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Impact of Weed Management Practices on Soil Moisture, Growth and Yield of 'Star Ruby' Grapefruit Trees under Toshka Conditions, Egypt

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A FIELD experiment was carried out in two consecutive seasons on 5-year-old grapefruit trees grown at a spacing of 4m by 5m at Toshka Research Station, South of Egypt to study the impact of environment friendly weed management practices on grapefruit growth and yield. Five treatments were tested to evaluate their effectiveness on suppressing weeds, maintenance soil moisture, promoting tree vegetative growth and yield of 'Star Ruby' grapefruit (Citrus *paradisi*): T1: hand weeding (used as the control); T2: weed flaming; T3: soil cover using weed residues; T4: cultivating Egyptian clover (*Trifolium alexandrinum*) as a cover crop; and T5: cultivating fenugreek (*Trigonella foenum*) as a cover crop. The treatments were used in a completely randomized experimental design. Weed number and fresh weight, tree canopy volume, yield and root distribution and soil moisture were measured. Results indicate that: soil moisture under the three types of soil cover (T3, T4 and T5) was significantly higher than for the control. In addition, weed abundance was significantly higher for control than for T2, T3, T4 and T5, respectively. Higher yield and larger tree canopy volume were recorded in T4 followed by T2; the least weed number resulted in T2 while T3 showed the higher root density. Based on these data and that of economic study it is recommended to use the weed flaming to manage weeds in organic grapefruit orchards and/ or cultivating cover crops for better yield and tree growth.

Keywords: Weed control, *Citrus paradisi*, Flaming, Cover crop, Yield, Tree growth

Toshka region is a new area, located South of Egypt, recently reclaimed and cultivated with the horticultural crops using the organic agriculture techniques. The region is characterized by a hot-dry summer and a warm winter. Grapefruit (*Citrus paradisi)* is one of the desirable fruits in Europe, therefore, it is a promising crop to be exported due to its nutritional value and the contents of pink and red pigments such as lycopene having beneficial antioxidant activity (Lee, 2000).

On the other hand, Toshka is known by the widespread of annual, perennial and wild plants and weeds which are considered a major problem in horticultural orchards. Thus, there is a need for weed management. The problem is more serious in organic orchards since the use of chemical herbicides is not allowed (EC, 1991a).

Most organic farmers rely on multiple tactics for weed management. Ecological weed management practices promote weed suppression rather than weed elimination by enhancing crop competition and phytotoxic effects on weeds (Kimberly, *et al.*, 2006).

The use of flamers could become an economical method of weed control for organic farming, providing a non-chemical method of controlling weeds and pests. It may also be more economic than the alternative herbicides as it also has no farm worker hazard, reentry period, or necessity for a pesticide license. However, the speed of flaming varies greatly; as they affected by the type of flamer, application rate, and climate (Ithaca, 2002).

Moreover, minimum tillage and natural and living mulches are used to regulate surface soil temperatures and reduce loss of soil moisture (Miles, *et al.*, 2005), improve soil quality, and suppress weed activity. Organic mulches suppress weeds, add organic matter to the soil during decomposition, thus increasing nutrients, soil porosity, water holding capacity, microbial populations, and cation exchange capacity of the soil. In this respect, straw and plant residue mulches are commonly used in organic horticultural operations (Sustainable Agriculture Network, 1998).

In addition, soil mulching with organic materials such as municipal yard waste, wood chips, weeds residues, straw, hay, sawdust and newspaper blocks light thus preventing weed germination and growth (Smith, *et al.*, 2000). As an example, rice straw mulch offers a practical and reliable means of conserving soil water and regulating soil temperature and it is likely to have advantageous effects on vegetative growth and yield of cultivated plants (Karaye and Yakubu, 2006).

This paper reports on experiments carried out with the aims of evaluating the effect of five practical ways to manage weeds on soil moisture and on yield of 'Star Ruby' grapefruit trees (*Citrus paradisi*).

Material and Methods

Experimental field

This experiment was conducted in two consecutive seasons (2005-2006 and 2006-2007) and carried out at the experimental farm of Toshka Research Station, located south of Egypt, 193 m above the sea level, at a latitude of 22° 22' 0" North and a longitude of 31° 37' 60" East.

The soil has a sandy loam texture (with 85% sand, 11% clay and 4% silt). Soil pH is 7.85 and its electric conductivity is 0.169 ds/m. Table 1 gives soil content of the main mineral elements.

TABLE 1. Main chemical constituents of paste extract of the soil .

N	P	K	Ca++	Mg++	Na+	Cl-	SO4	HCO3
	ppm				Meq l^{-1}			
36.00	38.00	13.04	2.99	0.70	11.46	2.94	12.90	0.53

Forty five 'Star Ruby' grapefruit (*Citrus paradisi*) trees 5-year-old and budded on Volkamer lemon rootstock were used. The trees were planted at 4m x 5 m (498 trees ha^{-1}). They are uniform in vigor and have received the customary practices for pruning, organic fertilization etc. The fertilization program was about 1.75 kg rock-phosphate / tree / year added in December in trenches made close to the root system around the tree canopy. In addition, on farm made tea compost extract was applied as foliar spray at monthly intervals from November to September. The compositions of the compost extraction tea was as follows; Ec 2.6 mm/cm, ph (7.9), NPK % were (1.6, 0.7, 1.25), Fe, Mn, Cu, Zn in ppm were (1587, 163, 65, 22).

A micro-jet irrigation system was used (4 sprinklers per tree 150 cm from tree trunk) to water the experimental trees and was done daily during Spring, Summer and Autumn, and it was done every two days during Winter. Trees received 5455 m^3 ha^{-1} $year^{-1}$. The irrigation water is derived from Nasser Lake; it has a ph of 8.3 and an electric conductivity of 0.179 ds/m. The chemical constituents of the irrigation water is shown in Table 2.

TABLE 2. Main chemical constituents of the irrigation water.

SSP %	SAR	K	Mg	Ca	Na	Cl	CO_3	HCO_3	SO_4
					Meq l^{-1}				
59	2.41	0.3	0.28	0.72	1.9	0.71	0.0	2.08	0.41

Experimental design

Five treatments were applied in a completely randomized experimental design with three replicates and three trees per replicate. These treatments are:

T1: Hand weeding (control)

Eight workers per hectare cut weeds in the area between tree rows monthly; the residues are taken a way of the farm.

T2: Weed flaming

A locally invented flamer was used (photo 1) to manage the growing weeds. Flaming was carried out after irrigation and was applied 8 times per season (Jan., Feb., March, May, July, Sept., Nov. and Dec.). It consisted in exposing the weed green biomass to the flames for 1 to 2 seconds. Two workers were used each time.

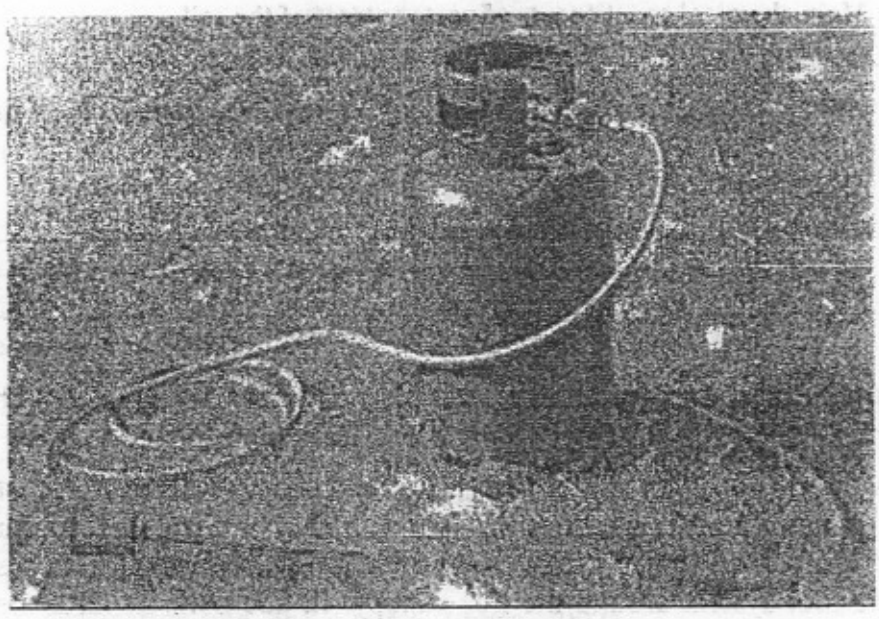

Photo 1: Locally invented weed flamer.

T3: Weed residues mulch

The cut weed residues were put as a layer to cover the entire soil between rows. The regrown weeds in the covered area were cut 5 times/season (Jan., March, June, Sept. and Dec.) and used to maintain the layer thickness to be 10 cm above soil surface.

T4: Trifolium (living mulch) + flaming

The soil between rows was well prepared and seeds of the Egyptian clover (*Trifolium alexandrinum*) were sown at the end of December 2005 at the rate of 30 kg/ha. After incorporating the cover crop into the soil in the beginning of June, the flaming method was used to mange weeds 4 times/season (at the end of June, Aug., Oct. and Dec.). Four workers were used.

T5: Trigonella (living mulch) + flaming

Fenugreek (*Trigonella foenum*) seeds were sown at the end of December 2005 at the rate of 35 kg/ha. After incorporating the cover crop into the soil in the beginning of June, the flaming method was used to mange weeds 4 times/season (at the end of June, Aug., Oct. and Dec.). Four workers were used.

Data were statistically analysed using the Statistical Analysis System (SAS, V8). The effects were tested using the general Linear Model. Multiple comparisons of means of the five treatments were performed according to Duncan's test (Snedecor & Cochran, 1972).

Soil analysis

Soil samples were taken three times (December, April and August) each season. Samples were taken horizontally at a distance 150 cm from tree trunk and vertically at a depth of (0 – 30 cm) from soil surface. Dimensions of the used auger cylinder were 5 cm radius and 25 cm height.

The samples were initially weighted and then dried at 105 °C till constant weight. Soil moisture content was calculated according to the following formula:

Soil moisture % = (Wi-Wd/Wd) *100%

where Wi: initial weight, Wd: dry weight.

Weed parameters

Weed number/0.25m^2 and fresh weight (g) were obtained by taking two samples of (0.5m*0.5m) using quadrates located 150 cm from tree trunk per each replicate in April, Aug. and December of each season.

Vegetative growth and generative attributes of grapefruit trees

Trees canopy volume (m^3) was calculated in the beginning and at the end of each growing season according to the equation: [Canopy volume = 0.5236 x canopy height x canopy diameter square] according to Turell (1965). The yearly increment was calculated.

In addition, ten shoots of the current spring flush, randomly distributed around the tree canopy, were tagged. Number of leaves per shoot were counted and leaf area (cm^2) was determined, in samples of 10 mature leaves were taken in September from the middle locations of non fruiting shoots of the previous autumn flush, using a leaf-area meter (model CI- 203, USA). The same labeled shoots were used to calculate fruit set percentage as follows: (number of set fruitlets/number of flowers) x 100.

Leaf mineral contents

Samples of mature leaves were taken in September from the middle locations of non fruiting shoots of the previous autumn flush. Samples were dried at 70 °C and finely ground and digested in a mixture of perchloric: sulphuric acid (1:3 v/v). The following determinations were carried out: total nitrogen (%) using Kjeldahl method (Naguib, 1969), phosphorus (%) by ascorbic acid method (Watanabe and Olsen, 1965), potassium using the photometric method (Brown and Lilliand, 1946).

Tree root distribution

At the end of the experimental period, root density (in g/cm^3 of soil) was determined at 100, 150 and 200 cm distance from the tree trunk and at (0–30 cm) depth in the four tree directions. The average was calculated.

Yield

The yield (in tons/ha) was theoretically calculated as = (average fruit weight x average fruit number/tree x 400 tree/ha).

Results and Discussion

Soil Moisture content

The soil moisture content of the tested treatments is shown in Fig. 1 Treatments effect was significant in both seasons. The lowest value was obtained from the hand weeding treatment while the highest soil moisture

content was recorded for the weed residue mulch in December and August measuring dates in both seasons. These results can be explained by the fact that mulching the soil with weed residues reduces soil surface temperature thus resulting in preventing soil water evaporation (Moody *et al.*, 1963).

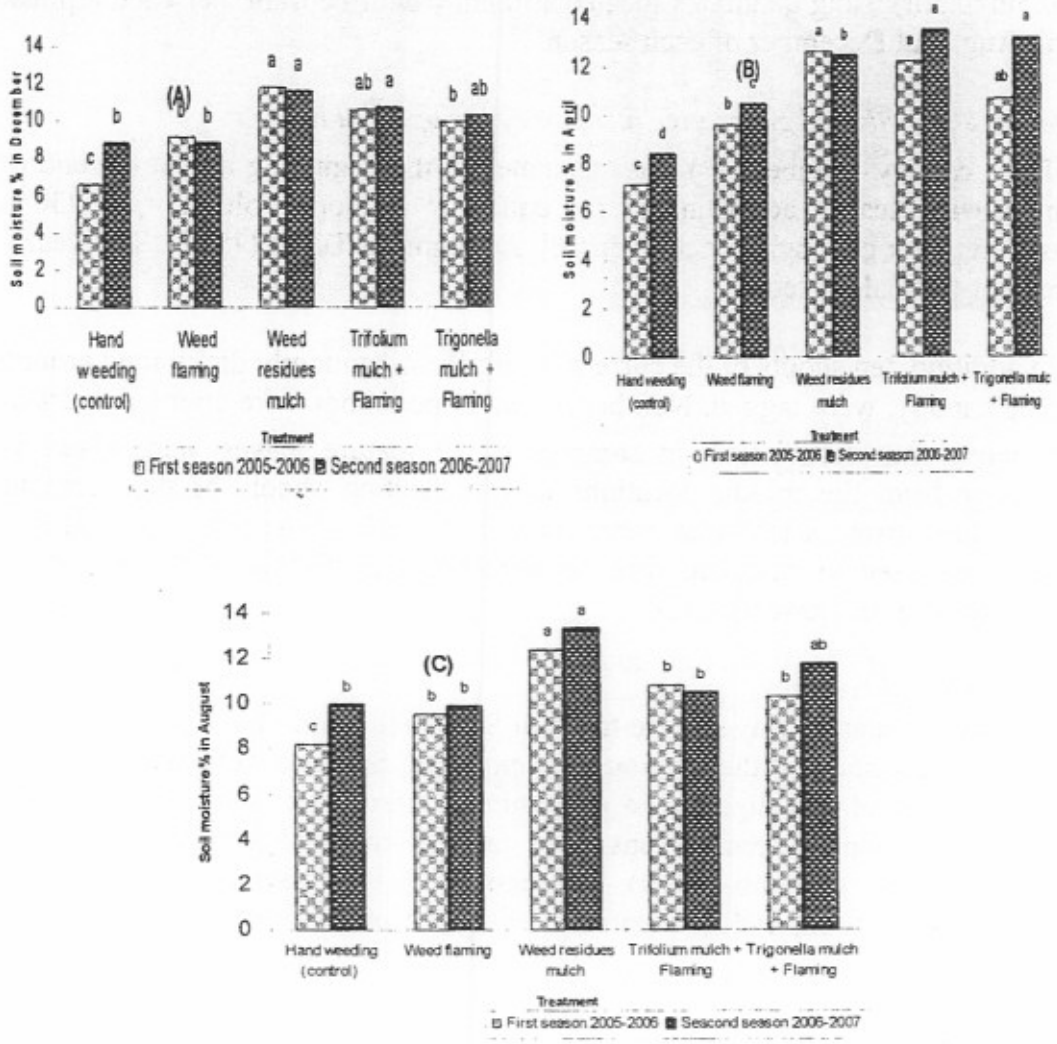

Fig. 1. Soil moisture percentages in December (A), April (B) and August (C) in both experimental seasons.

Means followed by the same letter are not significantly different at P =0.05 (Duncan test).

Moreover, decomposing of weed residues increase soil organic matter and enhances soil micro-fauna. In general, covering soil surface with living mulch increases soil moisture content (Lapointe, 2003). The increment in April was better than in December and August in both seasons. These results can be due to in December the vegetative growth of the living mulch was too low while in August the living mulch was incorporated and the soil was flamed. The lowest soil moisture content was obtained with the control treatments and the weed flaming treatments in both seasons.

Weed parameters

Fig. 2 shows the effect of weed management treatments on the weed number and fresh weight in April, August and December. The results showed significant differences in both experimental seasons. The highest weed number per 0.25 m^2 was obtained in the hand weeding treatment (control). Compared to the control, all treatments caused weed number reduction at all measurement dates. By the time, the flaming treatment severely decreased number of weeds per 0.25 m^2 .The least values of weed number and weed fresh weight were obtained when soil surface mulched with weed residues and living mulch treatments. These results may be due to the weed residues mulch prevent sunlight to reach soil surface as well as the competition between the living mulch and the weeds which reduced weed seeds germination and/or growth. With flamers, weeds are usually not burned, rather the operation proceeds at a speed such that surface vegetation is merely scorched, and essential enzymes are denatured, which disables the plants' metabolism. Weeds then wither and succumb over a period of several hours, without actually burning up. This conserves the plant residues as an organic matter and ground mulch for the soil (Ithaca, 2002). However, the difference between the two living mulch crops followed by flaming was not significant.

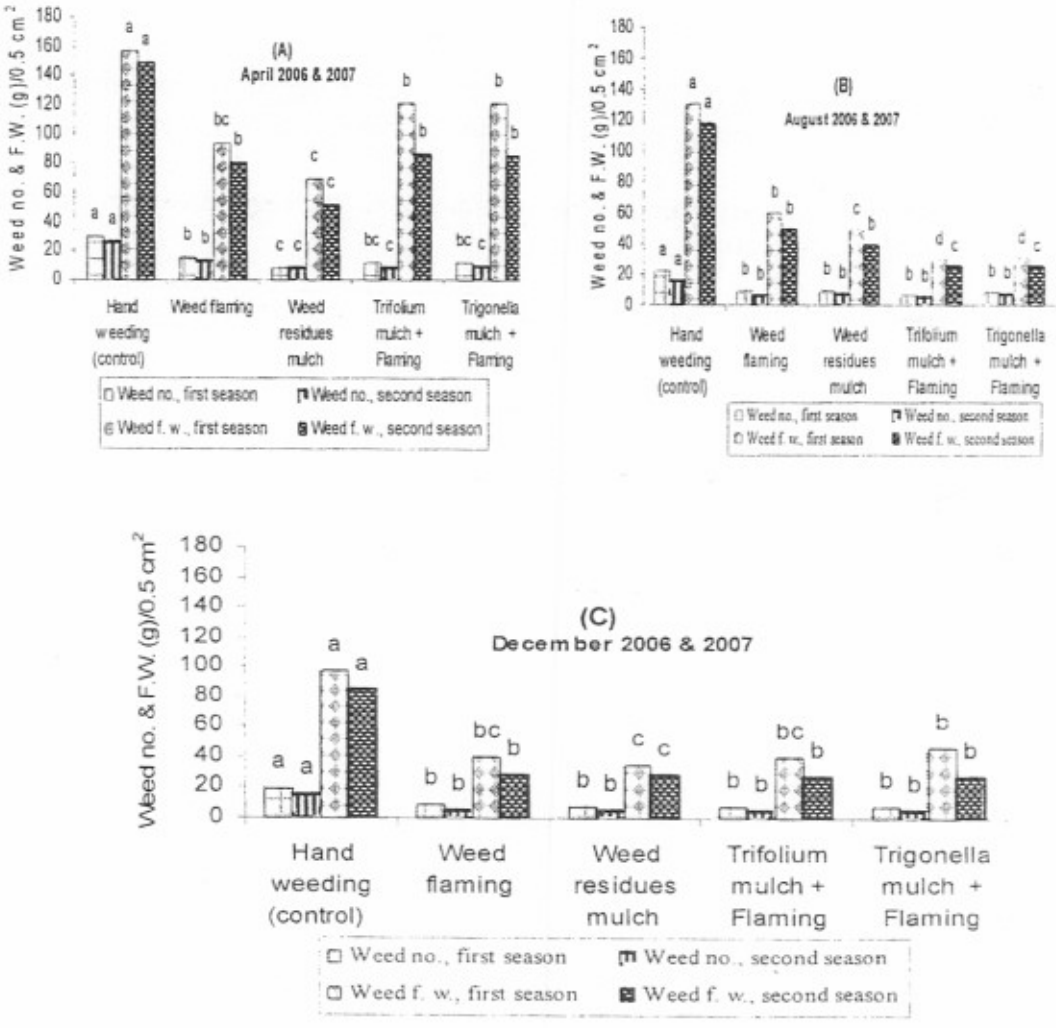

Fig.2. Weed number and weed fresh weight (g) in April (A), August (B) and December (C) in both experimental seasons.

Means followed by the same letter are not significantly different at P =0.05 (Duncan test).

These results indicate that when flamers are used, the soil is not disturbed, therefore new weed seeds aren't brought to the surface resulting in weed abundance. The weeds still look normal right after flaming, remaining green and still standing. After a few minutes to a few hours the thermal destroys plant cellular material, coagulating plant proteins, thus disabling respiration and normal plant functioning and thus weeds start to wilt and die. In the case of perennial weeds, the weeds grow back after 3 to 4 weeks therefore the mode of action is depending on the continual application to consume the reserved nutrients in the roots and other weed parts under the soil surface (Hewitt *et al.*, 1998).

Vegetative growth attributes of grapefruit trees

Table 3 shows significant differences between treatments in the case of tree canopy volume and leaf area in both seasons while the differences were significant in the first season only in the case of leaves number per shoot. In addition, the leaf N and K content showed significant differences in both experimental seasons while leaf P content showed insignificant differences between the treatments in both seasons. The obtained results can be explained by the fact that soil mulch increases soil moisture and reduces soil pH which enhance the nutrients uptakes (Bagayoko, 2000, Xiong *et al.*, 2008, Datta, and Singh, 2007).

The obtained results showed an improvement in the tree vegetative growth due to the reduction in weed competition on soil nutrition and moisture (Tucker *et al.*, 1997).

TABLE 3. The effect of weed management treatments on the vegetative parameters of the grapefruit trees.

Treatment	Tree canopy volume increment (m^3)	Leaf area (cm^2)	Leaf No./ shoot	Mineral leaf content (%)		
				N	P	K
	First season (2005-2006)					
Hand weeding (control)	0.35	33.00	25.00	1.63	0.26	1.50
Weed flaming	0.50	38.00	31.00	1.50	0.26	1.53
Weed residues mulch	0.60	40.00	33.00	1.57	0.25	1.90
Trifolium mulch + Flaming	1.00	44.00	32.00	2.70	0.26	2.27
Trigonella mulch + Flaming	0.90	40.00	30.00	2.80	0.27	2.27
LSD 0.05	0.05	1.77	4.71	0.47	N.S	0.41
	Second season (2006-2007)					
Hand weeding (control)	0.36	36.00	25.67	1.80	0.26	1.57
Weed flaming	0.57	42.00	31.33	1.77	0.26	1.70
Weed residues mulch	0.65	44.67	32.33	1.60	0.26	1.97
Trifolium mulch + Flaming	1.04	47.33	31.33	3.00	0.25	2.30
Trigonella mulch + Flaming	1.02	41.67	30.00	2.97	0.27	2.27
LSD 0.05	0.11	3.08	N.S	0.37	N.S	0.37

Fruit set and yield

Fruit set percentage data (Fig. 3) shows statistically significant differences among treatments in both experimental seasons. The least values resulted from the control treatment while the highest values were obtained from the use of weed residues and living mulch without significant differences among them. Therefore, it can be said that the reduction in weed density reduces the competition between weeds and the trees, which positively improves fruit set.

In contrary, yield differences between treatments were statistically insignificant in both experimental seasons.

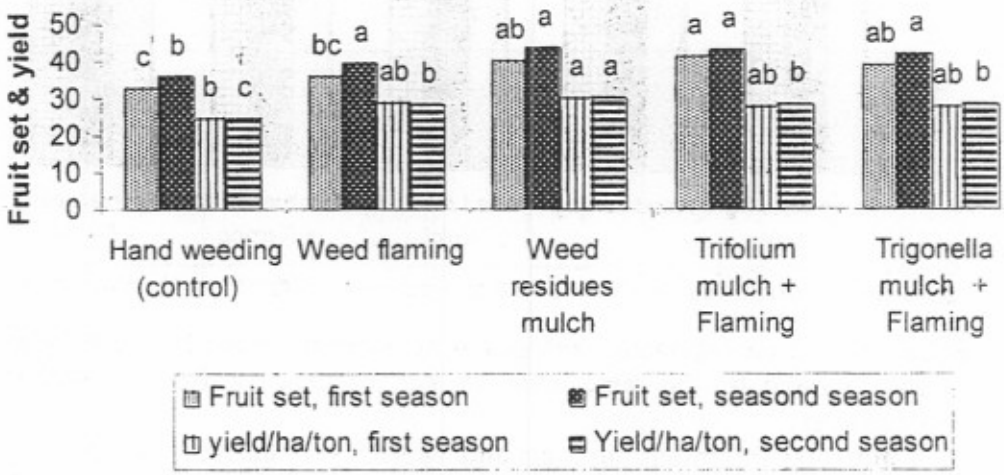

Fig. 3. Fruit set (%) and yield (tons/ha) in both experimental seasons.
Means followed by the same letter are not significantly different at P =0.05 (Duncan test).

However, the least yield resulted from the control treatments while both weed residues and the use of living mulch followed by flaming treatments gave the highest yield in comparison with the flame treatments alone. The flame treatments resulted in higher yield comparing to the control. These results give an indicator that all the weed management treatments reduce the weed competition with the experimental trees which lead to yield increment.

Tree root distribution

Fig. 4 shows the root distribution (Rd) at 100, 150 and 200 cm from tree trunk at the depth of (0-30 cm). Statistical analysis showed no significant differences between the tested treatments on Rd at 100 cm distance from tree trunk while there were significant differences at 150 and 200 cm. Root density at 150 cm was higher compared with the other two distances from tree trunk. This can be explained by the previous soil moisture results and the fact that the roots extended seeking for the area with higher soil moisture (Dasberg, 1992). The lowest root density at 150 cm resulted from the control treatment compared with the flaming treatment that has a reasonable root density value due to the renewable weeds that compete with tree roots. The results obtained from the living mulch were higher than for the control and the flaming treatments due to the less number of weeds and the better soil moisture. However, the values obtained from the weed residues

mulch were higher than the values obtained from the living mulch. This can be due to the competitiveness between the living mulch and the tree roots on the irrigation water and nutrients (Paolillo *et al.*, 1999).

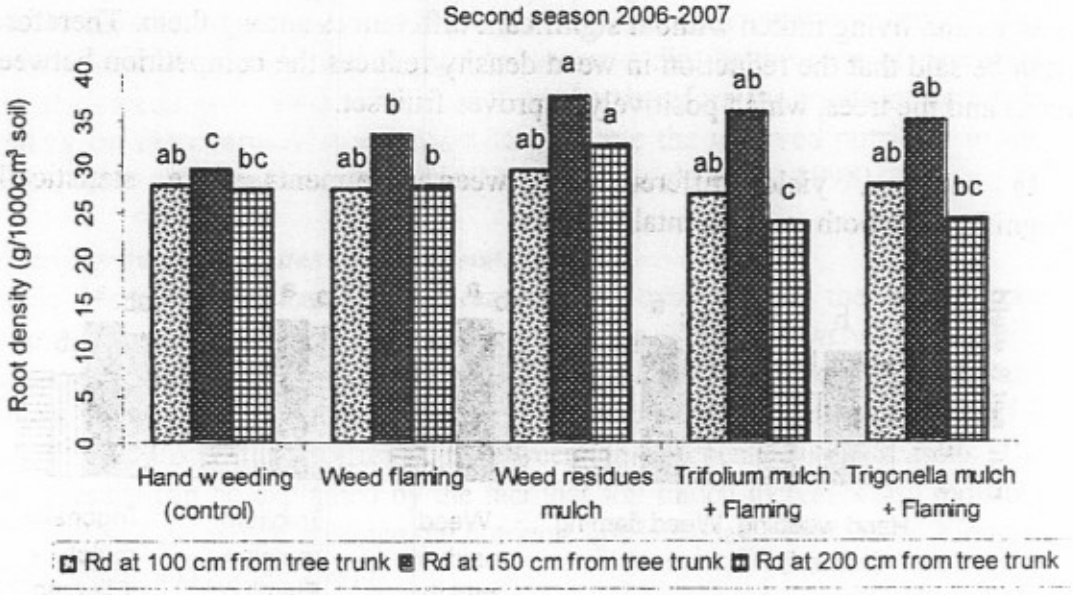

Fig. 4. Effect of weed management strategies on root density in the 2006-2007 seasons
Means followed by the same letter are not significantly different at P =0.05 (Duncan test).

Table 4 indicates treatment intervals and Table 5 summarizes total cost of one hectare of grapefruit trees under Toshka conditions. The results show that hand weeding has the highest cost followed by the two living mulch treatments. The most economical treatment was the use of weed residues followed by that of weed flaming.

TABLE 4. Treatment intervals during the experimental year .

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Treatments												
Hand weeding (control)	√	√	√	√	√	√	√	√	√	√	√	√
Weed flaming	■	■	■		■		■		■		■	■
Weed residues mulch	√		√			√			√			√
Trifolium mulch + Flaming	■	■	■	■	■	■		■		■		■
Trigonella mulch + Flaming	■	■	■	■	■	■		■		■		■

TABLE 5. Total cost of weed management per hectare of grapefruit trees under Toshka conditions, South Egypt.

Treatments	Initial preparation cost			Final cost				
	No. of labor/ ha (A)	Labor fee/day (In Euro) (B)	Total cost (in Euro) AB (T1)	No. of labor per treatmt (C)	Total cost/ each interval (in Euro) BC	Treatmt intervals /year (D)	Total cost/treatmt /year BCD (T2)	Total cost/year (in Euro) (T1+T2)
Hand weeding (control)	8	2	16	8	16	12	192	208
Weed flaming	8	2	16	2	4	8	32	48
Weed residues mulch	8	2	16	3	6	5	30	46
Trifolium mulch + Flaming	8	2	16	4	8	9	72	88
Trigonella mulch + Flaming	8	2	16	4	8	9	72	88

Recommendations

The use of weed residues as soil mulch can economically be used particularly at the infested orchards with high biomass of weeds whereas flaming works are relatively well for controlling annual weeds, but perennials may grow back rapidly after flaming or hand weeding therefore the application needs to be repeated (Storeheier, 1994). Meanwhile, the living mulch can be used in particular to give additional income as well as enhancing the soil properties of the orchards.

In contrary, flamers have disadvantages effect as they could ignite and burn mulches or other flammable materials. They are best being used following irrigation, or when there is dew on the vegetation surface to impede combustion of weeds.

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تاثير بعض معاملات مكافحة الحشائش على رطوبة التربة، النمو ومحصول اشجار الجريب فروت صنف ستار روبى تحت ظروف توشكى، مصر

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أجريت تجربة حقلية فى موسمين متتاليين على اشجار جريب فروت عمر ٥ سنوات منزرعه على مسافات 4x5 متر فى محطة بحوث توشكى ، جنوب مصر وذلك لدراسة تاثير استخدام بعض المعاملات الصديقة للبيئة لمكافحة الحشائش على نمو ومحصول الجريب فروت . تم اختبار ٥ معاملات لتقييم تاثيرها على تقليل نمو الحشائش ، الحفاظ على رطوبة التربة ، تشجيع النمو الخضرى والمحصول لاشجار الجريب فروت صنف ستار روبى وهى: (T١) الحش اليدوى للحشائش بين صفوف الاشجار (المقارنة) ، (T2) تعريض الحشائش الى درجة حراره عاليه باستخدام اللهب ، (T3) التغطية باستخدام مخلفات الحشائش ،(T4) زراعة البرسيم المصرى كمحصول تغطية ، (T5) زراعة محصول الحلبة كمحصول تغطية فى تصميم احصائى تام العشوائية . تم قياس عدد الحشائش، والوزن الغض للحشائش، حجم الاشجار، المحصول وتوزيع المجموع الجذرى ورطوبة التربة و قد أعطت رطوبة التربة نتائج معنوية تحت الثلاث معاملات للتغطية بالمقارنة بالكنترول .و قد أعطت معاملة الكنترول أكبر نسبة و كثافة للحشائش الموجوده بالمقارنة بالمعاملات T2 ،T٣ ،T٤ ، T5 على الترتيب و أظهرت النتائج أن أعلى محصول و زيادة فى حجم الأشجار قد تم الحصول عليه فى المعامله T4 تلى ذلك المعاملة T2 وكان أقل عدد للحشائش فى المعاملة T2 . وقد حققت المعاملة T٣ اعلى كثافة للجذور.

و بناء على هذه النتائج فانه و من الناحية الاقتصادية ينصح باستخدام أسلوب تعريض الحشائش الى درجة حراره عاليه باستخدام اللهب لمكافحة الحشائش فى بساتين الجريب فروت المنزرعة بأسلوب الزراعة العضوية أو بزراعة محاصيل تغطية للحصول على أفضل محصول و نمو للاشجار.

الكلمات الكشافة : مكافحة الحشائش ، الجريب فروت ، التعرض للهب ، درجات الحراره العاليه ، محاصيل التغطية ، المحصول ، نمو الشجرة .