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RENEWABLE ENERGY TECHNOLOGY PROJECT

LABORATORY TESTING REPORT NUMBER 3

TITLE: GROWHOLE PERFORMANCE COMPARISONS: WINTER CROP PRODUCTION - MOUNTAINS

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LOCATION: MALEFILOANE, LESOTHO.

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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 Khubetscana 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 growholes 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 winter food crop production in the Mountains at the Project's workshop in Malefiloane. 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 three pairs of growholes growing four different crops. Table 1 lists the three pairs of growholes according to their experimental number and according to the characteristics which the Project has used to describe them. Figures 1-4 contain sketches of the key configurations investigated during the experiment. 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. All plots faced to the North so as to get the best solar access throughout the day. All plots had a growing area of approximately 1.8 square meters and an equivalent glazing area of 2.9 square meters.

TABLE 1 List of Experimental Plots

PLOT DESCRIPTION	DESIGNATION	
	FREESTANDING	AGAINST WALL
Cover Only	1A	1B
Cover with Water-Tins	2A	2B
Open Plot With Walls and Night Insulation	3A	3B

All growholes were constructed of stone with mud mortar. The tops of the walls were plastered with cement to protect them from severe rains which might wash them away. All covers, with the exception of that on 1A, were prevented from blowing away by a rope secured to a hook in the ground next to the east and west walls. This was not necessary for 1A because its cover was hinged. The other transluscent covers were made with simpler, less expensive unhinged frames.

The freestanding units were protected by a berm of earth on the east, west and south walls. This earth berm acted as an insulated layer that helped keep the interior temperatures of the growhole somewhat modified when compared to the outside temperatures. It also helped to protect the units from excessive winds.

Brief descriptions of each pair of plots follow:

i. Cover Only

These plots had transluscent plastic covers. The cover material on Plot 1A was fibreglass, trade name, Filon, as was used in the Lowlands experiments. Plot 1B was covered with a plastic film caled Uvidek 602 made in the Republic of South Africa by Gundle. This material is specified by the manufacturer for use on greenhouses and has a rated life of at least 18 months. The cover on Plot 1A was hinged one quarter of the way down from the top of the growhole. (See Figures 1 and 2).

ii. Cover With Water Tins

These pairs of growholes 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. Both growholes had 22 tins and each was covered with the transluscent plastic film mentioned above. Unit 2B was built against the wall of a rondavel so that this configuration could be examined.
(See Figure 3).

iii. Open Plots With Walls and Night Insulation

These plots were built with the same walls as the other plots. However, instead of a transluscent cover, they received an insulated cover which protected them from night-time extremes. The covers were made from a combination of burlap and woven plastic sacks that were sewn together and stuffed with approximately 75mm of chaff and straw left over from a recent harvest. As it was known that Malefiloane was colder than Khubetsoana, the insulation was made thicker for this experiment. The covers were removed at 8 am and replaced between 2 and 4 pm depending on the severity of the weather. (See Figure 4).

Inorder 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-mimimum air temperatures, relative

FIGURE 1 SKETCH OF FREESTANDING GROWHOLE

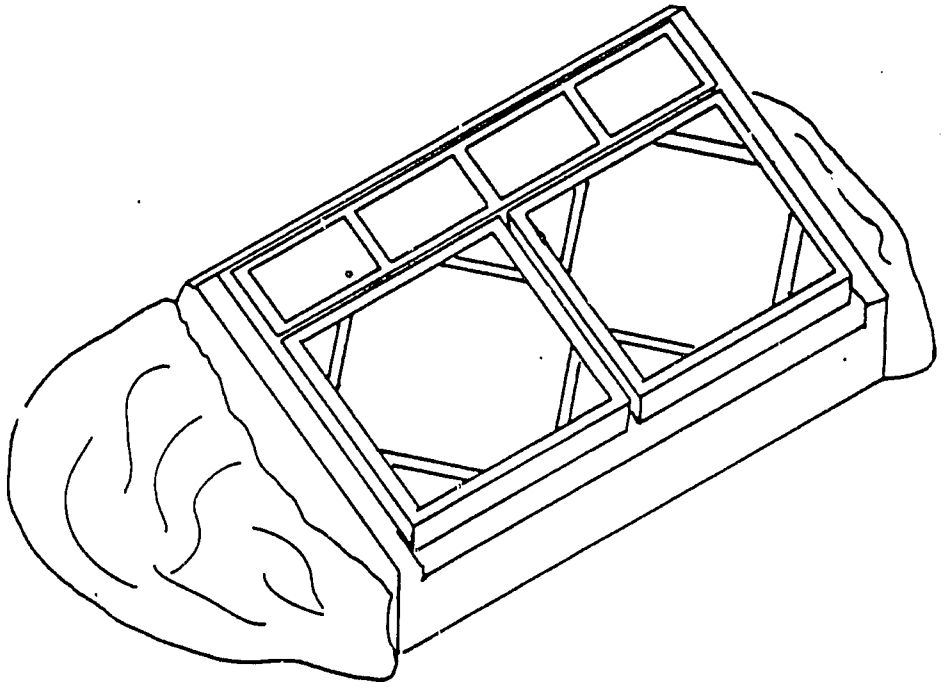


FIGURE 2 SKETCH OF GROWHOLE AGAINST THE WALL

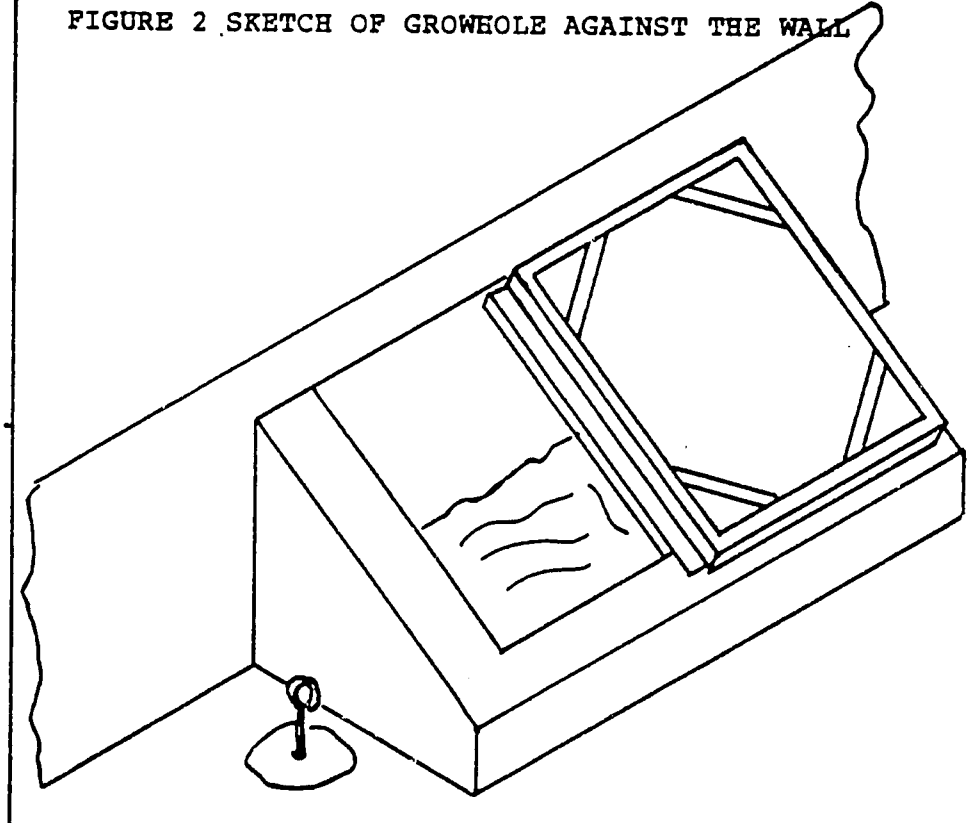


FIGURE 3 SECTION SHOWING WATER STORAGE TINS

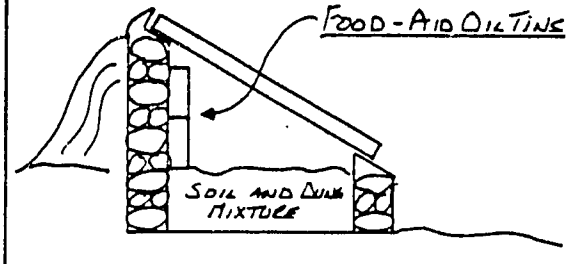
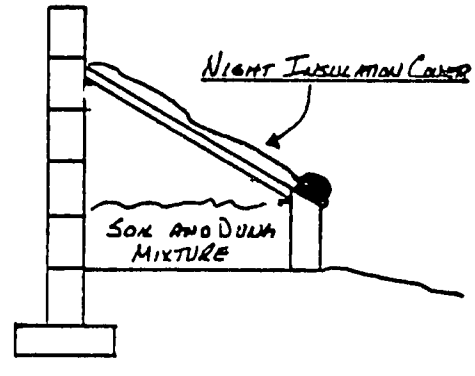


FIGURE 4 SECTION SHOWING NIGHT-INSULATION COVER



humidity and soil temperatures. Soil temperatures and relative humidity were recorded at 8 am and 2 pm. To control the amount of water each growhole received, a single watering can was used throughout the experiment. The mass of food produced in each growhole was measured on a spring balance accurate to 20 grams.

4. EXPERIMENTAL PROCEDURE

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 small pieces and mixed with soil which had been sieved. This mixture was then put into each of the growholes to a depth of 300 mm.

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 root crops and leaf crops. Beets were an exception to this because both root and leaves were useful. All growholes had 12 rows spaced approximately 150 mm apart. The spacing between the rows was 25 mm. Beets and carrots were not thinned.

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 15 litres per growhole per day. As the roots grew deeper, the plants were watered with 15 litres on Mondays and Wednesdays and 30 litres on Fridays. During October, the area was without water and this regular pattern was interrupted.

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 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 'lechuchuta' 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. It was not so simple to regulate this in the open plots with night insulation because in order for the plants to receive the sunlight required for their growth, it was necessary to remove the protective cover. Since this exposed to plants to the much harsher ambient conditions, at least during the day, these units would serve as controls for the experiment. The units with transluscent covers were to be opened depending on how cold and how sunny the weather was. If the temperature inside the growholes got much above 25 degrees the covers were to be opened. 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 be a suitable time for opening the growholes regardless of the weather.

g) Harvesting

Leafy green crops need to be harvested differently than root crops. In this experiment the spinach, rape and the leaves of the beet root 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 maintain high 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.

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 data collected is represented in Figure 5, bar graphs of production by crop from each of the growholes. A tabular representation of the same data is given in Table 2 for convenience. A number of apparent conclusions can be drawn upon examining these data:

* Growholes with glazing produce significantly larger crops than do those with no glazing and night insulation only. The night insulated growhole located on the wall of the building did slightly better than the freestanding analog.

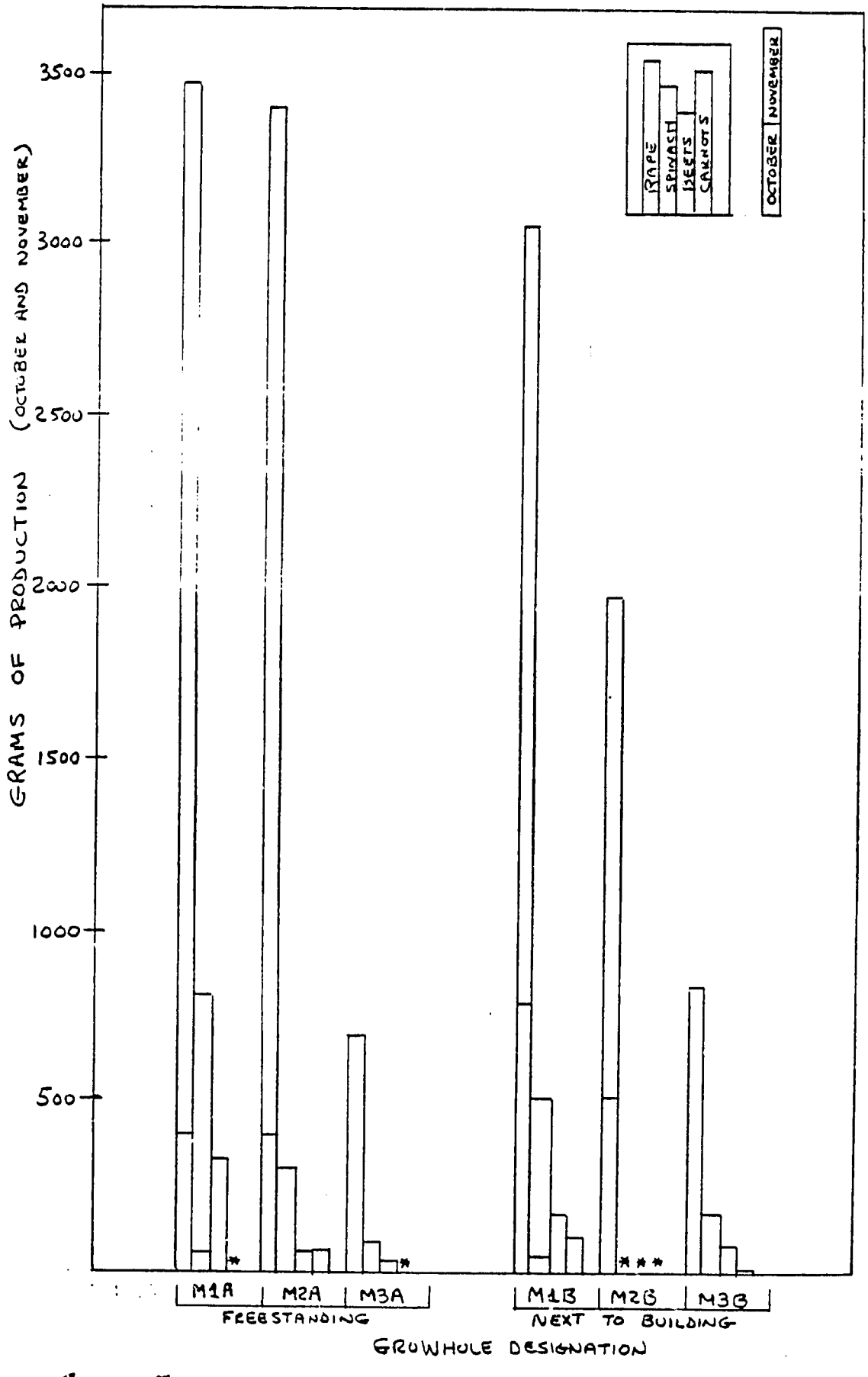


FIGURE 5 : WINTER CROP PRODUCTION AT MALEFILOANE

TABLE 2 : GROWHOLE PRODUCTION, TOTALS AND PER SQUARE METER (MASS IN GRAMS)

	RAPE		SPINACH		BEETS		CARROT		TOTAL
	total	per meter sq	total	per meter sq	total	per meter sq	total	per meter sq	
M1A	3470	1906	810	445	325	179	0	0	4605
M2A	3400	1868	200	110	65	36	70	38	3665
M3A	700	385	90	49	30	16	0	0	820
M1B	3050	1676	510	280	175	96	110	60	3735
M2B	1980	1088	0	0	0	0	20	11	2000
M3B	850	467	180	99	85	47	130	71	1245

TABLE 3: MONTHLY AVERAGE TEMPERATURES (C)

	FREESTANDING					AGAINST BUILDING				
	AUG	SEPT	OCT	NOV	AVE	AUG	SEPT	OCT	NOV	AVE
AIR MAX TEMP	28.6	29.5	23.6	23.9	26.4	29.7	28.8	23.2	22.9	26.2
AIR MIN TEMP	1.8	7.8	6.7	8.4	6.2	3.2	8.1	7.8	8.6	6.9
AIR DAILY SWING	27.1	21.9	16.7	15.5	20.3	26.3	20.7	15.5	14.4	19.2
SOIL MAX TEMP	15.2	15.7	13.9	14.6	14.9	14.9	15.1	13.5	13.8	14.3
SOIL DAILY SWING	11.7	13.7	12.8	13.6	13.0	11.6	13.2	12.3	12.7	12.5
SOIL DAILY TEMP	3.6	1.9	1.4	0.9	2.0	3.4	1.9	1.4	1.1	2.0

* The freestanding growholes appear, on the average, to have produced more than the ones located along the building wall. This was the case in four out of six cases, the exceptions being the night insulation pair. (See explanatory notes below.)

* The harvest in November was significantly greater than the combined figures for September and October. In other words, the growholes were likely approaching full production only in the latter part of the testing. Production figures were not yet available for December at the time of this report. They might well change the overall comparison considerably. Further information will be made available when December production figures come in.

* Rape was by far the best producer. Next, in order of production, were spinach, then beet greens, then carrots. One could conclude that leafy green crops did much better than root crops on a strictly kilogram output comparison.

* Carrots were the only crop which did better along the wall of the building than in the freestanding units. Being the crop with the smallest production, it had little effect on overall production comparisons between the two major growhole groupings (freestanding vs. along the building.)

* Root crop harvest was only possible in November, three months after initial planting.

* Growholes with covers only, units M1A and M1B, produced better than those with covers and water tins. These units in turn, produced better than growholes with only night insulation. This was true for both the freestanding and against-the-wall groups.

In other comparative growhole tests performed this year, at Khubetsoana in the Lowlands, open unprotected plots were planted as controls, both freestanding and against a building, to compare against the other growhole pairs. This was not done in the Malefiloane tests because of the lower ambient air temperatures which would severely inhibit or prevent growth in unprotected locations. People in the Malefiloane area normally begin planting only in November. These plots were planted in August, and would not have survived unprotected. In the more severe climate encountered in high mountain areas, the use of growholes thus becomes not a matter of simply increasing

production, as in the case in the lowlands, but of having any production at all in the early spring months.

A number of incidents occurred which influenced some of the production figures. In M1A, a cow ate a good deal of the rape crop just prior to the initial harvest in September. In M1B, a leaf fungus appeared on the rape crop which neccesitated the removal of much of its production in the end of October. The rape regained its vigor afterwards, but not enough to match the production of M1A in November. Due to these unexpected problems, a strict comparison of these two crops was not warranted. If no further incidents occur, the December crop figures will help clarify this situation. The production of all crops in M2B was unexpectedly low, if one extrapolates from the production in M1B. M2B was not built contiguous to the RET Project Malefiloane Office, as were M1B and M3B, but rather, next to a nearby rondavel. Since cooking was taking place periodically in the rondavel, mice were present. These mice became aware of the availability of fresh greens to be had simply by tunneling through the wall of the rondavel into the growhole. They thereby destroyed much of the total production. Only the rape crop, which grew quite quickly, was able to stay somewhat ahead of their foraging. This was the only growhole which experienced noticeable rodent damage.

This situation, though uncommon in the experimental testing, might well represent the rule rather than the exception should the use of growholes become widespread. To help counter rodent damage, a thin coat of concrete might usefully (and relatively cheaply) be applied to all the inner and outer walls of the growholes. This would serve a further purpose of lengthening the life expectancy of the structure itself, which would otherwise be worn down by the weather. Should the mice begin tunnelling underneath the walls, however, this solution would not apply.

The problem brought up by the cow suggests that some precautions are neccessary to prevent similar problems with chickens, goats, etc. This would imply a need for fencing around the growholes, if they did not have their covers closed most of the time.

Diseases and insects, like plants themselves, much prefer the warm and humid environments provided by the growholes to living outside. Infestations must be dealt with immediately. The Growhole Users' Guide should be consulted.

The Growhole Performance Comparisons: Winter Crop Production-Lowlands report noted that there was a considerable difference in production between the freestanding and the wall mounted growholes. The temperature profiles were analyzed in an attempt to determine why that might have been the case. It turned out the average soil and air temperatures in the wall mounted growholes were higher than the freestanding half of the pair, and the diurnal temperature swings were lower. These factors were thought to account for the differences in production.

A similar analysis was done on the temperature profiles of the growholes at Malefiloane. Clear differences between the two groups were not apparent. Referring to Table 3, it can be seen that there is very little difference in any of the parameters measured, including air temperature max/min, soil temperature max/min, and diurnal variations. The slight differences calculated were well within the range of instrument error, and should not be considered significant.

In summary, it has been found that night insulation does not result in the production obtained by using glazing, with or without the help of water tins. There seems to be no obvious difference between freestanding and wall mounted growhole placement in the mountains . Leafy greens such as rape and spinach do very well in growholes, and should be chosen over root crops such as carrots and beets. Growholes can be used to extend the growing season into early spring and late winter.

6. SUGGESTION FOR FURTHER STUDY

The results of the tests described herein, were, as noted, less useful than expected due to intrusion by animals and disease. Further testing should focus more closely on the growhole types which, inspite of these intrusions, still did relatively well. These two types were the cover only and the cover with water tin designs.

One conclusion from the testing of growholes in Khubetsoana was the suprisingly great contribution to production gained by using hotbeds. (See Growhole Performance Comparisons: Winter Crop Production - Lowlands). In view of the relatively low cost in both materials and labor involved, this feature should be included in all further designs.

Future testing should incorporate precautions taken against the intrusion of both large animals and mice. The scope of the tests should be expanded to include as many as ten growholes, in two groups. Five growholes would be

wall mounted (with cement facing to prevent rodent intrusion from the interior of the buildings) and five freestanding. These five pairs would vary as follows:

1) transluscent cover only;
2) transluscent cover with water tins;
3) transluscent cover with hotbed;
4) transluscent cover with water tins and hotbed;
5) transluscent cover with night insulation

These pairs should be tested throughout the year so that variations in seasonal performance can be determined.

In further experiments, water should be applied as the need is perceived by the experimenter(s). The amount of water should be measured to see if differences in requirements between the growholes can be ascertained. In an arid climate like that of Lesotho, such a parameter should have a bearing on the choice of growhole design for widespread dissemination efforts.

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	

KEY 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, WATERING, OPENING COVERS, ETC

KEI PROJECT - GROWHOLE PERFORMANCE TESTS
- WINTER VEGETABLE PRODUCTION

LOCATION _____ MONTH _____

TEST PLOT NAME _____ PLOT NUMBER _____

DATE	WEIGHT (KGS)	QUALITY, SIZE, ETC	WEIGHT (KGS)	QUALITY, SIZE, ETC	WEIGHT (KGS)	QUALITY, SIZE, ETC	WEIGHT (KGS)	QUALITY, SIZE, ETC

APPENDIX 2

PRODUCTION & THERMAL PERFORMANCE

CROP \ GROWHOLE DESIGNATION		M1A	M2A	M3A	TOTAL FREESTANDING	M1B	M2B	M3B	TOTAL AGAINST BUILDING
RAPE	OCTOBER	100 300 (400) *	100 300 (400)	0 (0)	(800)	200 200 400 (800) *	50 220 250 (520)	0 (0)	(1320)
	NOVEMBER	600 1220 1250 (3070)	940 1010 1050 (3000)	200 500 (700)	(6770)	580 850 820 (2250)	360 400 700 (1460)	500 350 (850)	(4560)
	TOTAL	3470	3400	700	7570	3050	1980 *	850	5880
SPINACH	OCTOBER	50 (50)	0 (0)	0 (0)	(50)	50 (50)	0 (0)	0 (0)	50 (50)
	NOVEMBER	170 140 450 (760)	60 40 100 (200)	10 80 (90)	(1050)	160 200 100 (460)	0 (0)	100 80 (180)	640 (640)
	TOTAL	810	200	90	1100	510	0 *	180	690
BEET GREENS	OCTOBER	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	NOVEMBER	200 125 (325)	40 25 (65)	30 (30)	(420)	100 75 (175)	0 (0)	65 25 (85)	260 (260)
	TOTAL	325	65	30	420	175	0 *	85	260
CARROTS	OCTOBER	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	NOVEMBER	(0)	(70)	(0)	(70)	(110)	(0)	(20)	(130)
	TOTAL	0	70	0	70	110	0 *	20	130
COMMENTS *		A COW ATE MUCH OF THE RAPE CROP 1 WEEK PRIOR TO INITIAL HARVEST				LEAF FUNGUS ON RAPE. ALL AFFECTED LEAVES WERE REMOVED PRIOR TO INITIAL HARVEST	MICE FROM INSIDE HOUSE REPEATEDLY DESTROYED ALL CROPS. RAPE RETURNED MARGINALLY		

TABLE 4 MALEFILOANE GROWHOLE PRODUCTION (GRAMS).

( ) - INDICATES MONTHLY SUBTOTALS

TABLE 5 GROWHOLE THERMAL PERFORMANCE (MACHI-LOANE) AUGUST, 1983

GROWHOLE NUMBER →	M1A	M2A	M3A		M1B	M2B	M3B		WS		IN FIELD	ON WALL			
AIR TEMP MEAN MAX	34.9	32.9	17.9		40.3	28.1	20.8		13.3		28.6	29.7			
ATMMX SD	6.5	7.8	2.6		5.6	5.1	3.6		3.7		5.6	4.8			
AIR TEMP MEAN MIN	0.5	0.6	4.3		3.6	0.3	5.7		-3.3		1.8	3.2			
ATMMN SD	2.6	3.5	2.0		1.5	2.8	2.7		2.6		2.7	2.3			
AIR TEMP MEAN SWING	34.4	33.3	13.6		35.8	28.0	15.2		16.6		27.1	26.3			
ATMS SD	6.7	6.9	3.2		6.5	5.3	4.6		4.4		5.6	5.5			
SOIL TEMP MEAN 2PM	18.3	14.9	12.4		17.8	14.2	12.7		9.6		15.2	14.9			
STM 2PM SD	2.3	1.0	1.4		1.7	1.0	3.3		1.1		1.6	2.0			
SOIL TEMP MEAN 8AM	12.6	11.7	10.7		12.5	10.7	11.6		6.2		11.7	11.6			
STM 8AM SD	1.5	1.0	1.3		1.3	0.6	3.1		0.7		1.3	1.7			
SOIL TEMP MEAN SWING	5.8	3.2	1.7		5.5	3.7	1.1		3.8		3.6	3.4			
STMS SD	1.5	1.4	0.9		1.8	1.2	0.7		1.0		1.3	1.2			

TABLE 6 GROWHOLE THERMAL PERFORMANCE (MACEFIELDS) SEPTEMBER, 1983

GROWHOLE NUMBER →	M1A	M2A	M3A		M1B	M2B	M3B		WS		IN FIELD	ON WALL			
AIR TEMP MEAN MAX	32.0	33.3	23.2		34.0	29.0	23.5		16.6		29.5	28.8			
ATMMX SD	6.1	5.0	2.8		6.1	3.1	3.4		5.8		4.6	4.2			
AIR TEMP MEAN MIN	5.4	8.1	9.8		8.0	6.7	9.5		2.9		7.8	8.1			
ATMMN SD	2.6	2.4	3.4		2.3	2.4	3.2		3.3		2.8	2.8			
AIR TEMP MEAN SWING	26.6	25.2	13.8		25.8	22.3	14.0		14.5		21.9	20.7			
ATMS SD	7.1	6.8	3.0		7.9	4.7	3.8		3.9		5.6	5.5			
SOIL TEMP MEAN 2PM	16.0	16.7	14.5		15.9	14.7	14.7		14.8		15.7	15.1			
STM 2PM SD	2.2	1.5	1.5		1.7	1.0	1.6		2.1		1.7	1.4			
SOIL TEMP MEAN 8AM	13.2	15.2	12.8		13.9	12.2	13.6		11.1		13.7	13.2			
STM 8AM SD	1.7	1.4	1.4		0.9	0.9	1.3		1.9		1.5	1.0			
SOIL TEMP MEAN SWING	2.8	1.5	1.5		1.9	2.5	1.4		3.6		1.9	1.9			
STMS SD	1.8	1.7	0.9		1.4	1.4	0.9		1.8		1.5	1.2			

TABLE 7 GROWHOUSE THERMAL PERFORMANCE (MACEFIELDANE) OCTOBER, 1983

GROWHOUSE NUMBER	M1H	M2H	M3H		M1B	M2B	M3B		WS		IN FIELD	ON WALL			
AIR TEMP MEAN MAX	25.6	25.5	19.6		25.5	24.4	19.6		17.9		23.6	23.2			
MTMAX SD	6.6	5.4	4.3		6.4	5.2	5.4		5.2		5.4	5.7			
AIR TEMP MEAN MIN	5.0	7.1	7.9		7.6	6.4	9.5		3.5		6.7	7.8			
MTMIN SD	3.0	2.3	3.5		1.7	1.6	3.0		1.9		2.9	2.1			
AIR TEMP MEAN SWING	20.6	18.4	11.2		17.9	18.4	10.1		14.4		16.7	15.5			
MTMS SD	7.0	5.5	3.0		6.4	5.4	4.7		5.0		5.7	5.5			
SOIL TEMP MEAN 2PM	13.4	13.6	14.6		13.1	13.8	13.5		12.1		13.9	13.5			
STM 2PM SD	0.8	1.2	1.6		1.2	1.4	1.1		1.9		1.2	1.2			
SOIL TEMP MEAN 8AM	11.7	13.3	13.3		12.1	12.2	12.7		10.1		12.8	12.3			
STM 8AM SD	1.2	1.5	1.3		0.8	1.3	1.6		1.4		1.3	1.2			
SOIL TEMP MEAN SWING	1.7	1.1	1.3		1.0	1.8	1.4		2.0		1.4	1.4			
STMS SD	1.2	1.2	1.6		0.8	1.1	1.0		2.0		1.3	1.0			

TABLE 8 GROWHOLE THERMAL PERFORMANCE (MACKERCOMBE) NOVEMBER, 1983

GROWHOLE NUMBER	M1A	M2A	M3A		M1B	M2B	M3B		WS		IN FIELD	ON WALL			
AIR TEMP MEAN MAX	24.3	25.8	21.5		25.0	23.2	20.4		17.9		23.9	22.9			
ATMMX SD	4.4	5.1	3.9		6.4	3.4	3.9		3.7		4.5	4.6			
AIR TEMP MEAN MIN	6.7	8.8	9.6		8.8	7.1	9.9		5.0		8.4	8.6			
ATMMN SD	2.5	2.2	2.4		2.3	2.0	2.3		2.1		2.4	2.2			
AIR TEMP MEAN SWING	17.6	17.0	11.8		16.9	16.0	10.4		12.9		15.5	14.4			
ATMS SD	5.3	5.7	3.6		5.4	3.8	3.6		3.4		4.9	4.3			
SOIL TEMP MEAN 2PM	13.6	14.7	15.5		13.6	14.4	13.3		10		14.6	13.8			
STM 2P SD	1.1	1.2	1.5		0.8	1.6	0.8		0.9		1.3	1.1			
SOIL TEMP MEAN 8AM	12.8	14.2	13.9		12.8	12.4	12.9		9.9		13.6	12.7			
STM 8AM SD	0.9	1.1	1.5		1.0	0.9	0.9		0.5		1.2	0.9			
SOIL TEMP MEAN SWING	0.8	0.4	1.6		0.8	1.9	0.6		0.2		0.9	1.1			
STM SD	0.8	0.8	1.3		0.6	1.4	0.7		0.5		1.0	0.9			