Productivity of Sesame as Influenced by Weeds Competition and Determination of Critical Period of Weed Control

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ABSTRACT

Two summer seasons (2011 and 2012) field experiments were conducted at El-Nubaria Research Station, Agricultural Research Center, to estimate the optimum time for weed control and determine the effect of weed competition period length (14, 28, 42, 56, 70, 84 and all season after emergence) and weed free duration on plant height (cm), inflorescence length (cm), number of capsules/plant, 1000-seed weight (g), biological yield (ton/ha), seed yield (ton/ha), straw yield (ton/ha), harvest index, oil % and oil yield (ton/ha). Treatments were arranged in Randomized Complete Block Design (RCBD) with three replicates. Results showed a significant effect of both weed free and weedy periods on all studied characters. The results showed that 79 and 81 % decrease in seed yield of all season weedy, compared to all season weed free, in the first and second season, respectively. The reduction in biological and seed yields between 14 days period and weedy all season reached 70.7 and 78.8 % in the first season, and 74.5 and 81.8 % in the second season, respectively. Also, data revealed that critical period for weed control (CPWC) in 2011 season ranged from 15-70 days after emergence (DAE) for acceptable yield loss (AYL) of 5 % and from 18-54 DAE for AYL of 10 %. However, in 2012 season, CPWC ranged from 18-41 DAS for AYL 5 % and from 20-30 DAS for AYL 10 %.

Key words: *Sesamum indicum* L., Critical period for weed control, seed yield and yield components, oil content

INTRODUCTION

Sesame is an important crop in Egypt. It is cultivated for its seeds that are high in oil and protein contents. Sesame is recognized as a poor competitor with weeds through the first four weeks due to its seedlings slow growth (Bennett *et al.*, 2003). Sesame yield losses are mainly due to delayed weeding or insufficient weed control (Tepe *et al.*, 2011). Severity of yield loss depends upon weed competition and competition period, in addition, to climatic conditions which affect weed and crop growth. Weeds can efficiently remove plant nutrients from the soil than sesame to grow faster and inhibit sesame growth due to the adverse effect on photosynthesis and assimilates accumulation (Rao, 2000).Therefore, effective and proper weed control time will result in higher seed yield of sesame and that depends on application of weed control program according to critical period consideration. Controlling weeds based on the critical period for weed control (CPWC) is the most appropriate way to reach optimum application and decide the efficient timing of weed control. Nevertheless, it could also enhance the efficiency of weed control by other methods such as cultivation to reduce herbicide treatments application to attain environmental safety and reduce yield losses due to weed interference (Knezevic *et al.,* 2002 and Mahmoodi and Rahimi, 2009). The CPWC is the time period in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield loss (Evans *et al.*, 2003), the length of time for crop tolerance to weed competition before arrival to yield loss more than the cost of weed control (Mahmoodi and Rahimi, 2009). The CPWC was, also, defined as the time between the maximum weed- infested and minimum weed free periods after crop emergence (Knezevic *et al.*, 2002). It is determined by calculating the time interval between two components of weed interference, i.e. weed competition and weed free periods (Uremis *et al.*, 2009).

Weed control in sesame in this study was carried out by hand hoeing that is effective in controlling weeds with increasing production costs and establishment of side effects when applied intensively and/or repeatedly. Studies have been conducted around the world to determine CPWC in sesame, with a range of environmental conditions. Beltrao *et al.* (1997) reported that sesame weed free period of 60 (in Sausa) and 30 to 35 (in Monterio) days after emergence (DAE). However, Venkatakrishnan and Gnanmurthy (1998) showed, in India, that the most critical period sesame-weed competition was from 30-45 DAE. In addition, Amare *et al.* (2009) found a critical period of weed competition of 10-30 DAE in sesame crop. Variation in CPWC values can be attributed to changes in weed species composition, weed-ground cover and climatic conditions, in which crops and weeds interfere (Knezevic *et al*., 2002). This investigation aimed to estimate the optimum timing for weed control and determine the effect of weed competition length and weed free duration on sesame yield under the prevailing conditions of El-Nubaria region, El Biehera governorate, Egypt.

MATERIALS AND METHODS

A two summer seasons field study (2011 and 2012) was conducted at Agriculture Research Station at El-Nubaria region, El Biehera governorate, Egypt to investigate the effect of weed free and weed infestation on sesame (c.v Shandawil 1) seed yield and some agronomical and quality traits. Soil chemical properties in the experimental site were 7.9 for PH, 1.3 % for organic matter, 16.5 ppm for available N and 9.5 ppm for inorganic phosphorus, as an average of the two seasons. Periods for weed free and weed competition were 14, 28, 42, 56, 70 and 84 days after emergence in addition to full season weed free and weedy checks (84 days after emergence). Treatments were arranged in a Randomized Complete Block Design with three replicates. Plot size was 3x4 m comprising 6.0 ridges (each 0.5 wide and 4 m length). Sesame was sown on one side of ridges and thinned to one plant/hill at 10 cm intra ridge spacing, on April 10 th and 15 th for the two successive seasons. Three square meter samples were taken at random from each plot. Weed biomass and major species for each season were determined (above- ground dry weights) by weeds clipping at the soil surface from each quadrate by hand hoeing and dried at 70 ^{o}c .

At maturity, the two inner ridges were harvested to determine plant height (cm), inflorence length (cm), number of capsules/plant, 1000-seed weight (g), biological yield, seed yield, straw yield (ton/ha), harvest index, oil percentage and oil yield (t/ha) . In addition, were determined broad, narrow and total weeds. Oil percentage was determined of dried mature seeds and were ground into very fine powder to determine oil % using Soxhelt apparatus and petroleum ether as a solvent according to A.O.A.C. (1990).

The onset and the end of critical period within which weed control is mandatory was estimated by the response curves of relative yield compared to all seasons weed free. The critical period of weed control was computed by fitting Logistic and Compertz model. A three-parameter logistic equation, proposed by Hall *et al.* (1992) and modified by Knezevic *et al.* (2002) was used to describe the effect of increasing duration of weed interference on relative yield. The Compertz model has been shown to predict the relationship between relative yield, as influenced by the length of the weed-free period. The logistic equation was used to determine the beginning of the CPWC, and the Compertz equation was used to determine the end of the CPWC for acceptable yield loss levels of 5 % and 10 %. Statistical analysis of data was performed according to Gomez and Gomez (1984) using SAS program ver. 8.

RESULTS AND DISCUSSION

The present study was designed to investigate the influence of weeds on several characters of sesame, and to determine the critical period for weed control (CPWC) under the prevailing environmental conditions of El-Nubariah region. The studied characters could be grouped as follow:

A- Weed characters:

Means presented in (table 2) revealed that broad leaf weeds comprised the major portion of the total weed population in the experimental site in both seasons. Increasing weedy period led to an increase in total weeds biomass in both seasons. The reverse, however, was observed for increasing weed-free period.

Table 1: Weed competition (%) of weed population in experimental sites in 2011 and 2012 seasons.

Species	2011	2012
Annual narrow-leaved weeds percentage:		
1. *Echinochloa colonum*	5.8	8.8
2. *Setaria viridis*	5.3	17.8
3. *Digitaria sanguinalis*	Negligible	6.4
Total	11.1	33.0
Annual broad-leaved weeds percentage:		
1. *Xanthium strumariam*	74.5	5.4
2. *Euphorbia geniculata*	2.3	23.4
3. *Amaranthus viridus*	2.6	18.3
4. *Portulaca oleraceae*	6.4	6.7
5. *Chenopodium murale*	3.1	Negligible
6. *Conyza aegyptiaca*	Negligible	7.4
7. *Corchorus oiltorus*	Negligible	5.8
Total	88.9	67.0

Table 2: Mean of dry weight for broad-leaved, narrow-leaved and total weed (g/m^2) in 2011 and 2012 seasons.

	Period (days)	Broad-leaved	Narrow-leaved	Total weeds	Broad-leaved	Narrow-leaved	Total weeds
		2011 season			2012 season		
Weed free	14	682.29	435.37	1117.66	871.71	323.22	1194.93
	28	141.18	110.74	251.92	222.84	123.49	346.33
	42	14.75	11.00	25.75	42.34	117.42	159.76
	56	14.61	6.99	21.60	26.62	68.31	94.93
	70	13.95	5.81	19.76	23.32	33.20	56.52
	84	10.51	4.63	15.14	19.85	13.64	33.49
	All season	9.73	0.46	10.19	14.88	9.88	24.76
Weedy	14	9.64	0.55	10.19	25.11	11.54	36.65
	28	14.19	12.31	26.50	67.52	49.80	117.32
	42	22.22	13.08	35.30	139.16	53.99	193.15
	56	25.53	17.78	43.31	139.59	71.60	211.19
	70	31.34	36.40	67.74	144.17	29.95	174.12
	84	243.79	68.56	312.35	497.49	28.92	526.41
	All season	2189.92	285.3	2475.22	2299.83	249.93	2549.76
LSD 0.05		162.91	59.35	152.48	232.7	74.65	253.99

The response of weed population to weed-free and weedy period are used to determine the two components of CPWC, i.e., critical weed-free period (CWFP) defined as minimum weed-free period required from time of planting to prevent unacceptable yield reductions, and critical timing of weed removal (CTWR) defined as the maximum amount of time early-season weed competition that can be tolerated by the crop before the crop suffers irrevocable yield reduction (Knezevic et al., 2002). These findings are in harmony with those reported by Amare et al. (2011), Zubair et al. (2011) and Tyagi et al. (2013) who reported an increase in weeds dry weight with increasing weedy period as a result of prolonged weed growth period.

B- Agronomic and yield characters:

B.1 - Plant height (cm)

Sesame plant height was significantly affected by the length of weedy and weed free period (Table 3). Plant height increased with prolonged weed free conditions and decreased with increasing weedy duration. Increased weed competition period up to 42 DAE produced taller plants that were statistically equal in length, however, extension of such period to all season-weed infestation established significant decrease in plant height in both seasons. On the contrary, weed free period of 14 DAE gave the significantly shortest plants, while increasing weed free period beyond 14 DAE gave taller plants with insignificant differences. Reductions in height due to weed competition may be attributed to faster weed emergence, compared to sesame plants which was reflected in greater uptake of growth resources leading to higher competitive ability of weeds for the remaining period of growing season and decreasing sesame vegetative growth in terms of decreased plant height. However, increases in weed free period was associated with lower weed emergence and greater resources uptake by sesame plants that caused plants to be tall. These results were in agreement with Amare (2011), Tepe *et al.,* (2011) and Abdul Hakim *et al.* (2013) in studies on sesame, chickpea and rice, respectively.

B.2. Inflorescence length (cm):

Means of inflorescence length in the two seasons, as affected by weed free/weedy periods are presented in (table 3). The data revealed a continuous increase in inflorescence length with increasing weed free period. That may be attributed to relief of sesame plants from weed competition leading to better growing conditions and more resources availability to the sesame plants. That character is closely related to an important yield component of sesame, i.e., number of capsules per plant, where increase in inflorescence length is expected to produce more capsules per plant.

B.3. Number of capsules/plant:

Concerning number of capsules/plant, data showed that plots of all season weed free produced the maximum values for that trait which was statistically superior to plants of 28 DAE and 56 DAE weedy free and weed infestation periods, respectively. Decrease in number of capsules/plant was observed as weed crop competition period was prolonged until it concluded the whole-crop growing season. Meanwhile, there was a gradual increase in that trait when the weed free period was increased till all season weed free.

Maximum number of capsules, in all season weed free treatment, may be due to the efficiency of photosynthesis which was supported by the ample uptake of water, nutrients and radiation in the absence of weeds. This increased photoassimilates allocation into reproductive parts that led to an increase in that trait. Serogy (1992) and Zubair *et al.*, (2011) reached the same conclusion.

B.4. 0ne-thousand seed weight (g)

Response of one thousand seed weight to weedy and weedy free treatments was significant (table 3). The maximum seed weight was obtained from all season weed free treatment, followed by weedy treatment of 14 DAE. The trend of data indicated that the weight of 1000-seeds was decreased with increasing of weed competition as weeding was delayed till the end of growing season of sesame. The decrease in seed weight with increasing competition period might be due to increase in weed population that was associated with greater resources removal by weeds leading to reduction in photoassimilate production and translocation to the reproductive organs of crop plant, hence decreasing seed weight. These results were in agreement with Spader and Vidal (2000) who noted a decrease in maize grain weight with increase in weed density. However, Zubair *et al.* (2011) found that weeds and sesame crop competition for a period of 3 weeks after emergence did not show significant decrease in such trait.

B.5. Biological yield (ton/ha)

Response of biological yield to weed free and weed competition was significant during the two seasons (table 3). Reciprocal differences were found between weedy and weed free treatments. With increasing in weed free period, there was an increase in biological yield and the reverse trend was obtained as weedy period increased. The maximum sesame biological yield was recorded in sesame all season weed free treatments in the first season and 14 DAE weedy in the second one. However, the minimum record of biological yield was observed in the all season weed competition followed by biological yield under 14 DAE weed free period. These results indicated that decreasing the biological yield in sesame might be due to weed competition as a consequence of depletion of nutrient supply and water by weeds which resulted in reduced growth, seed and straw yields of crop plants (Ali and Awan, 2004).

B.6. Seed yield (ton/ha)

Results presented in (table 3) indicated a significant reduction in sesame seed yield with increasing in the period of weed competition (weedy) up to 42 days after crop emergence. The decrease continued till the end of the sesame growth period with insignificant increments. That resulted in 79 and 81 % decrease in seed yield of all season weedy, compared to all season weed free, in the first and second seasons, respectively. These findings may be attributed to the increase in competition between crop plants and weeds for growth resources with prolonged weed growth. The slow early growth of sesame favor luxuriant weed growth throughout the season resulting in reduction of all yield components, i.e. number of capsules per plant and 1000-seed weight. Amare (2011) reported a 84 % reduction for weedy check compared to weed free. Similarly, Bhadauria *et al* (2012) found a 50 – 75 % reduction in seed yield for all season weedy treatment compared to all season weed free check.

B.7. Straw yield (ton/ha)

Data in (table 3) showed that both weedy and weed free periods had a significant effect on straw yield/ha. Full season weed competition period resulted in the lowest straw yield, corresponding to the maximum that was obtained as plant were kept weed free over the growth period. Increasing weed competition with the increase of weed-sesame plants association period up to 14 days after planting led to significant reduction in such trait. These results could be due to weeds were greater sharing in growth factors with sesame which was reflected in lower vegetative growth in term of losses in straw yields. These results are in close conformity with those of Bayan and Saharia (1998) and Martinková and Honek (2001) who found decreases in plant dry matter with increasing weed competition period in maize. A reduction in weed competition by increasing weed free period was associated with increasing in dry matter accumulation in shoots of sesame plant. Bennett *et al.* (2003) found that sufficient weed control increased sesame dry matter accumulation.

B. 8. Harvest index:

Results in (table 3) indicated a decrease in harvest index values with increasing weedy period. That implies a higher reduction in seed yield, compared to biological yield, at different periods. The reduction in biological and seed yields between 14 days period and weedy all season reached 70.7 and 78.8 % in the first season, and 74.2 and 81.8 % in the second season, respectively. High reduction in seed yield, compared to biological yield may be attributed to the reduction in important yield components, such as number of capsule per plant and 1000 seed weight which reached 63.4 % and 54.6 % as an average of the two seasons, respectively.

C. Oil percent and oil yield

Results presented in (table 4) revealed a decrease in seed oil content with increasing weedy period especially late in the season (70 days after emergence or more). The same trend was observed, as aforementioned, in seed yield per ha, which resulted in a decrease of oil yield per ha with increasing weedy period. These findings might be attributed to the competition between weeds and crop plants which takes place at two levels: 1- sub-soil level where weeds, especially broad-leaved species that had the same root system as sesame, compete with crop plants for water and nutrients resulting in an imbalanced nutritional status within sesame plants and hinders proper growth of the plant, and 2- aerial (above soil) level, where weeds compete the crop plants for light causing a reduction in photosynthesis process and photosynthates production, which are the basic compounds for production of organic compounds in the plant such as carbohydrates, proteins and fats. Hence, prolonged weed competition will cause a reduction in oil content of seeds, and eventually reduce oil yield per hectare due to the decrease in seed yield.

D. Determination of CPWC:

Critical period for weed control (CPWC) was defined as the time period in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield loss (Evans *et al*, 2003). Factors that directly affect CPWC include weed composition, weed density, time of weed emergence relative to the crop, crop and weed growth behavior, or acceptable yield loss (Mahmoodi and Rahimi, 2009). Thus, there is a wide range of variability in CPWC. Moreover, site specific factors such as planting pattern and environmental conditions may be added to the variation in CPWC. Hence, to provide more precise information, CPWC should be determined for a particular region (Knezevic *et al.*, 2002).

Table 3: Mean values for studied agronomic characters as affected by weed free and weedy periods in 2011 and 2012 seasons.

	Period (days)	Plant height (cm)	inflorescence length (cm)	No. of capsules /plant	1000 seed weight (g)	Bylogical yield (t/ha)	Seed yield	Straw yield (t/ha)	Harvest index
					Season 2011				
Weed free	14	88.0	49.75	29.8	2.45	2.27	0.37	1.90	16.29
	28	116.5	54.75	44.2	4.57	4.26	0.74	3.52	17.45
	42	114.0	61.75	47.5	4.82	4.43	0.88	3.55	19.81
	56	121.5	63.75	59.5	5.05	4.49	0.92	3.57	20.53
	70	123.2	64.75	60.2	5.55	4.58	1.00	3.58	21.84
	84	124.5	65.75	64.2	5.85	4.74	0.98	3.68	20.78
	All season	123.8	71.25	66.2	6.35	4.82	1.05	3.84	21.86
Weedy	14	125.5	65.50	58.5	5.37	4.74	1.04	3.71	21.90
	28	123.2	62.75	55.0	4.37	3.77	0.81	2.96	21.42
	42	116.0	56.75	49.8	3.60	2.33	0.46	1.87	19.57
	56	110.8	52.00	36.5	3.10	1.98	0.32	1.71	16.26
	70	99.8	44.75	30.5	2.90	1.92	0.27	1.59	14.14
	84	89.2	41.25	21.5	2.45	1.58	0.25	1.36	16.00
	All season	80.2	41.25	19.0	2.42	1.39	0.22	1.14	15.72
LSD 0.05		14.0	10.26	11.1	1.14	0.56	0.16	0.48	3.68
					Season 2012				
Weed free	14	99.0	56.00	36.5	2.80	2.65	0.49	2.16	18.38
	28	118.5	57.50	47.2	4.83	3.81	0.71	3.09	18.50
	42	116.5	60.25	48.0	5.53	3.95	0.85	3.11	21.62
	56	123.0	65.50	50.5	5.53	4.29	0.96	3.36	22.34
	70	122.5	66.50	58.0	5.75	4.36	0.92	3.40	21.04
	84	117.2	67.00	58.0	6.08	4.37	0.93	3.42	21.30
	All season	125.0	67.00	59.7	6.30	4.40	0.95	3.49	21.49
Weedy	14	127.5	67.50	64.0	6.03	4.80	0.99	3.81	20.70
	28	127.0	66.75	53.7	5.42	3.49	0.79	2.70	22.70
	42	112.0	58.75	47.0	3.28	1.93	0.36	1.57	18.85
	56	107.0	52.75	35.2	2.95	1.80	0.31	1.49	17.44
	70	98.2	50.25	34.7	2.95	1.28	0.20	1.10	15.30
	84	97.2	49.75	30.0	2.92	1.27	0.21	1.06	16.78
	All season	101.8	47.5	26.0	2.75	1.24	0.18	1.04	14.68
LSD 0.05		13.74	9.17	9.5	1.11	0.57	0.16	0.46	3.85

Table 4: Mean values for oil % and oil yield (t/ha) as affected by weed free and weedy periods in 2011 and 2012 seasons.

	Period (days)	Oil % (2011 season)	Oil Yield (T/ha) (2011 season)	Oil % (2012 season)	Oil Yield (T/ha) (2012 season)
Weed free	14	48.09	0.18	48.82	0.24
	28	49.13	0.37	51.01	0.36
	42	51.03	0.45	50.86	0.43
	56	50.26	0.46	51.70	0.50
	70	51.57	0.52	51.03	0.47
	84	51.15	0.50	51.37	0.48
	All season	52.40	0.55	52.03	0.49
Weedy	14	50.32	0.52	50.76	0.50
	28	48.87	0.39	48.12	0.38
	42	48.97	0.22	47.46	0.17
	56	48.08	0.15	47.80	0.15
	70	47.47	0.13	46.28	0.09
	84	46.28	0.12	46.83	0.09
	All season	46.78	0.10	46.33	0.08
LSD 0.05		1.64	0.08	1.56	0.07

Data presented in (Fig. 1 and 2) revealed that CPWC in 2011 season ranged from 15-70 DAS for acceptable yield loss (AYL) of 5 % and from 18-54 DAS for AYL of 10 %. However, in 2012 season, CPWC ranged from 18-41 DAS for AYL 5 % and from 20-30 DAS for AYL 10 %. The variation in CPWC between the two seasons could be explained by the differences in composition of weed population (Table 1). In 2011 season, the major predominant weed was *Xanthium strumarium* (74.5 %) a broad-leaved weed which produce fruits (bur) that contains two seeds, one that grows during the first year and one that grows a year later or when the plant growing from the first seed is removed (Weaver and Lechowitz, 1983). Hence, controlling of that weed early in the season may cause a second wave of infestation by that weed late in the season, thus increasing CPWC.

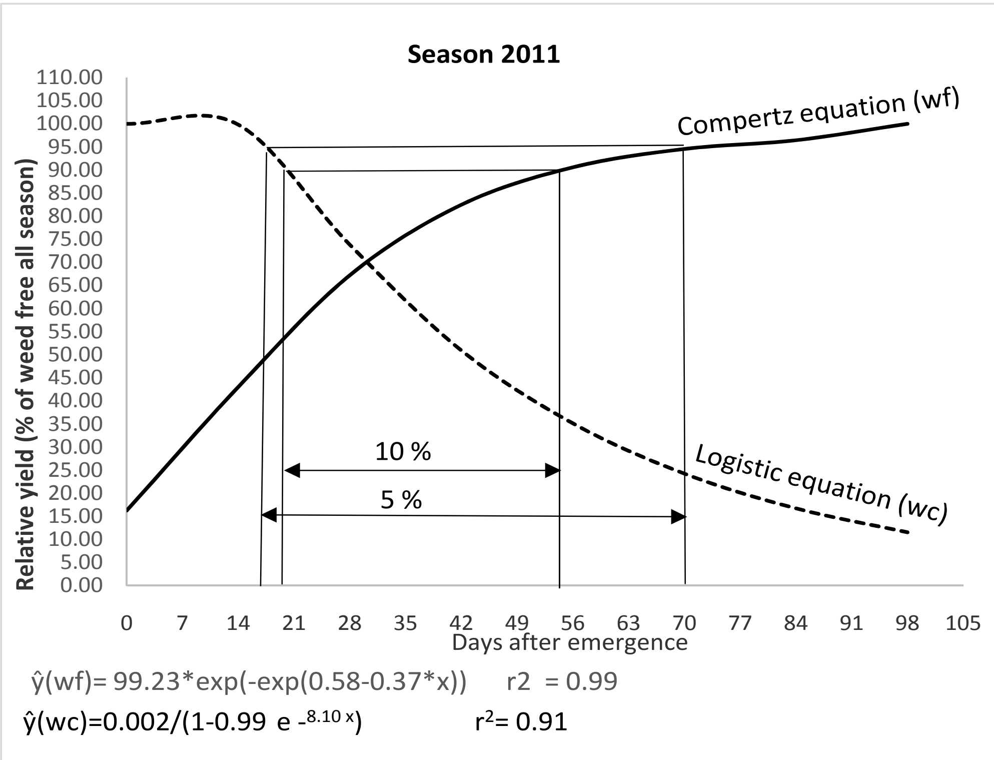

Fig 1: Critical period of weed competition in 2011 season

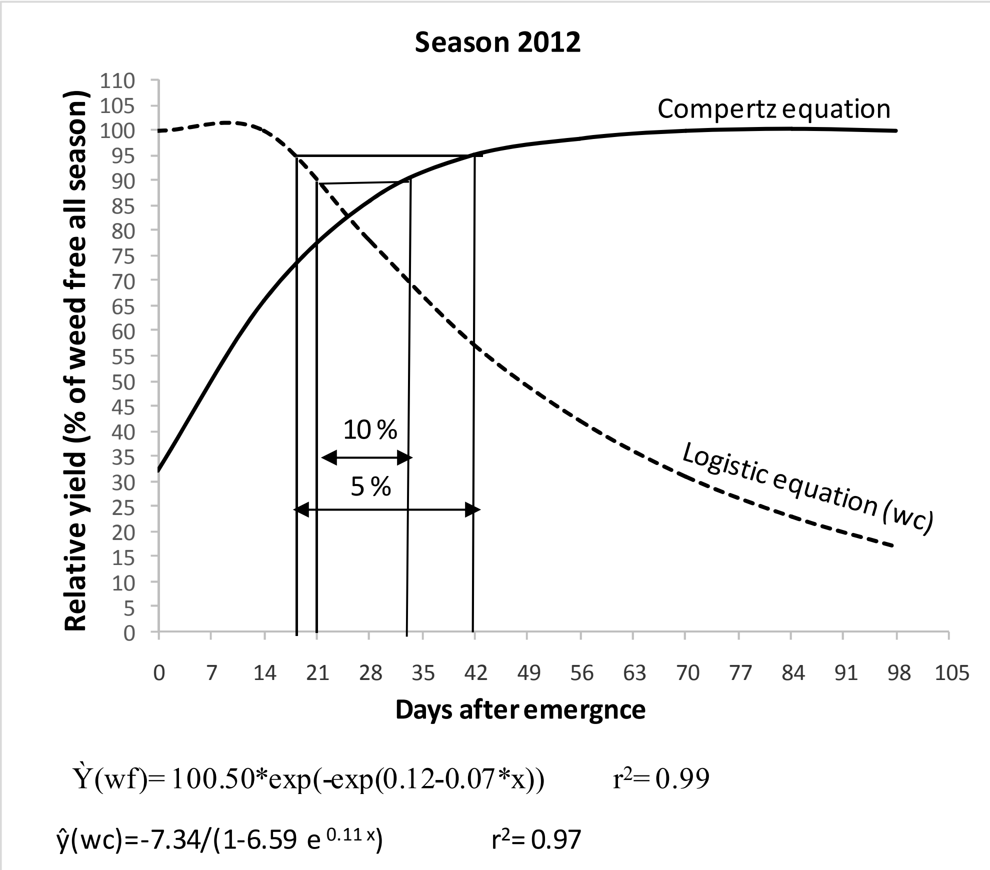

Fig 2: Critical period of weed competition in 2012 season.

These findings were in accordance with those reported by several investigators. Amare (2011) reported a CPWC of 14-28 days after emergence in sesame. Duary and Hazra (2013) reported a CPWC of 19-40 DAS in the first season and 20-42 DAS in the second season. Similarly, Tyagi *et al* (2013) found a CPWC of 15-45 DAS for sesame. Those variations could be explained by differences in environmental conditions and weed species diversity among research sites.

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الملخص العربى

إنتاجية محصول السمسم تحت تأثير منافسة الحشائش وتقدير الفترة الحرجة للمقاومة

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أجريت تجربتان خلال الموسم الصيفى لعامى ٢٠١١، ٢٠١٢ فى محطة بحوث النوبارية– مركز البحوث الزراعية لتقدير أنسب موعد لمقاومة الحشائش بالأضافة الى تقدير تأثير فترة أزالة الحشائش وفترة ترك الحشائش لمدة ١٤، ٢٨، ٥٦، ٧٠، ٨٤، طول الموسم على صفات أرتفاع النبات(سم)، طول الجزء المثمر(سم)، عدد الكبسولات/ للنبات، وزن ١٠٠٠ بذرة (جم)، المحصول الحيوى(طن/هكتار)، محصول البذور(طن/هكتار)، محصول القش(طن/هكتار)، معامل الحصاد، نسبة الزيت %، محصول الزيت(طن/هكتار) فى محصول السمسم صنف شندويل ١. أستخدم تصميم القطاعات العشوائية الكاملة فى ثلاث مكررات وقد أوضحت النتائج أن هناك تأثيراً معنوياً لكل من فترة ازالة الحشائش وفترة ترك الحشائش على جميع الصفات تحت الدراسة حيث انخفض محصول البذور بنسبة ٧٩، ٨١% خلال معاملة ترك الحشائش طول الموسم وازالتها طول الموسم فى الموسمين على التوالى. كذلك انخفض المحصول البيولوجى ومحصول البذور من ١٤ يوم حتى ترك الحشائش طول الموسم الى ٧٠.٧، ٧٨.٨% للموسم الأول، ٧٤.٢، ٨١.٨% للموسم الثانى على التوالى. كما أوضحت النتائج فى موسم ٢٠١١ ان الفترة الحرجة لمقاومة الحشائش والتى تراوحت بين ١٥-٧٠ يوم بعد الانبات أدت الى فقد ٥% من المحصول اما الفترة الحرجة والتى تراوحت بين ١٨-٥٤ يوم بعد الأنبات فقد أدت الى فقد ١٠% من المحصول. على الجانب الآخر فى موسم ٢٠١٢ تراوحت هذه الفترة من ١٨-٤١ يوم عند الحصول على فقد ٥%، بين ٢٠-٣٠ يوم بعد الأنبات عند الحصول على فقد ١٠ % من المحصول.