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Influence of Using Water Harvesting Techniques on Snake Melon (Cucumis melo L. var. flexuosus) Yield under Semiarid Conditions

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Influence of Using Water Harvesting Techniques on Snake Melon (*Cucumis melo L. var. flexuosus*) Yield under Semiarid Conditions

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Abstract:

The majority of cultivated crops in the West Bank are rain-fed; the productivity of these crops is far below its potential. Therefore, the objective of this study is to evaluate the impact of water harvesting techniques (contour ridge and half-moon structure) on snake melon (*Cucumis melo L. var. flexuosus*) yield under semiarid conditions. Three treatments (contour ridge, half-moon, and control) were evaluated during 2015/2016 and 2017/2018, using randomized complete block design with three replicates. The results showed that the yield of snake melon during a high-rainfall year was about triple (mainly for control treatment) the yield in a low-rainfall year. The yield of snake melon in water harvesting treatments shows a significant increase that ranges from 49.3% (in a high-rainfall year) to 95% (in a low-rainfall year) compared with the control treatment, no significant difference between the contour ridge and half-moon structure. These results show that water harvesting structures have the potential to improve the snake melon yield under semiarid conditions. Contour ridge is simple, practicable, easy to establish, and not costly; therefore, we recommend this technique to be applied by the farmers under similar environmental conditions. More studies are required to evaluate the impact of these water harvesting techniques on the yield of other rain-fed vegetable crops under semiarid conditions.

Key words: snake melon (*Cucumis melo L. var. flexuosus*), water harvesting techniques, rainfed farming, semiarid conditions

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تأثيراستخدام طرق الحصاد المائي على انتاجية الفقوس (*Cucumis melo L. var. flexuosus*) في المناطق شبه الجافة

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الملخص:

غالبية المحاصيل المزروعة في الضفة الغربية هي محاصيل بعلية، حيث ان كميات الامطار في معظم الضفة الغربية قليلة، فان انتاجية هذه المحاصيل قليل جدا مقارنة مع ما يمكن ان تنتجه في حال توفر المياه بالكميات المناسبة. ولذلك فان هذه الدراسة تهدف الى تقييم تاثير طرق الحصاد المائي (الخطوط الكونتورية و الهلالات) على انتاجية نبات الفقوس (*Cucumis melo L. var. flexuosus*) في المناطق شبه الجافة. تم تقييم المعاملات التالية: الخطوط الكونتورية، الهلالات، والشاهد خلال سنتين (2016/2015 و 2018/2017) وباستخدام تصميم القطاعات العشوائية الكاملة مع ثلاث مكررات. اظهرت النتائج انه خلال السنة التي كانت فيها الامطار عالية كان انتاج الفقوس تقريبا ثلاثة اضعاف الانتاج في السنة التي كانت فيها كمية الامطار منخفضة وخصوصا في معاملة الشاهد. كان هناك زيادة معنوية في انتاج الفقوس في معاملات الحصاد المائي تراوح بين 49.3% (في سنة سقوط الامطار العالي) و 95% (في سنة سقوط الامطار المنخفض) مقارنة مع معاملة الشاهد مع عدم وجود فروق معنوية بين معاملة الخطوط الكونتورية ومعاملة الهلالات. هذه النتائج اظهرت انه باستخدام طرق الحصاد المائي يمكن زيادة انتاج الفقوس تحت الظروف شبه الجافة. حيث ان الخطوط الكونتورية بسيطه، وعملية، وسهلة البناء، وغير مكلفة فاننا نوصي بهذه الطريقة لاستخدامها من قبل المزارعين في المناطق شبه الجافة. وكذلك نوصي باجراء مزيد من الابحاث حول تاثير طرق الحصاد المائي على انتاجية محاصيل الخضار البعلية الأخرى والتي تزرع في المناطق شبه الجافة.

الكلمات المفتاحية: الفقوس (*Cucumis melo L. var. flexuosus*)، طرق الحصاد المائي، الزراعة البعلية، المناطق شبه الجافة.

Introduction

Snake melon (*Cucumis melo* L. var. flexuosus) is a well-known rain-fed, summer crop that is traditionally cultivated by many farmers in almost all over the West Bank areas and many other countries. It has a significant contribution to the economy of the rural community. According to Grebenshchikov (1986) and Walters and Thieret (1993), snake melon is one of the ancient and worldwide horticultural crops in many countries, including Palestine (West Bank). Snake melon is a warm-season crop that is commonly grown in the Levant area, Asia Minor, and North Africa (Merheb et al., 2020). Ali-Shtayeh et al. (2015) and Abu Zaitoun et al. (2018) investigated the genetic diversity of snake melon accessions collected from Palestine. They indicated that these accessions belong to four important landraces of *Cucumis melo* var. flexuosus: Green Baladi, White Baladi, Green Sahouri, and White Sahouri.

In developing countries, most food for poor communities is produced from rain-fed agriculture with regional variation in its importance. Wani et al, (2009) indicated that the percentage of rainfed farming land is about 95% in sub-Saharan Africa, 90% in Latin America, 60% in South Asia, 65% in East Asia and 75% in Near East and North Africa. Grain food production worldwide depends mainly on rainfed agriculture, which accounts for 60 percent of agricultural production in developing countries (World Bank, 2006). However, crop productivity under rainfed cultivation in semiarid areas is low. Rainfall characteristics exacerbated by high runoff and evapotranspiration losses are the main reason for the low crop production in semiarid areas (Yosef and Asmamaw, 2015 and Haile and Tsegaye, 1980). According to Wani et al. (2003; 2011) and Rockstrom et al. (2007), the low productivity of crops under semiarid conditions in the rain-fed regions is attributed to water limitations, low rainwater use efficiency (35–45%), drought and land degradation, low investments in water use efficiency measures, poor infrastructure and inappropriate policies, among other factors. Therefore, rain-fed agriculture is considered a risky business. Mohammad (2005) pointed out that rainfall in semiarid regions is concentrated in short rainy seasons, with few intensive rainfall events, which are poorly distributed within and between seasons. In addition, Creswell & Marten (1998) concluded that in arid and semiarid regions, a significant part of precipitation is lost to evaporation and run-off; as a result, the amount of stored water in the root zone is far below crop water requirements (Oweis and Hachum, 2009).

In all arid and semiarid regions, appropriate management of soil and water resources represents a major challenge. Creswell & Martin (1998) identified the objective of such management as obtaining water, conserving it, using it efficiently, and avoiding damage to the soil. In a study on in-situ water harvesting techniques, Wani, et al. (2011) concluded that major attention should be directed towards managing soil and water resources as well as reducing rainfall-induced risks in order to increase agricultural productivity in rain-fed regions under semiarid conditions. Similarly, Yosef and Asmamaw (2015) found that the in-situ and ex-situ rainwater harvesting techniques have significant impact on improving soil moisture and increasing agricultural production.

Many researchers proved the efficiency of soil and water conservation practices in improving the productivity of a variety of crops such as fruit trees, field crops, and vegetables under a rainfed farming system. Soil and water conservation involves the use of methods that increase the amount of rain water storage in the soil profile (Hatibu & Mahoo, 1999; Stott et al., 2001). More than 80% of the reviewed scientific studies by Wolka et al. (2018) showed a positive effect of water harvesting techniques on crop yield, mainly due to the retention of nutrients and moisture; furthermore, this positive effect was increased by integrating water harvesting techniques with other land management methods such as soil fertility and conservation tillage. Dile et al. (2013) concluded that water harvesting techniques have the potential to support sustainable agriculture in water-scarce tropical regions through decreasing risk and improving yield. Ibraimo and Munguambe (2007) found that including rainfall management in sustainable and integrated production systems can upgrade the rain-fed agriculture production. Water harvesting systems have been established in many parts of the world for thousands of years. In Jordan, water harvesting structures were constructed 9000 years ago (Prinz, 1996); run-off-irrigation systems have been used in the semiarid and arid Negev desert region for 5000 years (Evenari et al., 1971); contour terracing have been in use in the central highlands of Mexico for 1000 years (UNEP, 1983).

The ridge and furrow rainfall harvesting system with mulches produced higher and more stable agricultural production in many areas of the Loess Plateau in northwest China (Li and Gong, 2002). The results of Li et al. (2007) showed that ridge and furrow technique had a significant increase in average alfalfa yield compared to the control treatment. The results of Safi and Mohammad (2019) demonstrated the positive effects of water harvesting practices on barley productivity. A significant increase was obtained in the grain and straw of barley weight by 37% and 76% respectively, using the strip planting compared to the traditional cultivation (control). In addition, Abdel Rahman et al. (2018) found that barley productivity was improved by using water harvesting structure compared with those grown according to the traditional method. The study of Mustafa (2005) found that the C-shaped catchment structure has the highest efficiency in water harvesting and in soil water conservation; hence, it gave the highest fodder and grain yields of sorghum in Sudan. Tabor (1995) results showed an increase in the yield of millet and sorghum by using micro-catchment water harvesting technique compared with the control. In Rwanda, Mudatenguha et al. (2014) found a significant increase ($P<0.001$) in soil moisture, maize plant dry weight, and grain yield by using in-situ rain water harvesting techniques. The results of Milkais et al. (2018) revealed that the in-situ rainwater harvesting techniques improved soil moisture storage, and significantly increased grain yield of the maize by 143.14% over the control treatment.

The results of Saeed et al (2019) showed that both the soil and plant parameters were considerably influenced by the water harvesting techniques through improving soil structure, infilterability and water storage capacity over control. The results of a study by Mohammedien et al. (2016) indicated that the application of rain water harvesting techniques increased yield and yield components of millet compared with control in Darfur, Sudan. Castelli et al. (2019) concluded that Jessour System, used in Tunisia, can adequately ensure water supply for olive trees. Tubeileh et al. (2008) concluded that, with proper water and nutrient management, it is possible to grow drought-tolerant olive varieties in arid areas under minimal or no irrigation.

According to the National Agricultural Sector Strategy (2017-2022) Resilience and Sustainable Development Strategy report (2016), the rainfed farming in Palestine represents 81% of total cultivated land. In the West Bank, the area planted with snake melon is about 3605 dunums, wherefrom 83% to 97% is under rain-fed farming system (PCBS, 2011). Productivity of snake melon under conventional rain-fed farming system in Palestine is about 475 to 572 kg/ dunum compared to about 1200kg/dunum under irrigation (PCBS, 1999). Our knowledge of the effectiveness of using water harvesting techniques on the yield of snake melon under semiarid conditions is merely limited. Therefore, the objective of this study is to evaluate the effects of water harvesting techniques (half-moon and contour ridge) on the yield of snake melon under semiarid conditions.

Materials and Method

Study Area

The study site is located in Dura town, 11 km southwest of Hebron city, with an elevation of 839 m above sea level. The town has a geographical position of 31°30′25″N 35°01′40″E and a climate typical of Mediterranean Sea, which is characterized by long, hot, dry summers and short, cool, wet winters (ARIJ, 2015). The rainy season usually extends from the middle of October until May, where most of the rainfalls during the period between November and March (ARIJ, 2015). The study site covers an area of about 2 dunums with a 5% slope.

According to the Municipality of Dura (2021), the amount of rainfall at the study site ranges between 300-400 mm. The rainfall records of South Hebron Directorate of Agriculture (unpublished, 2021) showed that the amount of rainfall at a nearby location during 2015/2016 was about 444 mm and during 2017/2018 was 337 mm.

Treatments

The study was conducted over two years, 2015/2016 and 2017/2018. Snake melon (*Cucumis melo L. var. flexuosus*) White Sahouri landrace was used for this study. The suitable cultural practices started by deep plowing the land before the winter season followed by land cultivation early in December. Water harvesting structures were established about one week after early cultivation, followed by cultivation (for weed control) and fertilization, using 25 kg (20:20:20) NPK /Dunum, late during the rainy season (March). All land was cultivated, including water harvesting structures, at the end of the rainy season and few days before seed sowing. The water harvesting structures under investigation were established one week after the cultivation in December as follows:

- *Half-moon (Treatment 1)*: Three rows of half-moon structures were established manually by workers, and they were perpendicular with the slope, 1.5 meters a part from each other with 30 cm deep.
- *Contour Ridge (Treatment 2)*: Three rows, 1.5 meters a part with 30 cm deep prepared by tractor.
- *Control (Treatment 3)*: no water harvesting structure.

A randomized complete block design was used with three replicates for each treatment. Each replicate consisted of three rows. One week before planting, the land was cultivated, and then snake melon seeds were planted at 1.5 m between rows and 1 m within rows.

Data Collection

Soil chemical and physical properties were measured once in November 2015. Three replicate soil samples at a depth of 0–10 cm were randomly collected from the study site. The bulk soil samples for each replicate were air-dried, crushed with a mortar and pestle and sieved to remove coarse (>2 mm) fragments. The soil chemical and physical properties (soil particle size distribution, bulk density, PH, electrical conductivity (EC), organic matter (OM), nitrate (NO_3^-), ammonium (NH_4^+), and phosphorus) were determined following the methods mentioned by Mohammad and Alseekh (2013). The results are shown in Table (1).

Table 1: Soil physical and chemical properties at the study site.

Soil texture class	**pH**	**EC**	**Bulk density**	**Organic Matter**	**Phosphorus**	**Nitrate (NO_3^-)**	**Ammonium (NH_4^+)**
	(1:2.5)	**ds/m**	**g/cm^3**	**(%)**	**(ppm)**	**(ppm)**	**(ppm)**
Clay loam	7.41	0.274	1.18	1.89	10.81	8.17	13.87

The yield of 40 plants from the center row was used at each harvesting date; each weighed (g/plant) separately and then averaged over the 40 plants. For each replication, the data was translated from grams per plant to kilograms per dunum. The data was analyzed by using Sigmastat® program, two-way ANOVA, and Fisher's multiple comparison tests ($P \leq 0.05$).

Results and Discussion

Snake melon yield was highly variable between years. In the good rainy year, the yield was about triple that in the low rainy year (Figure 1) for control treatment. As shown in figure (1), snake melon yield was 1558.4 kg/dunum for control treatment during the high rainfall year (2015/2016), while during the 2017/2018 year with low rainfall, the snake melon yield was 597.6 kg/dunum for the same treatment.

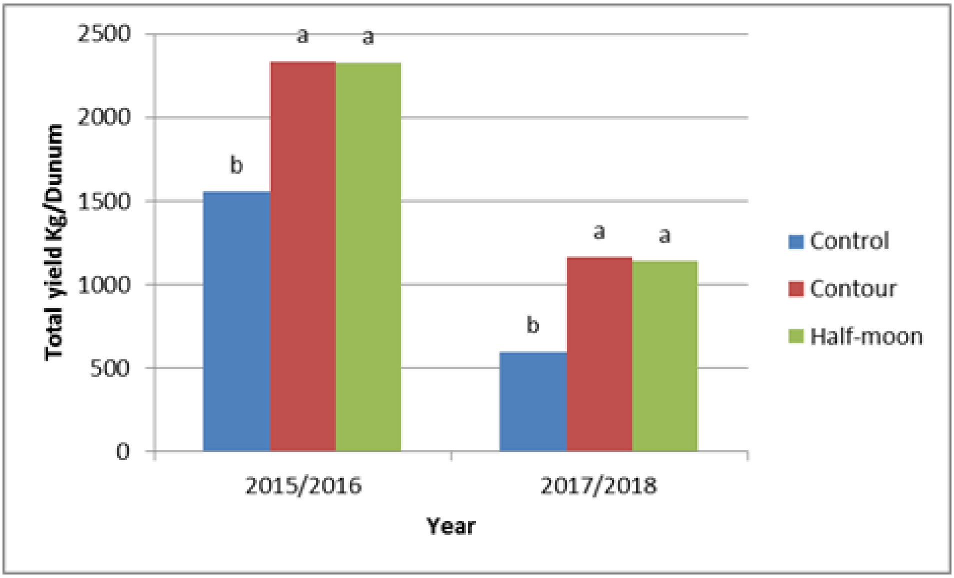

Figure 1: The average total yield (Kg/Dunum) of snake melon for contour, half-moon and control treatments during 2015/2016 and 2017/2018 years.

Columns with the same letter within the same year are not significantly different according to Fisher LSD test at $P \leq 0.05$.

Similar trends were also obtained for the other treatments. This result indicates that rainfall is the main limiting factor for crop production in semiarid areas. The variation in the productivity of snake melon for the control treatment is similar to that found by Omari et.al. (2018). They found that the average experimental yield of snake melon in the West Bank ranged between 0.8 and 2.3 kg/plant.

As for the effects of water harvesting structures within years, contour ridge and half- moon treatments have significantly ($p \leq 0.05$) higher yield than control treatment during both 2015/2016 and 2017/2018, with no significant difference between contour ridge and half-moon (figure 1). In 2015/2016, the yield increased 49.8% and 49.3% by using contour ridge and half-moon, respectively, compared to the control. While in 2017/2018 year the yield was increased 95% and 90.1% by using contour ridge and half-moon structures compared to the control. These results expressed the effectiveness of these water harvesting techniques in harvesting rain water and stored it in the root zoon were the plants can benefits from it by increasing yield. In addition, these results indicated that during the years of low precipitation, the effect of rain water harvesting on yield was higher than that during normal years. A similar result was found by Saeed et al. (2019) who showed that the variability of soil moisture content and plant parameters between water harvesting structures and control treatment increased during the drier season and decreased during the wetter season. In addition, Al-seekh and Mohammad (2009) found a significant increase in soil moisture by water harvesting techniques compared to the control in the West Bank under environmental conditions similar to the current study; also the same study found that the percentage of increase in soil moisture was higher in arid and semiarid regions than that in sub-humid regions. Many researchers (Nyagumbo et al., 2019; Yousef and Asmamaw, 2015) explained that water harvesting structures redirect local run-off to the plant roots and maximize rainfall infiltration that leads to an increase in soil moisture and yet crop productivity. Milkias et al. (2018) found that tied ridge, contour ridge and ridge furrow structures increased soil moisture storage by 134.59, 128.57 and 121.87%, respectively, compared to the control.

The 1st harvest was after 60 days from seed sowing and extended for 30 days during the high rainfall year; however, it was after 57 days from seed sowing and extended for 27 days in the low rainfall year. Omari et al.

(2018) mentioned that the 1st harvest for snake melon in the West Bank was after about 55 days of sowing. Although the harvested yield was higher in both contour ridge and half-moon structures, it showed no significant difference ($p \leq 0.05$) between the treatments during the first 1/3 of the harvesting period (figures 2 and 3).

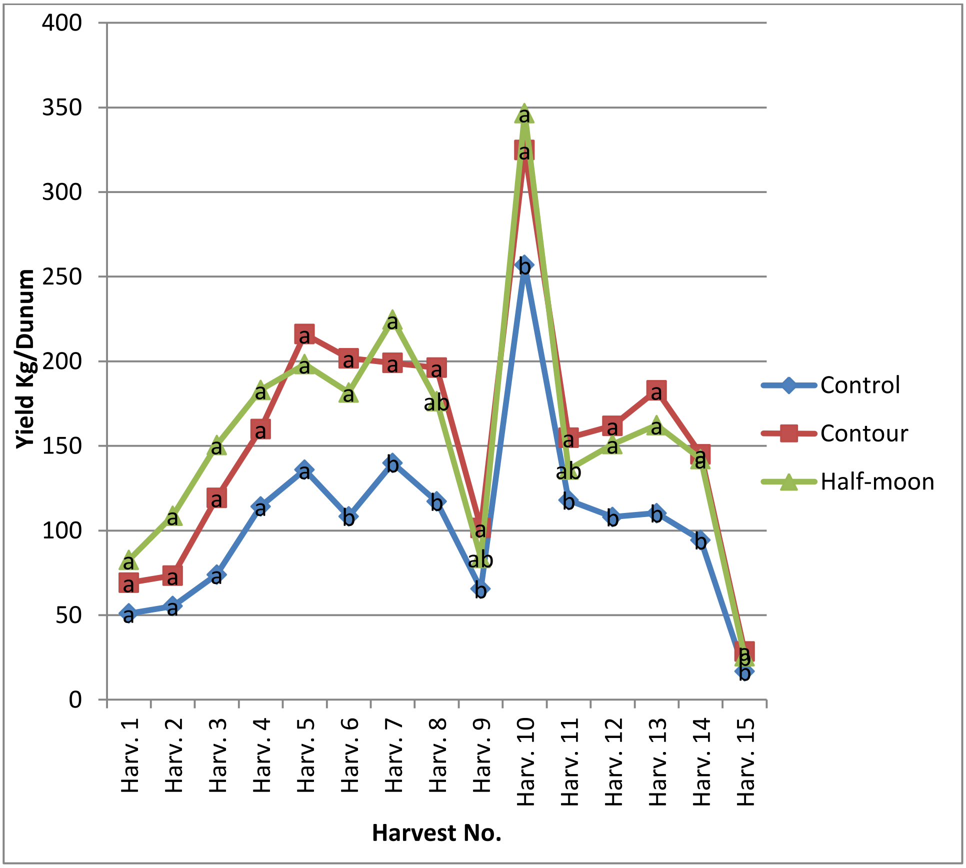

Figure 2: Average yield of snake melon (Kg/dunum) at each harvest during the year 2015/2016 for contour, half-moon and control treatments. Means with the same letter within the same harvest number are not significantly different according to Fisher LSD test at $P \leq 0.05$.

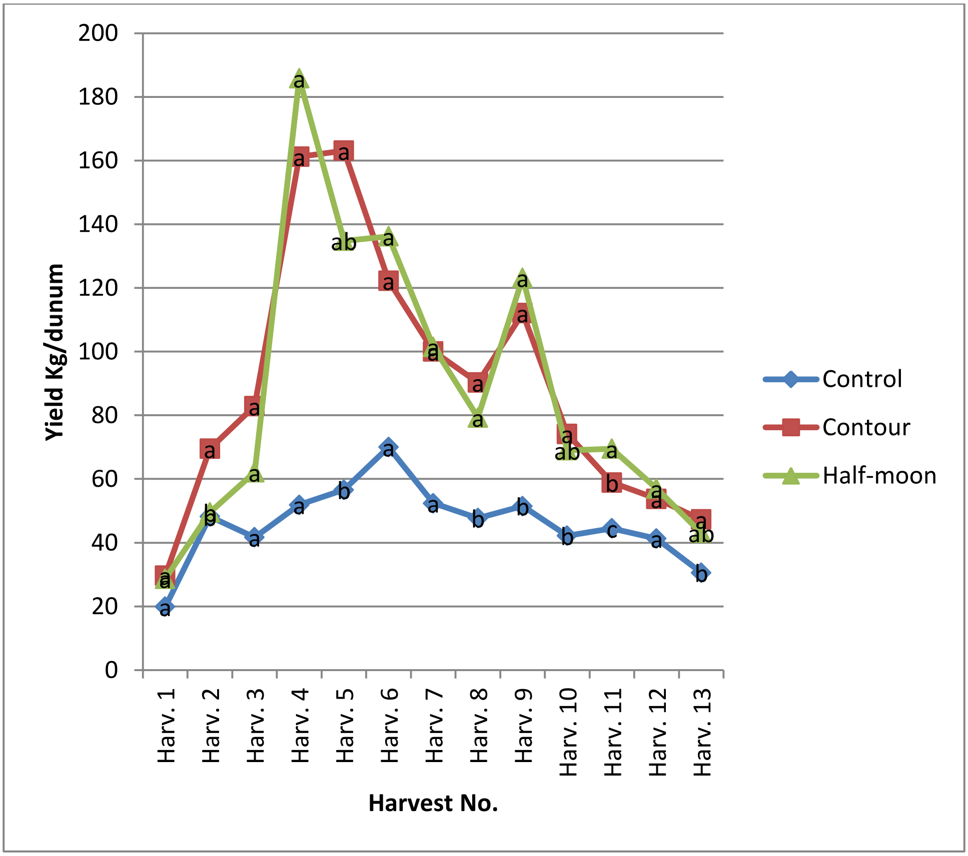

Figure 3: Average yield of snake melon (Kg/dunum) at each harvest during the year 2017/2018 for contour, half-moon and control treatments. Means with the same letter within the same harvest number are not significantly different according to Fisher LSD test at $P \leq 0.05$.

After that, and for most of the harvests of snake melon during both study years, both contour ridge and half-moon structures showed a significantly ($p \leq 0.05$) higher yield than control (figures 2 and 3). Such results might mean that during the early harvesting period, the soil moisture is not a limiting factor for the yield, but with the proceeding of the season into the higher summer temperature and low relative humidity, the soil moisture becomes a limiting factor for snake melon growth and yield. Alseekh and Mohammad (2009) found that water harvesting treatments keep soil moisture higher than it is in the control treatment; however, in all treatments it decreases as the summer season proceeds. In addition, all treatments showed approximately the same length for the period of fruit production (figures 2 and 3), which is about one month. This result might indicate that other factors such as high summer temperature and disease infection caused a decrease in the number of female flowers and fruit setting percentage during the late harvesting period. A similar conclusion was also obtained by Omari et al. (2018).

Conclusion and Recommendations

The results of this experiment demonstrated that, depending on the amount of precipitation, contour ridge and half-moon water collection techniques have the ability to improve snake melon yield by 49 to 95 percent when compared to the control treatment. When compared to high rainfall years, these strategies have been found to be more effective at increasing yield during low rainfall years.

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