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ANNUAL REPORT

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SOIL EROSION CONTROL BY NARROW STRIPS OF *VETIVERIA ZIZANIODES* AND OTHER SEDIMENT – TRAPPING GRASS BARRIERS

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SECTION I

A. Research Objectives:

1. To study the effects of some environmental parameters, such as: air-temperature, day-length, planting time and various substrates on Vetiver growth.
2. To determine the effects of irrigation conditions and cutting and burn of Vetiver foliage on plant growth.
3. To grow Vetiver plants in different climates and regions in Georgia.
4. To develop a model to predict the energy loss of surface runoff in a field planted with Vetiver.

B. Research Accomplishments:

B. 1. The Israel part

A propagated material of Vetiver (*Vetiveria zizanioides*, L. Nash) was imported to Israel from Reunion Island in the Indian Ocean, and has been grown and propagated in Newe Ya'ar Research Center, The Volcani Center, Israel for more than 15 years. The Vetiver plants used in the present study were produced in Israel from rooted shoots obtained by splitting mother plants. The following trials were conducted in Israel:

B.1.1 Growing in greenhouse under controlled conditions

This experiment was conducted in a greenhouse with controlled conditions (Phototron) at the Volcani Center, Bet Dagan, Israel. Rooted shoots of Vetiver were planted in 2-L pots containing a mixture of tuff and peat at a volume ratio of 1:1, one shoot per pot. The plants were irrigated daily to excess by a drip system with an application rate of 2 L h^{-1} per pot. Fertilizer was applied through the irrigation system by adding N:P:K at a 5:3:8 ratio, respectively, plus trace elements to the irrigation water at a 0.2% concentration. After three weeks of growing under natural air-temperature and day length conditions, the plants were subjected to two main treatments, exposing the plants either to 10 h of light (a short day) or to 20 h of light (a long day), and to five sub-treatments of various ranges of maximum and minimum temperature: 29-21, 28-26, 25-23, 20-12 and 17-9 °C. All the treatments were repeated four times (4 pots) in a completely randomized design. The treatments with maximum temperature < 25 ^{0}C were irrigated daily to excess, and the treatments of the 26-28 and 29-21 °C temperature ranges were irrigated to excess two and three times a day, respectively, because of the high level of transpiration occurring in these two latter treatments. The height of the plant and the number of sprouts in each pot were measured over time.

The plant height and sprout number per plant, during the Vetiver growing season in the Phototron, are presented in Fig. 1 for all day-lengths and air temperatures. In most of the treatments, the plant's height increased rapidly in the first six weeks of growing, and then increased gradually to reach a maximum value (Fig. 1A). In contrast, the number of sprouts generally increased over time, slowly at first but then rising exponentially in the later stages of the growing season (Fig. 1B). The number of sprouts in a plant represents the horizontal growth of the plant and could indicate the capability of the plant to protect the soil surface against raindrop impact and seal formation. These plant heights and number of sprouts (Fig. 1) represent the typical growth pattern of Vetiver plants.

In order to determine the effects of the day-length and the air temperature on Vetiver plant growth, the plant height and the number of sprouts per plant after ~24

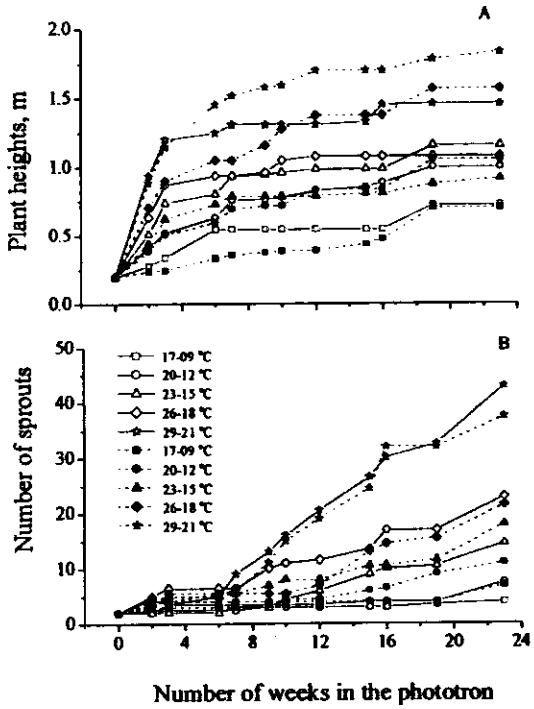

Fig. 1. Plant height and sprout number per plant, during the Vetiver growing season in the Phototron,

weeks of growing, as a function of air temperature for the two day-lengths, are presented in Fig. 2. An increase in the maximum/minimum temperatures to 29-21 ^{0}C significantly increased the plant height and the number of sprouts (Fig. 2). In contrast, the effect of the day-length on these plant parameters was less significant. Up to an air temperature of 15-23 ^{0}C, the effect of the day length on plant height was negligible or

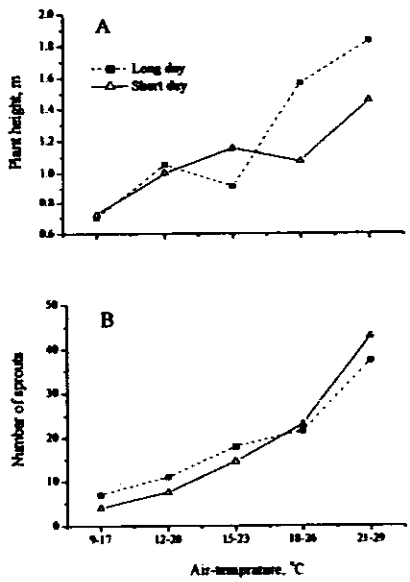

Fig.2. Vetiver plant height and number of sprouts per plant after ~24 weeks of growing, as a function of air temperature for two day-lengths.

resulted in taller plants in the short-day compared with the long-day (Fig. 2A). Conversely, in temperature ranges >15-23 ^{0}C, the plant heights in the long-day were significantly taller than in the short-day. The number of sprouts per plant was higher in the long-day than in the short-day at air temperature ranges up to 15-23 ^{0}C (Fig. 2B). In contrast, in air temperature ranges > 18-26 ^{0}C, the number of sprouts was higher in the short-day than in the long-day treatment.

B.1.2. Irrigation and foliage treatments

This trial was conducted in an open field at Newe Ya'ar. Vetiver plants were planted on April 4, 2001 with two rows, 1 m apart, in each bed and a population of 4 plants m^{-1}. A treatment plot comprised of a bed of 4-m-length with 16 plants. In order to establish the plants, the beds were drip-irrigated once a week until August 25, 2001 using one emitter line in the center of the bed. The irrigation amount was determined using a standard pan class A coefficient of 0.7. After August 25, 2001, the plants were subjected to two main treatments: irrigation and rain-fed conditions, and six sub-treatments of foliage harvesting and burning. Each treatment plot was divided into two equal parts: in one part, the irrigation continued regularly (irrigated treatment); in the second part, the irrigation was stopped (rain-fed treatment). In each of these treatments on June 12 2002, the plant foliages were cut at ~0, 0.05, 0.15, or 0.2 m above the soil surface or completely burnt by kerosene or not treated (control treatment). No fertilizer was given during the entire growing period in all of the treatments. The height of the plants in all of the plots was measured over time. Under commercial conditions, the plant foliage may be harvested in spring in order to enable the plants to survive the dry summer. The Vetiver foliage may also be reduced by grazing animals or by accidental fire.

The average height of the Vetiver plants, after different foliage treatments, under irrigation and rain-fed conditions in the open field, over time, are presented in Fig. 3. For the control treatment (untreated foliage) on June 8, 2002 and July 15, 2002, the average heights of the irrigated and rain-fed plants were similar, ~1.75 m, (Fig. 3A). These results suggested that the rainfall amounts in the winter of 2001/2002 and

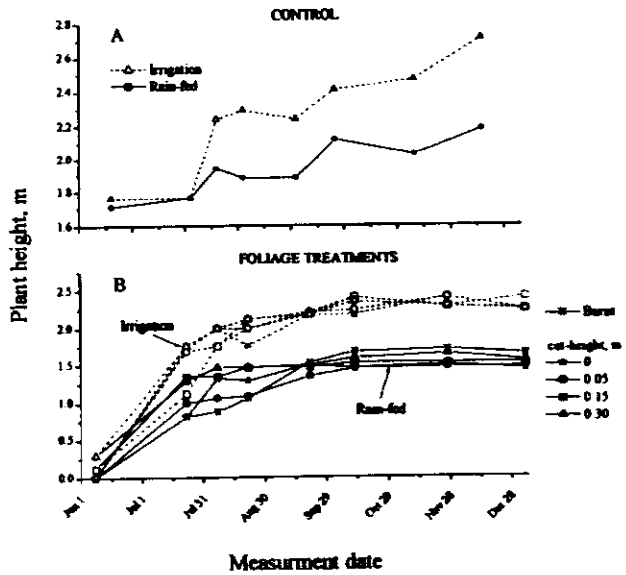

Fig. 3. Average height of Vetiver plants, after different foliage treatments, under irrigation and rain-fed conditions.

the residual water content in the soil until July 15, 2002 were large enough for Vetiver plants growing under rain-fed conditions. In contrast, after July 15, 2002, the heights of the irrigated plants were significantly higher than the plants under rain-fed treatments. The plant heights on November 28, 2002 under irrigation and rain-fed conditions were 2.8 and 2.2 m, respectively (Fig. 3A). It can be concluded from these results, that Vetiver plants, after establishment, could survive the dry summer in a semiarid region without irrigation.

After cutting or burning of the Vetiver foliage, the plant heights increased sharply until July 31, 2002, and then increased gradually to maximum values, where no significant differences were found between the various foliage treatments (Fig. 3B). The heights of the irrigated plants in all of the foliage treatments were significantly higher than those of the plants under rain-fed conditions (Fig. 3B). Under irrigation conditions, the heights of the plants after the various foliage treatments were, in general, similar to those in the control treatment after 15 July 2001 (Fig. 3). In contrast, under rain-fed conditions, the heights of the plants after the various foliage treatments were significantly lower than those in the control treatment. However, in the cut and burned plants under rain-fed conditions, the redeveloped foliage looked fresher, more upright, and greener than the foliage of the plants that were not cut or burned. Consequently, it can be concluded from these observations that, from a decorative point of view, under rain-fed conditions there is an advantage in harvesting the foliage of the Vetiver plant in the spring.

B.1.3 Time of planting

In order to determine the effect of the time of planting of Vetiver on its growing rate under semiarid conditions, 48 plants were planted in each month beginning in October 2001 until September 2002 in a bed of 6-m length. The experimental site was in an open field at Newe Ya'ar. The planting density and the irrigation management in this trial were similar to those in the previous trial (Irrigation and foliage treatments) for the irrigated plants. No fertilizer was given during the entire growing period. Plant height was measured in all the plots at various times.

The average heights of Vetiver plants after 200 growing days as a function of their planting date are presented in Fig. 4. The plants that were planted in February and March were the tallest, 2.3 and 2.4 m, respectively (Fig. 4). Planting the Vetiver

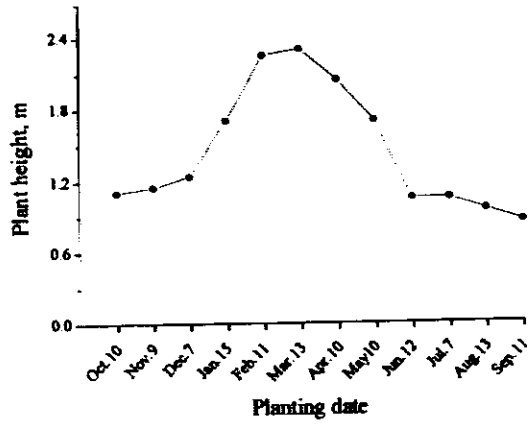

Fig. 4. average heights of Vetiver plants after 200 growing days as a function of their planting date.

plants earlier or later than February and March decreased sharply the plant heights (Fig. 4). The plant height after 200 growing days could be used as an indicator for the growth rate of Vetiver in the first year of growing .The results in Fig. 4 suggested that in order to obtain the fastest growing rate of Vetiver, the plants should be planted in February and March (in the winter season). It is important to note, however, that the final heights of the Vetiver plants may not be consistent with the heights after 200 days of growing.

Under irrigation conditions, there is an advantage in planting the Vetiver in the beginning of the summer. In this case, the plants have sufficient time to grow and develop a large root system before the beginning of the winter, thus their impact as soil stabilizers in the winter is maximized. In contrast, under rain-fed conditions, it is better to plant the Vetiver in winter. In this case, the plants can use the rainwater in the winter for growing and consolidation, which, in turn, increases their survival during the dry summer. However, under this regime, the Vetiver plants cannot be used as soil stabilizers during the first winter, because of their small root system and foliage at this time.

B.1.4. Growing in different substrates

The trial was conducted in a greenhouse in Newe Ya'ar. Rooted shoots of Vetiver were planted on June 7, 2002 in 10-L pots containing various substrates, one shoot per pot. Each substrate was used three times (3 pots) in a completely randomized design. The plants were irrigated daily to excess by a drip system, using emitters with an application rate of 2 L h^{-1}, one emitter per pot. The foliage of all the plants in all the substrates was harvested two times, on September 9, 2002 and November 6, 2002. Until the 1st harvest, no fertilizer was added to the plants. In contrast, between the 1st and 2nd harvests, all the plants were fertilized by adding N:P:K at a 5:3:8 ratio, respectively, plus trace elements to the irrigation water at 0.2% concentration. For each harvest, the height of the plant, the number of sprouts on each plant, and the fresh weight of the foliage were determined.

The height, number of sprouts and fresh weight of the foliage of Vetiver plants, grown in various substrates, after two harvests, are presented in Fig. 5. Except for the tuff substrate, the height of the plants after about three months of growing were relatively high, and the differences between the various substrates were small (5A). These results indicated that the Vetiver plants could grow in a wide range of substrates including ground limestone. In contrast, the differences in the number of sprouts of plants grown over the various substrates were relatively large and significant (5B). The combined effect of the substrates on the Vetiver growth can be determined by the fresh weight of the Vetiver foliage (5C). This foliage weight was significantly higher in the clay soil than in the other substrates, which were, in general, low and similar. This high fresh weight in the clay soil was probably a result of the high water retention capacity and fertility of this soil. In most of the substrates, the fresh weight in the first harvest was higher than in the second one, in spite of the addition of fertilizer after the first harvest. It should be noted here, however, that only one irrigation and fertilization management was tested. It is most likely that, using a proper irrigation and fertilization management system, tailored to the chemical and physical properties of the substrates, would have considerably improved the performance of these Vetiver plants in the various substrates.

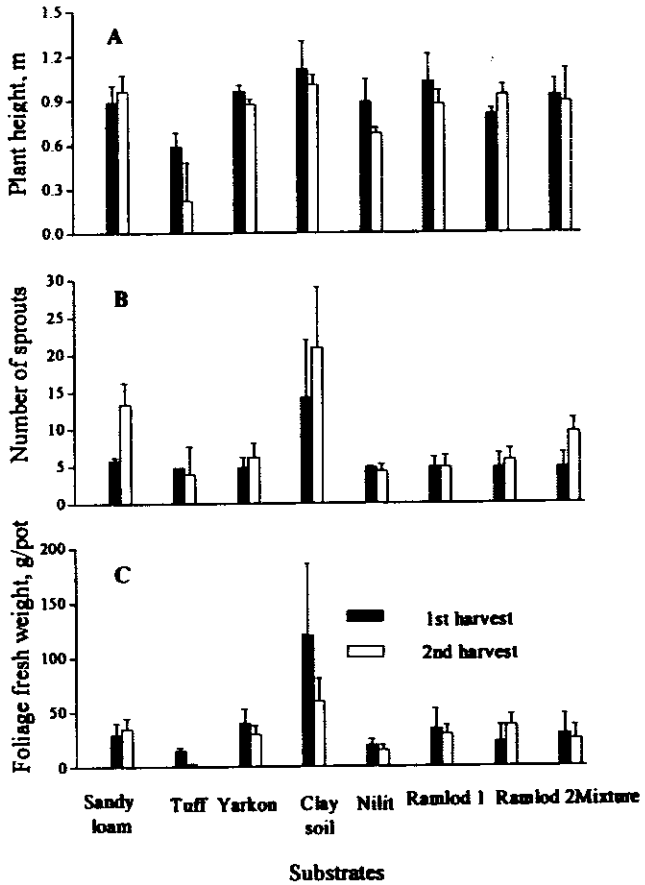

Fig. 5. Height, number of sprouts and fresh weight of Vetiver foliage plants, grown in various substrates and after two harvests.

B.2. The Georgia part

B.2.1 Growing Vetiver plants in various locations

Vetiver plants, which were shipped from Israel to Georgia, were planted in June 2003 in some plots at different locations in Georgia: (i) Tbilisi, (ii) Gldani residential area, North-West of Tbilisi (iii) Enamta in Sighnahi district, Eastern Georgia. The experimental plots in each location were 4 x 24 m in size. The Vetiver plants received a supplementary irrigation by flooding after planting for plant consolidation. The average heights of the plants on different dates were measured, and are presented in Table 1.

B.2.2. Model developing

A model to predict the energy loss of surface runoff in a field planted with Vetiver was developed. In this model, different distances and patterns of Vetiver plants in the field were considered in order to calculate the energy loss of surface runoff that flowed between the plants.

C. Scientific Impact of Collaboration:

. In this first stage of the project, the scientists of both Georgia and Israel had fruitful collaborations that was mainly via e-mail systems, faxing and in some cases by phone. Israeli scientists did not hesitate advising or giving recommendations on any issue, particularly, on growing and irrigation management of Vetiver. Moreover, the Israel side shipped 1200 seedlings of Vetiver, which were propagated in Israel, to

Georgia for the field experiments in Georgia. Both parties sincerely hope for a fruitful collaboration throughout the project period.

Table 1: Average heights of Vetiver plants in different location in Georgia and dates.

Site	Date	Plant Height, m
Tbilisi	26.6.2003	Planting
	30.8.2003	1.08
	06.9.2003	1.10
	31.10.2003	1.32
Glandi	29.6.2003	Planting
	30.8.2003	0.71
	30.10.2003	Plants were grazed by livestock
Enamta	28.6.2003	Planting
	26.10.2003	1.22
V. Arakhveti, Dusheti district	01.7.2003	Planting
	20.9.2003	0.57
V. Kakhati, Zugdidi district	01.7.2003	Planting
	10.9.2003	1.78

D. Description of Project Impact:

This report summarizes the first stage of the project that concentrated on the preparation, design and establishment of the trials in each country. Therefore, most of the scientific impact of this collaboration will be in the second stage, when we will have to implement the results that were collected in the first stage of the project

E. Strengthening of Developing Countries Institutions:

The Institute of Water Management and Engineering Ecology in Georgia acquired a new fax machine, computers, printer, pH meter, EC meter, balance and leaf area meter. All these greatly helped to improve communications with the world and to conduct scientific research. Internet connection has been initiated at the Institute in Georgia and this will also enhance the level of communication between the scientists in Israel and Georgia and allows access to good literature reviews.

F. Future Work:

The first delivery of 600 Vetiver seedlings was lost on its way to Georgia. This caused a delay in the field experiment in Georgia. Further work that has to be conducted: (i) Constructing runoff plots in Israel and Georgia. The runoff plots should be with Vetiver plants and without (control treatment). (ii) Greenhouse experiment in Israel to study the effects of different fertilization managements. (iii) Training of two young scientists from Georgia in Israel.

Section II

A) Managerial Issues:

First delivery of 600 seedlings of Vetiver was shipped to Georgia via DHL Worldwide Express. Unfortunately, this delivery was lost on its way to Georgia. Therefore, another delivery with new 600 seedlings of Vetiver was shipped to Georgia. These seedlings were used for the field trials in Georgia. The loss of the seedlings caused delay in the work in Georgia, and the field trials in this country started only in June 2003.

B. Budget:

Because of the delay in the field trails in Georgia, there was also a delay in the expenses for the Georgia side.

C. Special Concerns:

The Phytosanitary Certificates and the Shipment Airway bills of the two shipments of seedlings of Vetiver to Georgia are attached.

D. Collaboration:

Dr. N. Dudai from Newe Ya'ar Research Center, ARO, The Volcani Centre was attached to the Israeli scientists group. Dr. N. Dudai is an expert in growing management of Vetiver. The training of two young scientists from Georgia will be conducted in Dr. Dudai's laboratory for studying the growing management of Vetiver and in Dr. M. Ben-Hur's laboratory for training in runoff and erosion methods. Due to the difficulties that we had in the beginning of the project, we have decided to change the traveling arrangements of Dr. M. Ben-Hur and Dr. G. Levy to Georgia from the 1st year to the 2nd year of the project.

E) Request for American Embassy:

None