Mathematical Models for Determination of The Critical Period of Weed Competition In Sunflower (*Helianthus annuus* L.)

Tagour, R. M. H.
Weed Research Central Laboratory, Agricultural Research Center, Giza, Egypt.

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ABSTRACT

Two field experiments on sunflower were conducted during 2013 and 2014 summer seasons at EL-Serw Station, Damietta Governorate, Egypt. Each experiment included ten weed competition and weed removal treatments either at early or late times after sowing which were: - weed competition for the whole season, weed competition for 2, 4, 6 and 8 weeks from sowing, weed free for 2, 4, 6 and 8 weeks from sowing and weed free for the whole season, to determine when a natural infestation of weeds start to reduce sunflower yield and when to control without yield losses in sunflower. Dominant major weeds in experimental fields were *Portulaca oleraceae,* L.; *Corchorus olitorius,* L.; *Amaranthus caudatus*, L.; *Echinochloa colonum,* L. and *Chenopodium album,* L.

The obtained results revealed that which weed infestation rate under sunflower field was 5.885 and 6.527 ton fresh weight / fad., which reduced drastically seed yield of sunflower per faddan by 55.3 to 55.2% under weed competition treatment of sunflower for the whole season in 2013 and 2014 summer season, respectively, as compared with weed free for whole season treatment. The use of response curves with weed free or weed competition period showed that seed yield and oil yield of sunflower were the highest with the field free from weeds until 6 weeks after sowing , and the critical period of weed / sunflower competition was between lie 2– 6 weeks after sowing. In regression approach for sunflower seed yield, oil yield and weed free or weed competition period the polynomials (linear and quadratic) and logistic functions were tested and quadratic function was fitted to estimate the expected yields which had the high significant with the data recorded and have the highest values of R^2 than the other models (linear or logistic model.) for this reason it is used to estimate critical periods of weed competition with sunflower. Also, results showed that the quadratic equations were significant and had the highest R^2 (0.989, 0.982) and (0.989, 0.984) for weed free period, and (0.899, 0.992) and (0.919, 0.994) for weed competition durations in 2013 and 2014 summer seasons, respectively.

According to these results, the critical period of weed competition to sunflower is the first six weeks period from sowing was required to be weed free showed that to maintain 95% of maximum seed and oil yield of sunflower and one week of weeds infestation can be allowed after sunflower sowing without seed and oil yield sunflower reduction. The information should be taken in consideration for sunflower growers to plan their strategies of integrated weed management for this important crop.

Key words: Critical period – Weed - Competition – Sunflower.

INTRODUCTION

Many attempts have been carried out to increase and to improve the production of sunflower to face the increasing demand on vegetative oils. The most important factor in this concern is weed control. The infestation of sunflower fields with weeds is known to be a major constraint for obtaining high yields. Reduction in sunflower seed yield due to weed competition accounted for about 29-75% Singh *et*. al., 1993 and Giri *et. al*., 1998. Therefore, weed control during the first (50-60 days) after sowing sunflower is essential for successful yield (Wanjari et al. 2000). Associated weeds with sunflower fields severe reduction in sunflower productivity in quantitative and qualitative aspects. Sunflower is sensitive to weed competition and yield losses due to weed competition, weed - removal has a significant effect on yield of sunflower crop. The outcome of crop-weed competition should be practiced as early as possible in order to allow time of weed control measures (Knezevic, 2000). Wanjari *et al* (2001) mentioned that, green seeded sunflower need an extended period of effective weed management which is very necessary because the crop is direct seeded and is slow growing with an open canopy.

Thus, research was needed to determine the critical period for weed control in crop fields. Burnside *et al.*, (1998) mentioned that research was needed to determine the critical period for control in any field crop is usually done by (1) keeping the crop free from weeds until certain predetermine times and then allowing weeds to grow and (2) allowing the weeds to emerge and grow with the crop for certain predetermined times, after which all weeds are removed in a timely manner until the end of growing season, Nieto *et al.*, (1968) and Singh *et al.*, (1996), pointed out that the time interval between (1) and (2) is the critical period for weed control. (Zimdahl, 1988) mentioned that, historically critical periods have been calculated by mean separations (hereafter referred to as the classical approach) in experiments that evaluated the impact time of weed emergence and time of removal on crop yields. Using the classical approach, it is possible to identify the period within which no statistically detectable yield losses occur. The use of regression analysis (referred to as the functional approach), (Cousens 1985a; Knezevic *et al.,* 2002 and Mekky *et al.*, 2005).

The objectives of this study, which was conducted on variety medium maturity of the critical period is estimated to compete in the sunflower crop and connect it to remove the chosen periods and let weeds to be determined (1) when the early emerging weeds first began to reduce sunflower crop (2) when the late emerging weeds no longer reduce sunflower crop and (3) by using the above mentioned approaches to determine the critical period for weed control in of sunflower production fields in Egypt.

MATERIALS AND METHODS

Two field experiments were carried out during summer seasons of 2013 and 2014 at El-Serw Agricultural Research Station, Agricultural Research Center farm, Damietta Governorate, Egypt to determine the critical period of weed competition in sunflower. The soil texture was clay (Table 1).

The schemes of treatments were followed according to Dawson (1970) where two basic types of treatments were used. In first type of treatments the crop is kept weed free for different periods after planting and then allowed to become weedy. Conversely, in the second type of treatments weeds are allowed to grow with a crop for different periods then crop was maintained weed free for the remainder of the growing season as follow:

Each experiment included ten treatments which were:

1- Weed competition for the whole season.
2- Weed competition for 2 weeks from sowing.
3- Weed competition for 4 weeks from sowing.
4- Weed competition for 6 weeks from sowing.
5- Weed competition for 8 weeks from sowing.
6- Weed free for 2 weeks from sowing.
7- Weed free for 4 weeks from sowing.
8- Weed free for 6 weeks from sowing.
9- Weed free for 8 weeks from sowing.
10- Weed free for the whole season.

Sunflower c.v. Sakha 53 is a medium maturity variety at (100 days age) was sown on May 10^{th} in both seasons at 5 kg / faddan. Plot area was 16 m^2 (4m x 4m). Recommended cultural practices were followed except the treatments under study to maintain optimum crop growth. The experiment design was randomized complete block design with four replicates. Weeds were identified and classified and the total fresh and dry weights of weed species were recorded. Sunflower was harvested on August 20^{th} in both seasons.

Data recorded

I: Weed survey

Weeds were hand pulled from one square meter, taken at random from each plot, identified and classified to species and total fresh and dry weight (g/m^2) were recorded.

II: Sunflower yield component at harvest:-

samples of ten sunflower plants were taken at random from each plot and the following characters were measured: -

1- Head diameter (cm). 2- No. of seeds/head.
3- Seed weight/head (g). 4- 100-seedweight (g).

III: Seed yield

1- Seed yield was calculated from the seed yield per the whole plot and then converted to (ton/faddan).
2- Relative yield %.

Relative yield % = (seed yield for treatment plots ÷ seed yield for control plots) × 100

3- Seed oil content %.
4- Oil yield (kg/faddan):- Seed oil percentage was determined according to the methods described in A.O.A.C. (1975), using Soxhlet equipment and oil yield (kg/faddan) was determined by multiplying seed yield seed oil percentage.

All obtained data were statistically analyzed according to (Snedecor and Cochran 1967) LSD at 5% level of significance was used to compare between means.

IV:- Determination critical period of weed competition:-

to determine the critical period of weed competition in sunflower, two approaches were used: -

1– Classical biological approach: -

The critical period has been defined as the period during which weeds must be controlled to prevent yield losses. Since the concept of critical period was introduced, it has been used to determine the period when control operation should be carried out to minimize yield losses for sunflower crop (Zimdahl, 1988). The critical period for weed control as a "window" in the crop cycle during which weeds must be controlled to prevent unacceptable yield losses (Knezevic, 2000).

Table 1: **Chemical and physical analyses of soil of field experiments of 2013 and 2014 seasons**

Season	Soil Depth cm.	Particle size distribution				Texture class	Organic mater%	CaCo3 %	PH (1:2.5) Suspension
		Coarse sand%	Fine Sand%	Silt %	Clay %				
2013	0-30	1.73	13.35	21.72	63.20	clayey	1.21	2.35	7.9
2014	0-30	1.69	13.32	21.80	63.19	clayey	1.22	2.31	7.3

2- Polynomial Regression approaches (mathematical models)

According to Singh *et al.,* (1996) mathematical models were used to study about the relationship between crop yields (Y) and duration of weed-free or weed-competition period (x) by either be linear function: $\tilde{y} = a + b\,x$ where the parameters $\tilde{y}$ = expected yield, a and b represent intercept and slope of regression of yield on the duration, respectively, or by the quadratic function: $\tilde{y} = a + b\,x + c\,x^2$ where the parameters a,b and c represent intercept and slope of regression of yield on the duration, in a quadratic function.

The relative and actual yield was subjected to analysis of variance using fitting curve, estimation functions to analysis of statistical producers for Social sciences (SPSS 16.0 for windows), to evaluate the effect of the length of the weed – free periods and the duration of weed interference on relative sunflower yields according to (Knezevic *et al*., 2002). Three fitting curve models namely, polynomial (linear and quadratic) and Logistic curves were fitted to study the relationships between sunflower yield/fad. and duration of weed-free and/or weed-competition periods. First and second models are linear and quadratic to determine the onset of critical period of weed control (Neter *et al*., 1990). The third model of logistic function proposed by (Cousen, 1991) mentioned that, earlier work depend on Duncan's multiple test or LSD but they suggested that regression analysis appropriate and useful mean of determining the critical periods and modified by (Knezevic *et al*., 2003).

RESULTS AND DISCUSSION

I- Effect of weed competition and removal periods on weeds growth:

Data in Table (2) showed that weed infestation level was high in both seasons 2013 & 2014, reaching (1401.3 g/m^2) (5.885 ton/fad.) and (1554.1 g/m^2) (6.527 ton/fad.) fresh weight, as well as, 298.2 g/m^2(1.252 ton/fad.) and 329.4 g/m^2(1.383 ton/fad.) dry weight of weeds, respectively. The major weed species prevailing in the experimental fields were *Portulaca oleraceae*, L.; *Corchorus olitorius*, L.; *Echinochloa colonum,* L. and *Chenopodium album,* L. Thus, the previous level of weed infestation can be considered very suitable for estimating the critical period of weed competition to sunflower.

Table 2: Effect of weed competition and weed removal periods on total fresh and dry weight of weeds during 2013 and 2014 summer seasons.

Weed competition or weed removal periods	Total fresh weight of weeds (g/m^2)	Total dry weight of weeds (g/m^2)	Reduction %
2013 Season			
Weed competition for the whole season	1401.3	298.2	0
Weed competition for 2 weeks from sowing	21.1	4.5	98.5
Weed competition for 4 weeks from sowing	239.6	50.9	82.9
Weed competition for 6 weeks from sowing	630.6	134.2	54.9
Weed competition for 8 weeks from sowing	892.6	189.9	36.3
Weed free for 2 weeks from sowing	822.6	175.1	41.3
Weed free for 4 weeks from sowing	461.1	98.2	67.1
Weed free for 6 weeks from sowing	215.8	45.9	84.6
Weed free for 8 weeks from sowing	116.4	24.8	91.7
Weed free for the whole season	2.8	0.6	99.8
L.S.D. at 0.0 5	137.29	20.24	
2014 Season			
Weed competition for the whole season	1554.1	329.4	0
Weed competition for 2 weeks from sowing	23.4	4.9	98.5
Weed competition for 4 weeks from sowing	265.8	56.4	82.9
Weed competition for 6 weeks from sowing	699.4	148.8	54.8
Weed competition for 8 weeks from sowing	989.9	209.8	36.3
Weed free for 2 weeks from sowing	912.4	193.4	41.3
Weed free for 4 weeks from sowing	511.3	108.4	67.1
Weed free for 6 weeks from sowing	239.4	50.7	84.6
Weed free for 8 weeks from sowing	128.9	27.3	91.7
Weed free for the whole season	3.2	0.7	99.8
L.S.D. at 0.0 5	124.19	16.25	

In general, weeds reduction tended to increase with consisted prolonged periods of weed removal periods either early or late competition periods. In general, total weeds tended to reduce consist with increase either weed prolonged late or early weed removal competition periods.

II- Effect of weed competition on sunflower plant:

Data in Table (3) indicated that head diameter (cm), number of seeds/ head, seed weight/head (g) and 100-seed/weight (g) of sunflower plants, at harvest were significantly affected by weed competition and removal duration in both seasons. The treatments of weed free and weed removal periods significantly increased head diameter (cm), number of seeds/ head, seed weight/head (g) and 100-seed/weight (g) than weed competition for the whole season (unweeded check treatment) in both seasons. The highest results of head diameter (cm), number of seeds/ head, seed weight/head (g) and 100-seed/weight (g) were produced by weed free treatments and weed removal at 2 and 4 weeks from sowing, when compared with the other weed removal treatments as well as, weed competition for the whole season (unweeded check) in both seasons. On the contrary, the lowest value in this respect, was obtained from weed removal treatments at 8 weeks and weed competition for the whole season (unweeded check).

This may be due to that the competition of weeds affected crop growth due to minimizing the availability of nutrients, water and sunlight. The weed growth there will be one less unit of crop growth. Moreover, it with the establishment of crop plants foliage, they will begin to shade the ground. This shading effect reduced the amount of light available for weed development. Meanwhile, on the other side, weed competition during the whole crop life cycle caused reduction of growth characters and recorded with highest density of weeds. These results coincided with those obtained by Zimdahl (1988); Durgan *et al.* (1990); Onofri and Tei (1994); Carranza *et al.* (1995); Berti *et al.* (1996) and Lehoczky *et al.* (2006) reported who that the plants growth was affected by weed competition.

Table 3: Effect of weed competition and weed removal times on yield components of sunflower during 2013 and 2014 summer seasons.

Weed competition or weed removal periods	Head diameter (cm)	N0.of seeds/ head	Seed weight/ head (g)	100 -seed/ weight(g)
2013 Season				
Weed competition for the whole season	8.94	522	31.27	3.09
Weed competition for 2 weeks from sowing	17.52	1024	61.28	6.06
Weed competition for 4 weeks from sowing	15.63	912	54.58	5.39
Weed competition for 6 weeks from sowing	13.27	775	46.42	4.59
Weed competition for 8 weeks from sowing	10.63	621	37.20	3.68
Weed free for 2 weeks from sowing	13.13	767	45.92	4.54
Weed free for 4 weeks from sowing	15.65	914	54.72	5.41
Weed free for 6 weeks from sowing	17.34	1013	60.65	6.00
Weed free for 8 weeks from sowing	18.50	1080	64.70	6.39
Weed free for the whole season	19.95	1165	69.80	6.90
L.S.D. at 0.0 5	1.55	57.49	2.32	0.25
2014 Season				
Weed competition for the whole season	9.51	527	29.84	3.05
Weed competition for 2 weeks from sowing	18.65	1033	58.47	5.97
Weed competition for 4 weeks from sowing	16.61	920	52.08	5.31
Weed competition for 6 weeks from sowing	14.12	783	44.29	4.52
Weed competition for 8 weeks from sowing	11.32	611	35.50	3.62
Weed free for 2 weeks from sowing	13.97	774	43.83	4.47
Weed free for 4 weeks from sowing	17.44	922	52.21	5.33
Weed free for 6 weeks from sowing	18.46	1022	57.87	5.91
Weed free for 8 weeks from sowing	19.69	1091	61.74	6.30
Weed free for the whole season	21.24	1176	66.60	6.80
L.S.D. at 0.0 5	1.55	24.85	2.04	0.23

III - Effect of weed competition on yield:

Data presented in Table (4) showed that seed yield per faddan, relative yield, seed oil content and seed oil yield per faddan, at harvest were significantly increased due to weed free and weed removal periods treatments uses in both seasons. The loss in seed and oil yields due to weed competition for whole seasons reached 55.2 and 58.1% and 55.3 and 57.9% in 2013 and 2014 seasons, respectively as compared with weed free treatments. This may be due to the effective competition of weeds with sunflower plants particularly in the early stage of sunflower growth. Removal of weeds for 2 and 4 weeks from sowing then allowing weeds competition for sunflower until the end season caused seed yield reductions by 12.2 and 12.1%, and 20.7 and 21.8% in 2013 and 2014 seasons, respectively as compared with weed free in whole season, which reached 1.133 and 1.112 t/fad. respectively.

These treatments significantly produced the highest seed and seed oil yields per faddan compared with unweeded check in both seasons. The increase in yield induced by weed removal treatments may be due to control of annual weeds at the critical early period, consequently the competition between sunflower plant and associated weeds was decreased and giving good chance for sunflower growth and improve the filling of grains resulting heavier grains. These results are in agreement with those recorded by Durgan *et al.* (1990); Onofri and Tei (1994); Berti and Zanin (1994); Carranza *et al.* (1995); Sattin *et al.* (1996); Lehoczky *et al.* (2006); Azadbakht *et al.* (2012) and Heydarian *et al* (2012).

On the other hand, further delaying of weed removal accentuated the adverse effect of weeds on seed and oil yields at 8 weeks from sowing causing reduction that ranged from 33.4 to 33.5 and 46.6 to 46.7 % for seed yield, and from 36.8 to 36.9 % and 49.6 to 49.7% for oil yield respectively, in both seasons as compared with weed free treatments. Durgan *et al.* (1990); Onofri and Tei (1994); Carranza *et al.* (1995); Berti *et al.* (1996) ; Sattin *et al.* (1996) and Lehoczky *et al.* (2006) reported that, the reduction in seed and seed oil yields due to increasing of competition with associated weeds that decreased weight of seeds per head and simultaneously increased the dry matter production of weeds and weed density.

IV – Estimation of the critical period (CP) for weed competition in sunflower.

According to Cousens (1991) there are two approaches to determine the critical period of weed competition to any crop as follows.

Table 4: Effect of weed competition duration on seed and oil yield of sunflower plants at harvest during 2013 and 2014 summer seasons.

Weed competition or weed removal periods	Seed yield (ton/fad.)	Relative yield %	Seed oil content%	Seed oil yield (kg/fad.)
2013 Season				
Weed competition for the whole season	0.507	100	35.20	178.46
Weed competition for 2 weeks from sowing	0.995	196.16	37.05	368.65
Weed competition for 4 weeks from sowing	0.889	175.46	36.07	320.66
Weed competition for 6 weeks from sowing	0.753	148.47	35.68	268.67
Weed competition for 8 weeks from sowing	0.604	119.33	35.41	213.88
Weed free for 2 weeks from sowing	0.745	147.05	36.59	272.59
Weed free for 4 weeks from sowing	0.889	175.72	37.20	330.34
Weed free for 6 weeks from sowing	0.985	194.39	37.22	366.62
Weed free for 8 weeks from sowing	1.050	207.36	37.45	393.22
Weed free for the whole season	1.133	223.65	37.58	425.78
L.S.D. at 0.0 5	0.07	15.24	0.32	28.66
2014 Season				
Weed competition for the whole season	0.498	100	35.14	174.99
Weed competition for 2 weeks from sowing	0.977	196.24	37.02	361.68
Weed competition for 4 weeks from sowing	0.869	174.54	36.01	312.93
Weed competition for 6 weeks from sowing	0.739	148.42	35.53	262.57
Weed competition for 8 weeks from sowing	0.593	119.10	35.38	209.80
Weed free for 2 weeks from sowing	0.732	147.07	36.47	266.96
Weed free for 4 weeks from sowing	0.872	175.13	37.15	323.95
Weed free for 6 weeks from sowing	0.966	194.08	37.19	359.25
Weed free for 8 weeks from sowing	1.031	206.98	37.34	384.97
Weed free for the whole season	1.112	223.38	37.46	416.55
L.S.D. at 0.0 5	0.03	6.73	0.12	12.16

1- Curve fitting approach: -

Figure (1) depending on data of seed and oil yields/fad. by the use of biological response curves results show clearly that to obtain 95% of the sunflower crop need to make the field free from weeds for a period 2 – 6 weeks from sowing and the critical period of weed competition (CPWC) of the seed and oil yield of sunflower started after two weeks and ended at 6 weeks from sowing.

Obviously, the more delay of weed removal will cause more decrease in sunflower yield due to weed/sunflower competition which seriously affect seed and oil yield of sunflower. This may be attributed to the slow growth of sunflower in the first grown stages and poor vegetative growth in one side. Evidently, weed free maintenance for 2 to 6 weeks from sowing is required for good yield. Wanjari *et al* (2001) mentioned that, green seeded sunflower need an extended period of effective weed management which is very necessary because the crop is direct seeded and is slow growing with an open canopy.

2- Regression approach (mathematical models): -

In this approach polynomial and logistic models were tested for modeling the relationship between sunflower seed yields and weed free or weed competition periods Table (5), showed that the relationship between seed yield of sunflower and the period of weed removal or weed competition was statistically significant with mathematical models under this study in both season. These equations were $\acute{Y}^{\sim} = 0.513 + 0.123\ x - 0.007\ x^2$ and $\acute{Y}^{\sim} = 1.127 - 0.058\ x + 0.0001\ x^2$ in season 2013 and $\acute{Y}^{\sim} = 0.505 + 0.12\ x - 0.007\ x^2$ and $\acute{Y}^{\sim} = 1.107 - 0.058\ x + 0.0001x^2$ in season 2014.

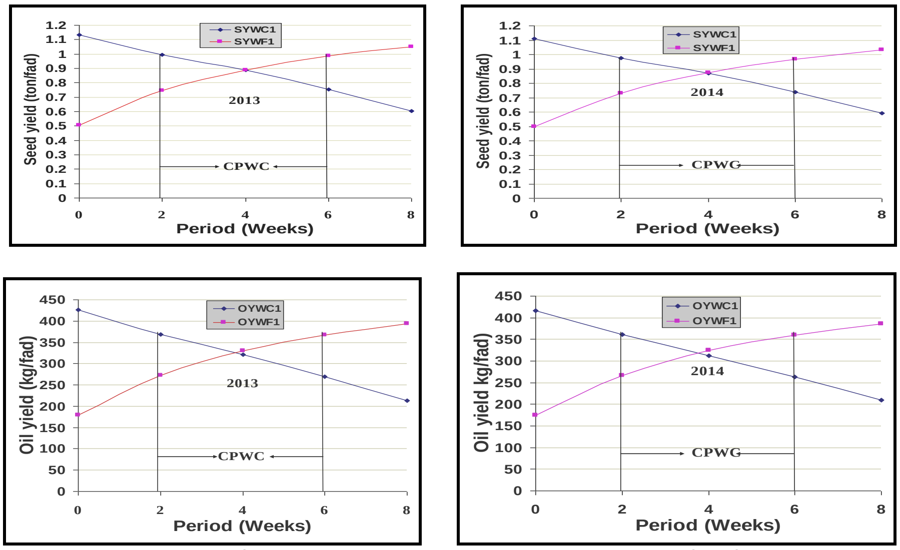

Fig 1: The critical period of weed competition and relative seed and oil yield of sunflower in 2013 and 2014 summer seasons.

Table 5: Estimation of the regression and the standard errors of three models to determine the relationship between seed yield of sunflower (t/ fad.) with weed – free or weed infestation periods in 2013 and 2014 summer seasons.

Treatments	Yield	Linear		Quadratic		Logistic	
		R^2	SE	R^2	SE	R^2	SE
2013 season experiment							
Weed-free	Seed yield t/fad	0.930	0.054	0.989	0.022	0.877	0.097
Weed competition		0.896	0.068	0.899	0.066	0.897	0.077
2014 season experiment							
Weed-free	Seed yield t/fad	0.924	0.055	0.982	0.028	0.875	0.149
Weed competition		0.991	0.018	0.992	0.018	0.975	0.036

Examining Table 5, it could be noticed that the best model fitted to study the yield of sunflower response to weed free and weed competition durations was quadratic that. It had coefficient of determination (R^2) greater than those of both linear and logistic model. Moreover, values of standard error estimate (SE) of quadratic equation were smaller than those of linear and logistic equations. Therefore, the quadratic model worked well for describing the relationship between seed yield of sunflower and weeds under weed free and weed competition duration in both first and second seasons.

Fig. (2 and 3) and Tables (5 and 6) show the effect of times duration of sunflower crop free from weeds on seed yield. The relationship between seed yields with the duration of weed free was significant and positive and prediction function with value R^2 (SE) 0.989 (0.022) and 0.982 (0.028), but, the relationship between seed yield with the duration of weed competition was significant and negative,

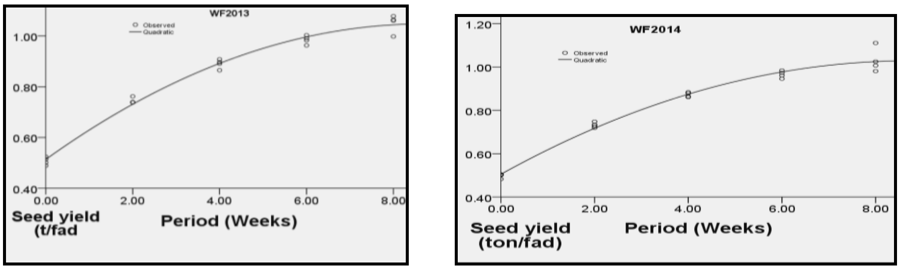

Fig. 2: The relationship between duration of weed free and seed yield (t/fad)

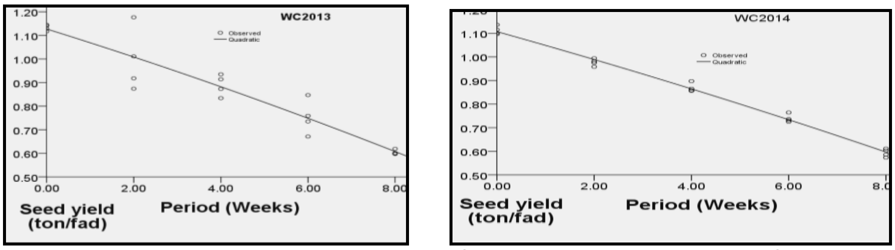

Fig. 3: The relationship between duration of weed competition and seed yield (t/fad).

Table 6: Estimation of expected seed yield and percent of yield losses by quadratic model under different weed free period and weed infestation period in 2013 and 2014 summer seasons.

	2013 Season Experiment				**2014 Season Experiment**			
	Weed free Period		**Weed infestation Period**		**Weed free Period**		**Weed infestation Period**	
Period (weeks)	**Predicted Seed yield (t/fad.)**	**Yield losses %**	**Predicted Seed yield (t/fad.)**	**Yield losses %**	**Predicted Seed yield (t/fad.)**	**Yield losses %**	**Predicted Seed yield (t/fad.)**	**Yield losses %**
	$\acute{Y}^{\sim}=0.513 + 0.123\,x - 0.007\,x^2$		$\acute{Y} \sim= 1.127 - 0.058\,x + 0.0001\,x^2$		$\acute{Y} \sim= 0.505 + 0.12\,x - 0.007x^2$		$\acute{Y} \sim=1.107 - 0.058\,x + 0.0001x^2$	
0	0.513	51.3	1.127	0	0.505	50.4	1.107	0
1	0.629	40.3	1.069	5.2	0.618	39.3	1.049	5.2
2	0.731	30.6	1.011	10.3	0.717	29.6	0.991	10.5
3	0.819	22.2	0.954	15.4	0.802	21.2	0.934	15.6
4	0.893	15.2	0.897	20.4	0.873	14.2	0.877	20.8
5	0.953	9.5	0.839	25.6	0.930	8.6	0.819	26.1
6	0.999	5.1	0.783	30.5	0.973	4.4	0.763	31.1
7	1.031	2.1	0.726	35.6	1.002	1.6	0.706	36.2
8	1.049	0.4	0.669	40.6	1.011	0.7	0.649	41.4
9	1.053	0	0.613	45.6	1.018	0	0.593	46.4
10	1.043	0.9	0.557	50.6	1.005	1.3	0.537	51.5

and prediction function with value R^2 (SE) 0.899 (0.066) and 0.992 (0.018), in the first and second season, respectively. Thus, to obtain 95% yield of either seed or oil yields per Fadden weeds should be eliminated between 1 – 6 weeks from sowing.

To determine the critical period of weed competition to sunflower crops, the regression approach was used. Application equation reported that to maintain 95% seed yield of sunflower earlier weed competition should not allowed exceed 1 week from emergence. The same situation the late duration of weed free period should not exceed 6 weeks from emergence.

Examining Table 7 it could be noticed the best model fitted to the oil yield of weed free and weed competition was quadratic. It had coefficient of determination (R^2) greater than those of the linear model and logistic. Moreover, values of standard error estimate (SE) of quadratic equation were smaller than those of linear and logistic equation. There fore, the quadratic model worked well for describing the relation between oil yield of sunflower and weeds under weed free and weed competition in the first and second season. These equations were $\acute{Y}^{\sim} = 181.107 + 48.775\ x - 2.825\ x^2$ and $\acute{Y}^{\sim} = 424.370 - 26.279\ x - 0.011\ x^2$ in season 2013 and $\acute{Y}^{\sim} = 177.549 + 47.639\ x - 2.753\ x^2$ and $\acute{Y}^{\sim} = 415.600 - 26.004\ x - 0.047\ x^2$ in season 2014.

Fig. (4 and 5) and Tables (7 and 8) showed that the relationship between oil yield with the duration of weed free had similar trend of seed yield where is significant and positive and prediction function value R^2 (SE) 0.989 (0.108) and 0.984 (0.108), but, the relationship between oil yields with the duration of weed competition was significant and negative and prediction function with value R^2 (SE) 0.919 (0.075) and 0.994 (0.033) in the first and second seasons, respectively.

Table 7: Estimation of the regression and the standard errors of three models to determine the relationship between oil yield of sun flower (kg/ fad.) with weed – free or weed infestation periods in 2013 and 2014 summer seasons.

Treatments	Yield	Linear		Quadratic		Logistic	
		R^2	SE	R^2	SE	R^2	SE
2013 season experiment							
Weed-free	Oil yield kg/fad	0.929	21.604	0.989	0.108	0.871	8.583
Weed competition		0.913	24.078	0.919	0.075	0.913	24.776
2014 season experiment							
Weed-free	Oil yield kg/fad	0.924	21.833	0.984	0.108	0.870	10.254
Weed competition		0.990	6.101	0.994	0.033	0.983	5.939

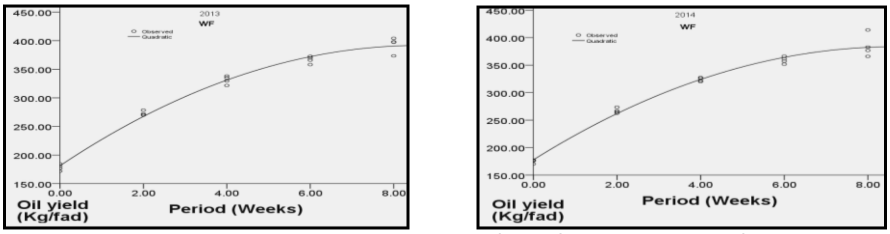

Fig. 4: The relationship between duration of weed free and oil yield (kg/fad).

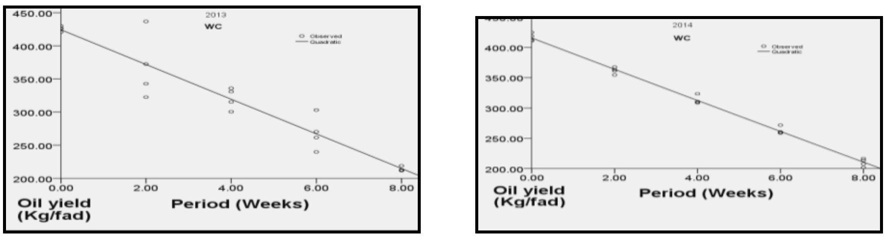

Fig. 5: The relationship between duration of weed competition and oil yield (kg/fad).

Table 8: Estimation expected oil yield and percent of yield losses by quadratic model under different weed free period and weed infestation period in 2013 and 2014 summer seasons.

Period (weeks)	2013 Season Experiment				2014 Season Experiment			
	Weed free Period		Weed infestation Period		Weed free Period		Weed infestation Period	
	Predicted oil yield (kg/fad.)	Yield losses %	Predicted oil yield (kg/fad.)	Yield losses %	Predicted oil yield (kg/fad.)	Yield losses %	Predicted oil yield (kg/fad.)	Yield losses %
	$\acute{Y}^{\sim}= 181.107 + 48.775x – 2.825x^2$		$\acute{Y} \sim= 424.370 - 26.279x - 0.011x^2$		$\acute{Y} \sim= 177.549 + 47.639x - 2.753x^2$		$\acute{Y} \sim= 415.600 - 26.004x - 0.047x^2$	
0	181.11	53.7	424.37	0	177.55	53.7	415.60	0
1	227.06	42.0	398.10	6.2	222.43	42.0	389.64	6.3
2	267.36	31.7	371.86	12.4	261.81	31.7	363.78	12.5
3	302.01	22.8	345.63	18.6	295.69	22.9	338.01	18.7
4	331.01	15.4	319.43	24.7	324.06	15.5	312.34	24.9
5	354.36	9.8	293.25	30.9	346.92	9.5	286.75	31.0
6	372.06	4.9	267.09	37.1	364.27	5.0	261.27	37.1
7	384.11	1.8	240.96	43.2	376.12	1.9	235.87	43.3
8	390.51	0.2	214.84	49.4	382.47	0.2	210.58	49.3
9	391.26	0	188.75	55.5	383.30	0	185.37	55.4
10	386.36	1.3	162.68	61.7	378.64	1.1	160.26	61.4

CONCLUSION

It could be concluded depending on the use of either biological and regression approaches that both weed free and weed competition duration show that the relationship with weed – free periods and weed competition periods fit with quadratic functions and the critical period of weed competition in sunflower from the above models was between 1 – 6 weeks from sunflower sowing, thus it is important to remove the weeds at this time to maintain the maximum seed yield potential.

~~**1- Yield/ vine:**~~

~~Data in Table (1) clearly show that spraying clusters of Early sweet grapevines with GA_3 at 10 to 40 ppm or Sitofex at 2.5 to 10 ppm was significantly effective in improving the yield relative to the check treatment. The promotion on the yield was accompanied with increasing concentrations of each plant growth regulator. Using GA_3 at 10 to 40 was significantly preferable than using Sitofex at 2.5 to 10 ppm in improving the yield. A slight and unsignificant promotion on the yield was attributed to increasing concentrations of GA_3 from 20 to 40 ppm and Sitofex from 5 to 10 ppm. The maximum yield was produced on the vines that received one spray of GA_3 at 40 ppm but the best treatment from economical point of view was the application of GA_3 at 20 ppm (since no measurable promotion on the yield was recorded between 20 and 40 ppm of GA_3). Under such promised treatment, yield/ vine reached 13.6 and 14.0 kg during both seasons, respectively. The control vines produced 9.1 and 9.6 kg during 2013 and 2014 seasons, respectively. The percentage of increase on the yield due to application of GA_3 at 20 ppm over the check treatment reached 49.5 and 45.8 % during both seasons, respectively. The beneficial effects of GA_3 on the yield might be attributed to their positive action on increasing cluster weight. The promoting effects of GA_3 on the yield was supported by the results of Dimovska *et al*., (2011) and Abu- Zahra and Salameh (2012) on different grapevine cvs.~~

~~The results regarding the beneficial effects of Sitofex on enhancing the yield are in harmony with those obtained by Juan *et al*. (2009); Abdel- Fattah *et al*., (2010) and Al- Obeed (2011).~~

~~**2- Harvesting date:**~~

~~It is clear from the data in Table (1) that all GA_3 and Sitofex treatments had significantly delayed on the harvesting date of Early Sweet grapevines rather than the control treatment. The degree of delayness on harvesting date was correlated to the increase of the concentrations of both GA_3 and Sitofex. Using GA_3 significantly delayed harvesting date comparing with using Sitofex. Increasing concentrations of GA_3 from 20 to 40 ppm and Sitofex form 5 to 10 ppm failed to show significant delay on harvesting date. A considerable advancement on harvesting date was observed on untreated vines the great delay on harvesting date was observed on the vines that received GA_3 at 40 ppm during both seasons. GA_3 and Sitofex were shown by many authors to retard the release of ethylene and the disappearance of pigments such as chlorophylls and carotenoids and onest of maturity start. Also they were responsible for prolonging pre-maturity stages Nickell (1985). These results regarding the delaying effect of GA_3 and Sitofex on harvesting date were in harmony with those obtained by Wassel *et al*., (2007), Kassem *et al*. (2011), Abu- Zahra and Salameh (2012) and Refaat *et al*. (2012).~~

~~**3- Cluster weight and dimensions:**~~

It is evident from the data in Table (1) that treating clusters with GA_3 at 10 to 40 ppm or Sitofex at 2.5 to 10 ppm was significantly accompanied with enhancing weight, length and width of cluster relative to the control treatment.

The promotion was significantly associated with increasing concentrations of GA_3 and Sitofex. Using GA_3 was significantly favourable than using Sitofex in this respect. The maximum values were recorded on the vines that received one spray of GA_3 at 40 ppm. Meaningless promotion was detected with increasing concentrations of GA_3 from 20 to 40 ppm and Sitofex from 5 to 10 ppm. The untreated vines produced the minimum values during both seasons. The positive action of GA_3 on cluster weight and dimensions might be attributed to its essential role on stimulating cell division and enlargement of cells, the water absorption and the biosynthesis of proteins which will lead to increase berry weight. Dimovska *et al*., (2011); Abu- Zahra and Salameh, (2012) and Dimovska *et al*., (2014).

The previous essential role of CPPU on cluster weight was attributed to its higher content of cytokinin when applied to plants (Nickell, 1985).

4- Shot berries %:

Data in Table (2) obviously reveal that percentage of shot berries in the clusters of Early Sweet grapevines was significantly controlled with spraying GA_3 at 10 to 40 ppm or Sitofex at 2.5 to 10 ppm relative to the check treatment. Using GA_3 was preferable than using Sitofex in reducing the percentages of shot berries. There was a gradual reduction on the percentage of shot berries with increasing concentrations of GA_3 and Sitofex. There was a slight reduction on such unfavourable phenomenon with increasing concentrations of GA_3 form 20 to 40 ppm and Sitofex from 5 to 10 ppm. The minimum values of shot berries (7.3 and 6.9 % during both seasons, respectively) were recorded on the clusters harvested from vines treated with GA_3 at 40 ppm. The maximum values of shot berries (12.0 & 12.5 %) during both seasons were recorded on the untreated vines during both seasons. The reducing effect of GA_3 on shot berries might be attributed to its important role on enhancing cell division and the biosynthesis of proteins Nickell, (1985). These results were supported by the results of wassel *et al*. (2007) and Abu-Zahra and Salameh (2012).

5- Fruit quality:

Data in Tables (2, 3 & 4) clearly show that spraying clusters with GA3 at 10 to 40 ppm or Sitofex at 2.5 to 10 ppm significantly was accompanied with enhancing weight, longitudinal and equatorial of berry, total acidity%, proteins % and percentages of P, K and Mg and T.S.S. %, reducing sugars %, T.S.S. / acid and total carotenoids relative to the check treatment. The effect either increase or decrease was associated with increasing concentrations of each auxin. Using GA_3 significantly changed these parameters than using Sitofex. A slight effect was recorded on these quality parameters with increasing concentrations of GA_3 from 20 to 40 ppm and Sitofex from 5 to 10 ppm. From economical point of view, the best results with regard to fruit quality were observed due to treating clusters with GA_3 at 20 ppm. Untreated vines produced unfavourable effects on fruit quality. These results were true during both seasons. The effect of GA_3 on increasing berry weight and dimensions might be attributed to its effect in promoting cell division and enlargement of cells, water uptake and the biosynthesis of proteins Nickell (1985). These results were in concordance with those obtained by Williams and Ayars (2005) and Dimovska *et al*., (2014).

The higher content of Sitofex from cytokinins surly reflected on enhancing cell division and the elongation of berries Nickell (1985). These results were in agreement with those obtained by Abu-Zahra (2013) and Retamales *et al*. (2015).

CONCLUSION

Treating Early Sweet grapevines once when the average berries reached 6mm with GA_3 at 20 ppm was responsible for promoting yield and fruit quality.

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الملخص العربى

النماذج الرياضية لتحديد الفترة الحرجة لمنافسة الحشائش لمحصول عباد الشمس

تاثير رش حامض الجبريليك والسيتوفكس فى تحسين المحصول وجودة حبات العنب الايرلى سويت فى منطقة المنيا– مصر

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رشدي محمد حسن تجور
المعمل المركزي لبحوث الحشائش، مركز البحوث الزراعية، الجيزة

محمد على مجاور عبادة، ماهر خيرى يواقيم، بسام السيد عبد المقصود بلال
قسم بحوث العنب – معهد بحوث البساتين– مركز البحوث الزراعية– الجيزة– مصر

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قسم بحوث العنب – معهد بحوث البساتين– مركز البحوث الزراعية– الجيزة– مصر

تم اقامة تجربتين حقليتين علي عباد الشمس خلال الموسمين الصيفين لعامي ٢٠١٣ و٢٠١٤م بمحطة البحوث الزراعية بالسرو محافظة دمياط – مصر. شملت التجربة علي عدد ١٠ معاملات من الإزالة المبكرة أو المتأخرة للحشائش من الزراعة وهي:- منافسة الحشائش طول الموسم منذ بداية الزراعة حتي الحصاد ومنافسة الحشائش لمدة ٢، ٤، ٦، ٨ أسابيع من الزراعة وإزالة الحشائش لمدة ٢، ٤، ٦، ٨ أسابيع من الزراعة وإزالة الحشائش طول الموسم تحت ظروف العدوى الطبيعية للحشائش لتحديد حجم النقص في ناتج محصول البذرة في عباد الشمس ومتى يتم التوقف عن النقص في المحصول.حيث كان مجتمع الحشائش السائدة في حقل التجارب في العامين هي حشائش الرجلة والملوخية وعرف الديك وابو ركبة والزربيح بكثافة عالية بما يلائم إجراء مثل هذا النوع من الدراسات.

أوضحت النتائج أن الفقد في محصول البذرة في عباد الشمس هو ٥٥,٣ إلي ٥٥,٢% تحت ظروف العدوى الطبيعية للحشائش بمقدار ٦,٥٢٧ و٥,٨٨٥ طن/فدان من الحشائش الغضة الكلية في الموسمين الأول والثاني علي التوالي. تم تقدير الفترة الحرجة بالطريقة التقليدية حيث وجد أن الفترة الحرجة لمنافسة الحشائش تبدأ بعد أسبوعين من الزراعة ثم يتوقف النقص في حاصل المحصول بعد ٦ أسابيع من الزراعة، أوضح استخدام التحليل الرياضي باستخدام منهج الانحدار أن النماذج الرياضية لدراسة العلاقة بين فترات منافسة الحشائش أو أزالتها وحاصل محصول البذرة والزيت من عباد الشمس يتبع معادلات من الدرجة الثانية. وكانت معاملات الارتباط قوية ومعنوية

علي مستوي ١% حيث كانت ٩٨٩,.، ٩٨٢,. و٩٨٩,.، ٩٨٤,. في الفتـــرات الخاليـــة مـــن الحشـــائش و٨٩٩, .، ٩٩٢, . و٩١٩,.، ٩٩٤,. ٪ في فترات المنافسة للحشائش خلال الموسم الصيفي ٢٠١٣ و٢٠١٤ علـــي التـــوالي. وأوضح تطبيق هذه المعادلات أنه للحصول علي ٩٥% من محصول البذرة والزيت مـــن عبـــاد الشـــمس مقارنـــة بمحصول البذرة والزيت في عباد الشمس الخالية من الحشائش طول الموسم فانه علي مزارعي عبـــاد الشـــمس ألا يتأخروا في بدء عمليات المكافحة عن الأسبوع الأول من الزراعة وأن تستمر عملية المكافحة حتى الأسبوع السادس من الزراعة من خلال استخدام التوصيات المناسبة باستخدام مبيدات تضاف بعد الإنبات لإبادة المدى الواســـع مـــن أنواع الحشائش المذكورة سابقا أو إجراء النقاوة اليدوية في هذه الفترة أو التكامل بينهما.

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