AD-A164 903 DESERT EMERGENCY - LACK OF WATER - HOW TO FIND AND COLLECT WATER PLANTS A... (U) BEN-GURION UNIV OF THE NEGEV SEDE BOQER (ISRAEL) JACOB BLAUST... Y GUTTERMAN 1/1

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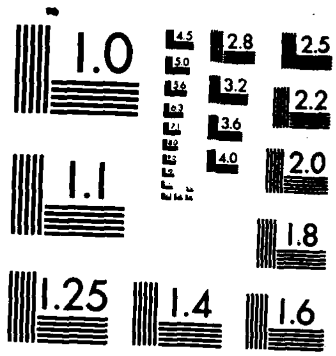

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Ben-Gurion University of the Negev
The Jacob Blaustein Institute for Desert Research
Sede Boker Campus 84990, ISRAEL.

Desert Emergency - Lack of Water - How to Find and Collect Water.

Plants and Human Survival in the Desert.

The Principal Investigator and Contractor:

Professor Yitzchak Gutterman

Contract Number: DAJA 45-83-C-0051
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This study concentrated on the plant and environmental factors which influence the yield of water transpiration which can be collected from 2 widespread plant species, Retama raetam and Phragmites australis; the latter plant gives a much higher yield. This is one of several other methods mentioned which could be of help in saving people stranded in the desert without water.

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A. INTRODUCTION

1. A Description of the Climate in the Investigated Area

The Israeli desert is a hot and dry area in summer whereas in winter rainfall comes in small amounts unpredictably and infrequently, over short periods of the year.

As was measured between the years 1960-65 (Evenari and Gutterman, 1976), the number of days of rain per year ranges, from 10-28 days and amounts of between 29.5 mm and 165 mm of rain per year. The average amount of rain over a number of years in the Negev Highlands was found to be about 85 mm. In most years January is the month with the maximum days of rain and possibly the maximum amount of rain per month. The lowest temperatures are also usually in the month of January during which the average minimum temperature is about 7.4°C and the average maximum temperature is 16.9°C. The average relative humidity per day is about 60%.

In the Negev highlands the minimum annual temperature reaches -3.4°C and the maximum is 47.4°C. The highest temperatures of the year are in July and August, during which the average minimum daily temperature is 19.5°C and the average maximum temperature is 33.5°C. The average relative humidity per day was found to be 42.4% during May. During the day it is dry and hot but at night it is wet and cool.

In the Negev Highlands about 200 nights of dew per year were measured which is equivalent to about 30 mm of rain per year. The months with the minimum amount of dew are April and May, with about 1.3 mm of dew per month; whereas the months of relatively heavy dew are September, October and November during which dew equivalent to 3.7-4 mm. of rain falls per month.

The annual amount of solar radiation is about 190-200 Kcal/cm^2 and the total annual evapo-transpiration reaches a level of 2300-2550 mm. The coefficient of aridity, which indicates how many times the evapo-transpiration is greater than the amount of precipitation per year, in the Negev highlands is 28-30 whereas near Eilat it is 105 (Evenari et al. 1982).

2. A Description of the Topography and Plant Habitats.

In such an area conditions for survival do exist but they are limited. The desert is not uniform in its topography and its heterogeny is displayed in its types of soil and rocks: the elevation in this area differs from 401 m below sea level in the Dead Sea, to 1035 m in the Mount Ramon in the Negev Highlands; active sand dunes, stabile sand areas, loess flat areas, narrow or wide wadis, or even deep and narrow canyons. In the canyons and wadis there are areas with pools and running water or areas where the water table is near the soil's surface. These areas dramatically influence the vegetation and create oases in the desert (Table 1). Even on a single hill, on slopes in different directions there are variations. There are differences in radiation, temperature, vegetation and water content of the slopes, especially during winter (in December) when in our region the angle of the sun to the earth's surface is about 42°C (at noon). Gentle or sheer slopes facing the north, are relatively shaded with lower light intensity, lower temperatures and therefore less evapo-transpiration and lower levels of salinity than the southern facing slopes, at this time of the year. In each of the above-mentioned habitats there is a typical vegetation therefore vegetation may be used as an indicator of specific habitats and other environmental factors (Table 1).

3. Behaviour in an Emergency Situation of Lack of Water.

A man in an emergency lack of water in the desert needs to keep out of the sun and to remain in the shade near a sheer incline facing north or in a cave during the day when it is hot and dry. At dawn when it is relatively cool and wet and the soil is frequently covered with dew, this is the most convenient time to move from one locality to another on condition that one is certain of the right direction to pursue. One needs to calculate how best to locate water and edible plants for water and food, according to the area in which he finds himself. From time to time people find themselves in the desert without water, and with a little knowledge they could save themselves. Without this knowledge there may be a disaster:

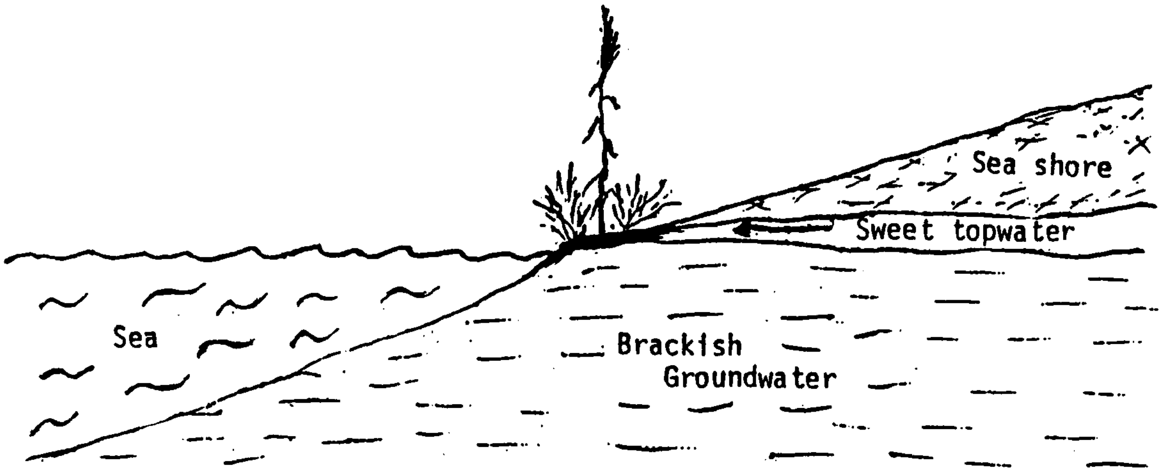


Fig. 1 Drinking water (topwater) is lighter than the brackish water and floats above the ground water. For this reason in certain places one can find topwater among certain species of plants near the seashore.

3.1. After the Six Day War, 1967, a large group of Egyptian soldiers were found dead between Ras Muhammad and A-Tur on the Sinai Peninsula, an extreme desert. There was no war in this area, and the soldiers were well provided with food. It seems that after Sharm-el-Sheik was overtaken by the Israeli Army, this group tried to retreat to the Egyptian forces who were still positioned in Al-Tur. These soldiers were found 300 m from the seashore. Along this seashore, we found plants that indicated the existence of drinkable water near the soil surface (Table 1). After shallow digging in sand mixed with gravel we found at a depth between 40-60 cm enough drinkable water to have saved this group (Fig. 1). This tradgedy shows how important it is to educate people how to act should they find themselves without water in the desert.

3.2. A few years ago a man's car broke down approximately 10 km from a main road in the Judean desert on a very hot day (Chamsin). Two days later he was found in such a condition that he was unable to be saved. Instead of staying in the shade beneath or in his car and even drinking the water from his car radiator, he preferred to expose himself to the heat in the midday. It was easy enough to find the car and had he remained beneath or near his car, also to save him; but because he left the shade and water that were available to him in order to try and find his way out in the heat of the day, unfortunately it was not possible to find him so easily or to save him.

3.3. In another incident on the other hand in midsummer a few years ago, a young couple went into the Judean desert and the young man fell from a cliff to the ground and was killed. His girlfriend stayed near him, in the shadow of the cliff, for approximately two days. When she was found, she was not dehydrated, in spite of the very high temperatures and extremely dry conditions during this period. Even such simple behaviour as this, is one way of surviving in desert conditions without water (see also E. Zohar, Man and Climate, Israel, 1980).

3.4. Essential facts for survival in the desert

1) About 10% of body weight is a reservoir of water for emergencies but if more than 10% of water is lost, life is endangered.

2) If involved in extreme activity in desert conditions, approximately four litres of water is lost per hour.

3) If involved in minimum activity in shady conditions, approximately 2-2.5 litres are lost per 24 hours.

4) The desert which is dry and hot during the day, is cool with high humidity during the night.

5) The coolest and most favourable time for activity is in the early morning before the sun rises.

6) According to the vegetation there are ways to find drinkable water near the seashore, in wadis, or in ancient cisterns.

7) There are methods of collecting drinkable water from shrubs, from wet soil, distilled saline water or from dew.

8) Edible plants and snails are also a possible source of water and food.

4. Ways of finding water in the desert.

4.1. Plants as indicators of drinkable water near the soil surface on the seashore.

Along the Negev and Sinai Peninsula seashores, especially facing the wadis, subterranean streams of drinkable water were found on their way to the sea. This water is relatively lighter than the seawater therefore near the shore it moves above the saline water and is close to the soil's surface. This water is indicated by particular plants which make use of it (Table 1) and it is not difficult to dig in the sand and gravel found here. In many cases the depth of the drinkable water table in these places is 20-60 cm beneath the soil's surface (Fig. 1).

4.2. Traces of plants as indicators of drinkable water in wadis

In the wadis, several species of plants grow in wet soil, water springs, cisterns and other visible sources throughout the whole year, with drinkable water just below the soil surface. In the large wadis, where, during the rainy season, floods pass through from time to time, parts of these plants (leaves, branches and roots) are mashed away and become attached to the branches of the trees and shrubs at various distances from the plants. It is easy to recognise them, by their leaves and stems in the upper reaches of the wadis , near springs and very often where they have established themselves at the foot of cliffs that become waterfalls during floods. Below these cliffs the water often remains in pools or below the soil's surface in gravel and sand. These are special habitats where drinkable water is indicated by these plants (Table 1).

Table 1: Plant as indicators of water quality. Adapted from: A. Danin, 1983.

WATER QUALITY	NAME OF PLANT	FAMILY NAME
Fresh water	TYPHA AUSTRALIS	TYPHACEAE
	CYPERUS DISTACHYUS	CYPERACEAE
	HOLOSCHOENUS AVULGARIS	CYPERACEAE
	MENTHA SPP.	LABIATAE
	SACCHARUM RAVENNAE	GRAMINEAE
	GREEN ALGAE	
	SALIX SPP.	SALICACEAE
Fresh to slightly saline water	POLYPOGON MONSPELIENSIS	GRAMINEAE
	PHOENIX DACTYLIFERA	PALMAE
	POPULUS EUPHRATICA	SALICACEAE
	PHRAGMITES AUSTRALIS	GRAMINEAE
	ARUNDO DONAX	GRAMINEAE
Fresh to saline water	JUNCUS ARABICUS	JUNCACEAE
	IMPERATA CYCLINDRICA	GRAMINEAE
	ALHAGI MAURORUM	PAPILIONACEAE
	TAMARIX SPP.	TAMARICACEAE
	NITRARIA RETUSA	ZYGOPHYLLACEAE
Saline water	TETRADYCLIS TENELLA	ZYGOPHYLLACEAE
	ZYGOPHYLLUM ALBUM	ZYGOPHYLLACEAE
	ARTHROCNEMUM MACROSTACHYUM	CHENOPODIACEAE
	ZYGOPHLLUM SIMPLEX	ZYGOPHYLLACEAE
	SPHENOPUS DIVARICATUS	GRAMINEAE
	SUAEDA MONOICA	CHENOPODIACEAE
	HALOCNEMUM STROBILACEUM	CHENOPODIACEAE

4.3. Shallow rocky reservoirs and ancient cisterns - How to recognise them?

In wadis, especially between rocky slopes, often heavy rain fills depressions in the rocks with water. Sometimes these depressions become filled with gravel which prevents most of the evaporation, thereby forming a natural reservoir which retains the water for a long time. These natural reservoirs are easily recognisable by the state of the plant species surrounding them such as, Typha australis, Phragmites australis, Juncus arabicus, Tamarix spp., Phoenix dactylifera, Populus euphratica and others (Table 1).

Along the ancient routes in the desert, and especially near the ancient cities, cisterns can often be found which were the water retainers for long gone civilizations. Sometimes, more than 100 m^3 of water can be found in these cisterns, which are easily recognizable from a distance because of the contrast of the white limestone extracted from the cisterns when it was created, against the surrounding dark brown patina. These cisterns are also easy to detect because of the canals which brought the water to them. Sometimes a Tamarix tree, which one can see from a great distance, grows from the cistern, and is another indication of its existence as are other plants such as Typha australis, Phragmites australis and Juncus arabicus (see Table 1). There are at least two principal methods of collecting water in cisterns: one is the accumulation of runoff water on the upper third of the hills from the north and west. Most of the storms in the Negev highlands come from these directions, therefore cisterns are located in the north west direction of hills in this area. In the second type of cisterns the water was channeled from flooded wadis during the rainy season. The different systems of cisterns found in the Negev are summarized in the book "The Negev" by Evenari, Shanan and Tadmoor, 1982.

5. Water transpiration of plants, and evaporation from the soil - Methods of collection.

5.1. Water transpiration in plants - Collection using plastic bags.

The stomata which are located on the leaves' surface or along the green stems are open during daylight to absorb CO_2. In this process water is lost. This transpiration has a cooling effect and prevents overheating of the leaves. If the leaves and branches of a plant are enclosed in a clear plastic bag the water which is released from the stomata accumulates in drops as a result of condensation on the sides of the bag. These drops slide along the side of the bag and accumulate at the bottom (Fig. 2). There are particular species of plants which inhabit wadis and have deep root systems which penetrate to acquifers below the surface of the wadis, or in sandy areas where these species also penetrate deep into the soil to a depth where water can be found throughout the year. These species have access to a plentiful supply of water and are therefore able to lose some of it.

The amount of water that can be collected in this manner differs, and depends on both the temperatures and air humidity and the sources of water that are available to the plant. On a hot, dry day it is possible to obtain approximately three quarters of a litre from a big shrub during the day, in comparison to approximately one tenth of a litre (100 cc) on a cool and cloudy day. This also depends on the direction of the branch. If the enclosed branches are on the southern side of the plant, usually more water is obtained than from any of the other sides. The more branches that are enclosed, the higher the collection of water (Fig. 2). It is interesting to note that there are differences in the yield of water which accumulates from the different directions from summer to winter, depending on the condition of the plant and the environment (see Tables and Figs. in chapter D). It is understood that this method of water collection should not be tried on plants that secrete salts from their leaves and stems and of course not on poisonous plants (Table 2).

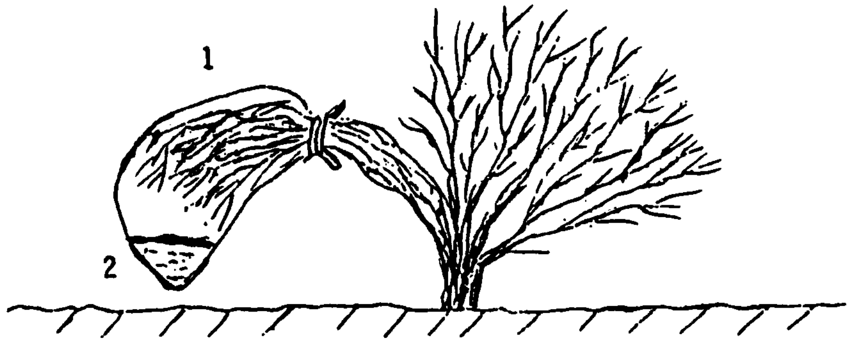


Fig. 2 Plants such as Retama raetam are covered with a transparent sheet of PVC or a clear plastic bag (1) which accumulates the evapo-transpirated water in the lower part (2).

5.2. Distilling of subterranean water or water from succulents using solar energy in a depression completely sealed by a transparent PVC sheet.

Whenever it is not possible to find suitable plants for the collection of water using plastic bags, it is possible to collect water in another way. The system that is most suitable is to dig a depression of approximately 40 x 80 cm along the seashore in the wet sand and completely seal it with a transparent and hydrophyllic PVC sheet, and to use solar energy to distill the salty water in the depression. At the centre of the depression a can is placed for water collection, and above on the PVC sheet a stone or weight is placed to raise the lower part of the sheet above the can. Water that evaporates from the soil or salty water which was placed on another sheet of PVC at the bottom of the digging, accumulates in drops on the inner sides of the sheet and drips towards the lower centre of the sheet into the receiving can. This happens because the inner side of the digging is hotter than the air outside which causes vapours to accumulae on the PVC sheet cooled from the air outside (Fig.3).

Table 2: Poisonous plants which inhabit deserts of Israel and the vicinity.
Adapted from: Waisel et al. 1977.

LATIN NAME OF PLANT	FAMILY	POISON
URGINEA UNDULATA	LILIACEAE	Oxalic acid
URGINEA MARITIMA	LILIACEAE	Oxalic acid
COLCHICUM RITCHII	LILIACEAE	Colchicine
COLCHICUM TUNICATUM	LILIACEAE	Colchicine
HYOSCYAMUS SPP.	SOLANACEAE	Hyoscyamine, Scopolomine
NERIUM OLEANDER L.	APOCYNACEAE	Oleandrin
DATURA SPP.	SOLANACEAE	Hyoscyamine, tropane scopolamine
WITHANIA SOMNIFERA (L.)	SOLANACEAE	Pyrazole, pyridine pyrrolidine
NICOTIANA SPP.	SOLANACEAE	Nicotine, anabasine nornicotine
ARUM PALAESTINUM BOISS.	ARACEAE	Aroin
SOLANUM SPP.	SOLANACEAE	Atropine, tropane pyrrolidine
URTICA SPP.	URTICACEAE	Allergens
PAPAVER SOMNIFERUM	PAPAVERACEAE	Morphine
CALOTROPIS PROCERA	ASCLEPIADACEAE	Calotropine
RICINUS COMMUNIS L.	EUPHORBIACEAE	Ricine
AMYGDALUS SPP.	ROSACEAE	Amygdaline

3). The exposure of the water's surface increases the evaporation and the yield of distilled water will increase in comparison to the amount of water when the soil at the bottom of the digging was wetted. If the PVC is hydrophobic, the drops will fall down before they reach the lower part of the plastic conus and they will not reach the can which collects the water (Fig. 4). It is possible to collect approximately one cup of water a day in this way.

This system can be used not only near the seashore, but also in salinities in the desert where the soil is very wet.

It is not possible to collect water from dry soil. In a dry area, this method can be employed by replacing the water around the can in the depression with succulent plants. If the cuticular layers in these plants are damaged, the resulting water which is easily lost is collected in the can. Approximately 10% of the total weight of the salty water or the plants placed in the depression is collected. For example from 2.5 kg. of plants approximately quarter of a litre of water can be collected (Fig. 3).

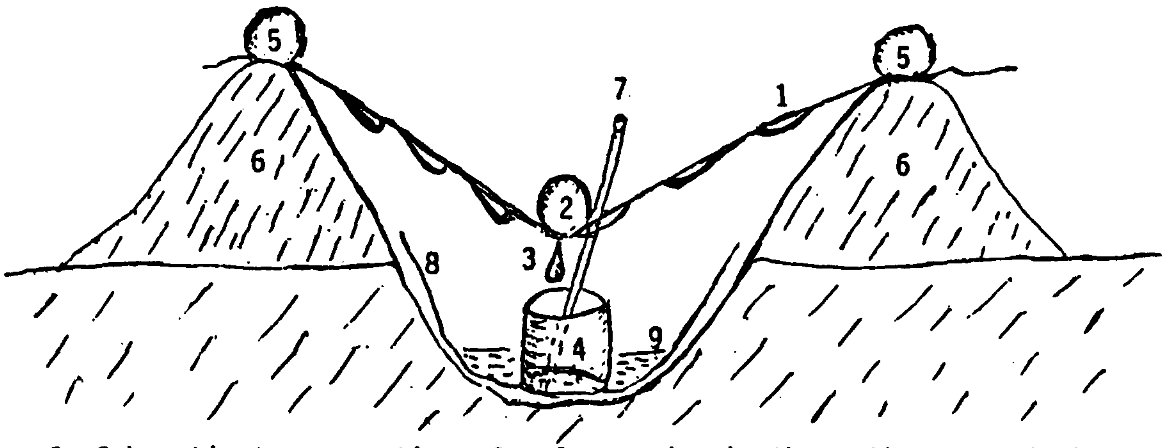


Fig. 3 Schematic trans-section of a furrow dug in the soil, covered with a transparent PVC sheet (1), with a stone in the center making a cone shape (2). The drops, which accumulate on the underside of the PVC sheet move to the lowest point of the sheet (3) and drip into the container in the center of the furrow (4). The plastic sheet is held and sealed by stones and soil placed around the furrow (5), using the soil that was dug out of the furrow to raise the outer edge (6), thus increasing the depth of the furrow. A straw is pushed through the PVC sheet (7) to such the water from the container without disturbing the continuation of the process. Another PVC sheet covers the furrow bottom (8) and salt water placed on this sheet (9) is distilled by the solar energy.

It is very important to note that only hydrophylic clear plastic is suitable for this method. With hydrophobic plastic, the water will drop before reaching the can, and be lost (Fig. 4).

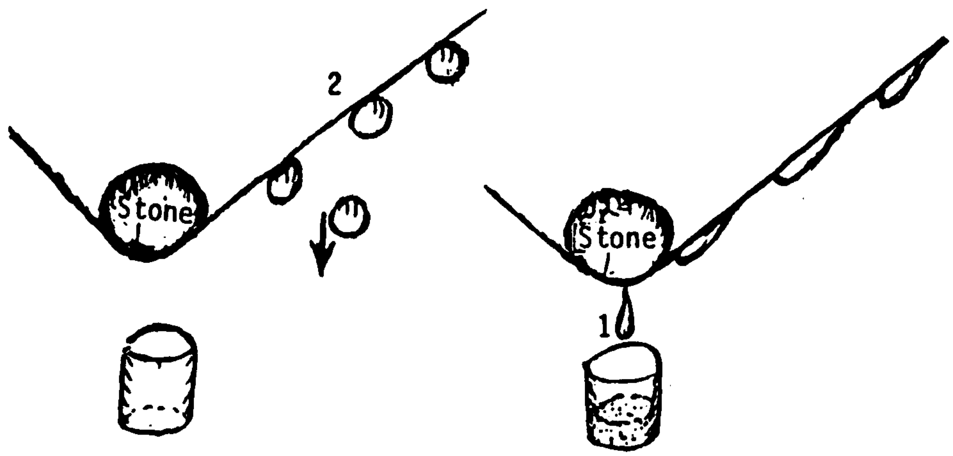


Fig. 4 A drop of water accumulates on the underside of the hydrophyllic PVC sheet and it drops only at the lowest point into the collection container (1). If the PVC is oily (hydrophobic) the drops do not reach the container and fall along the way.

6. Distilling boiling saline water in empty cans and collecting the resulting vapor.

Another possible way in which to distil saline water, from sea water or a spring is to boil this water in one can, collect the resulting vapour in a second can, and the distilled water in a third can (Fig. 5). This method is employed by closing the top of the can containing the boiling water so that the vapour only escapes from a small funnel over which one side of the second and largest can is placed, open side down at such an angle that the vapour condensing into water, drops on the opposite and coolest side of this second can into the third collecting can. A cloth dipped in saline water and placed over the can could be used to keep the second can cool . In this way it is possible to collect approximately quarter of a litre in one hour (Fig. 5).

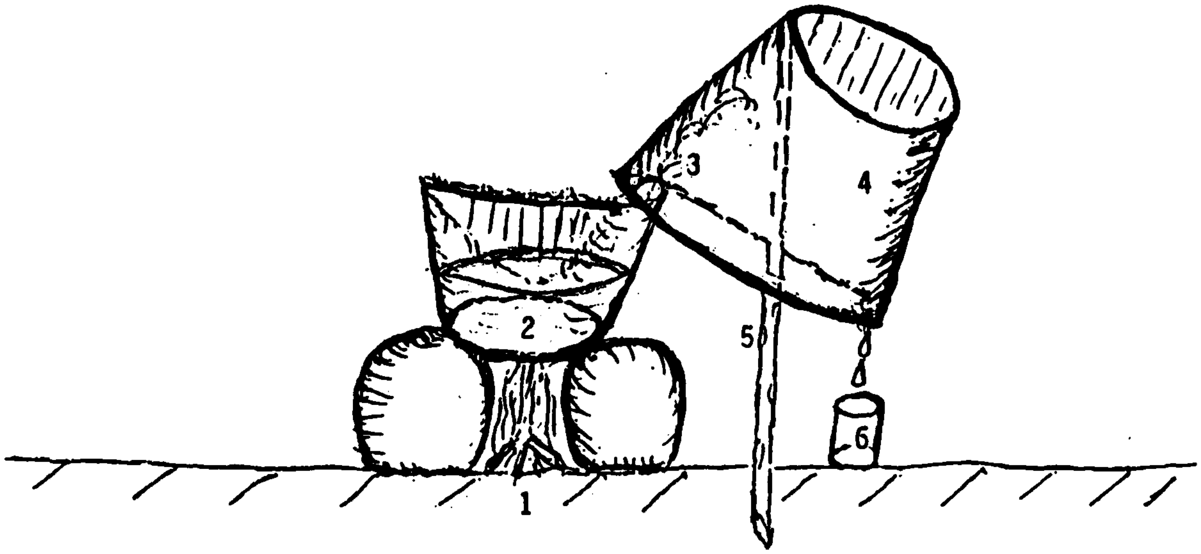


Fig. 5 Between 2 stones a fire is made (1). On the fire an empty tin can is filled with saline water (2) is placed and bent in such a way that the vapors will exit from only one place (3) into a larger empty can (4) which is held upside down by a stick (5) above the first can. The water that vaporizes drops into a third can (6) where it is collected.

7. Breathing through wet cloth in order to inhale moist air.

There is a very easy way to use undrinkable water to prevent dehydration of the body by transpiration. One can breathe through cloth wetted with undrinkable water. Under extreme desert conditions, when it is hot and dry the body loses a lot of water by inhaling hot and dry air and exhaling air with relatively high humidity from the lungs. By breathing in wet air we prevent this loss of water. In this way one can save about 1-1.5 litres of water stored in the body in a day.

8. Ways of collecting dew.

The hot and dry desert during the day is cool and wet at night, and according to data collected in Avdat over the last 20 years, it was found that in this area, there is an average of 200 nights of dew per year. In other words, an average of 2 nights of dew in every 3 nights. The total amount of dew is equivalent to approximately 30 mm of rain per year. In an area where the annual average of rain is 90 mm, an additional amount of 30 mm of water per year is a significant additional amount of water (Evenari et al. 1982).

The nights of dew are mainly from September to December during which dew equivalent to about 4 mm of rain falls per month. The amount of dew and number of nights of dew, depend on the distance fom the Mediterranean Sea. In the Arava valley nights of dew are very rare. Near the Mediterranean Sea there are a greater number of nights of dew and more dew than in the central Negev. On cloudy or strong windy nights, dew does not accumulate and the amount of dew that accumulates also depends on the substratum. The substratum which irradiates heat from itself at night and is elevated from the heat radiated from the ground, e.g. the metal roof of a vehicle, accumulates more dew on its top surface than its sides, which are exposed to the heat from the ground.

It is also possible to collect dew at night using nylon or PVC sheets over a depression in the ground (as in Fig.3). The lower surface must be isolated from the ground radiation in order to achieve a maximum cooling effect on the top surface of the sheet. This is done by filling the depression with dry plants thus protecting the lower surface from the ground radiation. Under optimum conditions, theoretically 1 litre per one m^2 can be collected on a night of heavy dew. Thus, so far, in our preliminary experiments we succeeded in collecting a maximum of only one third of this theoretical amount (300 ml per m^2 on a night of heavy dew). A substratum that has a lower irradiation and has a less efficient isolation from the ground radiation will also have a lower accumulation of dew.

9. Edible plants and animals as a source of water

9.1. Some desert plants with edible leaves or subterranean bulbs containing a higher percentage of water.

Edible plants in the desert as a source of water are relatively easy to find during winter and more difficult to find during summer. The majority of the edible plants are winter annuals, which appear only during the short rainy season between winter and spring. During summer, the leaves of the edible perennials, e.g. *Moricandia nitens* are less tasty, and often bitter. Subterranean bulbs which are found at a certain depth in the soil throughout the year and which contain approximately 90% water, are also easier to find during winter when the plants are in leaf and flower. During summer, often the only indication of these bulbs below the surface are a few dry remnants of the plants above the soil. On the other hand it is very dangerous to eat, indiscriminately, any plants in the desert without foreknowledge, because many plants are poisonous and even those that are non-poisonous can cause digestive problems thereby creating a loss of body fluids. Care must therefore be taken in consuming even those plants which are non-poisonous. A list of edible plants and their limitations are given in Table 3 and in Table 2 there is a list of poisonous plants (see Tables 2 and 3).

9.2. Desert animals as a source of water and food.

There are desert snails containing about 90% of water, which may in several years exist in very great numbers in certain areas.

(1) The most common and largest snails are the *Troichodea seetzenii* which climb on shrubs in wadis or flat areas.

(2) The *Sphinctorochila zonata* which are big, wide snails stay on the soil's surface.

Table 3: Summarizes the names of edible desert plants that are common in the Negev; the time of the year during which they are edible and juicy; the edible parts of the plant and its limitations. Adapted from: Zohary, M. and N. Feinbrun, 1930 and A. Danin, 1983.

PLANT SPECIES	FAMILY	EDIBLE PART	SEASON	LIMITATIONS
ERUCARIA BOVEANA	CRUCIFERAE	Young leaves	Winter, spring	-
REBOUDIA PINNATA	CRUCIFERAE	Young leaves	Winter, spring	-
DIPLOTAXIS HARRA	CRUCIFERAE	Leaves	Winter, spring	-
DIPLOTAXIS ACRIS	CRUCIFERAE	Leaves	Winter, spring	Cooked
MORICANDIA NITENS	CRUCIFERAE	Leaves	Winter, spring and beginning of summer.	*Oxalic acid, better cooked.
RUMEX CYPRIUS	POLYGONACEAE	Leaves	Winter, spring	*Oxalic acid, better cooked.
RUMEX VESICARIUM	POLYGONACEAE	Leaves	Winter, spring	*Oxalic acid, better cooked.
EMEX SPINOSA	POLYGONACEAE	Leaves, Juicy roots	Winter, spring	-
PORTULACA OLERACEA	POTULACACEAE	Leaves	Summer, in moist or watered places.	-
ERODIUM HIRTUM	GERANIACEAE	Tubers	All the year round	Light ones are tasty and juicy
ATRIPLEX HALIMUS	CHENOPODIACEAE	Leaves	All the year roun	*Oxalic acid, salt, better cooked
ATRIPLEX LEOCOCLADA	CHENOPODIACEAE	Leaves	All the year round	*Oxalic acid, salt, better cooked
MALVA AEGYPTIA	MALVACEAE	Leaves	Winter, spring	*Oxalic acid, salt, better cooked
MALVA PARVIFLORA	MALVACEAE	Leaves	Winter, spring	*Oxalic acid, salt, better cooked
MALVA SYLVESTRIS	MALVACEAE	Leaves	Winter, spring	*Oxalic acid, salt, better cooked
ERYNGIUM CRETICUM	UMBELLIFERAE	Leaves	Winter, spring	*Preferrably cooked
ERYNGIUM CRETICUM	UMBELLIFERAE	Fresh roots	Winter, spring	-
GUNDELIA TOURNEFORTII	COMPOSITAE	Flower buds	Spring	*Cooked
GUNDELIA TOURNEFORTII	COMPOSITAE	Root's neck	Winter, spring	-
GUNDELIA TOURNEFORTII	COMPOSITAE	Central vein of leaf	Winter, spring	_
SCORZONERA PAPPOSA	COMPOSITAE	Leaves	Winter, spring	-
SCORZONERA PAPPOSA	COMPOSITAE	Flower buds	Spring	-
SCORZONERA PAPPOSA	COMPOSITAE	Roots	All the year round	-

PLANT SPECIES	FAMILY	EDIBLE PART	SEASON	LIMITATIONS
SCORZONERA PSEUDOLANATA	COMPOSITAE	Roots	All the year round	Better grilled on coals
CENTAUREA HYALOLEPIS	COMPOSITAE	Leaves	Summer	*Cooked
CENTAURA IBERICA	COMPOSITAE	Leaves	Summer	*Cooked
NOTOBASIS SYRIACA	COMPOSITAE	Young stems	Spring	-
NOTOBASIS SYRIACA	COMPOSITAE	Central vein of leaf	Spring	-
TULIPA MONTANA	LILIACEAE	Bulbs	All the year round	Protected plant

*It is necessary to change the water from time to time and only to eat small quantities of uncooked plants containing oxalic acid.

(3) S. prothetarum which are the smallest of the three and hide underneath stones.

During some years one can very easily collect kilograms of these desert snails within a short time. It is also possible to hunt birds and other desert animals for this purpose.

In an emergency lack of water there are three main considerations.

(1) What is the proper behaviour to prevent quick loss of water from the body (when to move and when to remain in the shade)?

(2) How to minimise the loss of water (breathing air with high humidity through wet cloth)?

(3) According to the area one needs to calculate the best possible way to find or collect water.

10. Conclusions of the Introduction

As we have already seen there are many ways to get drinkable water under desert conditions in different deserts, areas and habitats. It is possible to use one or more method to obtain water depending on the environmental conditions and vegetation in each particular habitat.

It was mentioned above that there are ways of finding water in the desert using plants or parts of plants as indicators of water in a specific locality in the vicinity. There are also means of collecting water evaporation from the soil or distilled saline water by either solar energy or fire.

B. THE AIMS OF THIS STUDY

The aim of this study was to observe and to find out in different seasons the best way to get the greatest yield of water transpiration from plants and to find the easiest way to help the soldier and other persons stranded in the desert to choose the right plant and method in order to get the maximum yield of water, with a limited number of transparent PVC bags. We used two methods. The first was collecting water transpiration from branches trapped in a plastic bag. The second method was by absorbing the relative air humidity that passed along the branches by $CaCl_2$.

C. MATERIALS AND METHODS

1. Characteristics of Plants Suitable for Collecting Transpiratory Water and their Habitats.

One method of collecting water in the desert is to collect transpiratory water from plants. In some areas in certain seasons this is an important way of obtaining water. Transparent PVC bags are needed and the right plant species in the correct locality must be covered. In a group of plants it is necessary to choose the plant which will give the highest yield of water. In a preliminary set of experiments it was found that even the direction of the branches which were covered on a single shrub influenced the amount of transpiratory water that was collected. It seems that the effect of the direction of the branch on the yield of water changes with environmental conditions, so that the direction most suitable for collecting water varies in different seasons.

For this study we chose 2 plant species Retama raetam and Phragmites australis, which have the following characteristics:

1. They inhabit different desert habitats and are relatively easy to find in fairly large numbers.

2. They are not poisonous.

3. They do not secrete salts from inside their leaves (otherwise the water collected will be salt water instead of distilled water).

4. They have both a deep and a shallow roots system and if they only have a shallow roots system they stay in a habitat where water is available in the soil throughout the year.

5. They do not have deciduous leaves which will fall into the water and damage its quality.

Tests for water quality which were carried out on samples of water transpiration which were collected from Retama raetam branches and Phragmites australis leaves (Table 4), showed that the quality of the water is much higher than that of tap water in Israel. It was expected that the samples of water would be of the quality of distilled water but the chemicals that were found in this water could have been from the dust that stayed on the branches and leaves when the plant was covered with the plastic bag.

The most important plant which fulfills these criterion is Retama raetam (Papilionaceae), a shrub which may, in certain conditions reach a height of 4-5 cm.

Table 4: Chemical analysis of water transpiration collected on 20.1.1984 from Retama and Phragmites plants from near Sede Boqer.

CHEMICAL COMPONENT	RETAMA		PHRAGMITES Sample 1		PHRAGMITES Sample 2	
	A	B	A	B	A	B
HCO_3	92.037	1.509	-	-	-	-
CO_3	0.0	0.0	-	-	-	-
SO_4	22.677	0.472	-	-	-	-
Cl	11.644	0.328	29.110	0.820	24.850	0.700
Ca	34.800	1.737	17.600	0.880	9.600	0.480
Mg	2.675	0.220	4.864	0.400	2.918	0.240
Na	5.727	0.249	5.222	0.227	2.667	0.116
K	8.519	0.218	10.982	0.281	13.303	0.340
NO_3	2.550	0.041	-	-	-	-
pH	6.94		7.86		7.19	
EC (dsm)	0.200		0.165		0.126	

A = ppm (MG/L)
B = MEQ/L (Miliequivalent per litre)
EC (dsm) = Electrical conductivity

1.1. Retama raetam

1.1.1. Plant Habitats Typical of the Region

This is one of the few plants in Israel and the vicinity which is capable of inhabiting completely different habitats:

a.1.) Along the Mediterranean seashore, in the Mediterranean phytogeographic area where the plants occupy the zone of active dunes, this plant can survive in situations in which it is covered by sand, or when the plant and it's root system are exposed. Sometimes a sand dune of 2 or more metres will move through in a short time, yet the root system remains anchored and provides the plant canopy with water.

a.2.) Areas of stabilized sand dunes in which it is a dominant plant.

These two above mentioned habitats occupy large areas along the Mediterranean seashore, of the Negev and northern Sinai.

b) Inland sand areas in the Northern Negev and the Arava Valley, in which this plant is important to different plant communities of stabilized sand dunes.

c) Wadi beds in all the big wadis in the Jordan Valley, the Judean Desert, the Negev and Sinai, in which the plant uses it's root system for utilizing water from the depths of the wadi bed all the year round.

d) Soil pockets between rocky slopes on the east facing slopes of the Judean and Samarian deserts.

1.1.2. Characteristics of the habitats of Retama plants in the Negev highlands.

Wadi habitats in the Negev Highlands can be divided into a microscale of five different orders, each of which receives different amounts of water according to the distribution of precipitation and the number of floods/year in each of the five habitats. Order I is a small runnel which starts to develop on the hill slope. Two or more runnels develop order II which is deeper and accumulates more water. Order II becomes order III by the addition of more runnels of orders I and II.

In years of plentiful rain in which floods run through wadis of all orders, the most favourable habitat of the five orders is order IV as it is a wadi with a bed covered by loess which accumulates the most water. Orders I-IV are narrower, loess-covered wadis, while order V is wider and covered with gravel and stones. In years such as 1984, in which rainfall occurences were sparse and quantities were low, order I (and sometimes II) receive more water than either IV or V. However, V still has more water available to the plants, because in this order, the wadi bed is part of a wide wadi covered with gravel and the deep root system of the plants is able to reach tap water from the aquifer below which contains water accumulated from the previous year or even several years past. In a very good year, with a number of flood-quality rains, the amount of water available to the root systems in all wadi orders is much greater than in a year of lesser rainfall with little or no flooding.

1.1.3. Quality of Transpiratory Water and Plant Characteristics

Transpiratory water collected in a plastic bag covering the branches of the Retama are not harmful and people have not suffered from adverse effects after drinking this water (Table 4).

Retama raetam plants do not excrete salts.

They have two different root systems:

a) The deep root system which can penetrate to depths greater than 15 m in wadi beds, sand areas and other habitats to obtain water, as well as from underground aquifers at great depths. Therefore the plant does not need to depend only on the local precipitation but has access to more permanent, relatively rich, sources of water in the desert.

b) The shallow root system enables the plant to utilize even the very light precipitation in the area.

The plants do not shed their leaves. For only a short period of time in the year this plant has very tiny leaves and during most of the year, photosynthesis is carried out by the green branches which contain the stomata in depressions along the stems.

From the above-mentioned, we found that it is important to study and concentrate on *Retama raetam* for the purpose of collecting transpiratory water from plants under desert conditions.

1.2. Phragmites australis

The other plant species that is also suitable for this purpose is Phragmites australis (Gramineae) a common plant, from the tropics to the Aero Siberic region as well as in the desert, along rivers and in places where there is ground water close to the soil's surface (Table 1). From river banks of fresh water to saline soils, the seeds which were dispersed by wind were produced in large numbers and could easily reach a favourable habitat even though the distance between habitats may be great. This plant could be an indicator of water in the desert, from fresh to slightly saline water and sometimes even saline water in great gradients (Table 1).

This plant has very shallow wide root stocks, mainly parallel to the soil's surface. The root system is also shallow therefore this plant is an indicator of ground water near the soil's surface in the desert. Phragmites australis is also an important source for water transpiration. In cases of saline water or water that cannot be seperated from the soil; or that the plant is situated between rocks where it is impossible to dig, one can cover groups of branches with transparent PVC bags for water transpiration. The relatively high yield of water transpiration and the commonness of the plant makes it an important source of water transpiration (Table 4).

2. Experimental Materials and Methods

1) The first set of experiments started on 26/12/1983, 3 Retama raetam plants which grow naturally in a wadi (orders I-IV) near Sede Boqer were covered with transparent PVC bags, 60 x 50 cm. Temperatures were 2°C, 5°C during the night and 25°C, 30°C during the day. The resulting water yields from these three plants are summarized in Table 5.

2) In the second set of experiments, started on 13/2/1984, 6 plants naturally inhabiting wadis (orders I-IV) near Sede Boqer and 6 artificially irrigated plants (comparable to order V) within Sede Boqer campus, were covered as in the first

experiment (except with bags 120 x 80 cm), to compare the water yield between the groups. Temperatures measured in the PVC bags, were 0°C during the night (11°C, 14°C on a cloudy night) and 25°C-38°C during the day. After measuring the transpiratory water from the covered branches, the branches were cut and dried and the dry matter of the green parts of the branches was weighed, in order to calculate the yield of water (ml) per gram of dry matter of the branches. The results are summarized in Table 6.

3) In the third set of experiments, plants were covered with two layers of transparent PVC bags, with coloured cellophane paper between the layers , using blue, green, yellow, red and red + blue coloured cellophane and a control with uncoloured transparent cellophane. This preliminary study was to determine whether different wavelengths of light affect the stomatal openings and hence the water yield.

4) Water potential of the plants from experiments 1 and 2 was measured in two seasons using a pressure bomb by means of gas pressure passing into the xylem tissue. Measurements were carried out in the spring, at the end of February and at the beginning of March and in the summer on 9th July. At around noon, covered branches facing both south and north were measured with the pressure bomb, and results were compared. Comparisons were also made between branches from the past season and branches from a year ago, both with and without fruit, in both the south and north facing directions.

5) Anatomical Study. Samples of the branches measured with the pressure bomb were taken for anatomical study. Cross sections were cut to look for differences in the tissues from different branches, to connect the yield of water from a branch in a certain direction, to osmotic potential and anatomical characteristics.

6) Measurements of precipitation and distribution of rains were taken (Table 7).

7) Winter and summer water yield of Retama The results of a set of experiments

carried out during May 1984, on Retama raetam plants near Sede Boqer were compared with the results of experiments carried out in February on the same plant population in their natural environment. The results are calculated by the yield in mililitres per sample with biomasse of 500 g dry matter (Fig. 6). Minimum and maximum temperatures were measured in the PVC bags during the experiment as summarised in Fig. 7. The experiments lasted 4 days and each day the yield of water transpiration was measured as well as the temperatures.

8) Covered and uncovered PVC bags were used in a set of experiments, in order to study the role of overheating on the yield of water transpiration from Retama raetam per 500 g biomasse. Branches facing both north and south were covered with PVC bags, some of which were covered with white paper in order to shade the branches in the bag. Each number in Fig. 8 is a mean of 6 measurements which were taken in May 1984. The experiments lasted 4 days and each day the yield of water transpiration was measured.

9) Retama plants from the following 3 habitats near Sede Boqer were used to compare the yields of water transpiration.

a) A runnel on a hill slope, of order II, near the Zin valley.

b) A wadi, of order IV, in the Zin valley.

c) A wadi, of order V, in the Zin valley.

Branches were covered with covered and uncovered PVC bags, as mentioned above (Figs. 9, 10, 11 and 12). The daily maximum temperatures were measured as summarised in Fig. 13.

10) Water transpiration from Phragmites australis plants in the spring of Ein-Mur, of which the north and south facing branches were covered were measured. The yield from plants which grow in ground covered by a layer of water was compared with the yield from those plants which grow in wet soil (Fig. 14). The yield of water was from covered and uncovered plastic bags was also compared. The maximum daily temperatures in this experiment were measured and are summarised in Fig. 15.

11) The percentage of water content of leaves of Phragmites australis and Retama raetam branches were measured by drying out two samples of each plant in the oven for 48 hours at 75°C.

12 Water transpiration measurements of Retama raetam and Phragmites australis in an open system were taken, during June and July 1984, in the research area near Sede Boqer. Branches were placed in a transparent plastic pipe 8.5 cm in diameter and about 1 m in length. This pipe was connected to a ventilator which sucked the air from the pipe through 2 boxes of grained $CaCl_2$ which collects water from the air (water transpiration and air humidity). Parallel to this, another ventilator sucked the air from another pipe without branches, as a control. The difference between the amounts of water collected from the 2 pipes gives us the amount of water transpiration. All the measurements were made at noon. At the same time an experiment on the same plant with PVC bags was carried out, which enabled us to compare the 2 systems.

D. RESULTS AND DISCUSSION

1. The data from Experiment 1, which is summarized in Table 5, shows that there is a difference in water yield from branches from the same plants, oriented in different directions. During winter (Dec-Feb), the greatest amount of transpiratory water was collected from branches facing south - giving 37% of the total yield from the plant. In contrast, the branches facing north gave the lowest yield - only about 18% of the total. The western and eastern facing branches gave almost the same yields.

2. As can be seen in Table 6, the transpiratory water yield results of experiment 2 are the same as of experiment 1. In addition, the yield/500 g dry matter of green branches was also measured and these results are likewise summarized in Table 6. The average yield/500 g dry matter from branches facing south, from the 6 plants in their natural habitats, was 313.8 ml/500 g dry matter. The average from the branches

Table 5: Water collected from <u>Retama</u> <u>raetam</u> from branches facing south, north, west and east, covered with transparent PVC bags (60 x 50 cm). The experiment started on 26/12/83. The mean of evaporated water per bag per day are summarized from 3 different plants (1, 2 and 3) which naturally grow in a wadi near Sede Boqer.

* avg amount of water (ml) per day per bag

Direction / Plant #	South		North		West		East		Totals	
	total yield	avg*	total yield	avg*	total yield	avg*	total yield	avg*	total yield per plant	avg yield per plant
1	478.5	39.75	227.5	18.96	187	15.58	234	19.5	1127	939
2	724	60.3	312	26	543	45.25	312	26	1891	157.59
3	318.5	26.54	187	15.59	285	23.75	289	24.09	1079.5	89.96
avg/day		42.25		20.18		28.2		23.2		113.82
total yield	1521		7265		1015		835		4097.5	
% of total	37.12		17.73		24.77		20.38		100	

Table 6: Water collected from Retamaraetam from branches facing south, north, west and east, covered with transparent PVC bags (120 x 180 cm). The experiment started on 13/2/84. The mean of evaporated water per bag per day and the total yield of water during the 4 days, as well as the calculation of water yield per 500 g dry matter from green branches per day are summarized from 12 different plants, 6 each from: A - Natural habitat around Sede Boqer and B - artificially irrigated plants in Sede Boqer Campus.

	Direction	South		North		West		East		Totals	
	Plant #	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter	avg yield /day /bag	avg yield /day /500g dry matter
A	1	185	259	128.8	231	138	184.5	138.5	220	590.3	894.5
	2	129.7	277	68.3	130.5	122.8	229	89.7	227	410.6	863.5
	3	98.7	193	206.6	358.5	273.4	477	143.6	155.5	722.2	1184
	4	206.3	337.5	112	137	(bag leakage)*		148.9	155	(467.1)*	(629.5)*
	5	205.4	385.5	160.7	357	86	431.5	190	354	642.1	1528
	6	164.6	431	142	240	97.1	167	238	443	641.7	1281
	avg	164.9	313.8	136.4	242.3	(143.4)*	(297.8)*	158.1	259.1	(579)*	(1063.4)*
B	1	168	365	---	---	---	---	112	251	280	616
	2	154	289.5	---	---	---	---	180.1	315	334.1	604.5
	3	255	455.4	---	---	---	---	251	669.5	506	1125
	4	83	136	---	---	---	---	196	341.5	279	477.5
	5	120	327	---	---	---	---	120	276	240	603
	6	183	273	---	---	---	---	266	417	449	690
	avg	160.5	307.7	---	---	---	---	187.5	378.3	348	686

facing north from the same 6 plants was only 242 ml/500 g dry matter. The results from the west and east facing branches were 298 and 259 ml/500 g dry matter, respectively. Very similar results were found from the artificially irrigated plants in the campus, in which the south facing branches averaged 308 ml/500 g dry matter. However, the east facing branches gave a much higher yield than those in their natural habitat - 378 ml/500 g dry matter compared to only 259 ml/500 g dry matter. From these results it seems that there are environmental factors which influence the water yield even more than the direction of the branches of the shrub. This phenomenon was tested in a later sets of experiments.

3. From experiment 3, in which we measured the accumulation of water during the day compared to the night, we saw that during the dark period, when stomata are closed, there is no accumulation of transpiratory water. From the plants covered with plastic bags and different colours of cellophane paper, we found that red light gives the best results and far red light the worst results with blue, green and yellow light giving intermediate yields. From this experiment an interesting correlation was found between light that influences the opening of the stomata (red light) and the yield of transpiratory water. In far red conditions in which the light has a negative affect on the opening of the stomata the yield of transpiratory water was very low.

4. In experiment 4, the osmotic potential of branches with new growth from the winter and branches with fruit and flowers of plants from experiments 1 and 2 were measured, in spring. In addition, branches from south and north facing directions were compared. There was very little difference between branches with or without fruit and from different directions, from this year with branches from a year ago. All the measurements were in the range of -18 to -23 bars. Measurements from the artificially irrigated plants were also in the same range.

Another set of measurements which were taken in July showed results similar to those taken in the spring. There was no difference between branches facing north and south but the range of measurements was a little higher, -23 to -31 bars. From the results we can see that in July this plant did not suffer from a lack of water but a repetition of these measurements in August before the first rains of the winter, may show important results. In July, many plant species lack water but this is not so in the case of the Retama plant which has a very widespread root system as mentioned above.

5. The anatomical test of branches from the different directions and of branches of the past season as well as last year, showed no anatomical differences between branches of the same plant in different directions. From these results it seems that the anatomical structure has no connection with the different yield from the branches in different directions. In a shrub such as Retama with spread out branches, even the north facing branches are not in the shade and this could be the reason why there are no measurable anatomical differences between the branches in different directions.

Table 7: Distribution of rains during the rainy season, 1983/84; no. of days of rain and no. of floods

Month	No. of rainy days	Monthly total in mm	No. of floods produced
Dec	4	7.6	0
Jan	4	31.3	2
Feb	1	3.9	1
Mar	8	29.0	1
Total	17	71.8	4

---

6. The first experiment was carried out during December, when after the long, hot summer, 4 rainy days gave a total of only 7.6 mm of rain. The rainfall during the second experiment was much greater - 42.8 mm from 9 rainy days. However, only 3 of the rains produced 4-14 mm, resulting in only 3 small floods in the wadis. The total rainfall until the end of March was 71.8 mm, with 29 mm of this total falling during 8 rainy days in March (Table 7). These relatively late rains were less effective because of the relatively high temperatures and low air humidity.

As far as temperature is concerned, it seems that during winter, even if the maximum temperature (as was measured with a maximum thermometer), reached a level of 40°C, there was no drastic tissue damage; the high temperatures over a long period of time gave the highest yield from the branches facing south. The maximum temperatures in the plastic bags facing north, east and west, were nearly the same, but for a much shorter time. This could be the reason why the water yield from these branches was less than that from the south facing branches.

In experiment 3, in which coloured cellophane paper was placed between a double layer of transparent PVC bags, the maximum temperature reached more than 50°C owing to the insulation caused by a double layer of PVC and the tissue was damaged even after only a short time. This shows that to prevent overheating and subsequent damage to the plant it is important to use thin plastic bags to obtain water. On the other hand if the PVC bag will be too thin and weak, the slightest wind will damage it and therefore reduce the yield of water. We have seen that damaged branches do not transpire and therefore harmful, high temperatures which exist in the plastic bags, closed for a long time, will cause a decrease in the yield of water transpiration. In high temperatures, under experimental conditions (the covering of a plastic bag), there was a big increase in the yield of water transpiration on the second day but the damage that occurred caused a big decrease in the yield of water transpiration on the third and fourth days, as can be seen from the results of the experiments mentioned below.

From all the experiments and measurements detailed above, it seems that during the winter, the highest yield of transpiratory water, will be obtained from branches facing south, covered by a relatively thin plastic bag. There are no big differences between the habitats from wadi order I and wadi order V as was seen from the yield of water and the osmotic potential of the plants. This is due to the sophisticated root system of Retama raetam: the shallow one which utilizes water from even very light rainfalls; and the deep system, which can obtain water stored in the soil depths in the area, thus eliminating dependency on the rainfall in a particular area, during a particular season and year. The following sets of experiments compare the yield of water transpiration from the same plants during winter and summer. A further study was carried out to add information regarding the influence of the direction of the plastic bag and the plants' habitat on the yield of water transpiration.

7. The yield of water transpiration in winter and summer, were compared in a set of experiments which were carried out on the same plant population, in February and May 1984. From the results shown in Fig. 6, the yield of water transpiration for the first 2 days of the experiment was much higher in summer than in winter. The most pronounced effect was on the second day of the experiment. The water yield was much higher when the south facing branches of the shrub were covered in comparison with the north facing branches, this was true in both summer and in winter.

It is interesting to note that there was a big difference between winter and summer in the yield of water on the second and third days of the experiment. In summer there was a tremendous decrease in the yield on the third day compared with the yield of the second day. This phenomenon did not occur in winter when the yield on the third day was even slightly higher than that of the second day. In winter this did not happen. On the third day the yield was slightly higher than on the second day (Fig. 6). This phenomenon could be related to the maximum temperatures

Fig. 6: The average yield of water transpiration per day in mililitres as calculated from green branches which contain 500 g biomasse of dry matter (6 samples per treatment), from branches of <u>Retama</u> <u>raetam</u> plants from runnels on the hill slopes, covered with transparent PVC bags. The yield was compared: from south facing branches during summer (-o- SS) and winter (-o- SW) as well as from branches facing north during summer (-•- NS) and winter (-•- NW).

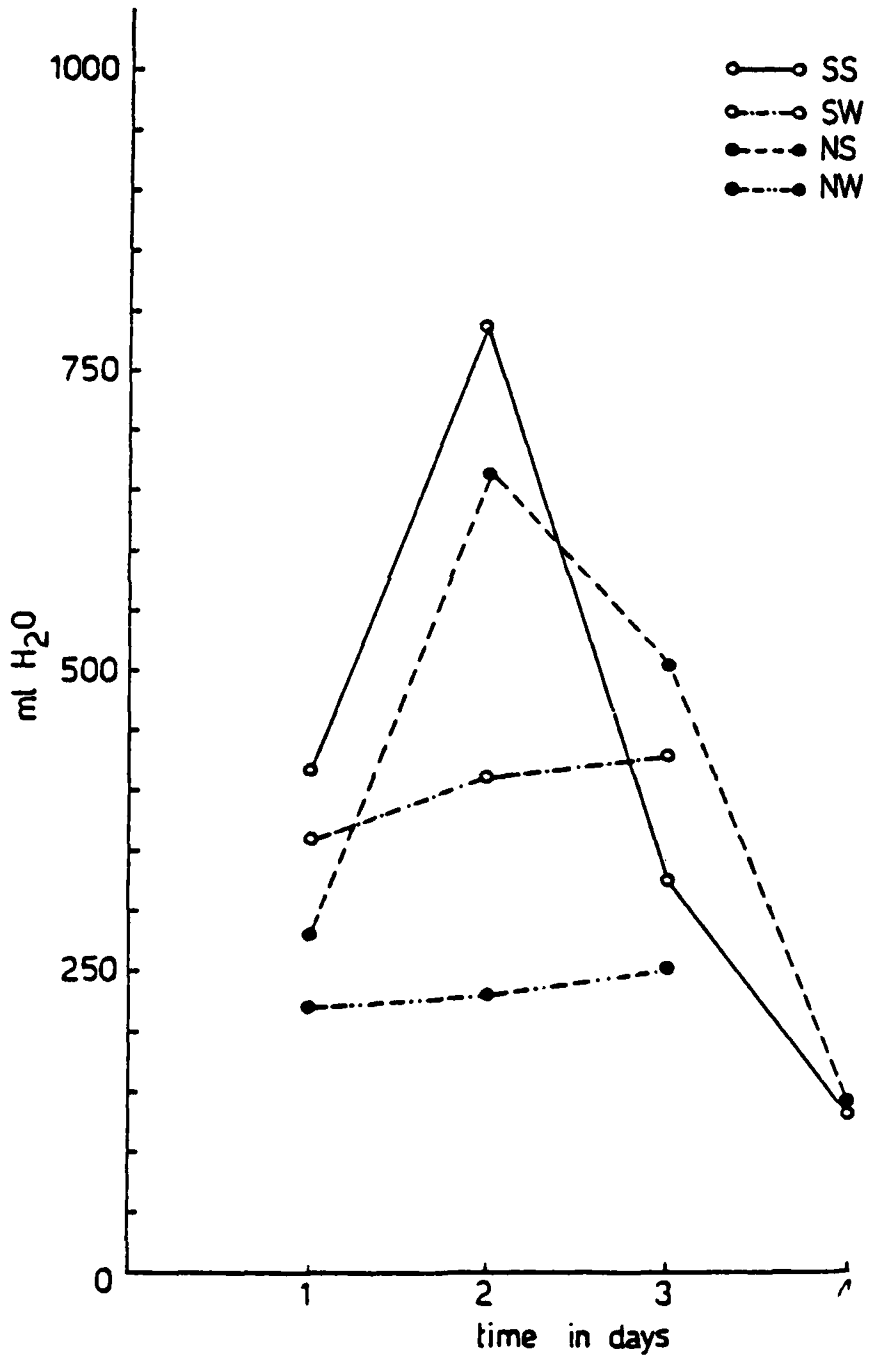


Fig. 7: Daily maxima and minima temperatures °C in the experiment mentioned in Fig. 6.

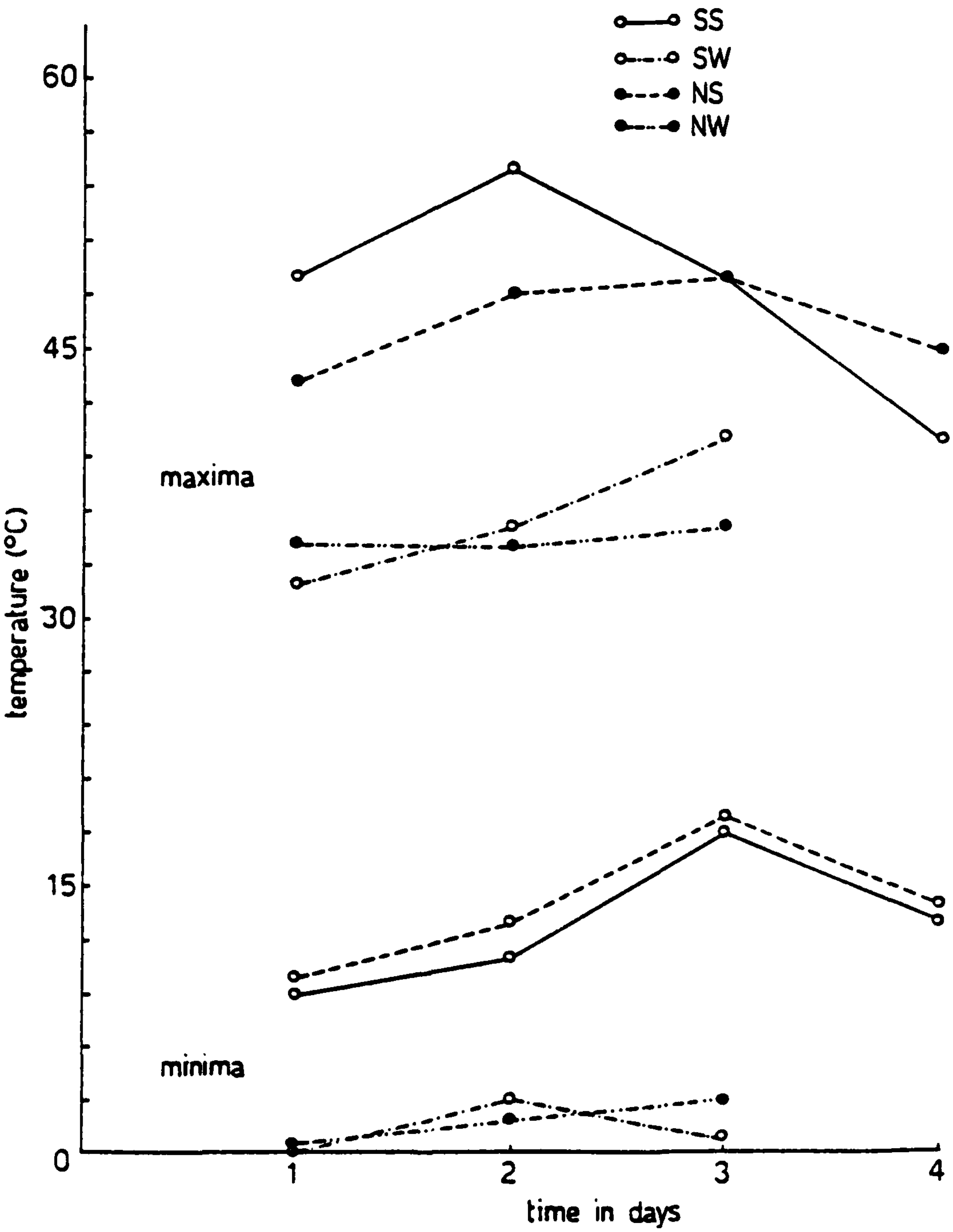


Fig. 8: The yield of water transpiration in mililitres per 500 g biomasse from branches of <u>Retama raetam</u> plants in uncovered (U) PVC bags was compared with the yield from bags covered with white paper (C), from south (-o- S) and north (-•- N) facing branches.

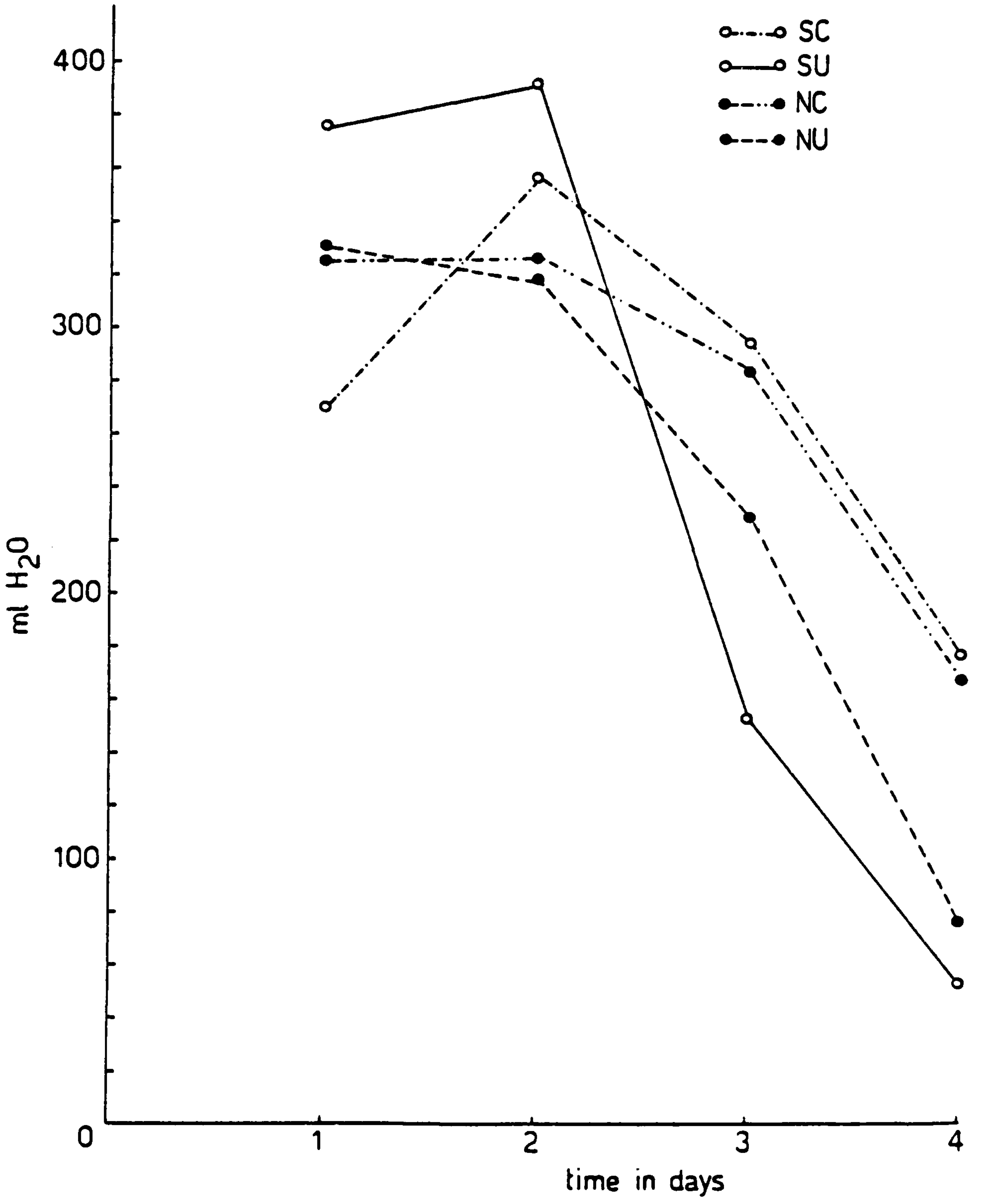


Fig. 9: The yield of water transpiration in mililitres from Retama raetam plants from 3 habitats was compared: (1) Runnel order II on the hill slopes and in the Zin valley: (2) Wadi order IV and (3) Wadi order V. The yield in uncovered plastic bags on north and south facing branches was also compared.

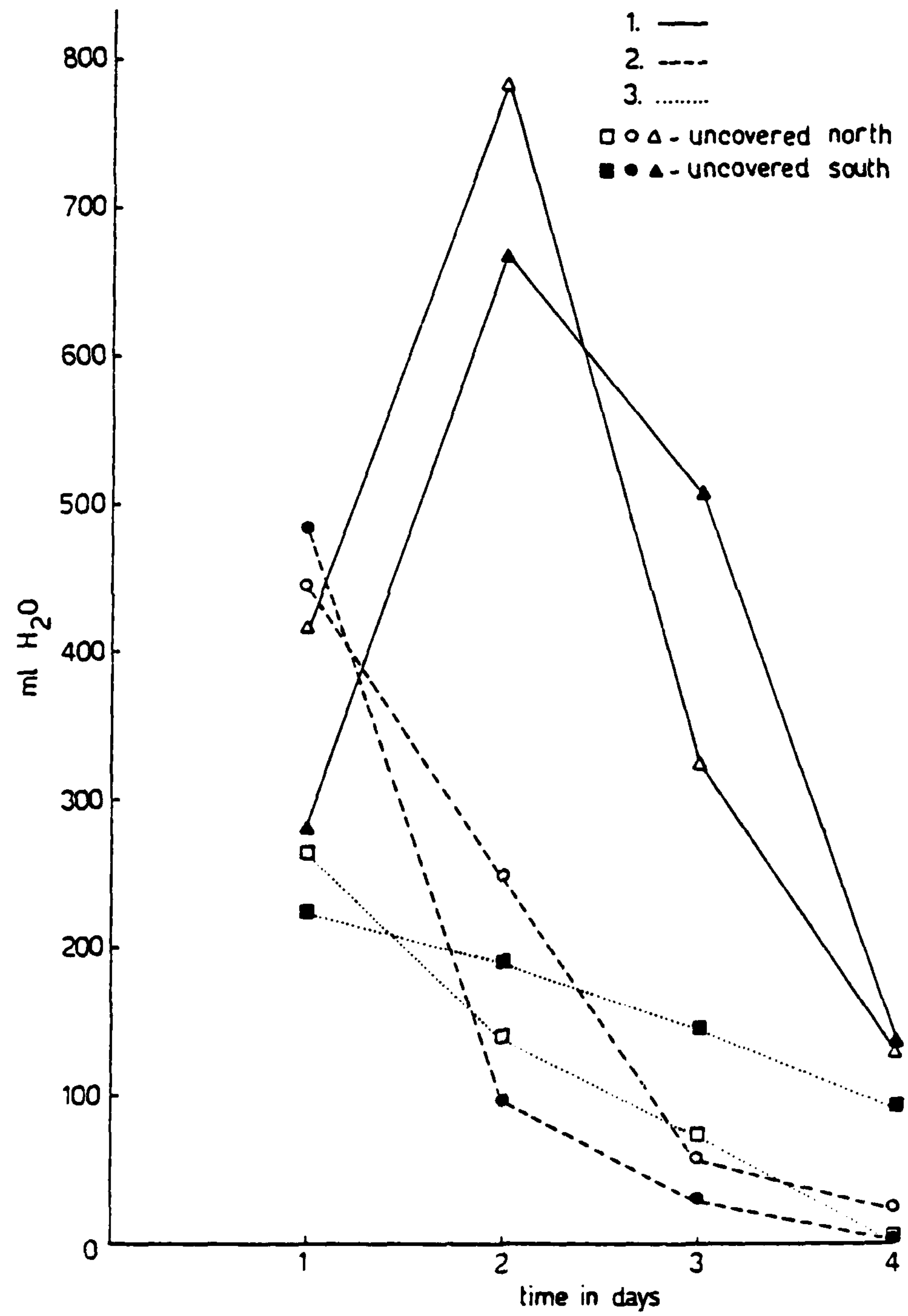


Fig. 10: As in Fig. 9 but PVC bags covered with white paper were used.

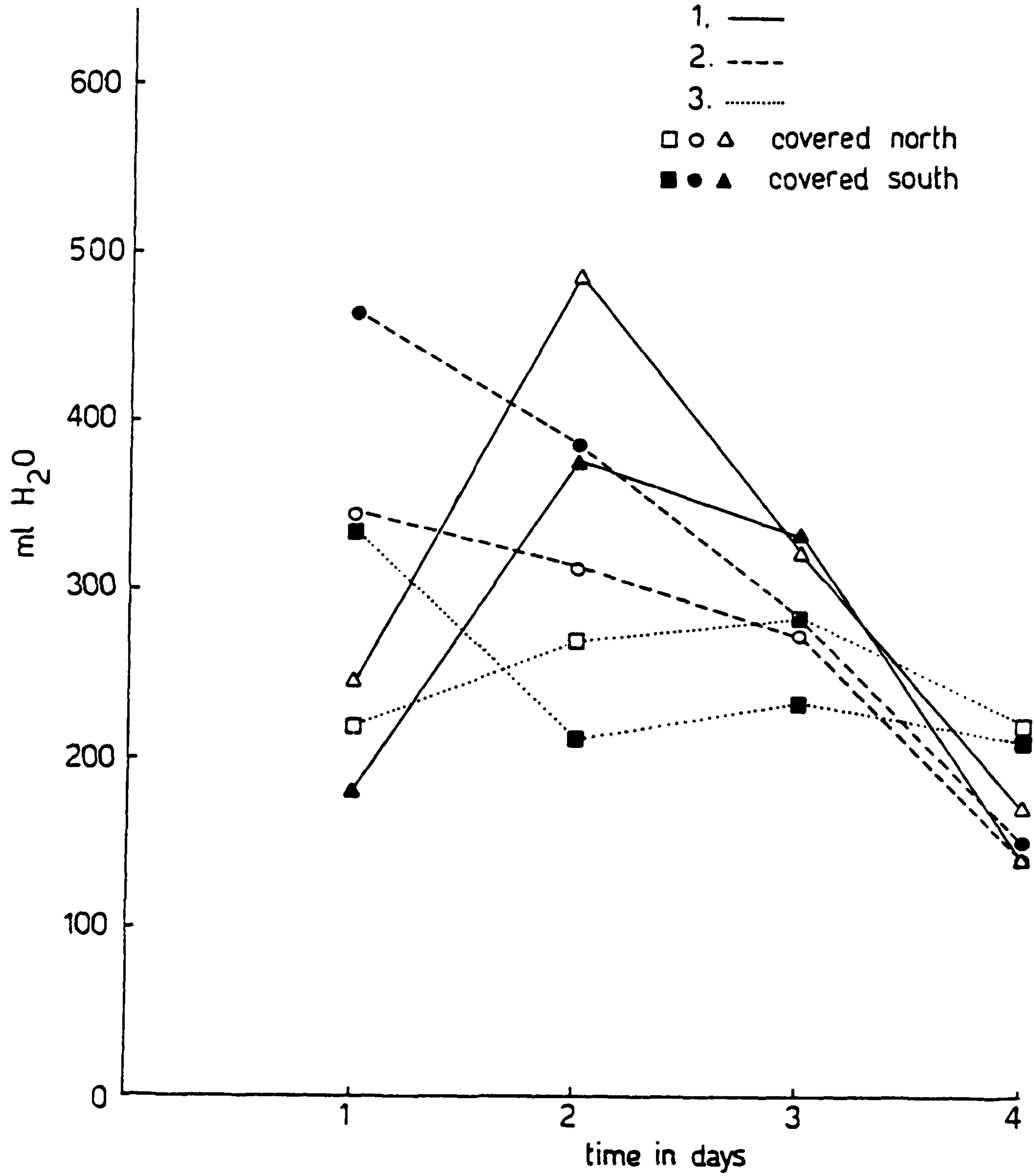


Fig. 11: The yield of water transpiration was compared from south facing branches in covered and uncovered PVC bags of plants from the 3 different habitats as mentioned in Fig. 9.

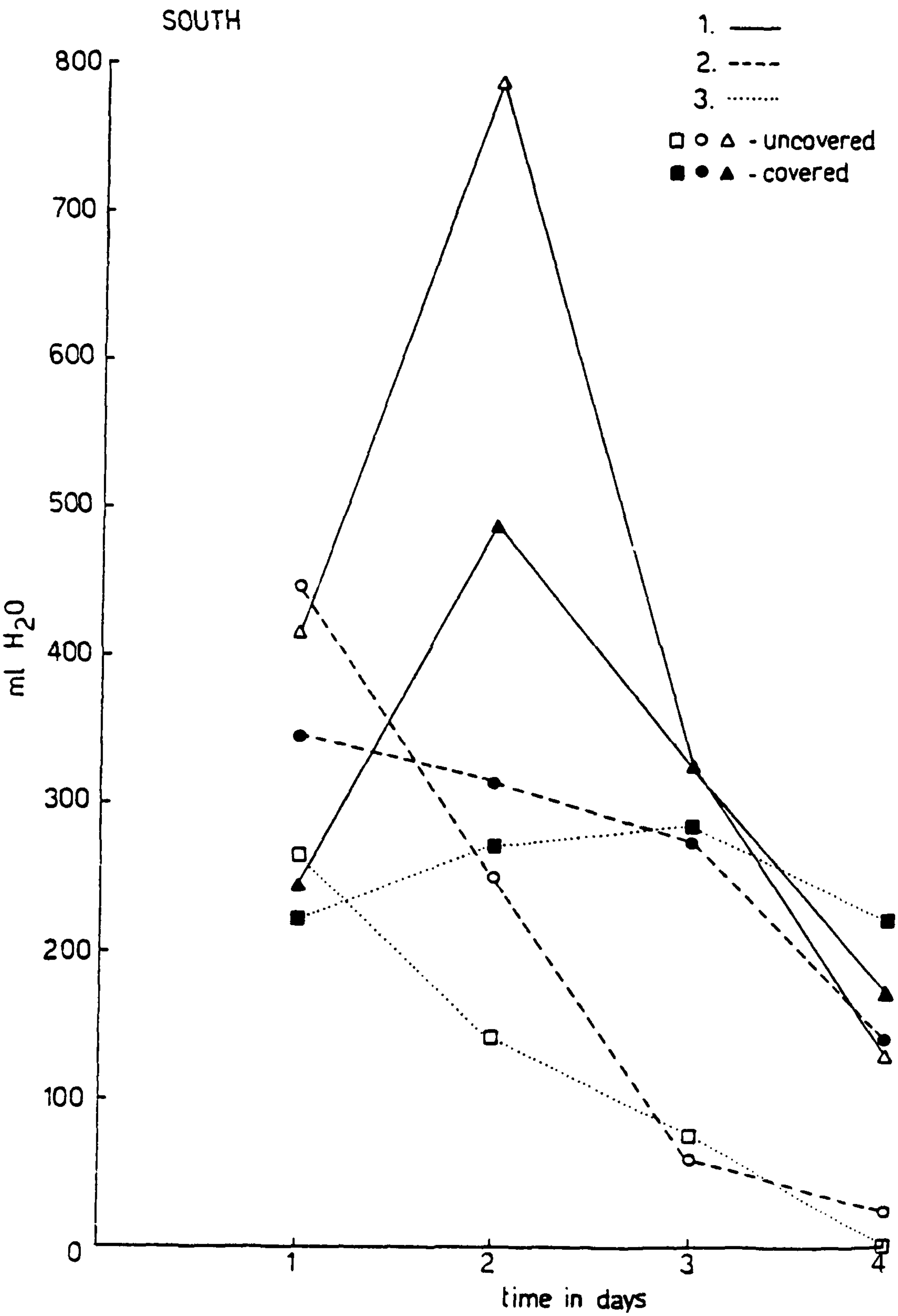


Fig. 12: As in Fig. 11 but from branches facing north.

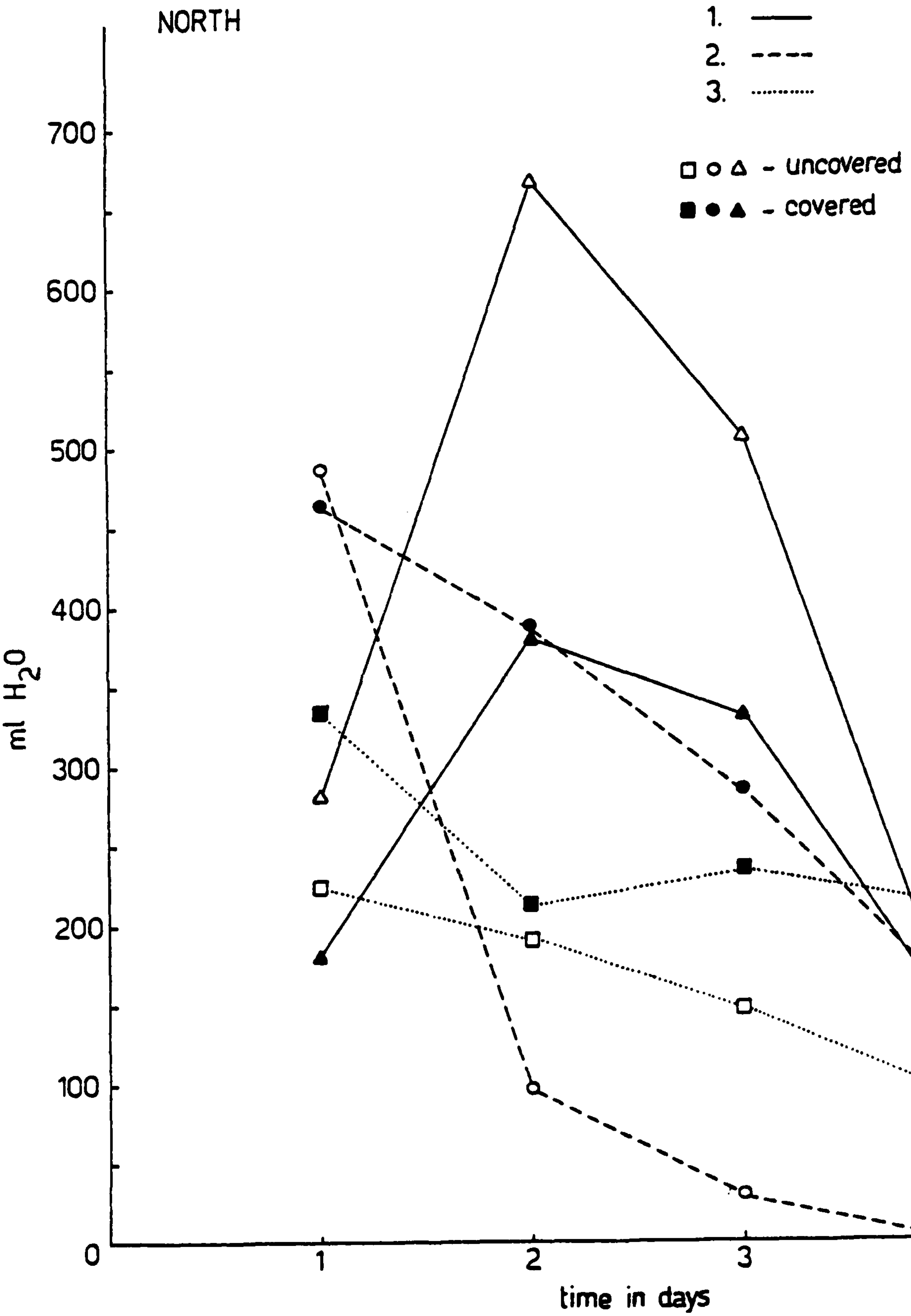


Fig. 13: Daily maximum temperatures in summer in uncovered (U) PVC bags and those bags covered with white paper (C). The bags covered <u>Retama raetam</u> plants from 2 habitats (I) Runnel order II and (II) Main wadi order V, from branches facing north (▲△) and south (● o).

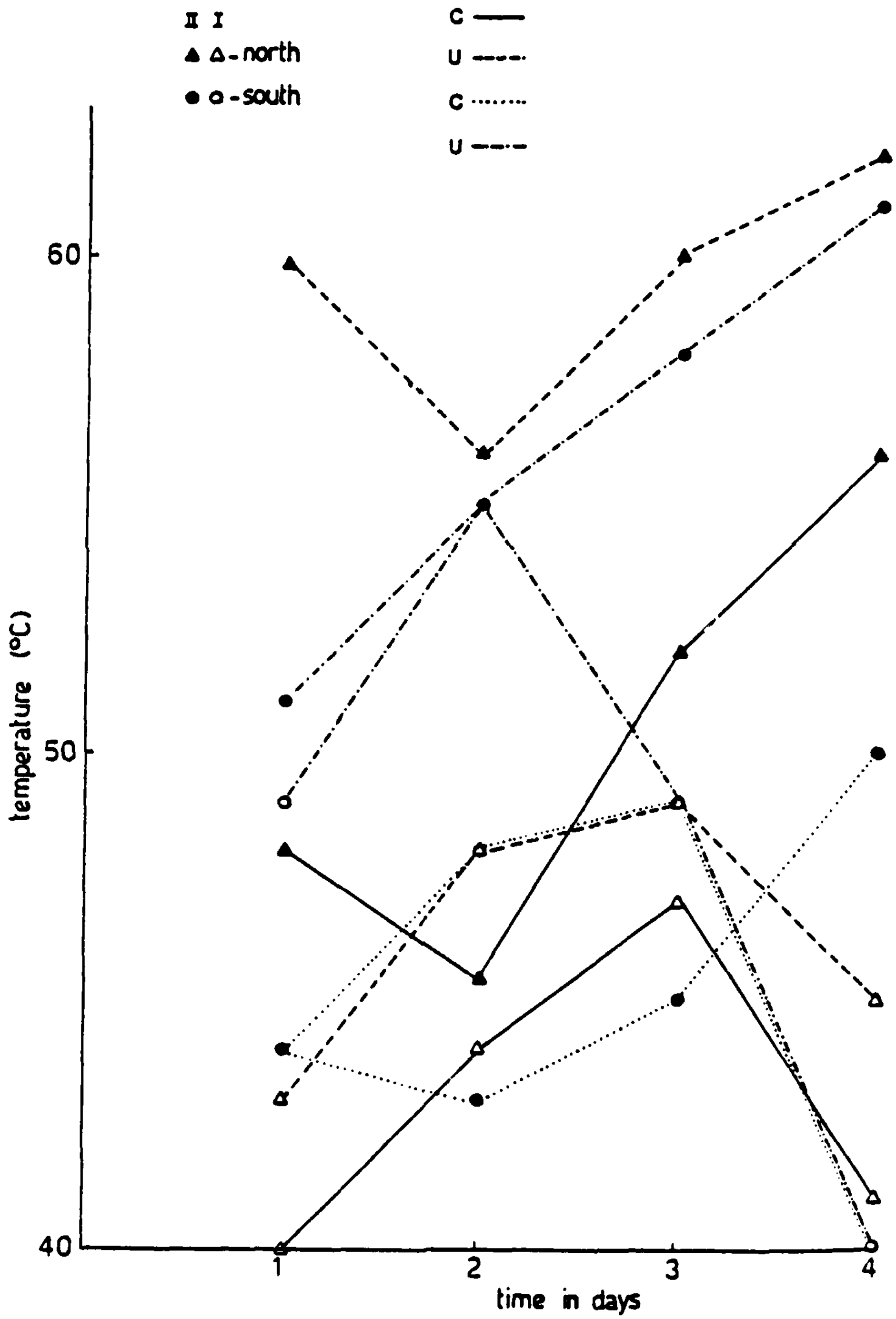


Fig. 14: The yield of water transpiration from leaves and branches facing north (▲△) and south (● o) in covered (C) and uncovered (U) PVC bags which was collected in the spring of Ein-Mur from <u>Phragmites australis</u> (I) plants growing in ground covered by a layer of water was compared with (II) plants growing in the wet soil. From green branches which contain 50 g biomasse of dry matter.

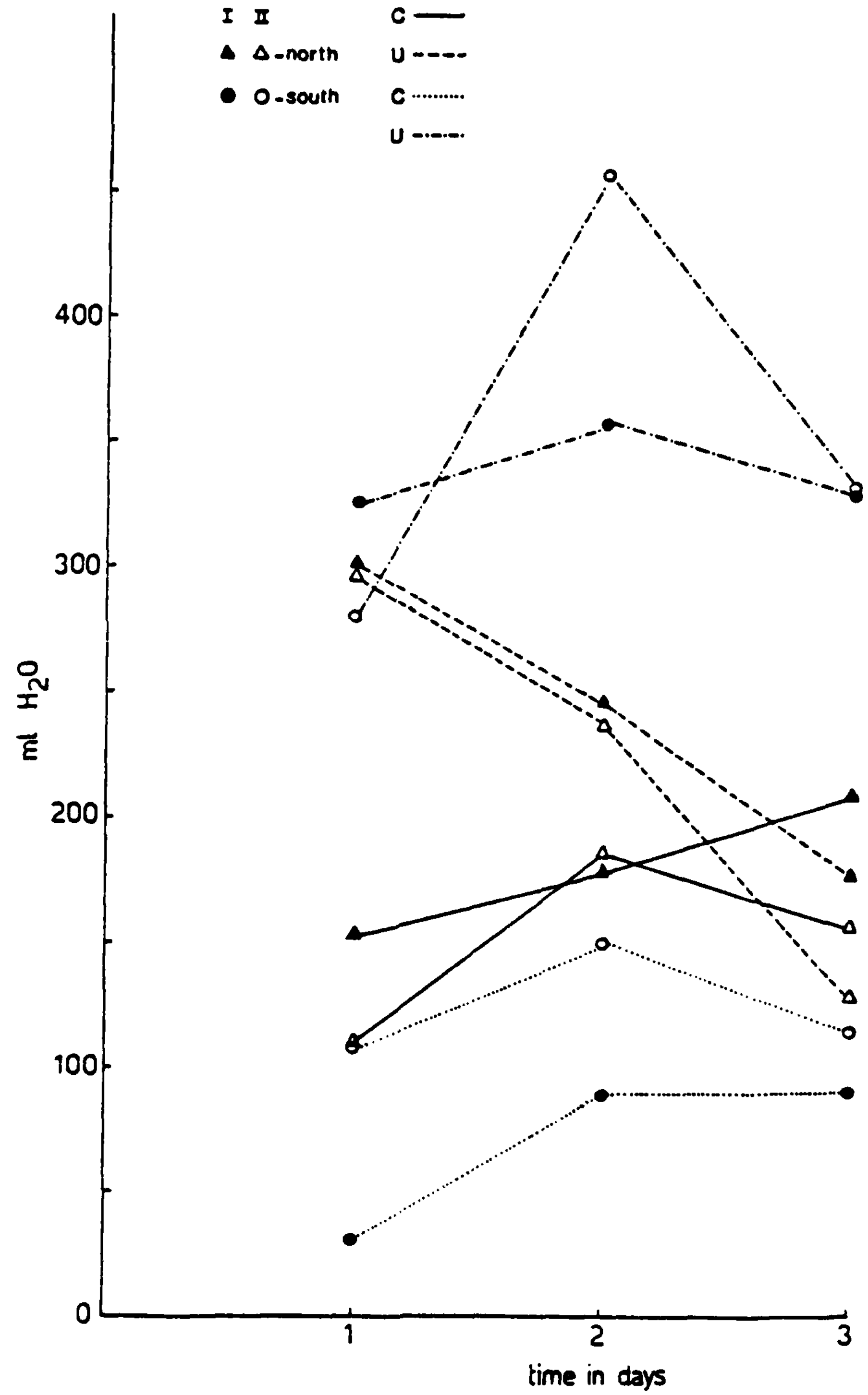
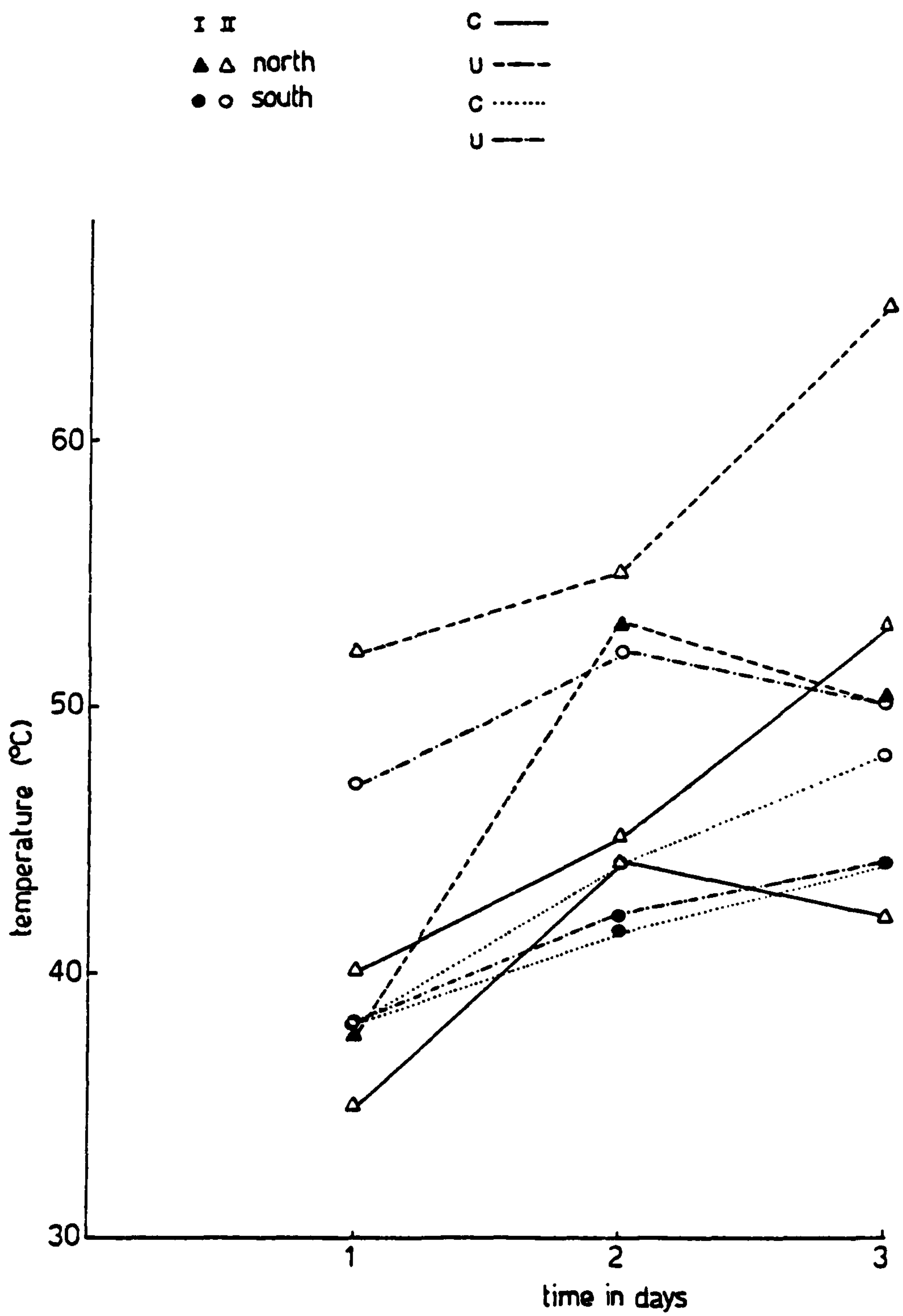


Fig. 15: Daily maximum temperatures in PVC bags covering <u>Phragmites australis</u> leaves and branches in the experiment measured in Fig. 14.



inside the PVC bag which is much higher in summer than in winter in bags on branches facing both north and south. In this experiment maximum temperatures in the summer reached 48-55^{o}C whereas during winter the maximum temperature reached 35-40^{o}C (Fig. 7). These high temperatures to which the temperatures were exposed day after day may have influenced the big differences in the pattern of the yield which was mentioned above. It is possible that the drastic decrease in the yield of water transpiration on the third and fourth days is related to the damage which accumulated in the living tissues of the covered branches.

In the winter when the maximum temperatures were much lower the water yield was also lower but the phenomenon of a reduced yield after the second day did not occur.

8. To test the possibility that in summer the high temperature in the plastic bags caused the great decrease in the yield of water transpiration from the second to the third day; a set of experiments was carried out to compare the yield from branches on the north and south facing slopes in uncovered PVC bags and in bags covered with white paper for shade.

From the results of this experiment as summarised in Fig. 8 and carried out at the beginning of May, it seems that: on the second day, the yield of water transpiration as calculated from green branches which contain 500 g biomasse of dry matter is higher from branches of the shrub facing south, in covered and uncovered plastic bags, than from those branches facing north. The interesting point is that in the covered PVC bags on the south facing branches, the reduction in the yield from the second to the third day is much lower in comparison with the yield from the branches facing south, in uncovered PVC bags. This phenomenon is much less pronounced in the yield from branches facing north, in covered and uncovered bags. These results support the likelihood that the temperature is one of the main reasons for the decrease in the yield of water transpiration from the second to third day.

9. Several experiments were carried out in order to compare differences in the yield of water transpiration from *Retama raetam* plants caused by differences in

the habitat, the diferent direction in which the branches faced, whether or not the branches were in covered or uncovered PVC bags and the role of various temperatures. Groups of 6 plants were selected in 3 habitats: a runnel of order II, on a hill slope; a wadi of order IV, in the Zin valley; a wadi of order V which is the main wadi in the Zin valley. The results are summarised in Figs. 9, 10, 11 and 12.

From Fig. 9 we can see that there were big variations in the yield of water transpiration from the 3 different habitats. The yield from *Retama raetam* plants inhabiting the runnel of order II, on the hill slope, gave the yield of water transpiration that is typical of the pattern of distribution that was found in the previous experiments. In this experiment there is a completely different pattern in the yield of water transpiration from plants in the Zin valley in wadis of orders IV and V. The yield, from plants in all the various conditions in these 2 habitats, decreased from day to day and in most cases, there was no great difference in the yield of water transpiration from north and south facing branches.

We can see that the results from the covered PVC bags (Fig. 10) are similar to those of the uncovered bags as summarised in Fig. 9 but the differences are much less pronounced. From Fig. 11, we can see that there are differences in the yield of water transpiration from plants as a result of their different habitats in treatments of both covered and uncovered PVC bags. The highest yield was from habitats in runnel order II, the intermediate yield was from wadi order IV and the lowest yield was from wadi order V. On the other days of the experiment these differences were not evident. The same pattern appeared as was mentioned above. In habitat I there is a typical decrease in yield from days 2-4, following a great increase in the yield of water transpiration from the first to the second day. The differences in yield in uncovered bags are greater than in covered bags. Fig. 12 which summarises the results from the measurement of the yield from north facing branches is similar to Fig. 11 but the differences are much less pronounced.

In most cases, as summarised in Fig. 13, the temperature that was measured in this experiment with Retama plants in the runnel on the hill slope which is an open area, was lower than the temperature in the Zin valley, in the main wadi of order V which is a closed area and the plants received a lot of radiation from the walls of the canyon. The wind is an important factor in the cooling system which decreased the temperature in the bags (Fig. 13).

The appearance of a great number of dried out branches in plastic bags which had the highest temperatures, reinforces the suggestion that the damage to the tissues from long exposure to high temperatures caused the greatest increase in yield on the second day and the big decrease in yield on the third and fourth day. The higher the temperature, the higher the yield of water transpiration on the second day and the greater was the visible damage to the branches which appeared on the third and fourth days of the experiment. In uncovered PVC bags this phenomenon is much more pronounced than in covered bags (Fig. 13).

10. The yield of water transpiration from Phragmites australis plants in Ein-Mur was studied in mid-May 1984. In Ein-Mur in the Zin valley, plants that grow in ground covered by a layer of water (habitat I), were compared with plants that grow in wet soil (habitat II). In this experiment we also compared the yield in covered and uncovered PVC bags. The highest yield was from the two treatments in which leaves and branches of the plants were covered with PVC bags facing south. On the second day the yield from plants in habitat II (460 ml), was higher than the yield from the same treatment in habitat I (360 ml), as calculated in mililitres per 50 g dry weight. Another difference in the water yield between plants from the habitats was found in covered branches facing south in which the yield from plants from habitat II was greater on the first and second days than the yield from those plants in habitat I. In the other treatments these differences are only slight (Fig. 14). It is interesting to note that in the uncovered PVC bag facing north, the highest temperatures were measured, 52-65°C (Fig. 15). There was a decrease in the yield of

water transpiration and the greatest damage to the plant tissues from the 1st-3rd day. This phenomenon has already been mentioned in section 9 with regard to Retama plants. It is interesting to note that the yield of water transpiration of Phragmites australis is in some cases as much as six times the yield of water transpiration from Retama raetam plants, at the same time of the year.

11. The average percentage of water content in the tissue of leaves of Phragmites australis was 48% in the range of 37-59%. The average percentage of water in Retama raetam branches is even lower, 45.5% in the range from 44-47%. The water content of the tissues of these 2 plants is low and the yield of water transpiration depends on the opening of the stomata and the activity of the living tissues which get the water supply from their roots system. Damage by temperature will interfere with this process and will reduce the yield of water transpiration.

12. Measurements of water transpiration from Retama raetam and Phragmites australis plants were carried out in June and July in an open system in order to compare the amount of water transpiration with that from the closed system in which the living tissue was enclosed in PVC bags. At the same time we used the two methods on the same shrubs and took 6 seperate measurements: 3 from branches facing north and 3 from branches facing south. The results from the Retama plants show that the yield of water transpiration from the covered branches facing south was nearly double; 130 ml per 500 g dry weight in comparison with only 66 ml from north facing branches. Opposite results were found in the open system; 39 ml from the north facing branches and only 18.5 ml from the south facing branches. These measurements are preliminary but it is possible to see that the system which influences the yield of water transpiration is a very complicated one, which depends on the condition of the plant as well as many environmental factors. It coud be important to examine the details of this system for a better understanding of the rules regarding the accumulation of water transpiration. This will lead us to develop a system which will increase the

yield of water that it is possible to collect from these plants.

ABSTRACT

This study concentrated on the plant and environmental factors which influence the yield of water transpiration which can be collected from 2 widespread plant species, Retama raetam and Phragmites australis; the latter plant gives a much higher yield. This is one of several other methods mentioned which could be of help in saving people stranded in the desert without water.

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