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RENEWABLE ENERGY TECHNOLOGY PROJECT

LABORATORY TESTING REPORT NUMBER 2

TITLE: GROWHOLE PERFORMANCE COMPARISONS: WINTER CROP PRODUCTION - LOWLANDS

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Preface

The Lesotho Renewable Energy Technology (RET) Project is part of the Appropriate Technology Section (ATS) of the Ministry of Cooperatives and Rural Development (MINCORUDEV). The Project is funded jointly by the Government of Lesotho (GOL) and the United States Agency for International Development, (USAID). Technical assistance is being provided by Associates in Rural Development, Inc (ARD), under USAID contract AFR-0206-C-00-1016-00.

The RET Project began in April 1981. The Project has three primary objectives:

* to develop and introduce renewable energy technologies that help rural people conserve scarce fuel

* to develop and introduce renewable energy technologies that help rural people increase the year-round availability of food

* to develop and have fully operational an Appropriate Technology Section to carry on the effort beyond the completion of this pilot phase.

This report is part of a series produced by the Project's Research and Development Laboratory to document the research activities that have taken place. Research centres are located at Malefiloane and Mokhotlong in the highlands and at Butha Buthe and Khubetsoana in the lowlands.

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1. Introduction

Fresh food is not very often available in remote locations in Lesotho during the winter and spring. If it is available, it tends to be very expensive. The RET Project is trying to evaluate a variety of grow holes which can be used for the production of food throughout the country. The Project is trying to determine which configuration of growholes might be most appropriate for the Lowlands, and for the Mountains, given construction skills and materials that are available at the present time. This report will focus on the enhancement winterfood crop production in the Lowlands at the Project's workshop in Khubetsoana. The time period investigated was from August through November, 1983.

2. Purpose of the Experiment

The purpose of the experiment was to determine whether the use of growholes results in increased winter food crop production over standard growing methods, as well to assess what parameters contributed most to this increased production.

3. Description of Experimental Apparatus

This experiment involved the comparison of seven different pairs of growholes growing four different crops. Table 1 lists the seven pairs of plots according to their experimental number and according to the characteristics which the Project has used to describe them. Those growholes labelled 'A' were located in the field and were called freestanding. Those labelled with a 'B' were built against a wall of a building. Figures 1-6 contain sketches of the key configurations investigated during the experiment. All plots faced to the North so as to get the best solar access throughout the day.

TABLE 1 List of Experimental Plots

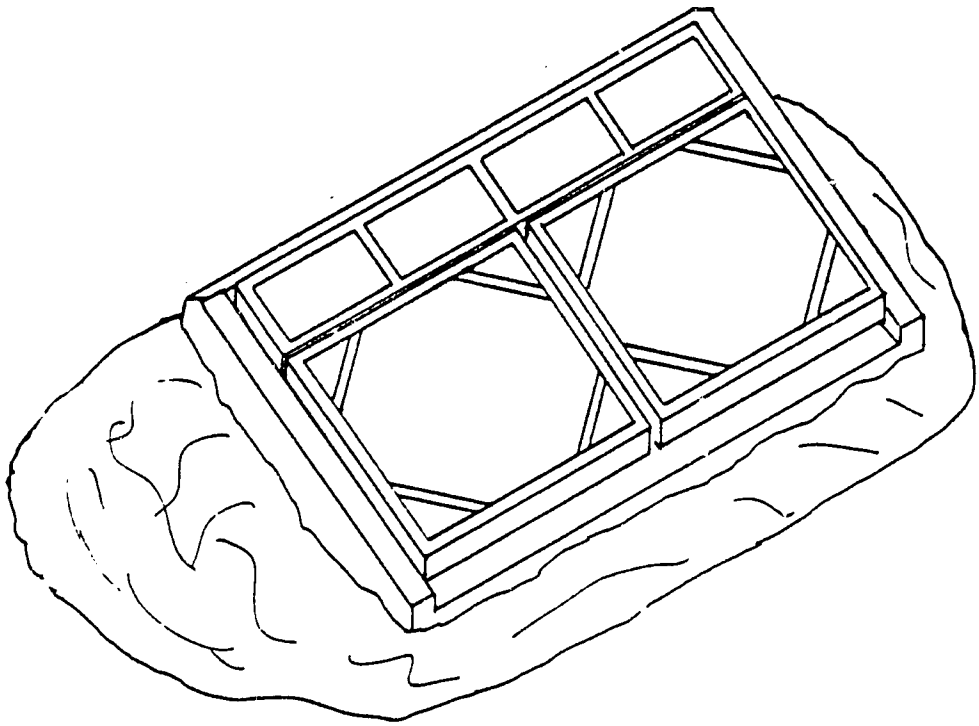
PLOT DESCRIPTION	DESIGNATION	
	FREESTANDING	AGAINST WALL
Open Plot With Walls	1A	1B
Cover Only	2A	2B
Cover with Hot-Bed	3A	3B
Cover with Water-Tins	4A	4B
Open Plot With Walls and Night Insulation	5A	5B
Open plot with Shade Netting	6A	6B
Open Plot-Control	7A	7B

The plots against the wall had an inside area of approximately 1.5 square metres while the plots in the field had an inside area of approximately 2 square metres. The equivalent glazing area of the 14 plots was approximately 1.2m x 2.4m or 2.9 square meters for those in the field and 1.2m x 1.8m or 2.2 square meters for those against the wall. This difference in size was due to the measurements of the building which could not accommodate enough of the larger greenhouses for this experiment. Another difference between plots 1-5 is that those located next to the wall had a high front (or north) wall compared to the freestanding units. This was due to a sloping site next to the building and to the fact that the freestanding units were intended to be essentially dug-into-the-ground. Brief descriptions of each pair of plots follow:

i. Open Plots With Walls:

These open plots were protected by three walls on the east, west and south . In the case of the unit against the building, the back wall is the building wall. In the case of the unit that was free standing the three side walls were protected by a berm of Earth. This earth berm acted as an insulated layer that helped keep the interior temperature of the greenhouse somewhat modified when compared with the outside temperatures. The berm also helped to protect the growhole from excessive winds. In both plots the interior walls were a natural building material colour and were not treated to be either specifically reflective or absorptive of solar radiation. (See Figures 1 and 2)

FIGURE 1 SKETCH OF FREESTANDING GROWHOLE



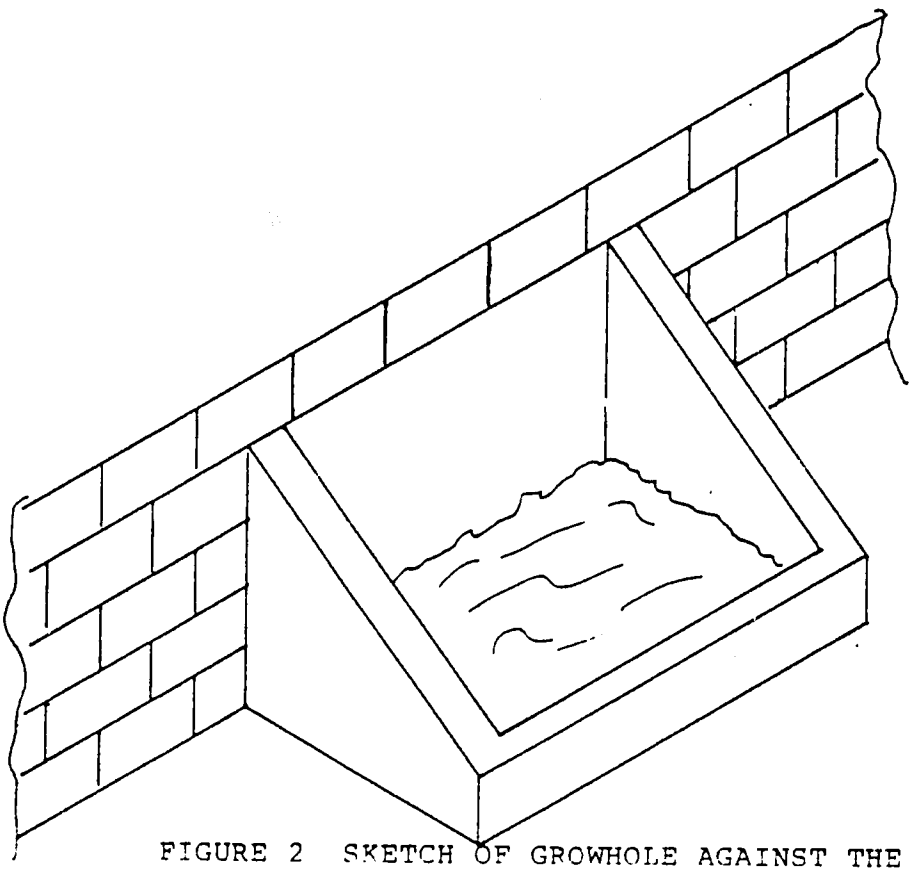


FIGURE 2 SKETCH OF GROWHOLE AGAINST THE WALL

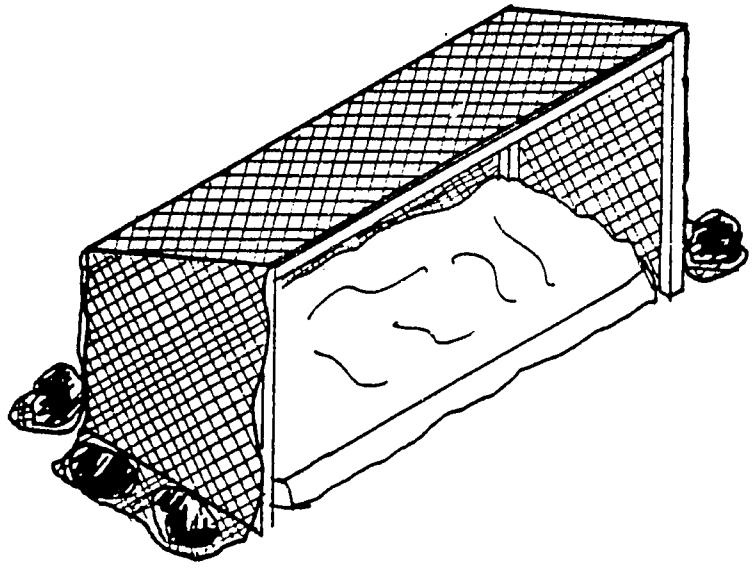


FIGURE 3 SKETCH OF FREESTANDING OPEN PLOT WITH SHADE

FIGURE 4 - CROSS SECTION OF HOTBED AGAINST WALL

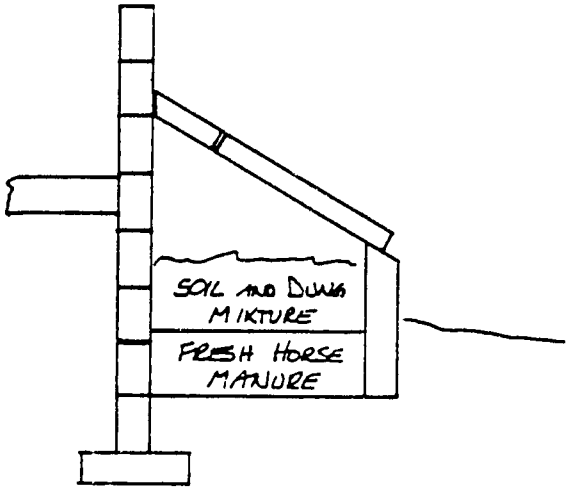


FIGURE 5 - CROSS SECTION OF FREESTANDING GROWHOLE WATER STORAGE IN TINS

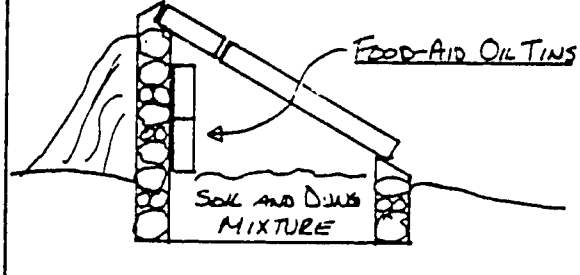
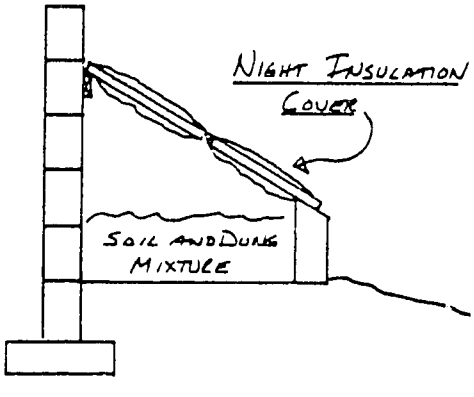


FIGURE 6 - CROSS SECTION OPEN PLOT WITH NIGHT INSULATION COVER AGAINST THE WALL



ii. Cover Only:

These plots had transluscent plastic covers and walls that were similar to those in the previous description. The covers were hinged approximately 1/4 of the way down from the top of the grow-hole. The transluscent cover was made from fibre-glass reinforced with nylon. Locally this product is called Filon. (See Figures 1 and 2)

iii. Cover With Hot-Bed:

These pairs of grow-holes had a hot-bed underneath the soil in addition to the transluscent plastic cover. The hot-bed was prepared according to the instructions listed in the Growhole Users Guide, draft copy, prepared by Sandra Jacobson RET Project, January 1983. The hot-bed consisted of fresh horse manure placed beneath the layer of soil in which the plants grew. The purpose of the hot-bed was to provide an additional source of heat, particularly important during the germination period. (See Figures 1,2 and 4)

iv. Cover With Water-Tins :

These pairs of grow-holes had tins full of water placed against the inside back wall of the growhole in order to store more heat during the day and release that heat slowly during the night. The tins were Food-Aid oil tins, each with a capacity of four quarts (U.S.) or 3.78 litres. Each unit had a double row of tins at the back, one on top of the other. Use of the tins reduced the growing area by 11%. The tins were painted flat-black on the side that faced North. There were 24 tins in the free standing unit and 18 tins in the unit against the wall. These growholes were also covered with translucent fibre-glass covers as in the previous two descriptions (See Figures 1,2 and 5)

v. Open Plots With Walls and Night Insulation:

These units were constructed exactly like those in description (i). At night however, these units received a cover which insulated them from night-time extremes. The covers were made from burlap-sacks that were sewn together and stuffed with stuffed with approximately 50mm of grass taken from the adjoining field. The covers were removed at 8 am in the morning and replaced at 4 pm in the afternoon unless there was particularly inclement weather. (See Figures 1,2, and 6)

vi. Open Plots With Shade-Netting:

These plots used shade netting to reduce night-sky radiation losses. The plots were open. There were no protective walls. The shade netting was angled back at approximately 30 degrees so that the sunlight could come in during the winter days, yet night-sky radiation losses were somewhat prevented at night. The shade netting draped down to the ground on the back and sides of each of the plots, leaving only the north face exposed. (See Figure 3)

vii. Open Plot :

These plots were open on unprotected plots acting as controls for the experiment. The areas of the control plots were 1.5 square metres for the one against the wall and 2.0 square metres for the one that was free-standing.

In order to record data on these experiments, a number of instruments were utilised. Air temperatures were recorded for each plot with the use of maximum-minimum thermometers. Soil temperatures were recorded at 8 am and 2 pm, using 150 mm, [6 inches] long dial-stem thermometers. All thermometers were calibrated prior to the beginning of the experiment. A weather station was set up to provide outdoor ambient measurements. These included maximum-minimum air temperatures, relative humidity and soil temperatures. Soil temperatures and relative humidity were recorded at 8 am and 2 pm. To control the amount of water each grow hole received, a watering can was calibrated in one litre increments. To record the mass of food produced in each grow hole a triple-beam single-pan balance by Ohaus (capacity 20 kg, accuracy 1gm) was used.

4. EXPERIMENTAL PROCEDURES

The experimental procedure for this experiment was developed over a period of several weeks during intensive discussions with the Ministry of Agriculture Horticulture Division, consultant Rick McGowan from Associates in Rural Development and the Memphramegog Group in Vermont. The outcome of these discussions resulted in the procedures that follow:

a) Preparation of Soil:

The soil used in each of the greenhouses was prepared en masse so that each of the samples would be virtually identical. Dried manure was broken up into very small

particles, sieved and then mixed with the soil which had also been sieved. This mixture was then put into each of the growholes to a depth of 300 mm. The only special preparation was in the pair of grow holes with hot-beds. These units 3A and 3B were supposed to have had the soil taken out to a depth of 600 mm. The first 300 mm was to have been replaced with fresh horse manure and then the second 300mm filled up mixture of soil and dung. However, this only happened for plot 3B. Plot 3A received a very thin (less than 3cm thick) layer of fresh horse manure just below the planting medium of soil and dung.

b) Planting :

Four crops were chosen for these experiments: carrots, beets, spinach (otherwise known as swiss chard) and rape. In order to remove any possible edge effects on any one crop, the crops were planted from front to back in alternating rows across the greenhouse. From left to right the order was carrots, rape, beets and spinach. It was done in this way so that rootcrops would alternate with leaf crops allowing the maximum amount of space for the plants. These crops were chosen so that production could be determined for two different kinds of rootcrops and leaf crops. Beets were an exception to this because both root and leaves were useful. The units against the wall had 12 rows or three rows of each type of plant, while the freestanding plots had 16 rows or four rows of each plant. Spacing between the rows was approximately 125 mm. The spacing within the row was 25mm. During the experiments carrots and beets were thinned to 50 mm.

c) Watering:

Two basic procedures are possible in this case. One is to water all the plants the same amount at the same time, thus reducing the number of variables in the experiment. Another option is to water the plants as required by observing whether or not they are wilting or the soil is dry or wet and record this information along with the experimental data. The first procedure was chosen for simplicity.

All growholes were watered at the same time and the amounts were recorded on the data sheets. The plants were watered regularly throughout the experiment, although the actual period between waterings varied depending on the age of the plants. When the plants were young they were watered approximately four litres per day per growhole. As the roots grew deeper, the plants were watered approximately three times per week at the rate of 25 mm of rainfall per square meter of growing surface. This amount was considered to be a minimum for production of these vegetables. The 25mm per square metre converts to proximately 50 litres of water per week for the free standing units and 37 litres per week for the units against the wall.

d) Daily Measurements:

At the weather station and in each growhole maximum and minimum temperatures were recorded every morning at approximately 8 am. At 8 am and also at 2 pm the soil temperature was recorded. Also at 8 am a subjective evaluation was made of the previous day's sunshine, wind and rain levels. These were recorded on a scale of zero to five, five being the highest. Sample data sheets for the weather station and the growholes are included in Appendix 1.

e) Control of Insects and Diseases:

Earlier this year the RET Project developed a Growhole User's Guide, written by Sandra Jacobson. This Guide contains procedures for the control of insects and diseases. These procedures were followed by the experimenters. Only home-made recipes such as soapy water, mixtures of 'lengana' and 'lelingoana' or mixtures including nicotine from cigarette butts were used by the experimenters. This would serve as a check on the value of the recipes in the Growhole User's Guide, which was designed to be utilised by people without access to store-bought insecticides.

f) Operation of Covers:

The Growhole User's Guide provided the model for these experiments. It has been found by other researchers that large variations and temperature extremes are injurious to the plants' health. Thus the major control strategy was to develop a warm, comfortable environment for the plants with adequate ventilation and without extremes of either cold or heat. In the case of the open plots it was not possible to regulate this. These would then serve as controls over the greenhouses, which had other measures for keeping the heat in. The units with fibre-glass coverage were to be opened depending on how cold and how sunny the weather was. If the temperature got much above 25 degrees (inside the growholes) to open them. On the other hand if it was cold and cloudy the experimenters were expected to keep the units closed. A further complicating factor in the operation of these covers was that all of the growholes needed a certain amount of fresh air each day. Again the Growhole User's Guide suggested that the hours from 11 to 2 would suitable for opening the grow holes regardless of the weather. The two units with night-insulation covers were expected to have their covers removed at 8 am and replaced at 4 pm thus only allowing for the effect of insulation at night.

g) Harvesting:

Leafy green crops need to be harvested differently than root crops. In this experiment the spinach, rape and the leaves of the beetroot were harvested following one procedure, while the carrots and the beet roots were harvested under a different procedure. The greens were harvested by removing full size leaves from each of the plants that were suitable for harvest. The criterion used to choose a plant for harvesting was that it had to be left with 4 or 5 good size leaves after some leaves were harvested. According to some reseachers in the United States this would mean that the plants would be able to produce at maximum production while being harvested. Prior to removing the leaves it was necessary to record the height of the plants that were being harvested and the average leaf size by measuring the length and breadth of each leaf. Carrots and beets were to be harvested as they grew large enough. When thinned, carrots and beets were weighed and the masses recorded as production.

The total production from all rows of each plant in the greenhouses was combined and then weighed on the scale. In addition to these quantitative measurements, subjective measures of the quality of each plant when harvested were expected of the experimenter. The information taken during the harvest was recorded on a separate data sheet. A sample data sheet is contained in Appendix 1.

5. Results and Conclusions

The most important variable measured in the experiment was the weighed quantity of produce grown in each of the plots. Bar graphs of these quantities, Figures 7 and 8 give firm evidence of the usefulness of using growholes for winter vegetable production (see Appendix 2 for monthly totals). Among the many observations deduceable from these graphs are the following:

* Production in each of the growhole pairs for all crops is invariably higher for the unit built along the wall than for the free-standing version.

* Production varied greatly depending upon which type of plant was measured. The production of rape, for instance, was much greater than the other three crops. In descending order, next came spinach, then beets (greens), then carrots.

* The growholes built with hot-beds produced more than any other pair.

FIGURE 7 WINTER CROP PRODUCTION AT KHUBETSCANA PLOTS AGAINST THE WALL

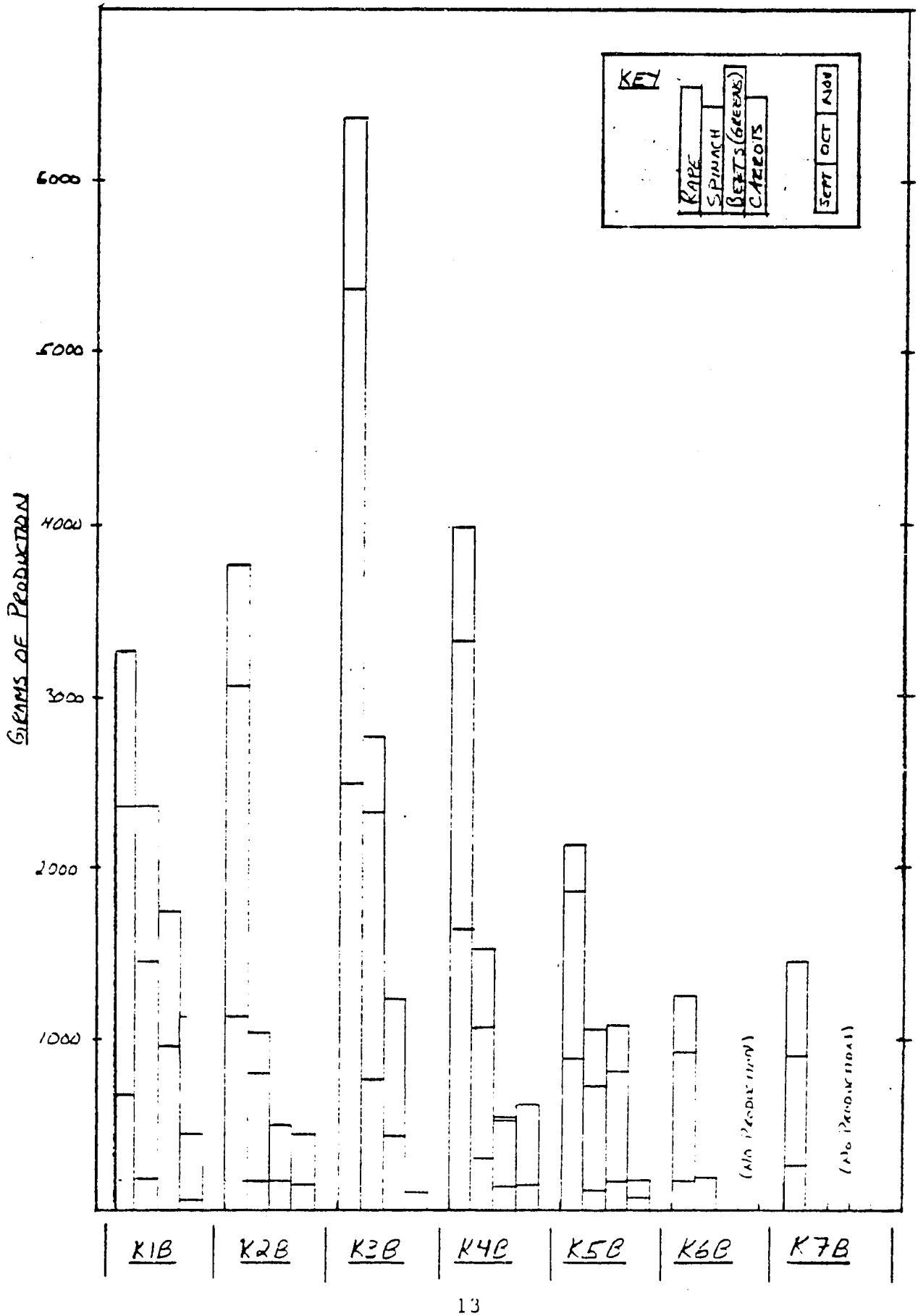
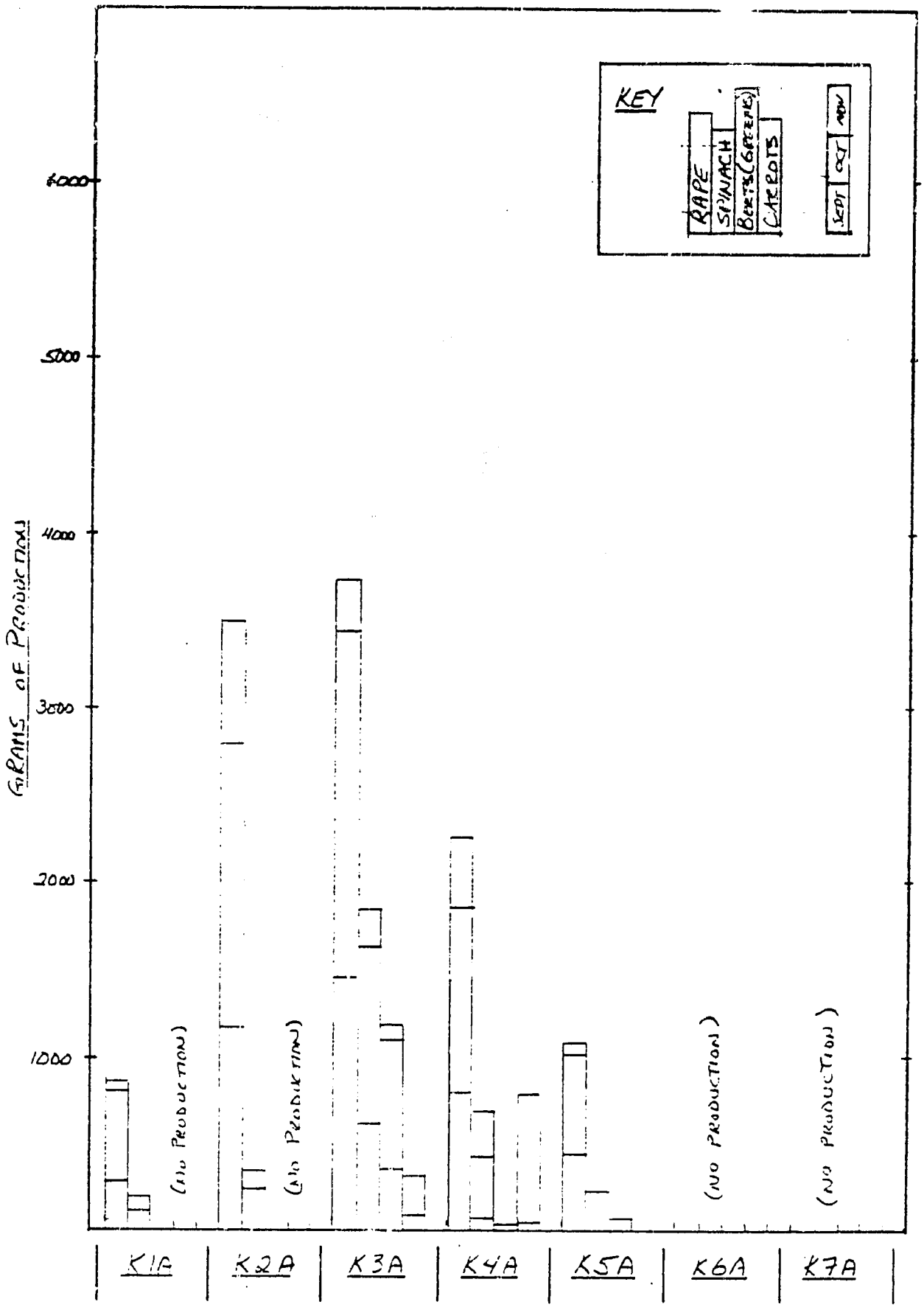


FIGURE 8 WINTER CROP PRODUCTION AT KHUBETSOMNA - FORESTANDING PLOTS



In most cases, the production from covered holes was far greater than for uncovered holes. The one exception to this was K1B, the open plot with walls but no cover built next to the building.

These and other conclusions will be examined in detail below.

There are a number of possible explanations for the obvious difference in production depending on the location of the growholes, either against the building or in the field. These explanations can be reduced from a careful examination of the temperature data taken at each of the sites (see Appendix 2 for monthly breakdowns). A synopsis of this information is given in Table 2. The plots are divided into two groups, one against the wall and the other free- standing. Maximum, minimum and swing temperature averages are given by month for each of the two groups, then monthly averages are combined to give averages over the entire period of the experiment. A pattern emerges from the data which helps to explain the differences in production.

All average temperatures, the air max/min and the soil max/min, are higher in the set of growholes next to the wall of the building. It is reasonable to assume that this made for more advantageous growing conditions in that set of growholes. There were two conditions that influenced these temperatures. First the building acted as a wind block. Even when winds were from the north, the growholes against the building were in a slow moving air layer, building reduces conduction heat loss, if one assumes the building is warmer than the ambient temperature. Also the magnitudes' of the soil temperature swing (daily variation) were smallest in the growholes along the wall, although the difference was slight. Examining the variation in air temperature over the diurnal cycle gives the intuitively unexpected result that the air temperature swing was greater for the growholes along the wall.

TABLE 2

MONTHLY AVERAGE TEMPERATURES (C) GROWHOLE GROUP "A" AND "B"

	AGAINST WALL ("B")				FREESTANDING ("A")			
	AUG	SEPT	OCT	TOTAL	AUG	SEPT	OCT	TOTAL
AIR AVERAGE MAXIMUM	31.6	32.8	31.8	32.1	28.3	31.2	32.9	30.9
AIR AVERAGE MINIMUM	4.3	9.9	11.9	8.7	3.4	9.6	11.8	8.3
AIR AVERAGE SWING	27.4	22.8	20.6	23.6	24.9	21.5	21.0	22.5
SOIL AVERAGE MINIMUM	19.1	18.7	19.7	19.2	15.1	17.6	19.9	17.5
SOIL AVERAGE MINIMUM	13.3	15.6	16.7	15.2	0.0	14.3	16.1	13.5
SOIL AVERAGE SWING	5.7	3.3	3.0	4.0	5.1	3.4	3.7	4.1

Table 3. Kilograms of Produce, is a tabular extension of the production graphs. The first column gives total production from each unit. The following eight columns give the production by crop type, first as a total for the particular growhole, then normalized for comparative purposes by dividing by the growing area of the plot. The third, fifth, seventh and ninth columns, production per square meter for each of the crops tested, are the most revealing.

The rape crop results are given in column 3. Scanning down the column gives the comparative production per square meter for each of the growholes and control plots. The greatest production was achieved in K3B- the covered hot-bed along the wall. It had nearly double the prodution of any other site. Because the rape crop production was a high proportion of the overall production, it is not surprising that this site also had the greatest total production as well.

Examining column 5 for spinach production leads to a similar conclusion. K3B gave the highest production of all sites. K1B, the uncovered walled site next to the building, also did quite well. This was also the case with the beet green crop, where K1B had the highest production of all sites. This fortunate result, the relatively high production in K1B, while awaiting the

TABLE 3

KILOGRAMS OF PRODUCE

	TOTAL	RAPE		SPINACH		BEETS		CARROTS	
		TOTAL	Per M^2	TOTAL	Per M^2	TOTAL	Per M^2	TOTAL	Per M^2
K1B	7.762	3.244	8.65	2.359	6.29	1.742	4.65	0.417	1.11
K2B	5.765	3.742	9.98	1.116	2.98	0.485	1.29	0.422	1.13
K3B	10.440	6.368	16.98	2.749	7.33	1.230	3.28	* 0.093	*
K4B	6.628	3.979	10.61	1.512	4.03	0.531	1.42	0.606	1.62
K5B	4.434	2.136	5.70	1.054	2.81	1.079	2.88	0.165	0.44
K6B	1.441	1.258	3.35	0.183	0.49	0.0	0.0	0.0	0.0
K7B	1.461	1.461	3.90	0.0	0.0	0.0	0.0	0.0	0.0
K1A	1.033	0.845	1.69	0.188	0.38	0.0	0.0	0.0	0.0
K2A	3.866	3.5[illegible]	7.05	0.341	0.68	0.0	0.0	0.0	0.0
K3A	7.124	3.756	7.51	1.820	3.64	1.177	2.35	0.371	0.74
K4A	3.805	2.242	4.48	0.704	1.41	0.058	0.12	0.801	1.60
K5A	1.371	1.085	2.17	0.214	0.43	0.072	0.14	0.0	0.0
K6A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K7A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

confirmation of additional experiments, would allow for very low-cost per unit costs. While this result will likely be the case in mild climates like that of Maseru, it is not the case in the much colder highlands (see Growhole Performance Comparisons:Winter Crop Production-Mountains).

K1B also did quite well with the carrot crop. However, rodents destroyed much of the carrot crop in what was expected to be the top performer, K3B. Comparisons must therefore be made with insufficient information. Carrots was the single crop in which a free-standing plot had comparatively high production, the site being K4A.

Both growholes built with hot-beds underneath far outperformed the other sites. This no doubt was a result both of the increased soil temperatures from the decaying manure, as well as the rich nutrient source provided to the plant roots.

The mean maximum soil temperature over the month of August, right after the seeds were planted, was 4.6 degrees C warmer in K3B than the mean maximum for all the growholes against the wall taken together. Also K3B's mean minimum soil temparature was 4.8 degrees C higher than the others. This no doubt greatly aided seed germination rates, partly accounting for the excellent overall production values attained. Although the hotbed under K3A was not constructed as planned, but in fact was made considerably thinner, and did not contribute to increased soil temperatures, its production was somewhat unexpected. It was the highest free-standing producer for all crops except carrots. The relatively minor additional cost in labout to include a hot-bed had a very high rate of return on investment. It certainly merits inclusion in further growhole construction experiments and planned dissemination efforts.

That the covered growholes have higher production seems reasonable. The covers tend to reduce the magnitude of temperature swings both in the air and the soil. They allow for higher interior temperature during the night and day (when closed) by reducing convective heat loss. They also slightly reduce radiative loss because the interior of the growhole is radiating to a slightly higher temperature (of the cover) than the ambient.

Thus, the perfomance of the walled, uncovered growhole, particularly KIB, was counterintuitive. Comparing the thermal perfomance of the uncovered, waled growhole along the wall-KIB with the walled growhole with night insulation along the wall-K5B, and their two free-standing analogues (KIA and K5A) reveals the following:

* In all cases, both maximum and minimum monthly average temperatures are higher in the growholes with the night insulation (K5B and K5A) than their pair without such covers (K1B and K1A).

* In all cases, both maximum and minimum monthly average soil temperatures were higher in the holes with night insulation than their pair in the field.

* In all cases, the magnitude of both air and soil temperature swings for all months is less in the units with night insulation than in the ones without.

Thus, the thermal parameters which characterized high performance in all the other growhole configurations did not result in high performance when comparing open versus night-insulated growholes in this particular test. This anomaly should be investigated in subsequent tests.

Root crop production was low in all plots. In fact, with the exception of thinnings, no beet root was even harvested. While in remote locations, planting a variety of crops in a growhole is probably desirable, if maximum production of food is the goal, then leafy greens would be the best choice.

6. Suggestions for Further Study

Given the very high production of the hotbed growhole and the minimal expense of incorporating this feature into all future designs, future experiments should be conducted comparing the other growhole configurations which did well in this experiment to hot-bed- based versions. In particular, the walled, uncovered growhole built along the wall of a building should be constructed with a hotbed. If the production rate of this design can approach that of the best design in the present experiment, high production rates would be combined with very low construction costs, allowing a much greater number of people to take advantage of growholes. If covered growholes are necessary, costs increase dramatically, and could preclude the possibility of widespread use.

Thus, further experiments should be conducted with versions KIB, K3B, K4B and K5B all fitted with hotbeds. K5B is included, inspite of its poor performance in the present experiment, simply because the anomalous nature of its performance requires further confirmation. At least two identical models of each version should be compared to strengthen the reliability of the data.

Another experiment would be to water the growholes according to the needs of the plants, rather than a periodic fixed amount. This would lead to a determination of the water demands of open and covered plots, with the expected result that covered plots would use less water because the evaporation from convection due to the wind would be reduced. This experiment could be combined with the one suggested above.

APPENDIX 1: SAMPLE DATA SHEETS

WEATHER STATION RECORD

MONTH _____

OCCUPANT _____ LOCATION _____

DATE	TIME	OUTSIDE TEMP		SOIL TEMP		TEMP		RELATIVE HUMIDITY		OBSERVATIONS			
		MIN	MAX	0800	1400	MIN	MAX	0800	1400	(WEATHER, USE OF AUX. HEAT, OCCUPANTS, ETC.)			
		°C	°C	°C	°C	°C	°C	%	%	S	W	R	

KET PROJECT – GROWHOUSE PERFORMANCE TESTS
– WINTER VEGETABLE PRODUCTION

LOCATION _____ MONTH _____

TEST PLOT NAME _____ PLOT NUMBER _____

DATE	TIME	AIR TEMP MIN	AIR TEMP MAX	SOIL TEMP 8AM	SOIL TEMP 2PM	RELATIVE HUMIDITY 8AM	RELATIVE HUMIDITY 2PM	WATER	OBSERVATIONS (GROWTH, DISEASES, INSECTS, WILTERING, OPENING CANOPY, ETC)

KET PROJECT - GROWHOLE PERFORMANCE TESTS
- WINTER VEGETABLE PRODUCTION

LOCATION _____ MONTH _____

TEST PLOT NAME _____ PLOT NUMBER ___

DATE								
	WEIGHT (GMS)	QUALITY, SIZE, ETC	WEIGHT (GMS)	QUALITY, SIZE, ETC	WEIGHT (GMS)	QUALITY, SIZE, ETC	WEIGHT (GMS)	QUALITY, SIZE, ETC.

APPENDIX 2: PRODUCTION and TEMPERATURE DATA

TABLE 4 GROWHOLE PRODUCTION BY CROP TYPE (GRAMS)

CROP AND MONTH ↓		WALLED ONLY K1B	COVER ONLY K2B	COVER HOT BED K3B	COVER WATER TINS K4B	NIGHT INSULATION K5B	SHADE NETTING K6B	OPEN PLOT K7B	WALLED ONLY K1A	COVER ONLY K2A	COVER PARTIAL HOT BED K3B	COVER WATER TINS K4A	NIGHT INSULATION K5A	SHADE NETTING K6A	OPEN PLOT K7A
RAPE	SEPT	103 73 482 (658)	267 216 554 (1117)	613 1562 311 (2486)	386 891 364 (1641)	203 331 347 (881)	166 (166)	241 (241)	62 158 106 (326)	449 374 327 (1150)	446 446 500 (1442)	223 294 291 (808)	257 204 (461)	0 (0)	0 (0)
	OCT	1001 669 (1670)	1083 841 (1924)	1491 863 601 (2755)	1019 238 406 (1663)	593 382 (975)	269 473 (742)	107 550 (657)	233 213 (446)	864 794 (1658)	1265 754 (2019)	667 367 (1034)	341 211 (552)	0 (0)	0 (0)
	NOV	371 545 (916)	194 [illegible] (461)	220 707 (927)	[illegible] [illegible] (675)	40 [illegible] (280)	350 (350)	563 (563)	73 (73)	336 381 (717)	144 151 (295)	162 238 (400)	72 (72)	0 (0)	0 (0)
	total	3244	3742	6368	3979	2136	1258	1461	845	3525	3756	2242	1085	0	0
SPINACH	SEPT	148 (148)	75 90 (165)	151 353 263 (767)	105 75 107 (287)	101 (101)	0 (0)	0 (0)	0 (0)	0 (0)	117 327 191 (635)	46 36 (82)	0 (0)	0 (0)	0 (0)
	OCT	603 200 479 (1282)	318 308 (626)	813 321 405 ([illegible])	[illegible] 443 (782)	322 294 (616)	183 (183)	0 (0)	108 (108)	261 (261)	383 581 (964)	123 223 (346)	0 (0)	0 (0)	0 (0)
	NOV	427 502 (929)	153 172 (325)	218 225 (443)	127 316 (443)	110 227 (337)	0 (0)	0 (0)	80 (80)	80 (80)	150 71 (221)	145 131 (276)	214 (214)	0 (0)	0 (0)
	total	2359	1116	2749	1512	1054	183	0	188	341	1820	704	214	0	0
BEET GREENS	SEPT	0 (0)	66 71 (137)	90 324 (414)	58 62 (120)	152 (152)	0 (0)	0 (0)	0 (0)	0 (0)	196 174 (370)	0 (0)	0 (0)	0 (0)	0 (0)
	OCT	600 351 (951)	179 169 (348)	315 501 (816)	193 194 (387)	328 318 (646)	0 (0)	0 (0)	0 (0)	0 (0)	393 316 (709)	28 30 (58)	0 (0)	0 (0)	0 (0)
	NOV	338 443 (791)	0 (0)	0 (0)	24 (24)	52 229 (281)	0 (0)	0 (0)	0 (0)	0 (0)	98 (98)	0 (0)	72 (72)	0 (0)	0 (0)
	total	1742	485	1230	531	1079	0	0	0	0	1177	58	72	0	0
CARROTS	OCT	63 (63)	114 (114)	93 (93)	128 (128)	60 (60)	0 (0)	0 (0)	0 (0)	0 (0)	79 (79)	69 (69)	0 (0)	0 (0)	0 (0)
	NOV	242 112 (354)	170 138 (308)	0 * (0)	348 130 (478)	57 48 (105)	0 (0)	0 (0)	0 (0)	0 (0)	170 122 (292)	414 318 (732)	0 (0)	0 (0)	0 (0)
	total	417	422	93*	606	165	0	0	0	0	371	801	0	0	0

* MICE DESTROYED CROP

( ) INDICATES MONTHLY SUBTOTALS

TABLE 5 GROWHOLE THERMAL PERFORMANCE (KHUBETSOANA) – AUGUST, 1983

GROWHOLE NUMBER →	K1B	K2B	K3B	K4B	K5B	K6B	K7B	K1A	K2A	K3A	K4A	K5A	K6A	K7A	WS
AIR TEMP MEAN MAX	31.7	34.3	32.2	34.3	32.0	27.3	29.6	27.6	27.7	31.5	30.6	27.3	26.5	26.9	23.8
AT MAX SD	3.9	3.8	4.0	3.5	4.5	3.5	3.7	4.8	2.8	3.1	3.4	4.0	4.5	4.2	3.5
AIR TEMP MEAN MIN	1.4	7.3	5.6	7.8	6.2	1.3	.3	1.3	5.3	6.0	7.0	5.0	0.3	-1.1	0.3
AT MIN SD	2.0	..8	2.7	2.5	2.0	2.0	2.5	1.7	1.7	1.9	2.2	2.8	2.6	2.0	2.5
AIR TEMP MEAN SWING	30.5	26.8	26.4	26.6	25.7	26.2	29.3	26.8	22.4	25.5	23.7	22.8	25.7	27.7	23.5
AT MS SD	4.6	5.0	4.9	4.0	4.8	4.4	4.4	4.1	3.6	3.3	3.5	3.9	4.4	4.9	4.2
SOIL TEMP MEAN 2 PM	16.8	20.4	23.7	14.9	18.4	17.0	17.7	14.8	17.0	16.3	14.3	17.0	13.2	13.3	14.5
STM 2PM SD	1.7	1.9	1.8	1.9	2.8	1.7	1.9	1.4	1.5	1.0	1.6	1.2	1.3	1.5	1.8
SOIL TEMP MEAN 8AM	10.5	14.3	18.1	15.6	14.3	10.8	9.8	9.1	12.5	12.0	10.3	12.3	7.7	5.8	9.4
STM 8AM SD	1.3	1.7	1.9	1.3	1.0	0.8	0.9	1.0	1.1	3.4	1.0	1.1	0.9	0.7	1.6
SOIL TEMP MEAN SWING	6.3	6.1	5.7	4.3	3.7	6.2	7.8	5.6	4.5	3.4	4.0	5.5	5.5	7.4	5.0
STMS SD	1.9	1.2	1.9	1.9	2.0	1.8	2.0	1.2	1.6	1.0	1.3	3.8	1.2	1.3	0.8

TABLE 7 GROWHOLE THERMAL PERFORMANCE (KHUBETSOANA) - OCTOBER, 1983

GROWHOLE NUMBER	K1B	K2B	K3B	K4B	K5B	K6B	K7B	K1A	K2A	K3A	K4A	K5A	K6A	K7A	WS
AIR TEMP MEAN MAX	36.5	27.9	29.9	31.6	35.1	31.2	35.7	34.4	31.1	31.9	33.5	36.4	29.9	32.8	28.5
ATMMAX SD	5.2	2.8	4.1	5.0	5.9	4.7	5.0	5.0	3.4	4.1	4.2	4.8	4.9	4.3	3.7
AIR TEMP MEAN MIN	9.29	14.6	13.4	14.3	13.8	8.6	9.5	9.4	12.5	13.3	13.8	13.8	10.8	8.7	10.8
ATMMIN SD	3.0	1.9	1.7	1.7	2.0	3.8	3.2	3.2	1.9	1.9	2.5	1.4	3.2	3.7	1.8
AIR TEMP MEAN SWING	27.2	13.3	16.4	17.3	21.3	22.6	26.2	25.0	18.8	18.6	19.7	21.6	18.9	24.1	17.7
ATMS SD	6.8	4.2	4.4	5.7	6.1	7.0	6.9	6.6	3.3	4.9	5.6	5.3	6.1	7.0	4.2
SOIL TEMP MEAN 2PM	19.3	20.0	20.0	19.0	19.7	19.0	20.8	21.0	20.2	19.3	17.4	21.6	18.4	21.2	22.1
STM SD	1.9	1.4	1.7	1.2	2.0	1.6	2.5	1.7	1.5	1.1	2.5	2.5	1.3	2.8	2.0
SOIL TEMP MEAN 8AM	15.4	17.4	17.9	17.9	16.9	16.1	15.3	16.6	17.2	17.2	14.9	17.1	15.1	14.8	17.3
STM SD	1.6	1.2	1.1	0.8	1.3	0.7	1.4	1.5	1.1	0.9	1.2	1.2	0.9	1.4	2.2
SOIL TEMP MEAN SWING	3.9	2.6	2.3	1.1	2.8	3.1	5.5	4.3	3.0	2.1	2.5	4.5	3.1	6.4	4.9
STMS SD	2.1	1.4	1.5	0.9	1.6	1.7	2.6	1.8	1.8	1.3	1.7	1.9	1.0	2.4	2.2

TABLE 6 GROWHOLE THERMAL PERFORMANCE (KHUBETSOANA) – SEPTEMBER, 1983

GROWHOLE NUMBER	K1B	K2B	K3B	K4B	K5B	K6B	K7B	K1A	K2A	K3A	K4A	K5A	K6A	K7A	WS
AIR TEMP MEAN MAX	34.1	33.3	30.4	32.9	33.4	30.7	34.0	33.1	28.9	29.9	31.7	34.7	28.8	31.1	28.8
ATMAX SD	3.4	3.2	3.0	3.6	3.6	3.5	5.0	3.5	3.2	3.2	3.3	4.7	3.5	4.3	4.6
AIR TEMP MEAN MIN	7.0	12.7	11.2	12.5	11.8	6.8	7.3	7.2	9.4	11.0	11.9	12.0	8.5	7.5	7.7
ATMIN SD	3.6	3.4	3.4	2.9	2.1	4.1	4.1	3.8	3.4	2.5	2.9	2.5	4.0	4.6	3.5
AIR TEMP MEAN SWING	27.0	20.7	19.7	20.4	21.7	24.4	26.7	25.7	18.8	18.7	19.8	22.7	20.3	24.7	21.2
ATMS SD	4.3	4.3	4.1	4.9	3.9	6.3	6.3	4.8	4.8	4.1	4.0	4.2	4.9	4.6	4.3
SOIL TEMP MEAN 2PM	17.3	20.1	20.2	18.4	17.9	18.2	19.1	18.3	17.8	16.6	15.0	20.1	16.4	19.0	20.3
STMAX SD	1.8	1.7	1.3	1.1	1.5	2.1	2.7	2.1	1.6	1.0	1.6	2.3	2.0	2.8	2.1
SOIL TEMP MEAN 8AM	13.6	16.6	17.9	16.8	16.0	14.3	13.7	14.6	15.7	15.3	13.3	15.8	12.7	12.5	15.7
STMIN SD	1.3	1.6	1.6	1.0	0.9	1.5	1.7	1.5	1.1	0.9	3.0	1.3	1.6	1.9	1.8
SOIL TEMP MEAN SWING	3.8	3.7	2.5	1.7	2.0	3.9	5.3	3.7	2.2	1.5	1.7	4.9	3.7	6.5	4.6
STMS SD	1.8	1.9	1.6	0.9	1.2	2.0	2.3	1.9	1.6	1.3	1.3	2.1	1.8	2.8	1.7