and 1980. Vines of different species differ in the degree to which their axillary shoots develop. In plants of C. ficifolia, C. mixta, and C. moschata, secondary and tertiary branches develop equally with the primary shoot. In C. pepo, these axillary branches do not develop greatly during the growing season, but when leaves and tips of the primary shoot are killed by the first fall frost the secondary branches quickly elongate and growth is renewed. This mechanism of regeneration after frost is associated with a greater cold-hardiness in C. pepo than in the other species.

Male blooms opened on plants of C. pepo and C. maxima at the end of July, and on plants of C. mixta, C. moschata, and C. ficifolia in late August. Male blooms were followed on the same plant by female blooms in one to two weeks. The initiation and development of female blooms is thought to be controlled by the size of the plant (measured as number of nodes on the primary shoot), daylength, and temperature. Most varieties that produced female buds or blooms did so when more than 20 nodes were present on the main shoot. The modern varieties of C. maxima that were planted have been selected for earlier fruiting, and initiated female buds at only 14 to 16 nodes. Only one of the five varieties of C. mixta that was planted produced any female buds at all. This could be due to unsuitable temperatures or to a short-day requirement. Surprisingly, however, C. ficifolia, reported to be an obligate short-day plant, produced several female blooms before frost at the lower garden and developed two small fruits at the upper garden.

The combination of short days and cool night temperatures is said to promote the conversion from male to female blooms in all five species (Bleasdale 1973), but did not do so at the DAP gardens in either 1979 or 1980. All plants persisted in producing excess male blooms and few if any female blooms throughout the fall until frost killed the plants.

Predation by grasshoppers affected some varieties at the lower garden but few at the upper garden. Foliage of C. moschata and Lagenaria siceraria and flower petals on all blooming plants were the most susceptible plant parts. Beneficial insects were also present and flies and bees collected pollen and pollinated the blooms. Moles dug up and ate seeds of C. mixta at the upper garden in June and returned in July and August to gnaw on the developing fruits of C. maxima.

Yield of fruits was very low at both gardens. Only the modern varieties of C. pepo ovifera (oramental gourds) and of C. maxima, a South American domesticate, produced mature fruit. One variety of C. pepo produced several large but immature fruits at the lower garden and C. ficifolia produced small immature fruits at the upper garden. Two species cultivated by the Anasazi, C. mixta and C. moschata, scarcely initiated any fruits and none of these grew to larger than 3 cm in diameter at either garden before frosts killed the plants.

This is in contrast to 1979, when plants of C. pepo, C. mixta, and Lagenaria siceraria produced medium to large mature fruits at both gardens.

Seeds from these very fruits, planted two weeks earlier this year in both gardens, did not produce any fruits. Much has been said about the potential for developing shorter-season varieties by selecting seeds from the first fruits to ripen each year (Bohrer 1970). While this is possible in the long run, setbacks can and do occur in the process. Table 35 summarizes the performance of some cucurbit varieties grown in 1980.

Other crops

Basic information on the other crops grown in the DAP gardens in 1980 is presented in table 36.

Nicotiana rustica (Indian tobacco) again grew vigorously. Leaves from all plants were collected and dried before frost. The average yield of dry leaf material was 75 g per plant. This species of tobacco has a very high nicotine content and is an effective insecticidal agent. Grasshoppers were attracted to and chewed holes in the leaves that were spread out to dry, but they were victims of their appetites; many dead insects had to be removed from the dried tobacco leaves before they were bagged for storage.

Capsicum annum (chile) transplants grew into stocky and attractive plants at both gardens. Cool nights at the lower garden limited flower initiation and fruit production, but at the upper garden over a dozen finger-long chiles had been picked from most plants by mid-September.

Citrullis vulgaris (Arikara watermelon) plants produced short thin vines with deeply lobed leaves. Several melons ripened at each garden before the first frosts killed the plants. The melons were sweet and juicy but small (9-12 cm in diameter) and filled with seeds. Melon seeds are edible as well as the flesh, and are used by Hopi women to grease the stones on which piki bread is baked. Melons are an introduction from South Africa that was quickly adopted historically by North American Indians.

Table 35. Comparison of cucurbit varieties grown, 1980

Variety	Male flowers open	Female buds	No. of Nodes	Green squash	Ripe squash	Max vine lenght at frost (cm)	Predation stress	Frost sensitivity
Cucurbita pepo								
DAP 1979	31 Jul	13 Aug	24	15 Sep		290	Low	Hardy
Bye 9515	28 Jul	31 Jul	24	28 Aug	21 Sep	450	Low	Hardy
Bye 9571	28 Jul	7 Aug	22	15 Sep		475	Low	Hardy
Gourds	1 Aug	7 Aug	20	13 Aug	21 Sep	350	Low	Medium
Cururbita mixta								
DAP 1979	14 Aug	20 Aug	18	21 Sep		170	Low	Sensitive
Bye 9543	15 Sep					180	Medium	Sensitive
Papago	26 Aug					300	Medium	Sensitive
Zapotec						280	Medium	Sensitive
Cucurbita ficifolia								
Bye 9597	30 Aug	2 Sep	21	21 Sep		450	Low	Medium
Cucurbita moschata								
Butternut	20 Aug	2 Sep	22	21 Sep		220	Very high	Sensitive
Cucurbita maxima								
Hubbard	31 Jul	31 Jul	18	13 Aug	15 Sep	200	Low	Medium
Buttercup	23 Jul	31 Jul	14	10 Aug	15 Sep	250	Low	Medium
Lagenaria siceraria								
Bottle gourd	15 Aug	19 Aug	20			235	Medium	Sensitive

NOTES: Squash seeds were planted over the period 28 May to 26 June. By the end of the growing season little difference was detectable between early and late plantings. Average germination was 75 percent.

Predation by grasshoppers was much more intense at the lower garden and affected foliage and blooms of susceptible varieties.

Due to killing frosts on 21-22 September, all squash were harvested at that time.

Table 36. Other crops grown in 1980

Crop	Seeds sown in greenhouse	Transplanted to garden	Flowers	Fruits	Comments
Nicotiana rustica Indian tobacco	20 Apr	29 Jun	14 Jul	15 Sep	Vigorous growth and production of foliage and fruits
Capsicum annuum Chimayo chile	28 Apr	29 Jun	16 Jul	25 Aug	Very productive of fruits, bushy plants
Capsicum annuum Tarahumara chile	24 Apr	29 Jun	20 Aug	20 Sep	Slower to grow and flower, and much lower yield than Chimayo chile
Citrullis vulgaris Arikara watermelon		11 Jun	23 Jul	30 Aug	Produced several small melons before frost killed vines
Gossypium hirsutum Hopi cotton	22 Apr				Some plants destroyed by aphids, others stunted by insects and cold weather
Proboscidea parviflora Devil's claw	29 Apr	29 Jun	8 Aug	10 Sep	Plants which grew from seeds in the soil rapidly exceeded transplants in size and vigor at the lower garden
Amaranthus hypochondriacus	23 May	30 Jun			All plants succumbed to frost or drought
Pisum sativum Zapotec peas		3 Jun	23 Jul	31 Jul	Very hardy, insect-resistant, and productive
Pisum sativum Tarahumara peas		3 Jun	23 Jul	31 Jul	Very hardy, insect-resistant, and productive

Table 36. Other crops grown in 1980--Continued

Crop	Seeds sown in greenhouse	Transplanted to garden	Flowers	Fruits	Comments
Vicia faba Faba beans		4 Jun			Poor germination, very susceptible to grasshoppers
Cicer auranticum Chick peas		12 Jun	1 Aug	18 Sep	Indeterminate growth; continued to flower and fruit until frost killed plants

Gossypium hirsutum (Hopi cotton) seeds were difficult to germinate and many plants died as seedlings due to diseases or aphid predation. Those plants brought to the gardens from the CU greenhouses were very weak and stunted and died after exposure to the cold nights. Perhaps if seeds could be germinated and grown directly in warm soil in the gardens they would not suffer this stunting, but it is likely that the Dolores area is outside the tolerance limits for even this hardy cotton.

Amaranthus hypochondriacus (grain amaranth) seeds germinated well but the tiny seedlings failed to become established. Early in the season, cold nights killed some of the seedlings; later in the season, hot, dry days killed more plants. It is characteristic of the genus that warm, moist conditions are needed for good seed germination and seedling establishment, and these conditions were not present in 1980.

A garden in the town of Dolores had a conspicuous row of tall, brightly colored amaranth plants. The elderly couple who tended the garden had seen the seeds listed in a catalog and decided to try something new. They said that they had tried eating the seedlings as greens but didn't like the taste. At maturity, the plants had large terminal heads full of white seeds and were missing the prickly bracts characteristic of weedy *Amaranthus* fruit clusters. Seed production was very high, nearly .5 L per plant.

Proboscidea parviflora (Devil's claw) seeds were difficult to germinate; the germination rate was less then 10 percent despite various treatments. Seedlings grew slowly in the CU greenhouse and were spindly when transplanted but gradually grew to produce plants up to 75 cm in diameter at the upper garden and 50 cm in diameter at the lower garden. Volunteer plants that grew from seeds released into the soil at the lower garden in the fall of 1979 quickly exceeded the transplants in size and vigor. Several fruits were produced on all of the plants in the lower and upper gardens, but for undetermined reasons, both vegetative growth and fruit production were considerably less than in the 1979 crop.

Weeds

Weeds with nutritious seeds are available in abundance and were well utilized by the Anasazi. To obtain an estimate of weed seed productivity, all infructescences were collected from the plants of *Amaranthus retroflexus* (pigweed) and *Helianthus annuus* (common sunflower) in several 1 m^2 sample plots on disturbed ground around the project area. Their seeds will be weighed and yields compared with that of beans. Such a comparison implies equal nutritive value, but there are indications in the literature that seeds of weeds can have very high levels of proteins with a good amino acid complement. The ease of collecting pigweed and sunflower seeds compared with the difficulty of growing beans, does lead one to speculate on why agriculture was adopted in place of gathering.

Vegetation Patterns

Natural vegetation was sampled in areas adjacent to both gardens, in unweeded portions of the gardens, and in places where the 1979 gardens were not replowed. These samples were analyzed for total aboveground biomass production and species composition. As shown in table 37, biomass production at both gardens declined during the first growing season after plowing; only those perennials whose rhizomes had not been destroyed were present. In the second year after disturbance, biomass production was greatly increased with the additional contribution of annual weedy species such as *Amaranthus retroflexus* and *Helianthus annuus*. A complete listing of observed species is presented in tables 22 and 23. Measurements of biomass production in Hopi blue corn were analyzed for comparison with these data; the preliminary results indicate that a much higher yield of biomass per unit area can be attained with a cultivated species than with weedy annuals or perennials.

Table 37. Biomass production of natural vegetation in relation to various disturbance factors

	Lower garden wt (g)	Upper garden wt (g)
Area adjacent to garden, undisturbed for 15 to 20 years	78	37
Area within garden, plowed in 1980 but not weeded	42	25
Area in 1979 garden, not plowed in 1980	94	73

NOTE: Weight given for each area is the mean number of grams from ten $.1m^2$ plots.

This relationship between soil disturbance, invasion by annuals, and increased biomass productivity has important implications. Maximum yields of biomass per area of land can be attained from populations of annual weeds or from cultivated plants, and biomass of both can be promoted by human activity.

Labor

The activities of planting and harvesting were very time consuming, and both had to be accomplished at both gardens during relatively short periods when weather conditions were appropriate. Spring activities included measuring rows and hills, preparing the seedbed, carrying water to irrigate the soil, and sowing the seeds . These activities required at least 175 person-hours during a two week period. Fall activities included picking and threshing beans, collecting squash, picking and husking corn, and gathering other crops. These activities required at least 150 person-hours in a three to four week period. These estimates are very conservative. If the ground had not been mechanically disked in the spring, preparing the soil for planting would have taken several additional weeks. If all plants had produced at the estimated capacity, harvesting would have required much more labor. If the time required to prepare plant products for storage (such as shelling corn and slicing squashes to dry) were included, the total harvest effort would have doubled.

During the growing season, 20-25 hours a week was the minimum required for weeding and cultivating the gardens. This again is a conservative estimate, since it is easier to cultivate in previously disked soil than in hard soil, and since weed populations at the upper garden were low during this dry year.

Aside from the horticultural aspects of maintaining the gardens, the scientific approach to gardening required an average of 10-20 hours a week for monitoring weather, making observations and taking measurements on plants, keeping records, and writing reports.

INTERPRETATION

Any study of agricultural productivity must take into account the abiotic, biotic, and human factors operating on the system. Two years of experience at the DAP gardens allowed for the following observations about these factors.

Abiotic Factors

Microclimatic factors include the effects of altitude, latitude, temperature, and precipitation patterns. Because of the high altitude setting, the short growing season, the great daily temperature ranges, and the low annual precipitation, the DAP gardens are located in a region that is marginal for agricultural activities.

The priority of drought as a limiting factor has often been emphasized in discussions of Anasazi agriculture, as, for example, in the "great drought" theory of abandonment. The 1979 and 1980 growing seasons in the project area were well below average in rainfall, but corn plants survived and produced respectable yields anyway. Water applied to the corn plants seems to have affected germination but did not enhance productivity. In the 1979 experimental corn plots, unwatered and watered plants were about the same in height and number of stalks per hill and all produced fruits. None of these plants were watered at planting time. More importantly, even those plants that had never been watered produced fruits. Water applied at planting time in 1980 increased germination over the 1979 germination rates. Therefore, it appears that water is more important at planting but plants can survive and produce even if they have not been artificially watered at all. A much more serious limiting factor to corn growth is the low nighttime temperatures recorded during the growing season. The number of days required for corn to reach maturity is strongly dependent on nighttime temperature. Papago corn grown during the summer of 1979 in Tucson matured in just 60 days, but the same corn required 120 days to mature during the summer of 1980 at the DAP gardens. This difference can be attributed primarily to the difference in nighttime temperatures between the two locations.

The frost-free period in the project area is also very short; at least it was during the two seasons that experimental gardens were planted. Most references to Hopi agriculture refer to their 120-130 day growing season as short enough to be a potential limiting factor for raising corn, but it appears that the growing season in portions of the project area is much shorter; only 90-100 days at the upper garden, and less at the lower garden. The combination of the short season with the cool night temperatures throughout the summer is doubly limiting.

Other microclimatic factors include local wind patterns, cold air drainages, and the effects of different exposure on north-facing and south-facing slopes. The lower garden is at the bottom of a cold air drainage and therefore has cooler temperatures in the morning and evening and a shorter frost-free season than the upper garden. If several small plots were cultivated rather than a few large ones, an alternative not impractical for hand agriculture, they could be located so as to minimize the problems of exposure and chill.

Edaphic factors include the physical and chemical characteristics of the soil and its water content. Soils at both gardens generally have neutral pH and adequate fertility. The soil at the lower garden has a higher organic content and holds more moisture, but it is heavier and more difficult to cultivate than the soil at the upper garden. The soil at the upper garden is mostly of mineral origin and dries out quickly, but it is easier to work with. Variations in soil type, which affect suitability for agriculture, occur on a very localized scale and even neighboring plants can be affected by these differences. Homogeneity of soil conditions was assumed for the experimental plots of Hopi blue corn but observations of growth suggest that this assumption was invalid. Again, smaller garden plots could be located in sites where soil conditions were optimal.

Because of the combined advantages of warmer nights, the longer frost-free season, less predation pressure, and less weed competition, plants of all species tested grew at least as well, and usually better, at the upper garden than at the lower garden. Yields of corn and beans were much higher at the upper garden, and in 1979 squashes also produced better at the upper garden. The expected advantage of higher soil moisture content at the lower garden was not significant in increasing biomass production or yield of crops grown there, compared to the same crops at the upper garden. If this is so even in very dry seasons and without irrigation, then in normal seasons or with irrigation, the upper garden could do even better than it has so far.

A look at historic and contemporary agricultural practices in the project area confirms these observations. The main local crops of wheat and beans are all grown on upland areas well removed from the river valley floor. Inhabitants of the valley grew some vegetables in their gardens but did not attempt any large scale field cropping since it was considered a marginal area.

The occurrence of prehistoric habitation sites in the river valley, such as Periman Hamlet (Site 5MT4671) does not mean that any farming activities were carried out there. Ethnographic studies in the greater Southwest give many examples of farming activities carried on at some distance from the community (cf. Hack 1942). This practice would have been appropriate in the Dolores area.

Biotic Factors

As presented in the "Results and Discussion" section, corn, beans, and squash showed different growth and yield potentials. Aside from the differences among crops, there are even greater differences among varieties within each crop. Variation can be expressed in terms of vegetative vigor, drought hardiness, cold tolerance, daylength sensitivity, maturation period, resistance to predation and disease, and potential fruit set, as well as flavor, appearance of fruit, nutritional quality and storage quality. Over long periods of time, varieties can be developed that are well adapted to the local growing conditions and that are the preferences of the growers. However, exotic introductions may not even survive or produce fruit the first year if conditions are too unsuitable.

The effects of interspecific and intraspecific competition on crop yield, which have been discussed for Hopi blue corn in the DAP gardens, show that both factors taken singly or together can influence corn growth and yield. Additionally, factors considered negative in the monoculture model of agriculture are positive if a broader perspective is taken. Weed competition reduces corn production, but weed seeds are easily collected and are nutritious. Predation by insects, birds, and mammals can reduce plant size and crop yield, but the predators themselves can be utilized as a food resource if desired or needed.

Human Factors

Selection of seeds, choice of garden sites, planting and cultivating techniques, harvest, storage, utilization practices and introduction of crops or varieties from outside the area are all variables subject to human choice, and can reflect both cultural tradition and individual innovation. At the DAP gardens, seeds from both local and exotic sources were raised using a combination of traditional and modern techinques. Individual crops were grown in an attempt to maximize potential yield, but observations and measurements were made on the garden ecosystem as a whole whenever possible.

CONCLUSIONS

Two years of garden studies conducted in the Dolores area have confirmed the possibility of raising some varieties of corn, beans, and squash to maturity, and have provided data on the growth and yield of these plants. Specimens have been preserved for future study and analysis and for use as comparative material for identification and for comparison with archaeological remains.

APPENDIX A

SEED SOURCES

by

Rita Shuster

This appendix is a list of seeds that were obtained for the 1980 DAP gardens. A botanical specimen (BT) of each type was retained; the BT number is listed with each type. Numbers with seeds supplied by R.A. Bye are numbers he assigned when collecting seeds. This list also includes the source of each type of seed. Not all of the seeds listed were planted in the gardens.

Hopi blue corn
Zea mays
BT 2700
Buena Foods, Santa Fe

Chapalote
Zea mays
BT 2701
Gary Nabhan, Tucson

Papago corn
Zea mays
Bt 2702
Gary Nabhan, Tucson

Posole
Zea mays
BT 2703
Plants of the Southwest

Strawberry pop corn
Zea mays
BT 2704
Northrup-King

Teosinte
Zea mexicana
BT 2705
Hudson seeds

Apachito corn
Zea mays
BT 2706
R.A. Bye 1977

Apachito corn
Zea mays
BT 2707
R.A. Bye 1977

Azul corn
Zea mays
BT 2708
R.A. Bye 1977 BQ

Blanco corn
Zea mays
BT 2709
R.A. Bye 1977 BQ

Cristallino corn
Zea mays
BT 2710
R.A. Bye 1977 BQ

Blando corn
Zea Mays
BT 2711
R.A. Bye 9604

Ladyfinger pop corn
Zea mays
BT 2712
W.J. Litzinger

Sweet corn
Zea mays
BT 2713
W.J. Litzinger

Peas
Pisum sativum
BT 2714
Hudson Seeds

Peas
Pisum sativum
BT 2715
R.A. Bye 7279

Faba beans
Vicia faba
BT 2716
R.A. Bye 7279

Bush lima beans
Phaseolus lunatus
BT 2717
Northrup-King

Cowpeas
Vigna unguiculata
BT 2718
R.A. Bye 6258

White tepary beans
Phaseolus acutifolius
BT 2719
Plants of the Southwest

Brown tepary beans
Phaseolus acutifolius
BT 2720
Gary Nabhan, Tucson

Jacob's Cattle beans
Phaseolus vulgaris
BT 2721
Vermont Bean Seed Co.

Jacob's Cattle beans
Phaseolus vulgaris
BT 2722
Bruce Stewart

Boleta beans
Phaseolus vulgaris
BT 2723
Plants of the Southwest

Hidatsa red beans
Phaseolus vulgaris
BT 2724
Museum of the Fur Trade

Zapotec black beans
Phaseolus vulgaris
BT 2725
John Carr

Blood beans
Phaseolus vulgaris
BT 2726
R.A. Bye 6263

Common beans
Phaseolus vulgaris
BT 2727
R.A. Bye 7277

Common beans
Phaseolus vulgaris
BT 2728
R.A. Bye 8408

Common beans
Phaseolus vulgaris
BT 2729
R.A. Bye 6257

Common beans
Phaseolus vulgaris
BT 2730
R.A. Bye 9646

Common beans
Phaseolus vulgaris
BT 2731
R.A. Bye 9649

Common beans
Phaseolus vulgaris
BT 2732
R.A. Bye 7276

Ojo de Cabra beans
Phaseolus vulgaris
BT 2733
R.A. Bye 8409

Speckled beans
Phaseolus vulgaris
BT 2734
R.A. Bye 8408

Speckled beans
Phaseolus vulgaris
BT 2735
R.A. Bye 9651

Scarlet runner beans
Phaseolus coccineus
BT 2736
R.A. Bye 8410

Scarlet runner beans
Phaseolus coccineus
BT 2737
R.A. Bye 9633

Scarlet runner beans
Phaseolus coccineus
BT 2738
Hudson Seeds

Wren's Egg pole beans
Phaseolus vulgaris
BT 2739
Vermont Bean Seed Co.

Christmas lima pole bean
Phaseolus lunatus
BT 2740
Vermont Bean Seed Co.

Southern Running sieva bean
Phaseolus lunatus
BT 2741
Vermont Bean Seed Co.

Chick peas
Cicer auranticum
BT 2742
Commercial Seeds

Squash
Cucurbita pepo
BT 2743
DAP 1979

Squash
Cucurbita pepo
BT 2744
R.A. Bye 9515

Squash
Cucurbita pepo
BT 2745
R.A. Bye 9751

Squash
Cucurbita pepo
BT 2746
R.A. Bye 9579

Squash
Cucurbita pepo
BT 2747
R.A. Bye 9598

Gourds
Cucurbita pepo
BT 2748
Northrup-King

Squash
Cucurbita mixta
BT 2749
DAP 1979

Squash
Cucurbita mixta
BT 2750
R.A. Bye 9543

Squash
Cucurbita mixta
BT 2751
R.A. Bye 9544

Papago squash
Cucurbita mixta
BT 2752
Gary Nabhan, Tucson

Zapotec squash
Cucurbit mixta
BT 2753
Hudson Seeds

Chilicoyote
Cucurbita ficifolia
BT 2754
R.A. Bye 9597

Butternut squash
Cucurbita moschata
BT 2755
Northrup-King

Buttercup squash
Cucurbita maxima
BT 2756
Northrup-King

Hubbard squash
Cucurbita maxima
BT 2757
Northrup-King

Bottle gourd
Lagenaria siceraria
BT 2758
Jose Torres, Chihuahua

Indian tobacco
Nicotiana rustica
BT 2759
DAP 1979 gardens

Chimayo chile
Capsicum annuum
BT 2760
Plants of the Southwest

Tarahumara chile
Capsicum annuum
BT 2761
Chihuahua

Arikara watermelon
Citrullis vulgaris
BT 2762
Museum of the Fur Trade

Hopi cotton
Gossypium hirsutum var. _punctatum_
BT 2763
Gary Nabhan, Tucson

Devil's claw
Proboscidea parviflora
BT 2764
DAP 1979 gardens

Grain amaranth
Amaranthus hypochondriacus
BT 2765
Plants of the Southwest

Dye amaranth - Tarahumara
Amaranthus cruentus
BT 2766
Hudson Seeds

Corn
Zea mays
BT 2767
R.A. Bye 8480A

Red pop corn
Zea mays, tunicate form
BT 2768
R.A. Bye 5905B

White pop corn
Zea mays, tunicate form
BT 2769
R.A. Bye 5905A

Tassel ear and tunicate form
Zea mays
BT 2770
Bernabe - Tarahumaran Indian

Corn
Zea mays
BT 2771
R.A. Bye 8480D

Yellow sweet corn
Zea mays
BT 2772
R.A. Bye 6151

Red maize
Zea mays
BT 2773
R.A. Bye 8398

Red maize
Zea mays
BT 2774
R.A. Bye 8412

Red dent corn
Zea mays
BT 2775
R.A. Bye 8480B

Yellow maize
Zea mays
BT 2776
R.A. Bye 8480C

Pink corn
Zea mays
BT 2777
R.A. Bye 8412

Mandan Bride flint corn
Zea mays
BT 2778
Johnny's Seeds

Mandan Red sweet corn
Zea mays
BT 2779
Museum of the Fur Trade

Assinboine corn
Zea mays
BT 2780
Museum of the Fur Trade

Country Gentlemen corn
Zea mays
BT 2781
Johnny's Seeds

Miniature sweet corn
Zea mays
BT 2782
W.J. Litzinger

Faba beans
Vicia faba
BT 2783
Plants of the Southwest

Squash
Cucurbita pepo
BT 2784
R.A. Bye 9599

Squash
Cucurbita mixta
BT 2785
R.A. Bye 9646

Squash
Cucurbita mixta
BT 2786
R.A. Bye 9548

APPENDIX B

THE EXPERIMENTAL GARDENS IN RETROSPECT

by
Kenneth Lee Petersen

During the summers of 1979 and 1980, R. Shuster grew corn, beans, squash, and cotton in two gardens at two different elevations (2073 m/6800 ft and 2207 m/7240 ft) within the DAP area. This experiment was designed to test the feasibility of growing such crops under modern climatic conditions in two small areas that might have served as fields prehistorically.

Positive results were anticipated from the outset of the experiment because many farmers and landowners at elevations equivalent to the DAP area commerically raise beans and wheat without irrigation. A number of local people also have small home gardens that produce modern varieties of corn, beans, and squash, often without irrigation. Beyond reaffirming that corn could be grown today, the experiment was designed to document the factors which affected productivity. Few previously reported experimental gardens associated with archaeological projects have sought to thoroughly document the source of seed, the resulting yield, and the amount of effort involved. An attempt was made also to examine the effects of intraspecific and interspecific competition and the climatic factor on yield.

The purpose of this appendix is to put the garden experiment results into a regional perspective. The original plan was to continue the project after the 1980 season, but with the dissolution of the Environmental Studies Group of the DAP, the garden project was also ended. Its results are invaluable, however, in documenting garden potentials for the past. Some of Shuster's preliminary conclusions are evaluated in light of regional precipitation, growing season, and farming practices. Year to year variability in either precipitation or growing season could be large and could spell the difference between success and failure in crop production historically and probably prehistorically.

The closest weather stations to the DAP area are in the communities of Dolores and Yellow Jacket. The Dolores Weather Station has precipitation records for 1908-1928, 1947-1952, and 1968-1980 and has averaged 45.77 cm (18.02 in) annually over those periods (Martin 1933, U.S. Department of Commerce, Environmental Data and Information Service, 1948-1980). This station is the closest to the project area and probably best approximates the project's canyon location. Killing frost data were kept from the 1908-1928 period and the killing frost-free season averaged 129 days (May 22 to Sept. 28) (Martin, 1933). No temperature or growing season data has been recorded at the Dolores station since 1928.

The Weather Bureau under the U.S. Department of Agriculture, recorded the last frost in the spring and first frost in the fall that were severe enough to kill agricultural crops in the area of the weather station and termed the intervening period the "killing frost-free" season. These dates were only recorded up until 1947 when the weather stations were put under the auspices of the Department of Commerce. Only numerical measures of warm season "frost-free" periods (such as the last 0°C/32°F to the first 0°C/32°F) have been recorded since then. Such numerical measures are not exactly equivalent to killing frost-free measures and make comparison between the pre- and post-1947 period difficult.

At Yellow Jacket, the frost-free period (0°C to 0°C) has been recorded since 1962 and precipitation has been recorded since 1963. Because of its elevation and proximity to the DAP area, Yellow Jacket weather data will be used in the following discussion to characterize the project area. Figure B.1 shows three weather stations in an elevational

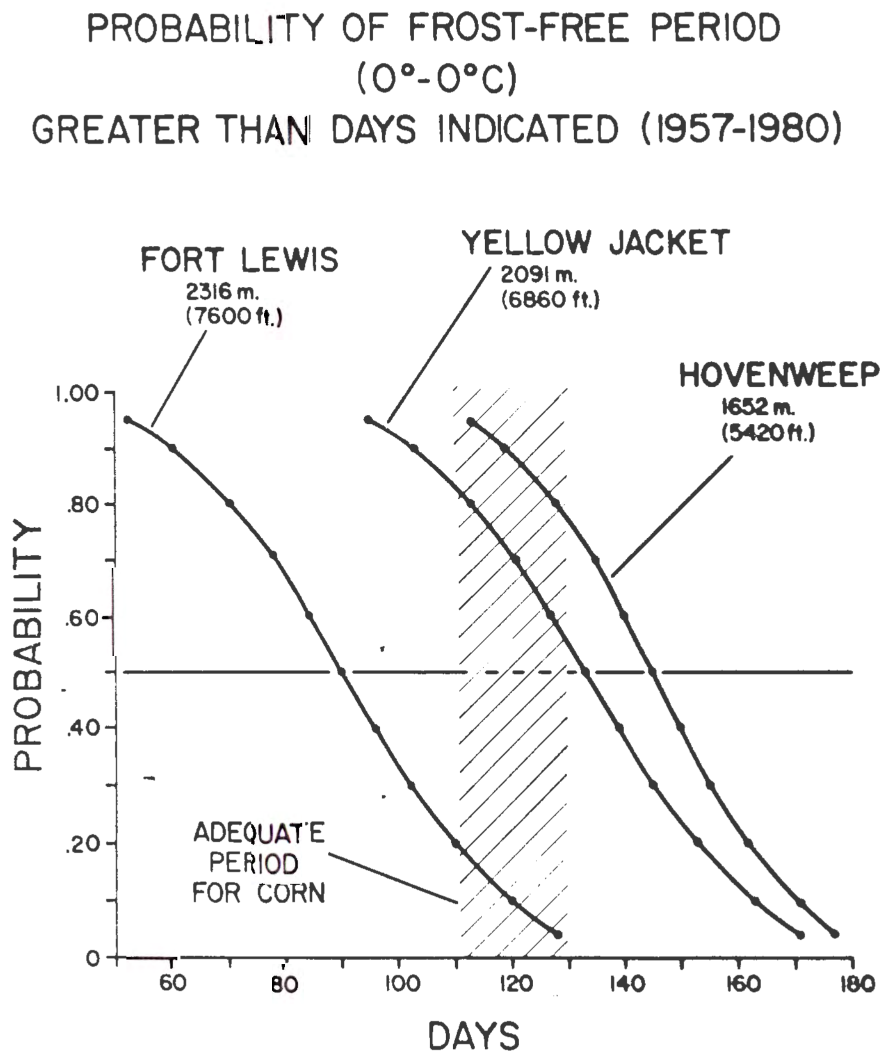

Figure B.1 Probability of frost-free period for three weather stations in the Four Corners region.

transect and illustrates a decrease of the growing season with an increase in elevation. Hovenweep averages 145 days with a SD (standard deviation) of 20 days, Yellow Jacket averages 133 days (SD 23) and Fort Lewis averages 90 days (SD 23). From figure B.1 it is clear that at about 2135 m (7000 ft), in areas that avoid the effects of cold air drainage, the probability that the frost-free period will be shorter than 110 days is 2 out of 10 years. The actual lengths of the growing season as measured at Yellow Jacket in 1979 and 1980 were 163 and 142 days, respectively. This exceptionally long growing season in the area during 1979 was reflected in the crop results in the experimental garden. Even though corn was not planted until the 13th and 14th of June a large mature crop was harvested. Cotton was not planted until 21 June and none of the bolls matured before winter. But, as Shuster notes in the body of this report, if cotton could be planted earlier in the season and if the seeds were planted directly in the warm soil, it might be possible to produce cotton in the Dolores area.

The preceding discussion was presented because Shuster's temperature data indicate a very short growing season (less than 100 days) for the project area. The number of frost-free days recorded for both gardens in 1979 was 87; in 1980 a frost-free period of 98 days was recorded for the upper garden and a frost-free period of 67 days was recorded for the lower garden. These data suggest much shorter growing seasons than would be expected using average Dolores (129 killing frost-free days) and Yellow Jacket (133 frost-free days) weather station data. If the weather data recorded for the gardens are taken as indicative of the frost-free period for the area as a whole, it implies that either (1) it was warmer when Anasazi lived in the DAP area, or (2) they faced constant crop failure if grown under conditions similar to the present. However, examination of the physical location of both garden sites indicates that they were located in areas subject to cold air drainage. The lower garden was on the Dolores River flood plain and the upper garden is in a hollow that faces nearly due east, a position that suggests a frost pocket (Geiger 1965). These physical locations obviously affected the thermometer readings. Average high temperatures for the garden localities are indistinguishable from the average high temperatures recorded for Cortez (table 25) but the lows are much lower. Low temperatures are the only temperatures affected by location in a frost pocket or cold air pool. Modern farmers usually plant only hardier grains and other crops in canyon bottoms and other frosty areas. They have learned by experience the limitations of agriculture in such areas. The Anasazi probably also would have avoided such areas when planting their crops if their growing season was similar to the present. Shuster also would have located her fields in more favorable locations if she had not been required to follow Bureau of Reclamation guidelines.

Historically, successful dry farming in Montezuma County has been practiced above 2010 m (6600 ft) elevation (U.S. Department of Agriculture, Soil Conservation Service 1976). Such elevations receive greater precipitation than lower elevations and are slightly cooler so that soil moisture carried over from the winter is not lost as rapidly through evaporation. Figure B.2 illustrates the increase of precipitation with elevation. Some figures on Montezuma County nonirrigated corn production above 2010 m (6600 ft) are available for the 1920s. For this period there was an average of 3500 (SD 700) acres of corn with an average production of 15 bushels (SD 4) per acre. This contrasts with the irrigated acreage

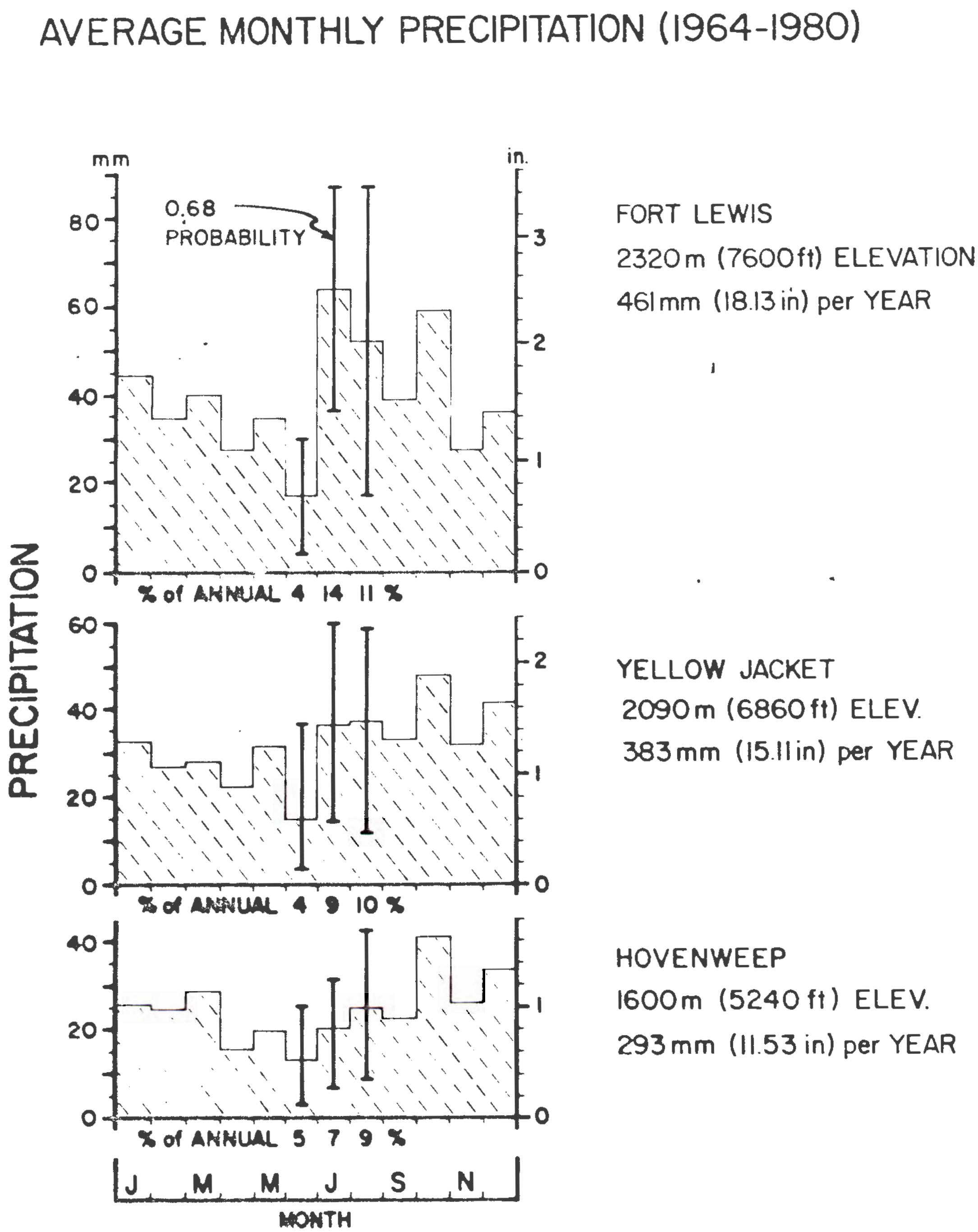

Figure B.2 Average monthly precipitation for three weather stations in the Four Corners region (1964 through 1980).

average of 1200 acres (SD 400) with an average production of 28 bushels (SD 2) per acre (State Board of Immigration 1920-1931). Although Shuster's estimate of 40 bushels per acre for 1979 corn production in the DAP area is high because nonproductive area was not included, when her estimate is compared to the 1920s' figures for nonirrigated corn of 15 bushels per acre it suggests that rather than being marginal, the DAP area is actually very productive.

Leonard et al. (1940) suggest that without the use of drought resistent varieties such as Hopi blue corn, corn growing in Colorado is seldom successful with less than 36 cm (14 in) of annual precipitation, except under irrigation. Yellow Jacket averages slightly higher than this (38.38 cm/15.11 in) but Dolores and the project area average closer to 46 cm (18 in) and should provide ample precipitation. When dependent upon just rainfall for farming, one of the best ways to take advantage of both summer and winter precipitation, if the growing season is adequate, is to locate fields at higher and cooler elevations. Winter moisture is conserved longer in the soil at such elevations and there is an increase of summer precipitation as illustrated in figure B.2. At 1600 m (5240 ft) elevation July precipitation accounts for 7 percent of the annual precipitation and is lower than the August precipitation. At 2090 m (6860 ft) elevation July precipitation is 9 percent of the annual precipitation and is about equal to the August precipitation. But at 2320 m (7600 ft) elevation the July precipitation is as high as 14 percent of the annual precipitation (twice that of the lowest station) and is greater than the August precipitation. Such an increase in July precipitation agrees with Farmer and Fletcher's (1971) observations of summer precipitation in various vegetation zones in Utah. This study also found that more convective storms occurred over the oak vegetation zone than over higher or lower vegetation zones. Following the vegetation zones of Iorn et al. (1965:80, plates 5 and 9), the DAP area and the Fort Lewis weather station are located in the mountain brush vegetation zone which is primarily characterized by oak. Some of the archaeological sites in the DAP area approach the elevations of the highest weather station used in figure B.2. Such high elevations, which are characterized by oak brush, receive greater July precipitation (critical after the droughts of May and June in this region) and are slightly cooler so that soil moisture loss due to evaporation is slower.

In summary, if climatic conditions at times in the past when Anasazi occupied the DAP area were similar to the present, then the DAP area was an attractive area to grow corn and other crops without irrigation. Rather than being marginal, the DAP area was one of the better farming areas in Southwest Colorado especially when compared with areas below 2010 m (6600 ft).

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