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INCREASING ONION, GARLIC AND CARROTS YIELD AND QUALITY AND CONTROLLING WEEDS BY SOIL SOLARIZATION

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ABSTRACT

Field experiments on soil solarization were 1996/97, 1997 and 1998/99 conducted in naturally weed-infested plots of onion, garlic and carrots in 96/1997, 97/1998 and 98/1999 seasons, at the Faculty of Agriculture Vegetable Farm, Ain Shams University. The well-prepared and moistened plots were covered with transparent polyethylene mulches for the duration of 6 weeks in August and September. Soil temperatures at 0,5 and 10 cm depths were recorded in solarized and non-solarized soil.

Soil solarization raised the average maximum soil temperature at 0,5 and 10 cm depths to 56.7, 49.3 and 45.3 °C respectively. An increase of 10.8, 9.8 and 7.6 °C over the non-solarized treatments respectively. Solarized plots gave the lowest number and weight of weed / m^2. compared to the untreated plots. Solarization gave 100%, 91.5% and 54.1% weed reduction in onion and 100%, 91.1 and 35.9% weed reduction in carrot for annual brood-leaved weeds, annual grasses and perennial weeds respectively.

Solarization improved onion, garlic and carrots plant growth. Solarized treatments gave plant length, number of leaves per plant and fresh and dry weight of plant more than 20%, 21% 67% and 51% for onion, 7%, 10%, 44% and 63% for garlic and 22%, 18%, 90% and 80% for carrot of that of the control, respectively.

Yield of bulbs, average bulb weight and diameter were increased by 48.1%, 35.1% and 18.2% for onion and 38.3%, 15.1% and 11.6% for garlic, respectively by solarization over control. Also solarized plots resulted in an increase in the carrot root yield, average root weight and root shoulder diameter by 65%, 55% and 17% for early yield and by 49%, 31% and 10% for late yield, over the non-solarized treatments, respectively.

In the case of baby carrot, seed-bed solarization increased the production of marketable roots per unit area as compared with control. Solarization resulted in a 17% and 40.2% increase in total number and yield of marketable baby carrots at harvest respectively, with a 47.6% increase in yield of baby peeled carrots. The solarization methods has great advantage for production of higher yields of clean crops without herbicidal use where carrot and baby carrots are usually processed for babies and children foods and onion and garlic are exported vegetables.

Keywords: Onion, Garlic, Carrot, Baby carrots, Weeds, Soil temperature, Solarization.

INTRODUCTION

Soil solarization has been introduced in the Middle East to control weeds as part of an integrated management of soilbone pests in Mediterranean vegetable crops (Horowitz *et al.,* 1983; Abu-Irmaileh 1991; and Abdallah 1991, 1998 and 2000). Solarization is an alternative to costly and unpractical hand weeding crops, especially crops planted at high

densities such as onion, garlic, and carrots (Bell, 1998).Solarization technique is simple, preferred by consumers for reduced use of pesticides, and does not cause any pollution to the crop products and environment. Solarization is done by wetting the soil during the season, then covering it with thin transparent polyethylene sheets for a few weeks. Planting vegetable crops with minimum soil disturbance occurs after words (Abu-Irmaileh, and Saghir 1994 and Abdallah 1998 and 1999). The technique utilizes solar radiation trapped under plastic mulch to create a "greenhouse effect", heating soil to temperatures which are deleterious or lethal to soil weeds (Horowitz *et al.,* 1983; Abdel-Rahim *et al.,* 1988; Abdallah 1991, Elmore 1991, and Stapleton 1998). However, soil solarization increased soil temperature above non-solarized soil from 5 to 18 c° (Abdallah 1991, and Ayson *et al.*, 1997).

Responses of weed species to soil solarization were reported as complete control of annual weeds (Egley, 1990; Silveira *et al.*, 1990, Abdallah, 1991; Elmore, 1991 and Abdallah, 1998) and partial control of perennials (Horowitz *et al.*, 1983; Abdallah 1998 and Abdallah *et al.,* 1998).

Soil solarization up to six weeks also increased growth, yield and yield quality of onion (Hartz *et al.,* 1989, Satour *et al.*, 1989; Afek *et al.*, 1991; Adetunji, 1994; Abdallah, 1998 and Sasanelli *et al.*, 1998), garlic (Maksoud and Fayed, 1984 ; Al-Masoom *et al.*, 1993; Basallate and Meler, 1993 and Farag, 1994) and carrots (Greco and Brandonisio, 1990).

These studies aimed to test soil solarization effects on yield and quality of onion, garlic and carrot and prevailing weeds in fields. Especially production of clean carrot and baby carrot by eliminating chemical use will be of great contribution because of their use as green vegetable and in processing babies and children food.

MATERIALS AND METHODS

Four studies were conducted during 1996/97, 1997/98, and 1998/99 in the Vegetable Experimental Farm of the Faculty of Agriculture, Ain Shams University as follows:

After land preparation and leveling for onion, garlic and carrot, the field was divided into 3 x 3.5m plots. Random plots to be solarized for each crop were irrigated early in August, each year, 3 days before covering with clear polyethylene tarps 80 μm for 6 weeks during August – September. The other plots in each crop experiment, were left and prepared for planting after various and were hand weeded during growing season. A Complete Randomize Block Design with three replications was used.

Soil temperature was measured every 2 weeks during day time at the depths of 0, 5 and 10 cm, and maximum day temperature was calculated.

Onion Experiment:

Onion (*Allium cepa, L*.) seeds of the cv. Giza 20 were directly sown in the plots after plastic removal and also in non solarized plots on October 12th and 11th in both 1996 and 1997 seasons with minimum soil disturbance.

Rows were of 3.5m long and 30 cm. a part. Each plot comprised 10 rows. Seedlings were thinned to distances of about 7-10 cm.

Weed species and their dry weight were recorded after four weeks from sowing using a quadrate of 50 cm x 50 cm thrown randomly 4 times in each plot. Data of weeds in onion fields were presented as example of Allium crops as weeds in garlic field were essentially the same as in onion fields.

At 90 and 135 days after onion seed sowing, a sample of 20 onion plants were taken at random from each plot to study plant characters. After harvesting onion plants from the inside undisturbed middle 4 rows were left to cure 21 days before cutting of dry leaves and onion yield and its components were recorded.

2- Garlic experiment:

Clovers of garlic (*Allium sativum , L*.) "cv. Baladi" were planted on October 10th and 12th in both 1996 and 1997 season, respectively in both solarized and non solarized plots, with minimum soil disturbance. Rows in each plot were 3.5 m long and 30 cm apart. Each plot comprised 10 rows. Calves were spaced 7 to 8 cm within rows.

At 45 and 105 days after plating, a sample of 20 garlic plants was taken at random from each plot to study plant characters. Garlic yield and its components were recorded at harvest from the inside undisturbed 4 rows after curing as reported for onion.

3- Carrot experiment :

Seeds of carrot (*Daucus carota L*.) of cv. "Redcore Chantinay" , were sown in plots each comprised ten rows of 3.5 m long and spaced 30 cm apart after plastic removal on 12th and 11th of October in both 1996 and 1997 seasons, respectively with minimum soil disturbance. At about 3-5 cm height, seedlings were thinned leaving about 100 carrot seedlings in each row to grow for plant characters and yield measurements.

At 45, 90 and 120 days after sowing a sample of 20 carrot plants was taken at random to study plant characters. Yield and its components were recorded at early harvest (90 days) and late harvest (120 days) each from inside undisturbed 2 rows.

4- Baby carrot experiment :

The field area in baby carrots experiment was prepared and raised beds were constructed. Beds were of 3.5 m length and 75 cm apart each plot comprised 4 beds. Soil solarization started early in August and extended for 6 weeks in both 1997 and 1998 seasons.

Carrot seeds of the cv. Redcore Centenary were sown at high rate (2.5 g / m^2) and emerged seedlings were left to grow crowded without thinning till harvest.

Baby carrots were harvested after 90 days from sowing using a quadrate 50 cm x 50 cm throwm randome 4 times in middle 2 beds. Harvested marketable baby carrot roots were classified according their length into 3 groups namely small > 2.5- < 5 cm (> 1 in´ < 2 in´) , medium > 5- < 7.5 cm (> 2 in´ < 3 in´) and large > 7.5 cm (> 3 in´) in length. The yield components were recorded at harvest before and after peeling.

Statistical analysis:

Data were statistically analyzed as Complete Randomize Block Design according to Snedecor and Cochran (1980). Data of the single years and combined are presented in the tables.

RESULTS AND DISCUSSION

Effect of solarization on soil temperature:

The biweekly absolute maximum soil temperatures at 0.5 and 10 cm depths for the solarized and non-solarized treatments over the 6 weeks solarization period are presented in Table (1). The data show that covering soil with transparent plastic tarps (80 μ thick) raised the average maximum soil temperature at 0 cm. depth (soil surface) to 57, 58 and 55 °C at 2, 4, and 6 weeks after soil covering this results in an increase of 11.5, 10.0, and 11.0 °C over the non-solarized control at the respective weeks. At other depths, maximum soil biweekly temperature increased by 11.5 , 10.0, and 8.0 c° for the 5 cm depth and by 8.0, 7.5 and 7.5 C° for 10 cm depth respectively over the uncovered soil. Soil temperature increase due to solarization was previously reported by (Abu- Gharbieh *et al.,* 1990; Abdallah, 1991; Duncan *et al.*, 1992 and Abu- Blan *et al*., 1998).

Effect of solarization on weed distribution :

Soil solarization was highly effective in reducing weed distribution in the plots of onion and carrot crops after 4 weeks of sowing. Data were more pronounced for annual weeds and almost eradication of annual broad leaved weeds was observed after 6 weeks of solarization (Table 2).

However, temperature recorded in the solarized treatments at the different soil layers (Table 1) are in the range of those reported to be lethal to various weed seeds (Egley, 1990). This explains the sensitivity of annual weeds, especially annual broud- leaved weeds to soil solarization as compared to perennial ones. The perennial weeds showed less response especially in the 1st growing season to soil solarization confirming previous reports (Egely, 1983; Abdallah, 1991 and 1998 and Elmore, 1998). A few of annual grasses emerged from soil layers deeper than 10 cm (Table 2). Similar finding was also observed by Abdallah (1991).

The total number of annual grasses that emerged during 4 weeks after onion and carrot sowing in solarized plots were 8.5% and 8.9% of the control, respectively. The growth of the emerged grass weeds in solarized onion and carrot plots was lower than in control plots by about 97.5% and 95.1% in dry weight, respectively as mean of the two seasons (Table 2). Concerning perennial weeds in solarized onion and carrot plots were 45.9% and 64.1% of the control respectively as a mean of two seasons. Perennial weeds dry weight per unit area was reduced with soil solarization in onion and carrot plots by 54.4% and 38% of the control respectively ass a mean of two seasons (Table 2). This confirms the previous results obtained by Horowitz *et al.* (1983) and Abdallah (1991 and 1998).

In contrast to the solarized soil, the untreated soil showed higher population of annual weeds through the two year trails in each of onion and carrot crops. Comparison of these data with the finding in different vegetable crops showed that soil solarization at the preparation of the field had a pronounced and durable effect on the elimination of weed distribution (Maksoud and Fayed, 1984; Abu-Irmaileh and Saghir, 1991 and 1994; Farag 1994; and Abdallah 1998).

Effect of solarization on vegetative growth:

Soil solarization improved onion and garlic plant growth. The results in Table (3) indicated that soil solarization for 6 weeks gave the higher rate of all growth parameters of onion at 90 and 135 days and of garlic at 45 and 105 days after planting compared to the non-solarized (control) treatments. Solarized treatments gave plants length, number of leaves per plant, base diameter and fresh and dry weight of plant more than 20%, 21%, 39%, 67% and 51% for onion and 7%, 10%, 22%, 44% and 63% for garlic of that of the control respectively (Table 3). Increased onion or garlic plant growth after solarization was reported previously (Maksoud and Fayed 1984, Basallate and Melero, 1993 and Abdallah, 1998).

Carrot plant growth was also improved by solarization. (Table 4). Solarized treatments gave plant length, number of leaves per plant, root length, root shoulder diameter and fresh and dry weight of plants that reached 22%, 18%, 41%, 60%, 90% and 80% more than that obtained by control, respectively at 45 days from sowing (Table 4).

In general the results presented here on the effect of soil solarization on onion, garlic and carrot vegetative growth are quite similar to those observed by different workers with solarization, namely growth stimulation (Grünzweig *et al.*, 1993; Abdallah, 1998 and 2000). Whether the phenomena are due indirectly to the control of weeds and soil pests and to changes in soil properties by soil solarization and its effects on increased plant growth and development (Katan 1997, Elmore 1998 and Stapleton 1998) or directly as solarization effects on endogenous hormone biosynthesis and action (Grünzweig et al. 1993 and Abdallah 2000) or due to combination of different factors.

Effect of solarization on yield and yield components:

A substantial increase in onion and garlic yields due to solarization was observed. Soil solarization resulted in increasing weight, diameter and yield ofonion and garlic bulbs at harvest stage (Table 5). Bulb diameter, bulb weight and total bulb yield per plot increased by 18.2%, 35.1% and 48.1% for onion and by 11.6%, 15.1% and 38.3% for garlic, respectively by solarization over control, as average of both seasons. The yield improvement after solarization of onion and garlic, was also reported by Maksoud and Fayed (1984); Abdel-Rahim *et al*. (1988); Hartz *et al*. (1989); Satour *et al*. (1989), Afek *et al*. (1991); Al-Masoom *et al*. (1993); Farag (1994) and Sasanelli et al. (1998).

Early and late carrot yields were also improved by solarization (Table 5). Soil solarization resulted in increasing average root weight and total topped yield (root yield) and untopped yield (whole plants yield) per plot by

55%, 65% and 65% after 90 days from sowing and by 31%, 49% and 44% after 120 days from sowing respectively over control, as average of both seasons. The carrot yield improvement after solarization was also reported by Greco and Brandonisio (1990).

Concerning baby carrot, solarized treatments gave about 26.4% more plants per square meter than the control (about 1269 plant in solarized and 1004 plants in control). Also, solarization increased number of maketable baby carrots about 17% over control (about 854 in solarized and 730 in control). This increased number was in the medium size (12.8%) and small one (28.1%) but number of large roots decreased (Table 6). These results may by due very high densities obtained in solarized plots compared to lower ones from non-solarized. The reduction of number of plants surviving until harvesting in the non-solarized plots may result from competition with weeds and pathogens. Because the medium and small root size is the preferable sizes for baby carrot production, then it is preferred to solaize fields to obtain higher numbers of marketable baby carrots.

Soil solarization resulted in increasing baby carrot length, root shoulder diameter and root fresh weight at harvest for all root sizes before and after peeling (Table 6). Average root length, root shoulder diameter and root fresh weight increased before beeling by 11.9%, 11.6% and 21.7% for large baby root size and by 17.2%, 9.5% and 23.3% for medium root size and by 13.2%, 17.7% and 56.3% for small root size respectively by solarization than control treatments, as average of both seasons.

Solarization resulted in increasing total yield of baby carrots per square meter at harvest before and after peeling. However, total peeled baby carrot yield (large + medium + small) per square meter was 5056 g. for solarized and 3425 g. for control treatments with an increase of 47.6% for solarization than control treatment. On the other hand, yield losses due to peeling were less from solarized treatment (about 25%) than from control treatment (about 30%). These data indicate that baby carrot production in solarized plots were more homogeneous in root shape.

Generally, the yield improvement of onion, garlic, carrot and baby carrots by solarization may be mainly due the better performance of plant growth of the treatment and the solarization effects as discussed before. According to Katan (1997), the better response of solarization may by due chemical and / or biological mechanisms, which were affected by heat generation in soil by solar radiation.

Finally, it could be concluded that solarization of the soil for 6 weeks before crop sowing can be used as a new method for weed control in onion, garlic and carrot fields. This new method has advantages over herbicides in that, it is a non-chemical method; there is no harmful residual effect especially for export crops such as onion and garlic and for producing safe carrots and baby carrots as a favourable vegetable crops for processing babies and children food. Morever, the weed-Killing effect of solarization may extend to deeper soil layers and / or subsequent crops. In addition soil-solarized fields produced higher yield and better quality of onion, garlic and carrot.

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أجريت تجارب على استخدام التعقيم الشمسى لحقول البصل صنف جيزة ٢٠ والثوم البلدى والجزر صنف "شنتناى" فى مزرعة الخضر بكلية الزراعة – جامعة عين شمس فى أرض تنتشر بها الحشائش طبيعياً خلال موسمى الشتاء ١٩٩٧/٩٦ ، ١٩٩٨/٩٧ وأجريت تجربتين خلال موسمى الشتاء ١٩٩٨/٩٧ ، ١٩٩٩/٩٨ على إنتاج الجزر الصغير الحجم (بيبى) باستخدام الصنف "شنتناى". وفى جميع التجارب تم تقسيم أرض كل تجربة إلى أحواض ٣ × ٣,٥ متر وإتمام ريها ثم تغطية أحواض معاملة التعقيم الشمسى جيداً باستخدام البولى ايثيلين الشفاف بسمك ٨٠ ميكرون فى أوائل شهر أغسطس من كل عام وتستمر تغطية الأحواض لمدة ستة أسابيع تركت خلالها أحواض المقارنة بدون تغطية للعزيق والنقاوة اليدوية للحشائش خلال مواسم النمو للمحاصيل. وخلال فترة التعقيم تم تسجيل أعلى درجة حرارة يومية كل أسبوعين على ثلاثة أعماق من التربة تشمل سطح التربة وعمق ٥ سم وعمق ١٠ سم. وعقب انتهاء مدة التعقيم الشمسى تم رفع غطاء البلاستيك ورى الأحواض قبل زراعة بذور البصل والجزر وفصوص الثوم فى النصف الأول من شهر أكتوبر سنوياً.

وأظهرت النتائج أن معاملة التعقيم الشمسى أدت لارتفاع متوسط درجة الحرارة العظمى للتربة خلال فترة التعقيم إلى ٥٦,٧ ، ٤٩,٣ ، ٤٥,٣°م على أعماق سطح التربة، ٥سم ، ١٠سم على التوالى بزيادة حوالى ١٠,٨ ، ٩,٨ ، ٧,٦°م أعلى من درجة حرارة التربة فى معاملة المقارنة على نفس الأعماق على التوالى.

وبالنسبة لمقاومة الحشائش حيث تم تقدير انتشار مجاميع الحشائش المختلفة فى تجربتى البصل (للمحاصيل البصلية) والجزر (للمحاصيل الجذرية). أدت معاملة التعقيم الشمسى إلى مقاومة الحشائش الحولية عريضة الأوراق بنسبة ١٠٠% فى كلا المحصولين. وتم التخلص من الحشائش النجيلة الحولية بنسبة ٩١,٥% ، ٩١,١% فى محصولى البصل والجزر على التوالى بينما قل التأثير على مقاومة الحشائش المعمرة حيث تم تقليل نسبة مقاومتها إلى حوالى ٥٤,١% ، ٣٥,٩% فى محصولى البصل والجزر على التوالى وهذا يوضح الإبادة الكاملة للحشائش الحولية عريضة الأوراق فى تلك المزرعة باستخدام التعقيم الشمسى.

وأظهرت معاملة التعقيم الشمسى أيضاً تفوقاً فى النمو الخضرى لنباتات البصل والثوم والجزر فى مراحل النمو المختلفة حيث ازدادت نمو النباتات من حيث الطول وعدد الأوراق والوزن الطازج والجاف لأكثر من ٢٠% ، ٢١% ، ٦٧% ، ٥١% فى نباتات البصل وحوالى ٧% ، ١٠% ، ٤٤% ، ٦٣% فى حالة الثوم وكذلك ٢٢% ، ١٨% ، ٩٠% ، ٨٠% لنباتات الجزر على التوالى أكثر من معاملة المقارنة. كما زاد كل من المحصول الكلى للأبصال ومتوسط وزن وقطر البصلة بمعاملة التعقيم الشمسى بمقدار ٤٨,١%، ٣٥,١% ، ١٨,٢% فى حالة البصل وحوالى ٣٨,٣% ، ٥١,١ ، ١١,٦% فى حالة الثوم على التوالى أكثر من معاملة المقارنة.وأدى التعقيم الشمسى أيضاً إلى زيادة محصول الجزر المبكر حوالى ٦٥% والمتأخر حوالى ٤٩% بدون العرش أكثر من معاملة المقارنة.

أما بالنسبة للجزر المنزرع بكثافة عالية لإنتاج الجزر الصغير الحجم (بيبى) فقد أدى التعقيم الشمسى إلى زيادة عدد الجذور الصالحة للاستهلاك والناتجة من وحدة المساحة بمقدار حوالى ١٧% أكثر من معاملة المقارنة. كما ازداد المحصول النهائى بعد التقشير والإعداد للاستهلاك بمقدار حوالى ٦.٤٧% مقارنة بالمحصول الناتج من معاملة المقارنة.

ومن النتائج المتحصل عليها تأكد أهمية استخدام التعقيم الشمسى كطريقة ناجحة فى مقاومة الحشائش لحولية وتحسين إنتاج محاصيل البصل والثوم والجزر دون اللجوء لاستخدام المبيدات من ناحية إلى جانب توافر مواصفات الجودة وكمية الإنتاج من المحاصيل الخالية من المبيدات وذات الأهمية التصديرية (كالبصل والثوم) والتى يمكن أن تفتح مجالات تصديرية واسعة للخلو من المبيدات كما أن المحاصيل ذات الأهمية التصنيعية لتغذية الرضع والأطفال كالجزر الصغير (بيبى) والتى يعتبر خلوها تماماً من المبيدات ضرورة لاستعمالها فى تصنيع الأغذية حيث لا يجب أن يتوفر أى آثار للمبيدات فى أغذية الرضع والأطفال.

Table (3) : Onion and garlic plant growth characters for control and solarized treatments at different dates during 2 seasons.

Growing season / Plant characters	96/1997			97/1998			Combined		
	Control	Solarized	significance	Control	Solarized	significance	Control	Solarized	Significance
Onion / 90 days after sowing									
Plant length (cm)	45.8	57.7	S	50.5	58.3	NS	48.2	58.0	S
Number of leaves / plant	5.0	5.6	NS	4.8	5.9	S	4.9	5.8	S
Base diameter (cm)	1.5	2.0	NS	1.5	1.8	S	1.5	1.9	S
Plant fresh weight (g)	19.8	37.8	NS	20.7	30.2	S	20.3	34.0	S
Plant dry weight (g)	2.23	3.80	NS	2.38	3.17	S	2.31	3.49	S
Onion / 135 days after sowing									
Plant length (cm)	57.7	73.0	S	67.0	74.1	NS	62.4	73.6	S
Number of leaves / plant	6.1	7.9	S	6.6	7.6	NS	6.4	7.8	S
Base diameter (cm)	2.1	3.3	S	2.5	3.1	NS	2.3	3.2	S
Plant fresh weight (g)	62.5	100.1	S	76.8	92.1	S	69.7	96.1	S
Plant dry weight (g)	8.91	15.48	S	11.19	14.50	S	10.05	14.99	S
Garlic / 45 days after planting									
Plant length (cm)	31.5	34.5	S	30.2	32.4	S	30.9	33.5	S
Number of leaves / plant	4.6	4.9	NS	4.7	4.9	NS	4.7	4.9	NS
Base diameter (cm)	0.49	0.63	S	0.47	0.58	NS	0.48	0.61	S
Plant fresh weight (g)	4.9	6.0	S	4.6	5.3	S	4.8	5.7	S
Plant dry weight (g)	1.04	1.10	NS	0.98	0.96	NS	1.01	1.03	NS
Garlic / 105 days after planting									
Plant length (cm)	52.8	57.2	NS	50.8	53.9	S	51.8	55.6	S
Number of leaves / plant	6.7	7.5	S	6.9	7.4	NS	6.8	7.5	S
Base diameter (cm)	1.50	1.87	S	1.44	1.73	S	1.47	1.8	S
Plant fresh weight (g)	19.6	29.3	S	18.3	25.4	S	19.0	27.4	S
Plant dry weight (g)	3.62	6.25	NS	3.42	5.27	S	3.25	5.76	S

S = Significant at 0.05 level
NS = Not significant

Table (4) : Carrot plant growth characters in control and solarized treatments at different dates during 2 seasons.

Growing season / Plant characters	96/1997			97/1998			Combined		
	Control	Solarized	significance	Control	Solarized	significance	Control	Solarized	significance
	45 days after sowing								
Plant length (cm)	12.1	13.9	NS	13.8	17.8	NS	13.0	15.9	S
Number of leaves / plant	4.0	4.8	NS	4.5	5.4	S	4.3	5.1	S
Root length “cm”	3.7	4.8	S	3.5	5.4	S	3.6	5.1	S
Root shoulder diameter “cm”	0.29	0.43	S	0.27	0.46	S	0.28	0.45	S
Plant fresh weight (g)	0.92	1.74	S	1.10	2.10	NS	1.01	1.92	S
Plant dry weight (g)	0.12	0.21	S	0.18	0.33	NS	0.15	0.27	S
	90 days after sowing								
Plant length (cm)	30.3	38.4	S	32.9	35.2	NS	31.6	36.8	S
Number of leaves / plant	11.4	13.5	NS	10.8	11.7	NS	11.1	12.6	S
Root length “cm”	9.3	11.3	S	10.2	12.0	NS	9.8	11.7	S
Root shoulder diameter “cm”	2.7	3.2	NS	3.0	3.6	S	2.9	3.4	S
Plant fresh weight (g)	48.5	75.2	NS	48.6	71.2	S	48.6	73.2	S
Plant dry weight (g)	5.34	7.61	NS	5.39	7.18	S	5.37	7.40	S
	120 days after sowing								
Plant length (cm)	41.2	47.0	S	41.9	46.1	S	41.6	46.6	S
Number of leaves / plant	18.4	21.5	S	17.6	19.4	S	18.0	20.5	S
Root length “cm”	11.5	13.2	S	11.7	13.5	NS	11.6	13.4	S
Root shoulder diameter “cm”	3.9	4.3	S	4.0	4.5	S	4.0	4.4	S
Plant fresh weight (g)	142.2	177.5	S	143.0	176.6	NS	142.6	177.1	S
Plant dry weight (g)	22.18	26.52	S	22.37	26.03	NS	22.28	26.28	S

S = Significant at 0.05 level **NS = Not significant**

Table (5) : Cured onion and garlic (3 weeks after harvest) and carrot (early and late) yield characters in control and solarized treatments in both growing seasons.

Growing season	96/1997			97/1998			Combined		
Plant characters	Control	Solarized	significance	Control	Solarized	significance	Control	Solarized	Significance
Cured onion									
Bulb diameter (cm)	5.5	6.9	S	5.4	6.0	NS	5.5	6.5	S
Bulb weight (g/plant)	68.7	98.9	S	62.4	78.2	NS	65.6	88.6	S
Bulb yield (kg./plot)[1]	25.28	37.12	S	22.41	33.53	NS	23.85	35.33	S
Cured garlic									
Bulb diameter (cm)	4.4	4.7	NS	4.2	4.9	S	4.3	4.8	S
Bulb weight (g/plant)	26.7	28.0	NS	23.6	29.9	S	25.2	29.0	S
Bulb yield (kg./plot)[1]	7.87	9.53	NS	6.02	9.67	S	6.95	9.60	S
Carrot / 90 days (early harvest)									
Root fresh weight (g/plant)	29.7	45.6	NS	29.5	46.4	S	29.6	46.0	S
Topped yield (root yield) kg/plot.	14.20	22.69	S	14.17	24.37	S	14.19	23.53	S
Untopped yield (wole yield) kg/plot.	22.77	38.62	S	23.40	37.68	S	23.09	38.15	S
Carrot / 120 days (late harvest)									
Root fresh weight (g/plant)	91.2	118.3	S	90.8	121.0	NS	91.0	119.7	S
Topped yield (root yield) kg/plot.	23.17	34.27	S	23.46	35.27	NS	23.32	34.77	S
Untopped yield (wole yield) kg/plot.	34.53	50.67	S	34.94	49.48	NS	34.74	50.08	S

S = Significant at 0.05 level NS = Not significant

1 = Plot = 10.5 m^2 ($^1/_{400}$ faddan)

Table (6): Marketable baby carrot characteristics at harvest (90 days after sowing) in solarized and control treatments in both growing seasons.

Growing season	97/1998			98/1999			Combined		
characters	Control	Solarized	Significance	Control	Solarized	significance	Control	Solarized	Significance
Large roots > 7.5 cm (> 3 in)									
Number of roots / m^2	57	35	S	65	30	S	61	32.5	S
Root length “cm” before peeling	8.5	9.6	NS	8.3	9.2	NS	8.4	9.4	S
Root length “cm” after peeling	7.5	8.2	NS	6.5	7.9	S	7.0	8.1	S
Root shoulder diameter “cm” before peeling	2.36	2.47	NS	2.14	2.55	S	2.25	2.51	S
Root shoulder diameter “cm” after peeling	2.05	2.32	NS	1.86	2.39	S	1.96	2.36	S
Root fresh weight (g) before peeling	22.0	25.1	S	14.7	19.6	S	18.4	22.4	S
Root fresh weight (g) after peeling	17.9	20.9	NS	12.2	16.4	NS	15.1	18.7	NS
Total yield (g/m^2) before peeling	1234	880	S	960	588	NS	1097	734	S
Total yield (g/m^2) after peeling	925	672	S	688	445	NS	807	559	S
Medium roots > 5- < 7.5 cm (>2 in´ < 3 in´)									
Number of roots / m^2	262	299	NS	199	221	NS	230.5	260	NS
Root length “cm” before peeling	5.8	6.8	S	5.7	6.7	NS	5.8	6.8	S
Root length “cm” after peeling	5.3	5.9	NS	4.7	5.6	S	5.0	5.8	S
Root shoulder diameter “cm” before peeling	1.86	1.98	NS	1.72	1.94	S	1.79	1.96	S
Root shoulder diameter “cm” after peeling	1.74	1.86	NS	1.60	1.81	S	1.67	1.84	S
Root fresh weight (g) before peeling	11.1	13.5	NS	9.5	11.8	S	10.3	12.7	S
Root fresh weight (g) after peeling	8.2	10.2	NS	6.9	9.2	S	7.6	9.7	S
Total yield (g/m^2) before peeling	2895	3996	S	1902	2595	NS	2399	3296	S
Total yield (g/m^2) after peeling	2145	3152	S	1345	1965	NS	1745	2559	S
Small roots > 2.5- < 5 cm (>1 in´ < 2 in´)									
Number of roots / m^2	374	547	S	503	576	NS	438.5	561.5	S
Root length “cm” before peeling	3.7	4.3	S	3.8	4.3	NS	3.8	4.3	S
Root length “cm” after peeling	3.3	3.8	S	3.0	3.7	S	3.2	3.8	S
Root shoulder diameter “cm” before peeling	1.33	1.52	NS	1.27	1.53	NS	1.30	1.53	S
Root shoulder diameter “cm” after peeling	1.21	1.44	NS	1.15	1.39	S	1.18	1.42	S
Root fresh weight (g) before peeling	3.5	5.0	NS	2.8	4.9	S	3.2	5.0	S
Root fresh weight (g) after peeling	2.7	3.7	S	1.85	3.37	S	2.28	3.54	S
Total yield (g/m^2) before peeling	1283	2737	S	1420	2800	S	1352	2769	S
Total yield (g/m^2) after peeling	823	1961	S	924	1917	S	874	1939	S

S = Significant at 0.05 level
NS = Not significant

Table (1) : Maximum soil temperatures at various soil depths for solarized and control plats during 2 season.

Time of measuring soil temperature		Maximum temperatures (c°) at different soil depths (cm)									Ambient (c°)		
		0 cm.			5 cm.			10 cm.					
		1996	1997	Average	1996	1997	Average	1996	1997	Average	1996	1997	Average
2 weeks													
	Control	48	43	45.5	40	38	39.0	38	37	37.5			
	Solarized	58	56	57.0	51	50	50.5	45	46	45.5	37	37	37.0
4 weeks													
	Control	48	48	48.0	42	39	40.5	41	38	39.5			
	Solarized	57	59	58.0	50	51	50.5	46	48	47.0	40	40	40.0
6 weeks													
	Control	44	44	44.0	40	38	39.0	36	36	36.0			
	Solarized	54	56	55.0	47	47	47.0	42	45	43.5	34	38	36.0
Average													
	Control	46.7	45.0	45.9	40.7	38.3	39.5	38.3	37.0	37.7			
	Solarized	56.3	57.0	56.7	49.3	49.3	49.3	44.3	46.3	45.3	37.0	38.3	37.7

Table (2) : Number and dry weight of weeds in onion and carrot field after 4 weeks from sowing in solarized and control treatments during 2 seasons.

Crop.		Onion								Carrot							
Characters		Number of weeds / m^2				Dry weight of weeds (g/m^2)				Number of weeds / m^2				Dry weight of weeds (g/m^2)			
Growing season	treatments	Perennial weeds	Annual grasses	Anneal broad leaved weeds	Total weeds	Perennial weeds	Annual grasses	Annual broad leaved weeds	Total yield	Perennial weeds	Annual grasses	Annual broad leaved weeds	Total yield	Perennial weeds	Annual grasses	Annual broad leaved weeds	Total yield
96/1997	Control	88	110	553	751	14.4	26.2	33.6	74.3	30.7	35.3	584	650	6.6	8.3	35.0	49.8
	solarized	72	11	0	83	13.3	0.5	0.0	13.8	17.3	3.7	0	21	3.5	0.4	0.0	3.9
	Significance	NS	S	S	S	NS	S	S	S	S	S	S	S	S	S	S	S
97/1998	Control	171	255	441	867	36.6	22.6	25.4	84.5	31.7	41.3	497	570	5.6	7.1	34.4	47.2
	solarized	47	20	0	67	9.9	0.7	0.0	10.6	22.7	3.0	0	25.7	4.1	0.4	0.0	4.5
	Significance	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Combined	Control	129.5	182.5	497	809	25.5	24.4	29.5	79.4	31.2	38.3	540.5	610.0	6.1	7.7	37.7	48.5
	solarized	59.5	15.5	0	75	11.6	0.6	0.0	12.2	20.0	3.4	0	23.4	3.8	0.4	0.0	4.2
	Significance	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

S = Significant at 0.05 level
NS = Not significant