OLIVE TREE SURVIVAL IN AN ARID DESERT ENVIRONMENT WITHOUT IRRIGATION IN THE NEGEV HIGHLANDS OF SOUTHERN ISRAEL

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Absztrakt

In the Negev Highlands of southern Israel, remnants of both abandoned and presently maintained Bedouin fruit trees are found. Most of the older groves were deliberately planted in preexisting agricultural systems that were built in the area's distant past, to collect rain runoff water and conserve soil, mainly during the Byzantine era. Most researchers agree that the Byzantine era was the most productive period of settlement and agriculture in the Negev. Wine and olive oil were central agricultural products, as well as the ubiquitous wheat. Information on the kinds of crops grown during the Byzantine era can be found in 6th and 7th century CE documents discovered at Nitzana, and known as the "Nitzana papyri". Moreover, the remains of oil presses found throughout the Negev Highlands indicate a desert olive oil industry. In the presently found groves, a variety of domesticated fruit trees—olive, fig, vines, pomegranate, almond, palm, carob, pistachio and bitter orange—were found. The trees in these abandoned sites, dispersed throughout the Negev Highlands, have not been irrigated for at least six decades. Nevertheless, some of them continue to flourish and a few are bearing fruit to this day. The study presented herein focused primarily on understanding the reasons for the survival of the abandoned trees. Examination of this question incorporated a discussion of the soil characteristics and geological structure at the different sites in the Negev Highlands, the unique characteristics of each site that support desert agriculture, and use of runoff water-harvesting techniques. The olive trees growing in the Negev Highlands were planted during several periods. The oldest trees found are the descendants of trees planted during the Byzantine period. A second group of trees are aged to between 300 and 600 years. The third group is represented by trees that are 60–150 years of age, while the fourth contains trees planted in the last three decades. Most of the trees are untreated and have not been irrigated for six or seven decades. However, they receive some runoff water via the remains of the ancient, deteriorating rain runoff-collecting systems. Some of the trees appear to be in relatively good shape, do not show signs of leaf or branch dehydration and as already noted, even yield fruit.

Introduction

The Negev Highlands region is a mountainous area located in the northern part of the Negev Desert in the south of Israel. The region is characterized by relatively high mountains (up to

1,000 m.a.s.l.) surrounding the Ramon anticline in the central Negev Highlands (Fig. 1). The average distribution of precipitation is between 90 and 130 mm per year (Bruins, 2012). The rainy season usually starts around November and ends in mid-April. Most of the precipitation is of a local nature; the affected area for each event is therefore relatively small and the efficiency of many events is often rather limited (Evenari et al, 1971).

Previous geological research highlighted the high value of specific geological units, with large and rather smooth rain-collection slopes, enabling increased and efficient water-runoff values in the Negev Highlands (Yair, 1983; Yair and Berkowicz, 1989; Yair and Kossovsky, 2002). These selected formations with better water-collection capacity might be the key to understanding the development of commercial agriculture in that region during the Byzantine era. The efficiency of the water-collecting systems resulted in enhanced amounts of available water for agricultural crops. Those geomorphological formations display an ancient methodology for growing different fruit tree species, such as olive, fig, and grapevine, pomegranate, almond, palm, carob, pistachio and bitter orange, as well as grain species—mainly wheat and barley (Evenari et al, 1971; Ashkenazi et al, 2012, 2015). Successful rainwater-harvesting techniques enabled a sustained agriculture throughout drought years characterized by a low number of rain events (Sharon, 1972; Yair, 1983).

Geological studies of the Negev Highlands area have described the existence of geological formations such as Avnun and Tamar of the Cenomanian age, Shivta and Netzer of the Turonian age, and Nitzana and Matrad from the Eocene age which contribute to the efficiency of generating water runoff (Braun, 1967; Anvi, 1991; Zilberman, 1977; 1991). These geological units are scattered around the remains of ancient cities and around ancient agricultural sites (Ashkenazi et al, 2012). A correlation was made between the present drainage basin runoff potential and the locations of the Byzantine runoff farms (Wieler et al, 2016).

In the Negev Highlands, loess sediments deposited during the upper Pleistocene era turned into soil with agricultural potential (Bowman et al, 1986; Bruins, 1986). The viability of fruit trees grown in desert regions has been shown to be affected by the soil's quality, such as texture, depth, composition, salinity, etc. (Evenari et al, 1971; De-Mal'ah and Shiloni, 2003). The viability of fruit trees of different species and at different sites is also influenced by the annual amount and distribution of precipitation (De-Mal'ah and Shiloni, 2003). The plants' ability to overcome extreme climatic conditions, such as freezing night temperatures and extremely high ones during the day, is critical for plant survival in this type of environment (Evenari et al, 1971).

Remnants of both abandoned and presently maintained Bedouin fruit trees can be found in the Negev Highlands. The older groves were deliberately planted in preexisting agricultural systems that were built mainly during the Byzantine era (Zohary, 1954; Markus, 1983; Haiman, 1986, 1993; Meshel, 1991; Ashkenazi et al, 2011, 2012, 2015). Most researchers agree that the Byzantine era was the most productive period of settlement and agricultural activity in the Negev. Wine and olive oil were central agricultural products, as well as the ubiquitous wheat (Baly, 1935; Woolley and Lawrence, 1936; Kirk, 1941;

Mayerson, 1960; Evenari et al, 1971; Cohen, 1985; Lender, 1990; Hirschfeld, 2004; Avni, 2010). Information on the kinds of crops grown during the Byzantine era can be found in 6th and 7th century CE documents discovered at Nitzana, known as the "Nitzana papyri" (Kramer, 1958). In addition, the remains of oil presses, found throughout the Negev Highlands, indicate a desert olive oil industry (Rubin, 1990). In the groves, a variety of domesticated fruit trees, including olive, fig, vines, pomegranate, almond, palm, carob, pistachio and bitter orange, have been found. Most of the trees were untreated, and they have not been irrigated for six or seven decades (Ashkenazi et al, 2011, 2015).

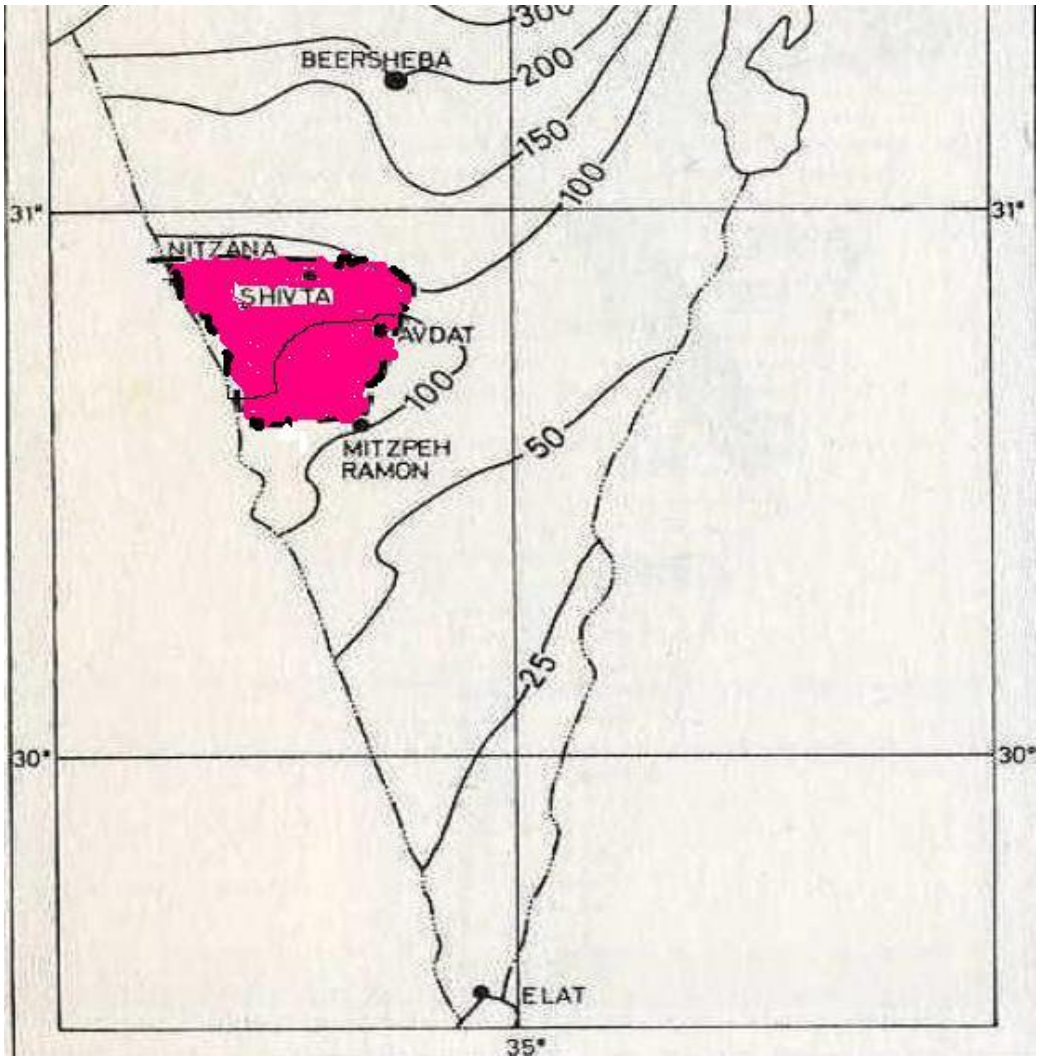

Fig. 1: Regional map of the Negev Highlands indicating the borders of the present study area

Methods

An intensive field survey was performed between 2006 and 2015 in the area between Machtesh Ramon in the south and the Shivta-Nitsana line in the north (Fig. 1). The survey included mapping of individual fruit trees and recording the species at the various locations. The performance of each tree at each location was evaluated yearly on a scale of 0–10. This evaluation included the degree of annual shoot development, rate of shoot growth, leaf size and number of dry branches.

Results

To date, 37 sites with historical agricultural-support systems containing groves with some live fruit trees have been located and are being studied (Fig. 2). A variety of live domesticated fruit trees, including olive, fig, grapevine, pomegranate, almond, date palm, carob, pistachio and bitter orange, have been found scattered individually in these groves, including 9 species and 122 trees. The second-highest number of trees for a single species, after fig, was olive, representing about 18% of all fruit trees in the studied zone (absolute number of 23 individually scattered trees).

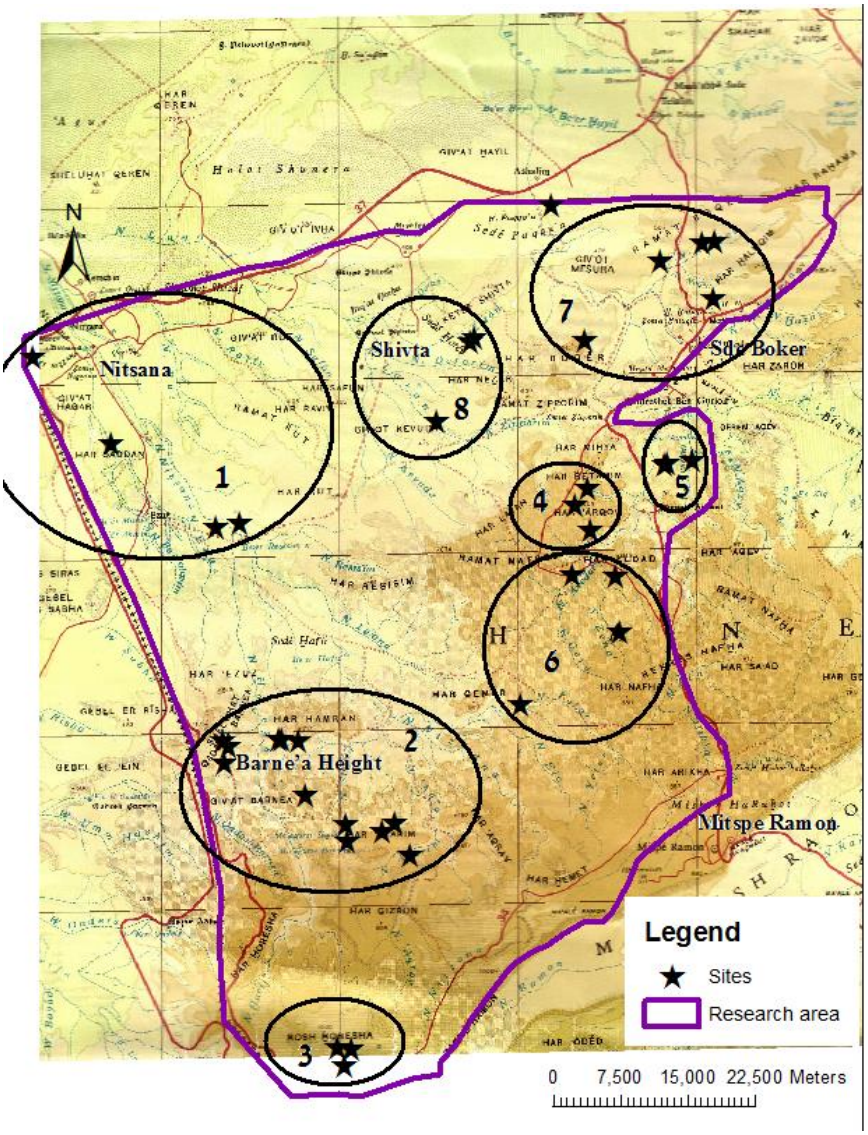

Fig. 2: Location of the investigated historical agricultural sites with living fruit trees in the Negev Highlands (1 – Lower Nitzana dry river basin, 2 – Barnea Heights, 3 – Upper Hursha dry river basin, 4 – Retamim dry riverbed and eastern Mihya Mountain, 5 – Division Heights, 6 – Matred Heights, 7 – Boker Ridge and Boker dry riverbed, 8 – Shivta region)

The trees found in these abandoned sites, dispersed throughout the area between the Avdat Heights, Barnea Heights, and Negev Mountain area, have not been irrigated for at least six or seven decades. Their survival is solely dependent on water from the ancient,

partially deteriorated rain runoff-collection systems. Despite these harsh conditions and an annual period of water stress, some of the trees—particularly olive, fig, pomegranate and almond—continue to bear fruit to this day. The olive trees growing in 11 sites in the Negev Highlands (Fig. 3) can be divided into several periods of establishment. The 4 oldest trees are the descendants of trees planted in the area during the Byzantine period. According to Rotem (1971), 1 of these trees was estimated by Prof. Felix from Bar-Ilan University to have originated in that period, a date that requires solid support by 14C dating (Fig. 4). A second group was estimated to have been established between 300 to 600 years ago. The third group consists of 60- to 150-year-old trees, while the fourth group contains trees planted in the last three decades. The olive trees introduced in the Negev Highlands during each of those periods were all planted by the Bedouins in preexisting sites with rainwater-runoff systems developed and used for tree crops in the Byzantine era. The recently planted olive trees in that region are also entirely dependent on rain fortified by runoff water. Consequently, the growth of these trees is slow, and signs of water stress are frequently apparent in the summer (Fig. 5).

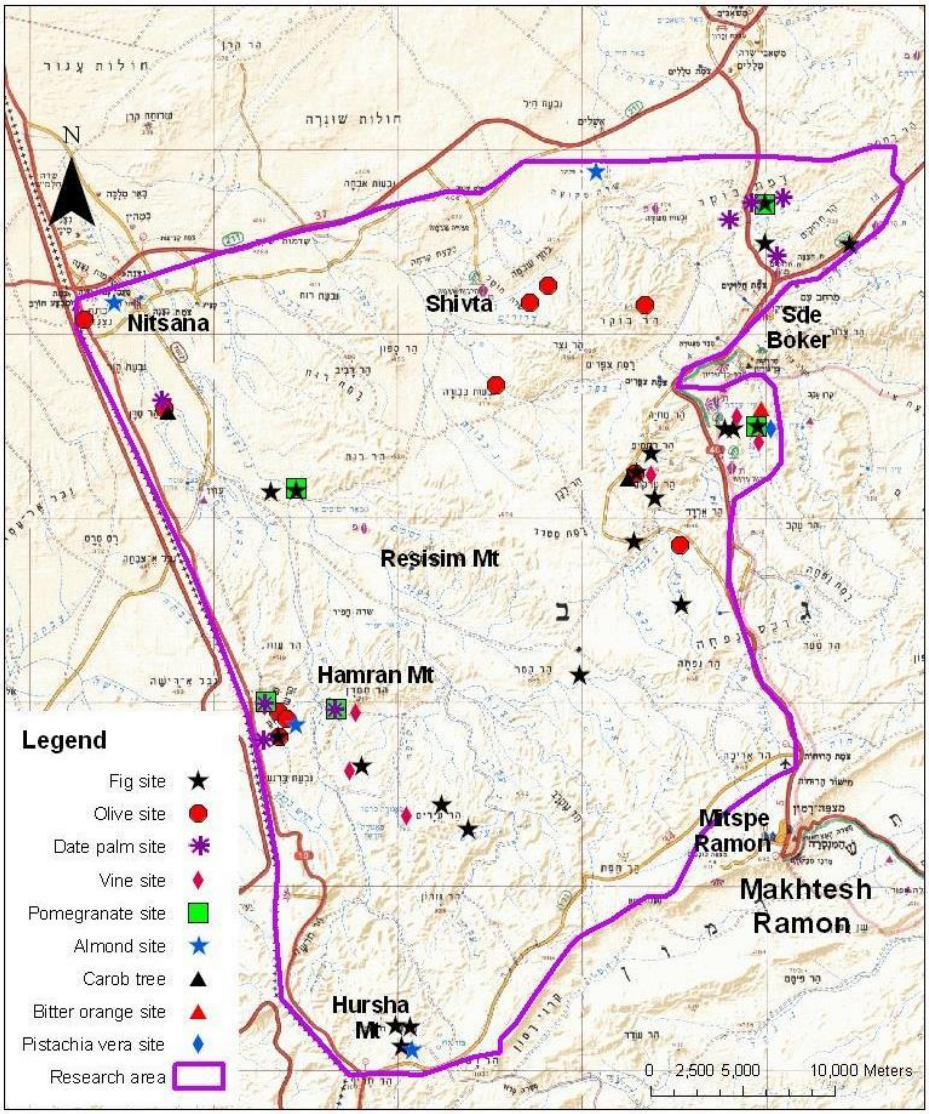

Fig. 3: Distribution of fruit tree species at the different sites in the Negev Highlands

Fig. 4: Ancient olive tree growing at the bottom of a cliff

Fig. 5: Olive trees planted about 30 years ago by Bedouins in the south of the Haricha dry riverbed

Summary

Some factors affecting the survival of the olive trees include:

A. Geological factors: rock units with high potential contribution to water runoff. These rock units are also instrumental to the soil sedimentation that has evolved and accumulated in specific geological formations. The olive trees growing under the cliffs of the Shivta

Formation showed the highest survival potential. All of these trees were in very good growing condition.

B. Topographic gradients expressed by short and steep slopes contribute more runoff water than long and moderate slopes. Thus, the conditions for olive trees growing under short and steep slopes are considerably better than those for trees growing under long and moderate ones. In many cases, exposed short and steep slopes gradually develop into cliff formations and contribute to soil accumulation. All of the olive trees growing under the short and steep slopes showed high survival potential and were found in good growing condition. Four trees were found to be in poor condition due to their location near moderate slopes with low generation of runoff water. However, none of the olive trees have died since the groves were abandoned.

C. The structure of the terrace: the ancient agricultural terraces where most of the trees are planted have a major impact on their development. The terrace heights have in one of the most cases a significant effect on tree development. High terraces stop and spread the runoff water across the top of the agricultural plot (Fig. 6). In some cases, the terraces deteriorated and the olive trees declined, including their main trunk.

D. Tree distance from the edge of the terrace: this has a significant effect on tree development as well. A distance of 2 m from the edge is usually optimal for tree development, with those further away showing considerably weaker growth. This is, as expected, mainly related to the depth and thus the water-holding capacity of the soil. As the investigated groves have been abandoned for decades, the level of deterioration of the ancient structures is critical for the amount of floodwater remaining on the terraces before continuing to flow to the next terrace. Some trees were found to be in poor condition due to their large distance from the wall of the farming terrace. However, despite the harsh conditions, none of the olive trees have died.

E. In some places, location of the ancient Byzantine water conduits leading the rainwater runoff from the slopes was shown to be significant for olive tree development. Most of the surviving olive trees in the ancient groves were located at the most efficient sites for water absorption and preservation, relatively close to the terrace walls (Fig. 6).

F. A few olive trees were found growing in locations near Byzantine water conduits. These trees obtained most of the water for their development directly from the occasional water floods in the riverbed. Nevertheless, even at those locations, the trees are supplied with some additional water originating from partially deteriorated rain-runoff systems which could be seen even in some small and narrow riverbeds (Fig. 7).

Old Bedouins who were children in the Negev Highlands before 1948 claim that the favored trees for planting were fig and olive, because these trees are mentioned in the Quran (the central religious text of Islam), and they are considered sacred. In fact, the largest number of trees for a single species was of fig, representing about 32.5% (absolute number of 47 scattered individual trees), and olive, representing about 18.8% (absolute number of 23 scattered individual trees), out of 122 fruit trees in the studied zone.

Fig. 6: A relatively well-developed olive tree in Um Zeytoon dry riverbed, planted fairly close to the terrace wall

Fig. 7: An olive tree growing in a low-order tributary of the Lavan riverbed

References

Ashkenazi E. Chen Y. Avni Y. Lavee, S. (2011). Olive trees in past desert agriculture in the Negev Highlands. Acta Hort. 888. 353-360.

Ashkenazi, E, Avni Y, Avni G, (2012). A comprehensive characterization of ancient desert agricultural systems in the Negev Highlands of Israel. Arid Environ. 86. 55-64.

Ashkenazi E. Chen Y. Avni Y. Lavee, S. (2015). Fruit trees survival ability in an arid desert environment without irrigation in the Negev Highlands of Southern Israel. Israel Journal of Plant Sciences. 62. 5-16.

Avni G. (2010). The Byzantine – Islamic transition in the Negev - An Archaeological Perspective. Jerusalem Studies in Arabic and Islam. 35/2. 7-35.

Avni Y. (1991). The Geology, Paleogeography and the Landscape Evolution of the Central Negev Highlands and the western Ramon structure. Geological Survey of Israel Report GSI/6/91 (Hebrew, English abstract).

Baly C. (1935). S`baita. PEFQST, 62. 171-181.

Bowman D. Karnieli A. Issar A. Bruins H.J. (1986). Residual Colluvial-Aeolian Aprons in the Negev Highlands (Israel) as Paleo-Climatic Indicator. Palaeogeography, Palaeoclimatology, Palaeoecology, 56, 89-101.

Braun M. (1967). Type Sections of Avdat Group, Eocene Formations in the Negev (southern Israel). Geological Survey of Israel, Stratigraphic sections. No 4.

Bruins H. J. (1986). Desert Environment and Agricultural in the Central Negev and Kadesh-Barnea during Historical Times. Ph.D tesis, Midbar Foundation. Nijkerk. Nederlands.

Bruins H.J. (2012). Ancient desert agriculture in the Negev and climate-zone boundary changes during average, wet and drought years. J. Arid Environ. 86, 28-42..

Cohen R. (1985). Archaeological Survey of Israel Map of Sede-Boker-West (167). 12-03. Department of Antiquities and Museums. Jerusalem.

De-Mal'ah Y. Shiloni Z. (2003). The Development of the Agricultural research in Ramat Negev 1943-2001. Ben-Gurion University, Sde-Boker (Hebrew).

Evenari M. Shanan L. and Tadmor N. (1971). The Negev: The Challenge of a Desert. Cambridge: Harvard University Press Cambridge, Massachusetts.

Haiman M. (1986). Archaeological Survey of Israel Map of Har Hamran Southwest (198) 10-00, Department of Antiquities and Museums. Jerusalem.

Haiman M. (1992). Early Settlement Patterns of the Negev Highlands, Ph.D. Dissertation, The Hebrew University of Jerusalem, (Hebrew, English abstract).

Hirschfeld Y. (2004). A Climatic Change in the Early Byzantine Period? Some Archaeological Evidence. PEQ. 136. 2. 133-149.

Haiman M. (1993). Archaeological Survey of Israel Map of Har Hamran Southeast (199). Jerusalem. Israel Antiquities Authority.

Kirk G. E. (1941). The Negev or Southern Desert of Palestine. PEQ. 74. 57-71.

Kraemer C. J. (1958). Excavations at Nessana. III: Non-Literary Papyri. Princeton.

Lender Y. (1990). Archaeological Survey of Israel Map of Har Nafha. Jerusalem. Israel Antiquities Authority.

Markus M. (1983). Negev Highlands and Ramon Makhtesh. Nature Reserves Authority. Jerusalem (Hebrew).

Mayerson P. (1960). The Ancient Agricultural Regime of Nessana and the Central Negeb. The British School of Archaeology in Jerusalem. London.

Meshel Z. (1991). Along the Border Road. The Negev Highlands. Ministry of Defence. Tel-Aviv (Hebrew).

Rotem R. (1971). The olive tree in the Zaitan river bed in the Negev. Teva Vehaaretz. 13. 234 (Hebtew).

Rubin R. (1990). The Negev as a Settled Land – Urbanization and Settlement in the Desert in the Byzantine Period, Jerusalem. Yad Ben Zvi (Hebrew).

Sharon D. (1972). The Spottiness of Rainfall in Desert Area. J. Hydrol, 17. 161-175.

Wieler N. Avni Y. Rosensaft M. (2016). The significance of the geological strata on desert runoff agriculture: Indications for stable desert environment over the last 1600 years in southern Israel. Arid Environ. 135. 147-163.

Wooley C.L. Lawrence T.E. (1936). The Wilderness of Zin. New York.

Yair A. (1983). Hillslope Hydrology Water Harvesting and Areal Distribution of some Ancient Agricultural Systems in the Northern Negev Desert. Arid Environ. 6. 283-301.

Yair A. Berkowicz S.M. (1989). Climatic and Non-Climatic Controls of Aridity: The Case of the Northern Negev of Israel. Catena Supplement. 14. 145-158.

Yair, A. Kossovsky A. (2002), Climate and Surface Properties: Hydrological Response of Small Arid and Semi-Arid Watersheds, Geomorph. 42. 43-57.

Zilberman E. (1977). The Geology of the Saad - Nafha lineament, Avedat Plateau, (Hebrew; English Abstract). Geological Survey of Israel MM/6/77 and M. Sc. Thesis, The Hebrew University. Jerusalem.

Zilberman E. (1991). Landscape Evolution in the Central. Northern and Northwestern Negev During the Neogene and the Quaternary. Geological Survey of Israel Report GSI/45/90 (Hebrew, English abstract).

Zohary D. (1954). Notes on Ancient Agriculture in the Central Negev, IEJ, 4, 17-25.