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Mathematical Models for Determination of the Critical Period of Weed Competition in Maize (*Zea mays* L.)

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ABSTRACT

Two field experiments were conducted on maize during 2014 and 2015 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 maize yield and when to control without yield losses in maize. The most appropriate study of the critical period of weed competition is on the weed community as a whole than single weed specie. Dominant major weeds in experimental fields were *Portulaca oleraceae*, L.; *Corchorus olitorius,* L.; *Amaranthus caudatus*, L.; *Echinochloa crus-gali*, L. and *Echinochloa colonum,* L. The obtained results revealed that which weed infestation rate under maize field was 5.834 and 6.043-ton fresh weight / fed., which reduced drastically grain yield of maize /fed by 56.8 to 57.2 % under weed competition treatment of maize for the whole season in 2014 and 2015 summer seasons, respectively as compared with weed free for whole season treatment. The use of response curves with weed free or weed competition periods showed that grain yield of maize / fed were the highest with the field free from weeds until seven weeks after sowing and the critical period of weed / maize competition was between 3 to 7 weeks after sowing. In regression approach for maize grain 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 predict yield losses due to weed competition periods with maize. Also, results showed that the quadratic equations were significant and had the highest R^2 (0.990 and 0.985) for weed free period, and (0.994 and 0.993) for weed competition durations in 2014 and 2015 summer seasons, respectively. The important stage of weed competition to maize is the 1-9 weeks period from sowing was required to be weed free showed that to maintain 95% of maximum grain yield of maize and one week of weeds infestation can be allowed after maize sowing without grain yield maize reduction. This information should be taken in consideration for maize growers to plan their strategies of integrated weed management for this important crop. It could be concluded that weeds should be removed within the period of first week and nine weeks in maize crop to pass up 5 and 10% grain yield reduction, respectively.

Keywords: Critical period; Weed; Competition; maize

INTRODUCTION

Maize (Zea mays, L.) is considered one of the most important cereal crops in the world, especially in Egypt. It ranks the third after wheat and rice. Productivity of maize plants depends on the available amount of light interception, nutrients and water. Weeds are considered as a major problem in production of maize in Egypt. Maize is often infested with numerous types of weeds which compete with the crop plants.

The critical period for weed control (CPWC) is the period in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield losses. Thus weed competition is a critical factor affecting growth and productivity of maize plants. Yield losses due to the prevailing weeds were estimated to be about 43-57% (Varshney, 1991) and by about 87% (Kozlowski, 2002). The relative competitive ability of crop plants and weeds changes in the course of plant life cycle (Hall *et al*., 1992). Ferrero *et al*. (1991) and Varshney (1991) they noticed that early competition usually reduce maize yield more than later season weed growth, therefore early weed control is extremely important. Grain yield reduction due to weed infestation in maize varied from 35 to 83% (Usman *et al*., 2001).

The length of the critical period during which weed competition must be absent to avoid crop loss, varies with the crop grown, the weed present and other factors. The critical period of weed competition in maize was 14-21 (Ferrero *et al*., 1991); 21-42 (Shad *et al*., 1993) and 28-56 days after sowing (Hall *et al*., 1992).

Time of weed removal has a significant effect on yield of maize crop. Varshney (1991) found that weeding at 40 DAS is essential for getting maximum yield in maze. Metwally and Youssef (1998) reported that weeding at 20 DAS as well as, 35 DAS gave the highest yield in maize /fed as compared with unweeded check. Ahmed (2000) showed that weed free in maize until harvest and weed removal 2, 4 and 6 weeks after sowing (WAS) gave the maximum yield /fed as compared to unweeded check. Weed control for 9 weeks after sowing in corn gave the best crop yield than uncontrolled weed (Usman *et al*., 2001).

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, 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), (Knezevic *et al*., 2002 and Mekky *et al*., 2005).

Therefore, this study was planned to establish the effects of different weeds competition periods on growth traits and yield attributes of maize under field conditions and to estimate the vital weed period in maize.

MATERIALS AND METHODS

Two field experiments were carried out during summer seasons of 2014 and 2015 at El-Serw Agricultural Research Station, Agricultural Research Center, Damietta Governorate, Egypt to determine the critical period of weed competition in maize. The soil texture was clay (Table 1).

Table 1. Chemical and physical analyses of soil of field experiments of 2014 and 2015 seasons.

Seasons	Soil Depth cm.	Particle size distribution				Texture class	OM %	EC mmhos	PH	N ppm	P ppm	K ppm
		Coarse sand%	Fine Sand%	Silt %	Clay %							
2014	0-30	1.75	13.27	21.53	63.31	clayey	0.85	3.2	8.0	30	8.3	420
2015	0-30	1.71	13.23	21.68	63.20	clayey	0.88	3.5	7.8	32	8.5	430

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:

The experimental trails treatments as follows:

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.

Maize c.v. variety single cross 30K8 was sown on May 25th in both seasons at 20 kg / fed. The experimental plot was consisted of 5 ridges each 3 m long and 70 cm width (10.5 m2 =1/400 of fed). Grains of maize were planted in hills 25 cm apart. 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 randomly taken from an area of one m2 from each plot at harvest. Weeds were identified and classified and the total fresh and dry weights of weed species were recorded. Maize was harvested on October 15th in both seasons.

Data recorded

I: - The survey of weeds:

Weeds were hand pulled from 1 m^2, random from each plot, recognized and classified to species and total fresh and dry weight (g/m^2) were recorded.

II: - Maize yield components at harvest: - Samples of ten maize plants were taken at random from each plot and the following characters were measured: -

1- Plant height (cm). 2- Ear length (cm).
3- Ear weight (g). 4- No. of grains per row.
5- Ear grains weight (g). 6- weight of 100 grains (g).
7- Grain yield was calculated from the seed yield per the whole plot and then converted to (ardab /fed).

III:- Chemical composition of maize grains:

1- Crude protein percentage was determined according to A.O.A.C. (1980).
2- Oil content was determined using the method described and used by (Bedov, 1970) using Soxhlet equipment.

All statistical and data analyses and mathematical models determination obtained data were subjected to statistically analyses 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 maize, 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 maize 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).

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: $\tilde{y} = a + b\,x + c\,x2$ 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 maize 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 maize yield/fed. 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 (Cousens, 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

The dominant weeds in the experimental field in the two seasons were *Portulaca oleraceae*, L.; *Corchorus olitorius,* L.; *Amaranthus caudatus*, L.; *Echinochloa crus-gali*, L. and *Echinochloa colonum,* L.

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 2014 & 2015, reaching (1389.2 g/m2) (5.834 ton/fed) and (1438.9 g/m2) (6.043 ton/fed) fresh weight, as well as, 280.7 g/m2(1.178 ton/fed) and 331.5 g/m2(1.392 ton/fed) dry weight of weeds, respectively. The previous level of weed infestation can be considered very suitable for estimating the critical period of weed competition to maize.

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. The maximum accumulation of weed biomass after emergence in maize. It is evident that weeds emerged during the early stages of maize growth. While, biomass of weed species associated with maize plants was eventually reduced at the later stages of maize growth. This because the weed species that emerged later suppressed by the crop shading, in addition to the competition between weed species and between the weeds and crop. These results are in harmony with those obtained by Ferrero *et al.* (1991), Varshney (1991), Hall *et al.*(1992), Shad *et al.* (1993), Hussein (1996), Metwally and Youssef (1998), Maqsood *et al.* (1999), Ahmed (2000) and Saad El-Din (2003).

Table 2. Effect of weed competition and weed controlled periods on total fresh and weight of dry weeds during 2014 and 2015 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 %
2014 season			
Weed competition for the whole season	1389.2	280.7	0
Weed competition for 2 weeks from sowing	89.7	20.7	92.62
Weed competition for 4 weeks from sowing	296.5	68.3	75.67
Weed competition for 6 weeks from sowing	658.8	151.8	45.92
Weed competition for 8 weeks from sowing	815.8	188.1	32.99
Weed free for 2 weeks from sowing	788.4	181.6	35.30
Weed free for 4 weeks from sowing	372.6	85.9	69.39
Weed free for 6 weeks from sowing	280.2	64.6	76.98
Weed free for 8 weeks from sowing	155.3	35.8	87.25
Weed free for the whole season	63.8	14.7	94.76
LSD at 0.0 5	19.55	7.35	
2015 season			
Weed competition for the whole season	1438.9	331.5	0
Weed competition for 2 weeks from sowing	98.6	22.8	93.12
Weed competition for 4 weeks from sowing	310.6	71.6	78.40
Weed competition for 6 weeks from sowing	690.8	159.2	51.97
Weed competition for 8 weeks from sowing	860.5	198.3	40.18
Weed free for 2 weeks from sowing	795.1	183.2	44.74
Weed free for 4 weeks from sowing	397.4	91.6	72.37
Weed free for 6 weeks from sowing	307.2	70.8	78.64
Weed free for 8 weeks from sowing	171.2	39.4	88.11
Weed free for the whole season	77.5	17.8	94.63
LSD at 0.0 5	18.62	7.36	

II - Effect of weed competition on growth characters and yield components of maize:

Data in Table 3 indicated that plant height, ear length, ear weight, number of grains / row, ear grains weight and 100-grain weight of maize plants were significantly affected by weed competition and removal duration at harvest in both seasons. The treatments of weed free and weed removal periods significantly increased plant height, ear length, ear weight, number of grains / row, ear grains weight and 100-grain weight than weed competition for the whole season (unweeded check) in the two studied seasons. The maximum values 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 respects in weed removal treatments at 6 and 8 weeks from sowing and weed competition for the whole season (unweeded check). Unweeded treatment reduced the lowest thicker of this trail. This may be due to that the competition of weeds affected crop growth and minimizing the availability of nutrients, water and sunlight. The weed growth there will be one less unit of crop growth.

Moreover, 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 were recorded with highest density of weeds. These results coincided with those obtained by Varshney (1991), Shad *et al.* (1993), Hussein (1996), Metwally and Youssef (1998), Ahmed (2000), Evans *et al.* (2003), Saad El-Din (2003), Hussein *et al*. (2012) and Safdar *et al.* (2016). They recorded that the weed competition effects on such maize plants growth and yield component.

II - Effect of weed competition on yield :

Data presented in Table 4 showed that grain yield per faddan, grain protein percentage and grain oil percentage at harvest were significantly increased due to weed free and weed removal periods treatments uses in

both seasons. The loss in grain yield, grain protein percentage and grain oil percentage due to weed competition for whole seasons reached 56.8, 14.9 and 14.1% and 57.2, 13.6 and 13.7% in 2014 and 2015 seasons, respectively as compared with weed free treatments. This results may be due to the effective competition of weeds with maize plants particularly in the early stage of maize growth. Removal of weeds for 2 and 4 weeks from sowing then allowing weeds competition for maize until the end season caused seed yield reductions by 15.8 and 29.9% and 15.7 and 28.8% in 2014 and 2015 seasons, respectively as compared with weed free in whole season, which reached 26.36 and 27.48 ardab/fed respectively.

Table 3. Effect of weed competition and weed removal times on yield components of maize during 2014 and 2015 summer seasons.

Weed competition or weed removal periods	Plant Height(cm)	Ear Length (cm)	Ear weight (g)	No. of grains /row	Ear grains weight(g)	100 -grain weight(g)
2014 season						
Weed competition for the whole season	220.0	18.05	165.0	34.5	129.91	33.70
Weed competition for 2 weeks from sowing	265.0	24.30	255.0	52.0	209.87	44.00
Weed competition for 4 weeks from sowing	256.2	22.53	229.0	48.7	187.32	42.50
Weed competition for 6 weeks from sowing	237.5	22.18	211.0	46.2	167.59	40.87
Weed competition for 8 weeks from sowing	232.0	19.90	187.0	42.7	149.81	38.72
Weed free for 2 weeks from sowing	233.0	21.30	190.0	45.7	152.80	40.28
Weed free for 4 weeks from sowing	255.0	22.43	218.0	48.2	177.89	41.78
Weed free for 6 weeks from sowing	261.2	23.33	246.0	50.7	196.90	42.46
Weed free for 8 weeks from sowing	263.7	23.88	250.0	51.5	206.25	43.00
Weed free for the whole season	280.0	24.88	270.0	53.0	223.86	45.54
LSD at 0.0 5	4.70	1.46	8.06	3.78	7.31	3.84
2015 season						
Weed competition for the whole season	228.7	18.25	165.0	40.5	131.93	35.95
Weed competition for 2 weeks from sowing	273.7	25.18	259.0	54.2	212.38	44.20
Weed competition for 4 weeks from sowing	258.7	23.63	237.0	50.0	193.27	42.80
Weed competition for 6 weeks from sowing	256.5	22.95	217.0	47.7	171.37	41.20
Weed competition for 8 weeks from sowing	240.0	21.13	192.2	44.0	154.79	39.80
Weed free for 2 weeks from sowing	253.7	22.73	204.0	46.2	165.26	40.49
Weed free for 4 weeks from sowing	257.7	23.13	229.0	49.0	185.54	42.66
Weed free for 6 weeks from sowing	263.7	24.08	241.0	52.2	201.97	43.60
Weed free for 8 weeks from sowing	265.0	24.38	253.0	52.7	206.89	43.90
Weed free for the whole season	290.0	25.25	275.0	54.5	228.30	45.69
LSD at 0.0 5	5.24	1.52	8.08	3.31	7.43	3.57

Table 4. Effect of weed competition duration on grain yield, grain protein and grain oil percentage of maize plants at harvest during 2014 and 2015 summer seasons.

Weed competition or weed removal Periods	Grain yield *(arad/fed.)	Grain protein %	Grain oil %
2014 Season			
Weed competition for the whole season	11.49	8.40	4.03
Weed competition for 2 weeks from sowing	22.37	9.75	4.60
Weed competition for 4 weeks from sowing	18.60	9.38	4.41
Weed competition for 6 weeks from sowing	16.98	9.03	4.30
Weed competition for 8 weeks from sowing	15.12	8.70	4.19
Weed free for 2 weeks from sowing	16.11	8.88	4.24
Weed free for 4 weeks from sowing	17.77	9.19	4.35
Weed free for 6 weeks from sowing	20.19	9.52	4.50
Weed free for 8 weeks from sowing	21.67	9.68	4.54
Weed free for the whole season	26.57	9.87	4.69
LSD at 0.0 5	2.36	0.23	0.15
2015 Season			
Weed competition for the whole season	11.75	8.60	4.08
Weed competition for 2 weeks from sowing	23.14	9.84	4.63
Weed competition for 4 weeks from sowing	19.56	9.50	4.50
Weed competition for 6 weeks from sowing	17.67	9.11	4.38
Weed competition for 8 weeks from sowing	15.29	8.83	4.27
Weed free for 2 weeks from sowing	16.16	8.97	4.33
Weed free for 4 weeks from sowing	18.33	9.30	4.42
Weed free for 6 weeks from sowing	21.37	9.61	4.50
Weed free for 8 weeks from sowing	22.65	9.70	4.57
Weed free for the whole season	27.48	9.95	4.73
LSD at 0.0 5	2.34	0.19	0.11

***ardab =140 kg shelled grain**

These treatments significantly produced the highest grain yield per faddan, grain protein percentage and grain oil percentage 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 maize plant and associated weeds was decreased and giving good chance for maize growth and improve the filling of grains resulting heavier grains. Weed control through those period is necessary to obtain a maximum grain yield in maize and the more the delay of weed control, the less yield was obtained. Our findings are in good accordance with those obtained by Varshney (1991), El-Wekil *et al.* (1992), Shad *et al.* (1993), Ramos and Pitelli (1994), Hussein (1996), Metwally and Youssef (1998), Ahmed (2000), Evans *et al.* (2003), Saad El-Din (2003), Hussein *et al.* (2012) and Safdar *et al.* (2016).

On the other hand, further delaying of weed removal accentuated the adverse effect of weeds on grain yield per faddan, grains protein percentage and grains oil percentage at 6 and 8 weeks from sowing causing reduction that ranged from 36.1 to 35.7 and 43.1 to 44.4 % for grain yield per faddan and from 8.5 to 8.4 % and 11.9 to 11.3% for grains protein percentage and from 8.3 to 7.4 and 10.7 to 9.7 % grains oil percentage respectively, in both seasons as compared with weed free treatments. Ahmed (2000), Evans *et al.* (2003) and Saad El-Din (2003). reported that the least grain protein and grain oil percentage were recorded from unweeded check in both seasons. On the other hand, further delay in weed removal reduced grain protein and grain oil percentage in maize grains.

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

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

1-Biological yield approach: -

Figure 1 depending on data of grain yield per faddan by the use of biological response curves results show clearly that to obtain 95% of the maize crop need to make the field free from weeds for a period 3 – 7 weeks from sowing and the critical period of weed competition (CPWC) of the seed and oil yield of maize started after 3 weeks and ended at 7 weeks from sowing.

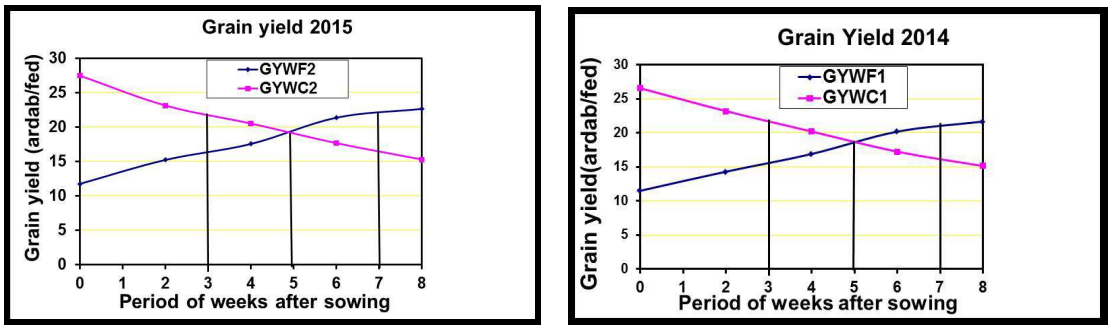

Fig. 1. Biological critical period of weed / maize competition on grain yield.

Obviously, the more delay of weed removal will cause more decrease in maize yield due to weed/maize competition which seriously affect grain yield of maize. This may be attributed to the slow growth of maize in the first grown stages and poor vegetative growth in one side. Evidently, weed free maintenance for 3 to 7 weeks from sowing is required for good yield. Evans *et al.* (2003) and Saad El-Din (2003) mentioned that, green seeded maize 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): -

The relationship between maize grain yield and removal weed period was highly significantly with linear, logarithmic and quadratic models. The highest value of coefficient of determination (R2), in addition less stander error (SE) was obtained from quadratic model, under weed free and weed competition conditions, respectively and the best model fitted to the yield of weed free and weed competition was quadratic. It had R2 higher than those of the linear model and logistic. Furthermore, standard error (SE) values of quadratic equation were lower than those of linear and logistic equation. Hence, the quadratic model worked well for concerning the relation between maize grain yield and weeds under weed free and weed competition in the two studied seasons. These equations were Ý~= 11.378 + 1.3594 x - 0.035 x2 and Ý~= 26.602 - 1.808 x + 0.046 x2 in season 2014 and Ý~= 11.708 + 1.811 x - 0.052 x2 and Ý~= 27.317 - 2.020 x + 0.066x2 in season 2015.

Table 5. Coefficient of regression and the standard errors of three models to decide the relationship between maize grain yield (ardab/ fed.) and weed–free or weed infection periods in 2014 and 2015summer seasons.

Treatments	Yield	Linear		Quadratic		Logistic	
		R^2	SE	R^2	SE	R^2	SE
		2014 season					
Weed-free	Grain yield	0.986	0.472	0.990	0.413	0.972	0. 419
Weed competition		0.989	0.458	0.994	0.337	0.993	0.401
		2015 season					
Weed-free	Grain yield	0.978	0.626	0.985	0.028	0.959	0.051
Weed competition		0.981	0.611	0.993	0.018	0.992	0.020

Figs. 2 and 3 and Tables 5 and 6 showed that the times duration effects on maize crop free from weeds on grain yield (ardab/fed). The relationship between grain yields with the weed free duration was positively significant and prediction function with value R2 (SE) 0.990 (0.413) and 0.985 (0.028), but the relationship between grain yields with the weed competition duration was negatively significant and prediction function with value R2 (SE) 0.994 (0.337) and 0.993 (0.018), in the 2014 and 2015 seasons, respectively. Safdar *et al.* (2016) showed that maize grain yield exhibit a quadratic trend with increasing weed competition period during two studied seasons.

Table 6. Estimation of expected grain yield (ardab/ fed.) and percent of yield losses of maize by quadratic model under varied weed free period and weed infestation period in 2014 and 2015 summer seasons.

Period (weeks)	2014 Season				2015 Season			
	Weed free period		Weed infestation period		Weed free period		Weed infestation period	
	Predicted grain yield (ardab/fed.)	Yield losses%	Predicted grain yield (ardab/fed.)	Yield losses%	Predicted grain yield (ardab/fed.)	Yield losses%	Predicted grain yield (ardab/fed.)	Yield losses%
	$\hat{Y} \sim = 11.379 + 1.3594X - 0.035X^{**2}$		$\hat{Y} \sim = 26.602 - 1.808X - 0.046X^{**2}$		$\hat{Y} \sim = 11.708 + 1.811X - 0.052X^{**2}$		$\hat{Y} \sim = 27.317 - 2.020X - 0.066X^{**2}$	
0	11.38	42.75	26.60	100	11.71	40.68	27.32	100
1	12.94	48.60	24.84	93.38	13.47	46.80	25.36	92.85
2	14.43	54.20	23.17	87.10	15.12	52.55	23.54	86.18
3	15.95	59.92	21.45	76.89	16.83	58.48	21.65	79.27
4	17.47	65.65	19.74	74.20	18.54	64.41	19.76	72.35
5	18.99	71.37	18.02	67.75	20.24	70.34	17.88	65.44
6	20.52	77.10	16.31	61.30	21.95	76.27	15.99	58.53
7	22.05	82.82	14.59	54.84	23.66	82.21	14.10	51.62
8	23.57	88.55	12.87	48.39	25.36	88.14	12.21	44.71
9	25.09	94.27	11.16	41.94	27.07	94.07	10.32	37.80
10	26.62	100	9.44	35.49	28.78	100	8.44	30.88

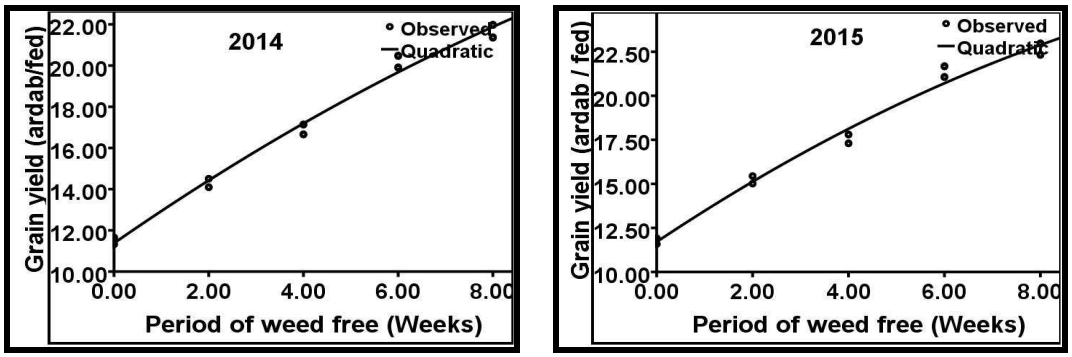

Fig. 2. The relationship between weed free duration and grain yield (ardab/fed).

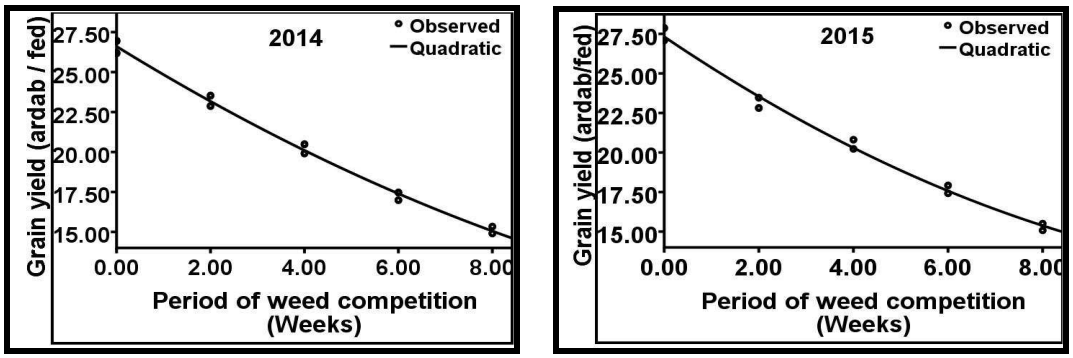

Fig. 3. The relationship between weed competition duration and grain yield (ardab/fed).

To decide the vital period of weed competition to maize crops, by regression approach was used. Appliance equation report that to keep up 95% grain yield of maize earlier weed competition should not allowed surpass first week from emergence. The same position the late weed free period duration should not surpass 9 weeks from emergence.

The acceptable yield loss (AYL) levels used to predict the critical timing of weed removal (CTWR) were five and ten percentage. The model illustrate that maize grain yield reduction due to weed infestation occur during the season and increased with time. The CTWR to prevent five and ten percentage maize grain yield reduction was 8 and 17 DAE in year 2012, and 13 and 23 DAE in year 2013 (Safdar *et al.*, 2016). While, Maqbool *et al*. (2006) also reported that with increasing weed-crop competition period from 15 to 60 days after crop emergence, a significant linear reduction in grain yield of

maize was noted. Moreover, the highest grain yield loss of 51% was observed in response to weed competition for full growing season. According to most recent studies by Gholami (2014), significant reduction in grain yield of maize was observed by weed competition period of 5 weeks after crop emergence compared with weed free control treatment. Therefore, he concluded that weed control must be employed during this period to avoid drastic yield reduction in maize.

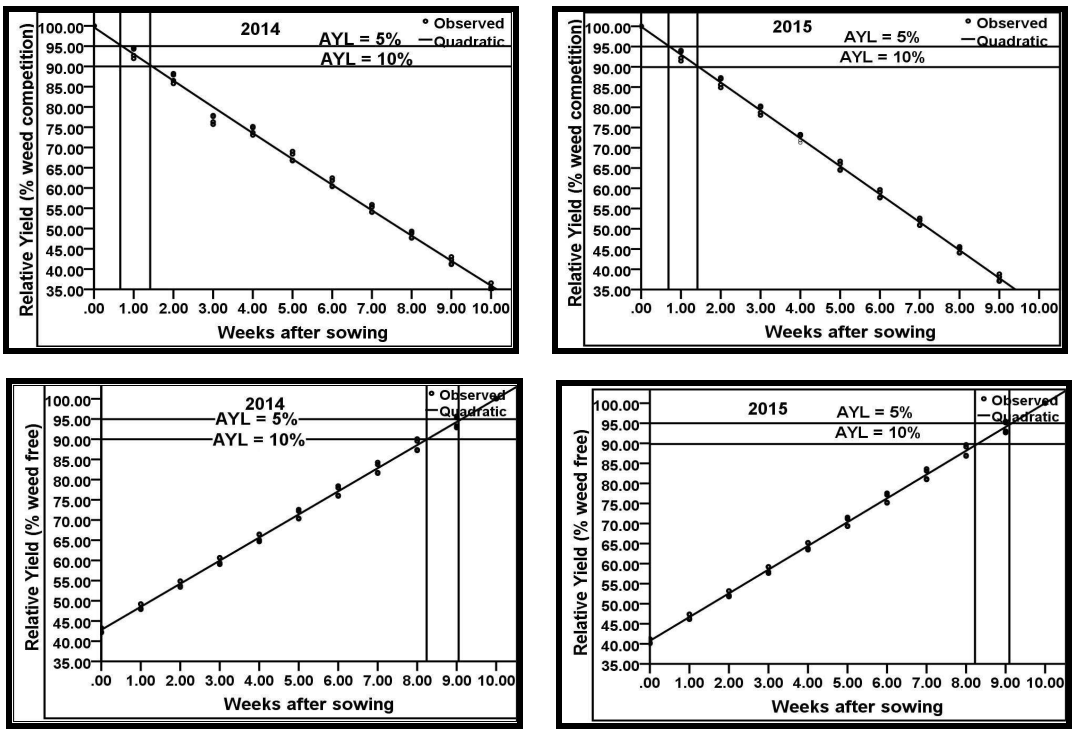

Fig. 4. Effect of timings weed control on maize grain yield (weedy yield up to harvest). Quadratic equation was fitted to grain yield (% of weed-competition and free yield) for 2014 and 2015. Parameter estimates of the equations are provided in Table 6. The critical timing for weed removal (CTWR) to achieve 5% and 10% of acceptable yield loss (AYL) are provided between the broken vertical lines. Individual points shown across the lines depict the variability of the response (relative yield-% of weed competition and free) at each treatment level (weeks after sowing).

CONCLUSION

Results of this study give procedure to maize growers for making decisions with respect to the weed competition period during which it makes economic sense to employ weed control measures in maize. The relationship between the reductions of weed weights in the treatments was accompanied by an increase in yield and components. Results concluded that weeds should be controlled within the period of 1st and 9th weeks in maize crop to avoid five and ten percentages grain yield reductions, respectively.

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استخدام النماذج الرياضية لتحديد الفترة الحرجة لمنافسة الحشائش لمحصول الذرة الشامية

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إقيمت تجربتان حقليتان علي نباتات الذرة الشامية خلال الموسم الصيفي لعامي 2014 و 2015 بمحطة البحوث الزراعية بالسرو محافظة دمياط – مصر. اشتملت التجربة علي عدد 10 معاملات من الإزالة المبكرة أو المتأخرة للحشائش من الزراعة وهي:- منافسة الحشائش طول الموسم منذ بداية الزراعة حتى الحصاد ومنافسة الحشائش لمدة 2 , 4 , 6, 8 أسابيع من الزراعة و إزالة الحشائش لمدة 2 , 4 , 6, 8 أسابيع من الزراعة وإزالة الحشائش طول الموسم تحت ظروف العدوى الطبيعية للحشائش لتحديد مقدار النقص في انتاجية محصول الحبوب في الذرة الشامية ومتى يتم التوقف عن النقص في المحصول. وتعتبر انسب دراسة للفترة الحرجة للمنافسة علي مجتمع الحشائش ككل وليس علي نوع واحد. حيث كانت الحشائش السائدة في حقل التجارب خلال موسمى الدراسه هي حشائش الرجلة والملوخية وعرف الديك والدنيبة وأبو ركبة بكثافة عالية بما يلائم إجراء مثل هذا النوع من الدراسات. وقد تم تنفيذ التجربه فى تصميم القطاعات الكامله العشوائيه فى اربع مكررات. أوضحت النتائج أن الفقد في محصول الحبوب في الذرة الشامية هو 56,8 إلي 57,2% تحت ظروف العدوى الطبيعية للحشائش بمقدار 5,834 و 6,043 طن/فدان من الحشائش الغضة الكلية في الموسمين الأول والثاني علي التوالي. وقد تم تقدير الفترة الحرجة بالطريقة التقليدية حيث وجد أن الفترة الحرجة لمنافسة الحشائش تبدأ بعد الاسبوع الثالث من الزراعة ثم يتوقف النقص في حاصل المحصول بعد 7 أسابيع من الزراعة. وقد أوضح استخدام التحليل الرياضي باستخدام منهج الانحدار أن النماذج الرياضية لدراسة العلاقة بين فترات منافسة الحشائش أو أزالتها وحاصل محصول الحبوب من الذرة الشامية يتبع معادلات من الدرجة الثانية . وكانت معاملات الارتباط قوية ومعنوية علي مستوي 1% حيث كانت 990,. و 985, . في الفترات الخالية من الحشائش و 994, . و993, .٪ في فترات المنافسة للحشائش خلال الموسم الصيفي 2014 و 2015 علي التوالي. وأوضح تطبيق هذه المعادلات أنه للحصول علي 95% من محصول الحبوب من الذرة الشامية مقارنة بمحصول الحبوب في الذرة الشامية الخالية من الحشائش طول الموسم. وتوصى الدراسه على انه علي مزارعي الذرة الشامية ألا يتأخروا في بدء عمليات المكافحة عن الأسبوع الأول من الزراعة وأن تستمر عملية المكافحة حتى الأسبوع التاسع من الزراعة من خلال استخدام التوصيات المناسبة باستخدام مبيدات تضاف بعد الإنبات لإبادة المدى الواسع من أنواع الحشائش المذكورة سابقا أو إجراء النقاوة اليدوية في هذه الفترة أوالتكامل بينهما.