Egypt. J. Phytopathol., Vol. **30**, No.1, pp. 57-66 (2002)

Soil Solarization for the Control of Fusarium Disease of Gladiolus (*Fusarium oxysporum* f.sp. *gladioli*) in the Field and its Effects on the Yield Components

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Efficacy of solarization (solar heating) against Fusarium disease of gladiolus was evaluated for the first time in Egypt. Sandy clay soil mulching with polyethylene sheets (200μ thick) for 6 weeks during summer of 1997 and 1998 (28 July - 7 Sept.) raised the maximum soil temperature to 42°C-48°C instead of 33°C-34°C in the unmulched soil. High drop in total count of soil microorganisms; fungi (91.40% and 92.68%), bacteria (46.0% and 51.90%) and actinomycetes (90.90% and 87.69%) was recorded in the solarized soil in comparison with the same soil before mulching.

The survived gladiolus plants in mulched areas reached 100%, in both seasons, against 62.5% and 66.5% in unmulched soil. High reduction in Fusarium disease occurrence on: (1) field plants (86.67% and 100.0%), (2) the produced corms (90.26 and 76.43%) and the stored corms (56.86% and 51.61%) were recorded for both experimental seasons.

As for flower yield (flowering %, spike length and No. of florets/spike), solarized soil realized high increase values of such parameters in both seasons, *i.e.* (43.84% and 49.81%), (46.33% and 53.33%) and (74.96% and 91.34%), respectively. Whereas, increases by (90.95% and 82.30%) and (36.66% and 36.97%) in No. of corms/plot and weight/corm, respectively, as well as (46.74% and 103.81%) and (400.0% and 306.25%) for the same parameters of cormels were recorded.

Key words: Corm yield, *F. oxysporum* f.sp. *gladioli*, gladiolus, solarization and Flower yield.

Fusarium disease (*F. oxysporum* Schlecht. f.sp. *gladioli* (Massy) Snyd. & Hans.) causes heavy losses in gladiolus plantations in Egypt as well as corms in stores (Hilal *et al.*, 1994 and Abdel-Malak, 2000). The disappearance of visible infection symptoms on the corms of planting stock, *i.e.* latent infection (Henis and Ziberstein, 1973 and Magie, 1984) and continuously of planting gladiolus in the same land with weak sanitation methods and control programmes are very important factors causing these pronounced losses.

Solarization is inexpensive and effective means of pasteurizing soil whereby solar energy entrapped beneath plastic sheets spreads on the soil surface (Jarvis, 1992). The process was first described by Katan *et al.* (1976) and nowadays it is practiced in Mediterranean countries for many soil types (Tjamos and Faridis, 1980; Tjamos, 1983, Malathrakis *et al.*, 1983; Garibaldi and Tamietti, 1984 and Yih and Hwa, 1995).

Mulching with polyethylene sheets increased the soil temperature which resulted in the control of soilborne pathogens (Jacobsohn *et al.*, 1980; Sztejnberg *et al.*, 1987; Sarhan, 1990 and Satour *et al.*, 1990). Formae specialis of *F. oxysporum* were sensitive to solarization, therefore, inocula of each was reduced or eliminated in soil, so the disease incidence was always depressed (Sepulveda *et al.*, 1997; Montealergre *et al.*, 1997 and Elena and Tjamos 1997a and b).

In Egypt, there are no pervious studies concerning the efficacy of soil solarization for the control of Fusarium disease of gladiolus, therefore, the purposes of this investigation were: (1) to determine the elevation in temperature of mulched soil and the reduction in the total microbial counts and (2) to evaluate the efficacy of soil solarization on disease incidence (fields and stores) and production of gladiolus yields (flowers , corms and cormels).

Materials and Methods

Field experiments:

Field experiments were carried out at Mansouryia, Giza governorate, during two successive seasons 1997/1998 and 1998/1999. The chosen sandy clay soil has been previously cultivated with gladiolus and recorded as heavy infested with *Fusarium oxysporum* f.sp. *gladioli*. Five replicates were used for mulched or unmulched soil. Sixty healthy corms of cv. Peter Pears were planted per each replicate; 20 corms/row.

The effect of soil mulching with transparent polyethylene sheets (4.5 m width and 200 μ thick) during summer season and before planting on Fusarium disease incidence and yield components of gladiolus was studied. Soil was flooded with water 2 days before mulching and the control plots were watered only. Mulching treatment was for 6 weeks (28 July - 7 September) before removing the sheets. A block of soil (100 m^2) was divided to 5 plots (20 m^2 each) as replicates and covered with one long sheet of polyethylene. Other block was used as check. Soil temperatures were measured by distance thermograph at a depth of 20 cm in solarized and non-solarized.

The total number of microorganisms, *i.e.* bacteria, fungi and actinomycetes was also determined in soil samples of mulched as well as unmulched soils. Determinations were done twice; the first was before soil mulching and the second after removing the sheets. Soil samples from each plot were collected from the upper layer (30 cm) in plastic bags. Samples from each treatment were mixed to prepare a stock for determinations.

The dilution-plate counts technique (Johnson *et al.*, 1960) was used for the assessment of the soil microflora including the total fungi, bacteria and actinomycetes. Ten grams of soil were shaken in 90 ml of sterilized distilled water in a 250 ml flask for 20 minutes on a shaker to make a $1/10^{th}$ dilution of soil sample. Serial dilutions up to 10^{-7} were prepared in a similar fashion by transferring 10 ml of soil suspension to 90 ml sterilized distilled water in 250 ml flasks. Portions of 1.0 ml soil suspension from each of the dilutions 10^{-4}, 10^{-5} and 10^{-7} were transferred to 4 sterile Petri dishes. The respective cooled melted media were poured, about 20 ml to each plate.

Total fungi were counted on Peptone Dextrose Agar medium at the dilution of 10^{-5} at 25°C for 3-4 days. Bacteria were counted on Soil Extract Agar medium at dilution of 10^{-7} at 25°C for 2 days. The actinomycetes were counted on Jensen's agar medium (Jensen, 1930) at dilution of 10^{-4} at 25°C for 5 days.

The number of colonies appeared were counted in each plate till the number of any was nearly fixed. Each microbial colony was considered to originate from one microbial cell. The average number of the colony forming units (cfu) was calculated in each plate for all treatments. The total counts of soil microflora were adjusted to one-gram soil.

The recommended agricultural practices were carried out as usual. Germination of corms, plant growth parameters and yield of flowers, corms and cormels were determined as follows:

1. Percentages of emerged seedlings, 30 days after planting (survivals).
2. Percentage of diseased (wilted) plants, 90 days after planting.
3. Percentages of flowering plants, during growing season.
4. Length of spike (cm).
5. Number of flowers/spike.
6. Number of new sound corms.
7. Average weight of new sound corms (g per one cormel).
8. Number of new sound cormels.
9. Average weight of new sound cormels (g per one cormel).
10. Percentage of diseased (rotted) corms:
    a. At harvest.
    b. After storing at 5°C for 60 days.

All corms were examined during storage period for symptoms of corm rot and were excluded after their record. At the end of storage period, the percentage of diseased (rotted) corms was calculated.

Results

I. Effect of soil solarization in the field during summer season (1997 and 1998) on the total microbial count (fungi, bacteria and actinomycetes):

Data in Table (1) show the total number of fungal and bacterial colonies isolated from solarized soil (mulched with transparent polyethylene sheets for

Table 1. Effect of soil solarization on microorganisms population at Mansouriya (Giza governorate) during two successive seasons 1997 and 1998

No of forming * units (cfu)	1997		1998	
	Mulched** soil	Unmulched soil (Control)	Mulched soil	Unmulched soil (Control)
1. Fungi				
Pre-treatment	26.25	27.25	20.50	19.50
After-treatment	2.25	16.75	1.50	11.20
Reduction %	91.40	38.53	92.68	24.56
2. Bacteria				
Pre-treatment	12.50	13.50	15.60	14.75
After-treatment	6.75	10.50	7.50	11.25
Reduction %	46.00	22.22	51.90	23.73
3. Actinomycetes				
Pre-treatment	5.50	4.50	6.50	5.50
After-treatment	0.50	3.50	0.80	3.90
Reduction %	90.90	22.22	87.69	29.10

* cfu: colony forming units.

** The real number of cfu is multiplied by 10^4 for fungi, 10^7 for bacteria and 10^5 for actinomycetes in one gram of soil.

6 weeks during 21 July - 7 September) as compared with unmulched soil. It is clear that soil mulching has resulted in a great reduction in fungi, actinomycetes and bacteria as compared with the unmulched soils (control). The reduction in fungal colonies reached (91.43 and 92.68%) at 1997 and 1998, respectively, where it reached 46.00 and 51.97% in bacteria for the same two seasons. As for actinomycetes, the reduction percentages reached 90.0 and 87.69% indicating similar response to fungi.

II. Effect of soil mulching with transparent polyethylene on soil temperature:

Data in Table (2) show the temperature degrees of field soil plots under mulching treatments during the period form July 28th till September 7th of the two successive seasons, *i.e.* 1997 and 1998. It is obvious that covering the watery flooded soil with polyethylene during summer (42 days) has raised the temperature degrees of soil to a range between (18-50%) and (15-48%), respectively.

III. Effect of solar heating (solarization) on Fusarium disease incidence and quantity and quality parameter of gladiolus yield:

Data in Table (3) indicate the effect of mulching of field soil for 6 weeks on Fusarium disease occurrence and quantity and quality parameters of gladiolus yields. It is evident that mulched soil enhanced great increase of survived seedlings 30 days after planting as it reached 100% at both seasons (1997/1998 and 1998/1999). However, increases relative to the unmulched soil reached 60.00%

Table 2. Effect of solar heating (solarization) for six weeks during summer season on soil temperature, 1997 and 1998 seasons

Date of temperature recorded		Mulched soil		Unmulched soil		Raise (%) *	
		Min.	Max.	Min.	Max.	Min.	Max.
28/7	1997	37.3	48.2	29.0	33.5	28.6	43.9
	1998	38.1	49.0	29.4	38.6	29.6	26.6
4/8	1997	38.6	46.1	29.1	39.1	32.6	17.9
	1998	35.4	46.1	28.9	38.5	22.5	19.7
11/8	1997	35.2	47.3	28.3	35.2	24.4	34.4
	1998	36.0	48.2	29.3	35.3	22.9	36.5
18/8	1997	36.4	44.4	28.9	35.0	26.7	26.9
	1998	35.5	46.2	29.5	36.4	20.3	26.6
25/8	1997	37.5	46.1	29.1	33.5	28.9	37.6
	1998	36.1	42.4	30.3	34.4	19.1	23.3
3/8	1997	37.3	42.3	28.2	34.4	32.3	23.0
	1998	35.1	44.0	27.5	34.5	27.6	27.5
7/9	1997	35.1	48.2	27.4	32.5	28.1	48.3
	1998	35.0	46.0	28.2	35.5	24.1	29.6

* Raise relative (%) to unmulched soil.

and 50.38% for both trial seasons. Also, high reduction in Fusarium disease incidence in field at 90 days of planting (86.67% and 100.0%) and on corms at harvest (90.26% and 76.43%) or at the end of storage period (56.86% and 51.61%) were counted for both seasons if compared with the unmulched soil.

Table 3. Effect of solar heating (solarization) for six weeks during summer on Fusarium disease incidence and quantity and quality parameters of gladiolus yield components, 1997/1998 and 1998/1999 seasons

Parameters studied	1997/1998			1998/1999		
	Mulched soil	Unmulched soil	Increase or*** decrease (%)	Mulched soil	Unmulched soil	Increase or decrease (%)
Survivals * (%)	100.00	62.50	60.00	100.00	66.50	50.38
Diseased plants** (%)	1.00	7.50	(-)86.67	0.0	10.50	(-)100.00
Flowering plants (%)	99.25	69.00	43.84	100.00	66.75	49.81
Spike length (cm)	95.32	65.14	46.33	99.08	64.62	53.33
No. of florets/spike	17.12	9.80	74.69	17.68	9.24	91.34
No. of corms/plot	105.50	55.25	90.95	103.00	56.50	82.30
Mean weight of one corm (g)	18.19	13.31	36.66	15.71	11.47	36.97
No. of cormels/plot	504.20	343.60	46.74	716.20	351.40	103.81
Mean weight of one cormet (g)	1.25	0.25	400.00	1.30	0.32	306.25
Diseased corms (%) at harvest	3.75	38.50	(-)90.26	9.25	39.25	(-)76.43
Diseased corms (%) after storing at 5°C for 120 days	5.50	12.75	(-)56.86	7.50	15.50	(-)51.61

* Survival (%) = Percentage of emerged seedlings, one month after planting.
** Diseased plants (%), 90 days after planting..
*** Increase or decrease (-)(%) relative to unmulched soil.

As for quality parameters, solarization treatment gave highly increased values of flowering, spike length and number, and weights of corms and cormels. This increase reached the maximum rate of flowering (99.25 and 100.00%), number of corms per plot (105.5% and 103.0%) and number of cormels (504.2% and 716.2%) for the two seasons tested, respectively. However, increases relative to the unmulched soil for flowering, spike length, No. of florets/spike, no. of corms/plot, average weight per corm, No. of cormels/plot, average weight per cormel were (43.84% and 49.81%), (46.33% and 53.33%), (74.69% and 91.34%), (90.95% and 82.30%), (36.66% and 36.97%), (46.74% and 103.81%) and (400.00% and 306.25%), respectively, for both trial seasons. The positive effect of solarization treatment on production of new corms and cormels from the planted one corm was clearly evident in Figure (1).

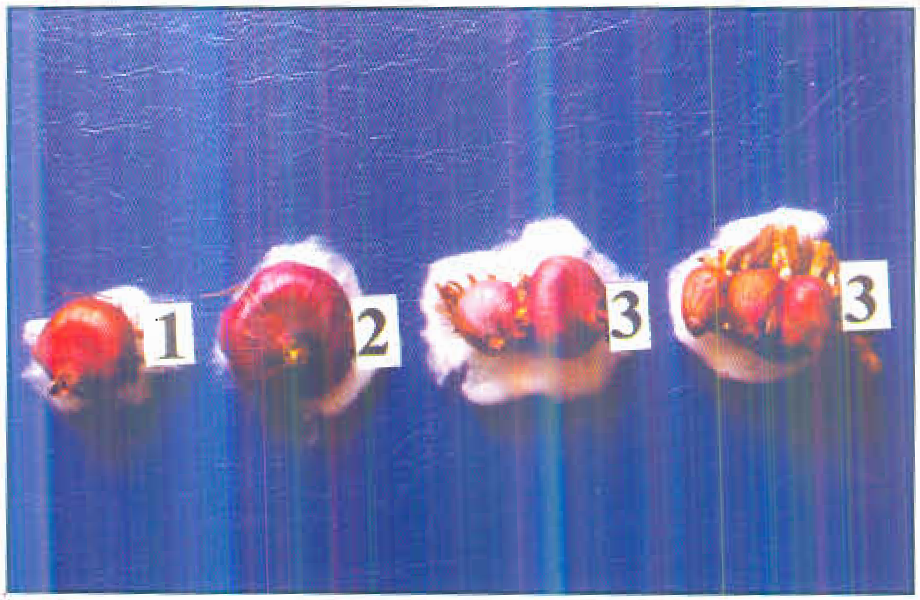

Fig. 1. Positive efficacy of solarization on corm and cormel yields of gladiolus. A small corm of non solarized soil (1), a big one of solarized soil (2) and more than one corm and cormel yielded from growing one corm in the solarized soil (3).

Discussion

Soil mulching by transparent polyethylene sheets during summer season resulted in clear significant reduction in Fusarium disease incidence on gladiolus plants at field and on the produced corms. Consequently, the survived plants in mulched soils raised from 62.5, 66.5% at 1997/1998 and 1998/1999, respectively, to about 100% and the development of corms rot in these treatments was greatly checked. The raise in soil temperature during mulching period ranged between 6-9°C for minimum temperature and 6-16°C for maximum temperature at the two seasons of experiment. This raise in temperature accounted for the drop in total count of soil microorganisms, *i.e.* fungi, bacteria and actinomycetes. Such reduction reflected on the inhibition of the pathogen *Fusarium oxysporum* f.sp. *gladioli* activity was confirmed with the great increase in survived plants and corms.

The beneficial effect of soil mulching preplanting extended to growth characters and yield quality of gladiolus as high increase in all these parameters were detected as result of mulch treatments. Perscott (1920) demonstrated the natural solarization without mulch in hot countries during summer season that high temperature caused an increase in the amount of nitrogen in soil. Baker (1957 and 1962) stated that the resting structures of pathogens are thermal sensitive in mulched soil. Meanwhile, Katan *et al.* (1976) reported that the moistened soil before mulching resulted in eradication of inoculum of *F. oxysporum* f.sp. *lycopersici* or sclerotia of *Verticillium dahalie* with a level of 95 and 100% for these two pathogens, respectively, after incubation period of one hour at 50°C. Also, Elena and Tjamos (1997a) found that soil solarization for nearly 7 weeks significantly reduced or eliminated inocula of *Fusarium oxysporum* f.sp. *dianthi* added to soil as a conidial suspension of chlorate-resistant mutant prior to the application of mulching. Fusarium wilt on carnation was 1-7% dead plants in solarized plots, while it reached 75% in control plots. The disease incidence in the second experiment following year was 6.2% for solarized, and 53.4% for non solarized control plots.

References

Abdel-Malak, S.G.A. 2000. Minimizing of chemicals application for control of Fusarium disease on gladiolus by integrated management programme. M.Sc. Thesis, Inst. Environ. Studies and Res., Ain Shams Univ.

Baker, K.F. 1957. The U.C. system for producing healthy grown plants. *Calif. Agric. Exp. Stn. Manual*, **23**: 1-33.

Baker, K.F. 1962. Principles of heat treatments of soil and planting material. *J. Aust. Inst. Agric. Sci.*, **28**: 118-126.

Elena, K. and Tjamos, E.C. 1997a. Soil solarization for the control of Fusarium wilt of greenhouse carnation. *Phytopathologia Mediterranea*, **36**: 87-93. (C.f. *Rev. Pl. Pathol.*, 77: 221, 1998).

Elena, K. and Tjamos, E.C. 1997b. Evaluation of soil solarization method for control of Fusarium wilt of carnation in field. *Annales de L'Instiut Phytopathologique* Benak (Greece), **18**: 13-24. (C.f. *Rev. Pl. Pathol.*, 77: 1185, 1998).

Garibaldi, A. and Tamietti, G. 1984. Attempts to use soil solarization in closed greenhouses in northern Italy for controlling corky root of tomato. *Acta Hortic.*, **152**: 237-243.

Henis, Y. and Ziberstein, Y. 1973. Detection of latent Fusarium in gladiolus corms. *J. Hort. Sci.*, **48**: 189-194.

Hilal, A.A.; El-Shinnawy, S.A.; Essmat, N.E.A. and Hanafie, S.M. 1994. Fusarium disease of gladiolus: occurrence and new corm treatments in relation to disease infection, flowers, corms and cormels yield. *Egypt. J. Appl. Sci.*, **9**(8): 158-173.

Jacobsohn, R.; Greenberger, A.; Katan, J.; Levi M. and Alon, H. 1980. Control of Egyptian broomrape and other weeds by mean of solar heating of the soil by polyethylene mulching. *Weed Science*, **28**: 312-316.

Jarvis, W.R. 1992. *Managing Diseases in Greenhouse Crops*. APS Press. Minnesota, USA.

Jensen, H.L. 1930. Actinomycetes in Danish soils. *Soil Sci.*, **30**: 59-77.

Johnson, L.F.; Curi, E.A.; Bond, J.H. and Friboury, H.A. 1960. *Methods for Studying Soil Microflora Plant Disease Relationship*. 2nd Edition. Burgess Publishing Company. Minneapolis, M.N.

Katan, J.; Greenberger, A.; Alon, H. and Grinstien, A. 1976. Solar heating by polyethylene mulching for the control of diseases caused by soil-borne pathogens. *Phytopathology*, **66**: 683-688.

Magic, R.O. 1984. Fusarium rot is just around the corner. *Gladio Grams Bull.*, **55**: 9-10.

Malathrakis, N.E.; Kapetanakis, G.E. and Linardakis, D.S. 1983. Brown root rot of tomato, and its control in Crete. *Ann. Appl. Biol.*, **102**: 251-256.

Montealergre, J.R.; Defilippi, B. and Henriquez, L.J. 1997. Soil solarization and methyl bromide fumigation in the control of *Fusarium oxysporum* f.sp. *fragariae* in a monocropped strawberry soil. *Fitopatogia*, **32**: 18-31.

Perscott, J.A. 1920. A note on the sharaki of Egypt. A study in partial sterilization. *J. Agric. Exp. State Bull.*, No. 651, 1919-1920.

Satour, M.M.; El-Sherif, E.M.; El-Ghareeb, L.; El-Hadad, S.A. and El-Wakil, H.R. 1990. Achievement of soil solarization in Egypt. Pages 200-212 in Proc. 1st Internat. Conf. on Soil Solarization. Amman, Jordan, 19-25 February 1990.

Sepulveda, G.; Montealegre, J.; Siaz, C.; Diaz, R. and Sackenheim, R. 1997. The effect of solarization on the control of *Fusarium oxysporum* f.sp. *lycopersici* in Azap Valley, Chile, *Fitopathologia*, **31**: 114-121.

Sarhan, A.R.T. 1990. Control of *Fusarium solani* in broad bean by solar heating of the soil in Northern Iraq. Pages 108-117 in Proc. 1st Internat. Conf. on Soil Solarization. Amman, Jordan, 19-25 February 1990,

Sztejnberg, A.; Freeman, S.; Chet, I. and Katan, J. 1987. Control of *Rosellinia necatrix* in soil and in orchard by solarization and *Trichoderma harzianum*. *Plant Dis.*, **71**: 365-369.

Tjamos, E.C. 1983. Control of *Pyrenoehaeta lycopersici* by combined soil solarization and low dose of methyl bromide in Greece. *Acta Hortic.*, **152**: 233-258.

Tjamos, E.C. and Faridis, A. 1980. Control of soilborne pathogens by solar heating in plastic houses. Pages 82-84 in Proc. 5th *Cong. Mediterr. Phytopathol. Union*.

Yih, L.C. and Hwa, H.S. 1995. Mechanism of solarization for controlling soil-borne disease. *Bulletin of Taichung District.* Agricultural Improvement Station. No. 94, 19-31. (C.f. *Rev. Pl. Pathol.*, **76**: 697, 1997).

(Received 11/02/2002;
in revised form 15/04/2002)

أستخدام التعقيم الشمسى للتربة فى مكافحة مرض الفيوزاريوم على الجلاديولس فى الحقل وتأثيره على مكونات المحصول الناتج

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تم تقييم فعالية التعقيم الشمسى فى مكافحة مرض الفيوزاريوم على الجلاديولس لأول مرة فى مصر، حيث ثبت أن تغطية التربة الرملية الطميية بشرائح من البولى إيثيلين ذات سمك ٢٠٠ ميكرون لمدة ستة أسابيع خلال صيف عامى ١٩٩٧م، ١٩٩٨م (٢٨ يوليو - ٧ سبتمبر) يؤدى إلى رفع الدرجة العظمى لحرارة التربة إلى ٤٢-٤٨°م بدلا من ٣٣-٣٤°م فى التربة غير المغطاه. ولقد تم تسجيل إنخفاض كبير فى العدد الكلى للكائنات الحية الدقيقة بلغ (٩١,٤٠%، ٩٢,٦٨%) بالنسبة للفطريات، (٤٦,٠٠%، ٥١,٩٠%) للبكتيريا و (٩٠,٩٠%، ٨٧,٦٩%) للأكتينوميسيتات فى التربة التى تم إجراء التعقيم الشمسى بها بالمقارنة بأعداد تلك الكائنات فى نفس التربة قبل تغطيتها خلال موسمى التجريب على التوالى.

ولقد بلغت نسبة النباتات المتبقية حية فى التربة المغطاة ١٠٠% خلال موسمى التجريب بينما بلغت ٦٢,٥%، ٦٦,٥% فى التربة الغير مغطاة (مقارنة) خلال نفس الموسمين. ولقد سجل انخفاض كبير فى نسبة الإصابة بمرض الفيوزاريوم على النباتات النامية فى الحقل خلال موسمى التجربة (٨٦,٧٦%، ١٠٠,٠٠%)، وعلى الكورمات الناتجة عند الحصاد (٩٠,٢٦%، ٧٦,٤٣%) وعلى الكورمات المخزنة (٥٦,٨٦%، ٥١,٦١%).

ولقد أدى التعقيم الشمسى للتربة إلى زيادة كبيرة فى قيم مكونات محصول أزهار الجلاديولس خلال موسمى التجريب بالمقارنة بالتربة الغير مغطاه وصلت إلى (٤٣,٨٤%، ٤٩,٨١%) بالنسبة للإزهار، (٤٦,٣٣%، ٥٣,٣٣%) لطول الشمراخ الزهرى. و (٧٤,٩٦%، ٩١,٣٤%) لعدد الزهيرات فى الشمراخ. بينما وصلت الزيادة فى عدد الكورمات لكل وحدة تجريبية إلى (٩٠,٩٥%، ٨٢,٣٠%) ووزن الكورمة الناتجة (٣٦,٦٦%، ٣٦,٩٧%) بينما كانت الزيادة فى اعداد الكريمات لكل وحدة تجريبية (٤٦,٧٤%، ١٠٣,٨١%) ووزن الكريمة (٤٠٠,٠٠%، ٣٠٦,٢٥%).