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YIELD COMPONENTS AFFECTING SEED YIELD AND THEIR RELATIONSHIPS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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Abstract

Path and correlation analysis were performed to investigate the relationships between seed yield and other important yield components in sunflower during 5 years period in Edirne–Turkiye conditions. To determine the level and forms of these relationships, regression analysis was utilized. Plant height, 1000 seed weight and head diameter were found positively and significantly correlated with sunflower yield. However, earliness of hybrids also played an important role in determining seed yield in sunflower. To get higher yield performance, oil type sunflower hybrids should have higher seed volume, higher oil content, taller plant height, larger heads, and lower husk contents. These hybrids should have also earlier flowering period and shorter physiological maturity duration than 107 days.

Introduction

Seed yield in sunflower is a quantitatively inherited component highly influenced by environmental factors. However, yield is also dependent upon the genetic potential of the cultivar and contributions of other yield components such as seed weight, head diameter, etc., should be considered in improving yield. Sunflower breeders should pay attention to these components with seed yield while evaluating experimental hybrids.

Path coefficient analysis makes it possible to measure the interrelationship among yield components for their direct and indirect effects on seed yield *via* correlation (Singh & Chaudhary, 1979). The investigation of direct and indirect effects of various components on yield is of major importance to increase the yielding capacity of the sunflower crop. The path coefficient was the rate of standard deviation in total standard deviation of examined component due to the effect of other components calculating the direct and indirect effect of this component on seed yield, which was dependable variable. This study also provides the basis for success in breeding programs and thus the seed yield could be increased more effectively. Selections based on correlation only without considering interactions among yield components may mislead the breeders to reach their main breeding goals.

Many researchers examined the relationships among yield components generally using correlation and path analysis and concluded that selection for grain yield in sunflower should largely be dependant on 1000 seed weight, head diameter and early maturity (Alza & Martinez 1997; Kaya & Atakisi, 2003, Kaya *et al*., 2003, Joksimovic *et al*., 2004, Sridhar *et al*., 2005; Farhatullah, & Khalil, 2006; Goksoy & Turan, 2007; Amorim *et al*., 2008). However, plant height was also indicated as valuable yield component in recent works (Dagustu, 2002; Kaya & Atakisi, 2003, Kaya *et al*., 2003; Hladni *et al*., 2004; Dusanic *et al*., 2004; Kaya *et al*., 2005).

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Regression analysis describes the level of the relationship among yield components. However, sunflower researchers generally prefer correlation and path analysis to explicate yield relationships only. Kaya *et al*., (2005) observed that sunflower yield positively increased until 46% oil content and 160 cm plant height under Edirne conditions in the 2002-2003 seasons. They also mentioned developing higher oil content hybrids over 46% in the breeding program from the seed yield performance in sunflower.

This study was conducted to examine the relationships between seed yield and other important traits in detailed evaluation, especially in levels by utilizing regression analysis in longer periods. There is no published research in sunflower before to explain levels of yield relationships. Longer period data (6 years) strengthen and make reliable of results of this research.

Materials and Methods

The experiments were conducted as part of Turkish National Sunflower Research Project at the Trakya Agricultural Research Institute fields in Edirne, Turkiye between 1999 and 2005. Edirne has the largest sunflower growing area (25% of total) among provinces of Turkiye and is the center of sunflower production, so the results reflect precisely on sunflower conditions in Turkiye and also Black Sea Region which has 34% of the sunflower planted area and 50% of the production of the world. The candidate hybrids obtained by crossing female CMS and restorer lines (mostly a couple male and female oil type inbred lines) and 5 check hybrids which had the highest market share were compared in these experimental hybrids existed each year in the research. The 635 hybrids in 26 yield trials in 1999, 650 hybrids in 23 trials in 2000, 457 hybrids in 17 trials in 2001, 365 hybrids in 15 trials in 2002, 176 hybrids in 8 trials in 2003, 295 hybrids in 13 yield trials in 2004 and 355 hybrids in 16 trials in 2005 were planted (total of 2932 sunflower test hybrids) and tested in this study.

The experimental design was a Randomized Complete Block Design with three replicates. The three rows plots were 6-m long with the 70 x 35 cm plant spacing. The middle row was harvested and the border rows were discarded, and plot size was 3.78 m^2 at harvest. Trials were planted mostly in April and were harvested in September by hand. Seed yield (SY), 1000 seed weight (TSW), flowering and physiological maturity period, plant height (PH), head diameter (HD), husk (HC) and oil content (OC) were measured.

The flowering period (FP) of hybrids were measured at stage which 50% of plants in the plot with first open ligule petals. The physiological maturity period (PM) of hybrids were counted at the stage which the back of heads were yellow and 10 % were brown color. The plant height and head diameter of hybrids were measured from 3 plants at mid rows of the plots in each replication at PM stage. Oil content of the hybrids were determined utilizing Nuclear Magnetic Resonance (NMR) analysis at institute lab. Oil content of hybrids were not measured in 1999 due to some problems on NMR machine in the lab and the husk content of hybrids were counted in only 1999-2001 period.

To analyze the relationships between seed yield and yield components accurately, correlation and regression analysis was performed for all hybrids using SPPS 11 statistical package. The path analysis was carried out according to Singh & Chaudhary (1979) utilizing from the TARPOPGEN statistical program (Ozcan & Acikgoz, 1999).

Table 1. Correlation values among traits of sunflower hybrids tested.

		SY kg ha^{-1}	TSW g	HC %	FP Day	PM Day	PH cm	HD cm	OC %
S.Y	(kg ha^{-1})	-							
TSW	(g)	0.413**	-						
HC	(%)	-0.219**	-0.444**	-					
FP	(Day)	-0.158**	-0.032ns	-0.151**	-				
PM	(Day)	-0.083**	-0.036ns	0.170**	0.318**	-			
PH	(cm)	0.514**	0.471**	-0.598**	0.218**	-0.069*	-		
HD	(cm)	0.444**	0.437**	-0.400**	0.004ns	-0.056ns	0.541**	-	
OC	(%)	-0.089**	0.133**	-0.404**	0.316**	-0.118**	0.249**	0.066*	-
DF		3096	3094	1817	3065	3038	3095	3096	2443

**p*<0.05, ***p*<0.01, ns= Non-significant, DF = Degree of freedom.

Results and Discussion

Highly significant correlations were obtained between seed yield and other components in the study. Oil content, physiological maturity and flowering period had the lowest coefficients among yield components in sunflower (Table 1). The highest correlation coefficient was found between plant height and seed yield but the highest correlation among components was between plant height and head diameter (positive) and between plant height and husk content (negative). These correlation results showed that plant height played an important role for improving both seed yield and other yield components. Other higher and significant correlation coefficients among the yield traits were observed between TSW & HC, TSW & HD, TSW& HD, HC & HD, HC & OC, FP & PM and FP & OC. On the other hand, as expected, HC & OC correlation is negative way and higher as mentioned many studies (Dagustu, 2002; Kaya *et al*., 2003 and 2005; Hladni *et al*., 2004; Dusanic *et al*., 2004; Kaya *et al*., 2005, Goksoy & Turan, 2007).

The path analysis confirmed the correlation results in that the highest contribution was given by PH having the maximum direct effect (effected SY % 60 portion directly and % 40 over other yield traits) in the experiment (Table 2). PH also played an important role determining SY giving higher indirect effects to other yield components forming of SY. FP was another important factor in patterning with SY in sunflower having the second highest direct and indirect effects in the research but in negative way. Therefore, these results implied those higher yields were obtained from earlier hybrids in this study similarly with Kaya & Atakişi (2003), Kaya *et al*., (2003, 2005) results. On the other hand, while FP, PM and OC had negative coefficients, other yield components had positive coefficients. Also, HC and FP were other more contributing yield traits indirectly composing seed yield in sunflower based on path analysis results in the research.

The seed yield of sunflower hybrids ranged between 800–4250 kg /ha with the 2160 kg/ha average in the experiments. Exceedingly large differences were obtained in yield components because of that the very extreme and different climatic conditions encountered during the years 1999 to 2005. There were highly significant relationships between seed yield and other yield components based on regression analysis (Table 3). However, this significance was observed under 5% level in husk content. The research results proved that these yield components were playing an important role in determining seed yield in sunflower like other studies (Joksimovic *et al*., 2004, Sridhar *et al*., 2005; Farhatullah, & Khalil, 2006; Goksoy & Turan, 2007; Amorim *et al*., 2008).

Table 2. The path (p) coefficients and percentages (%) in hybrid seed yields.

	1000 S weight		Husk content		Flowering period		Physiologic maturity		Plant Height		Head diameter		Oil content	
	g		%		Day		Day		cm		cm		%	
	P	%	P	%	P	%	P	%	P	%	p	%	P	%
SW	**0.182**	**31.5**	-0.081	12.0	-0.006	1.5	-0.007	4.0	0.086	10.2	0.080	13.7	0.024	5.9
HC	-0.065	11.3	**0.147**	**21.8**	-0.022	5.9	0.025	15.3	-0.088	10.5	-0.059	10.2	-0.060	14.5
FP	0.006	1.1	0.030	4.4	**-0.196**	**51.8**	-0.063	38.4	-0.043	5.1	-0.001	0.1	-0.062	15.1
PM	0.000	0.1	-0.002	0.3	-0.003	0.9	**-0.010**	**6.4**	0.001	0.1	0.001	0.1	0.001	0.3
PH	0.237	41.0	-0.301	44.5	0.110	29.0	-0.035	21.2	**0.504**	**60.0**	0.273	46.9	0.125	30.4
HD	0.070	12.1	-0.064	9.5	0.001	0.2	-0.009	5.5	0.086	10.3	**0.160**	**27.5**	0.011	2.6
OC	-0.017	3.0	0.052	7.7	-0.041	10.7	0.015	9.3	-0.032	3.8	-0.009	1.5	**-0.129**	**31.3**
Cor.	**-0.219**		**-0.158**		**-0.083**		**0.514**		**0.444**		**-0.089**		**0.413**	
DF	**3094**		**1817**		**3065**		**3038**		**3095**		**3096**		**2443**	

*Bold lines direct effect of component. Cor.: Correlation values, DF = Degree of Freedom.

Table 3. Regression coefficients between seed yield and yield components.

Yield component	Avg	SdD	Range	R^2	DF	F value	P level	b 0	b1	b2
1000 Seed weight	48	10	23-87	0,183	3094	347,2	0,000	-31,6	7,9	-0,1
Oil content	45	4	30-58	0,036	2443	45,4	0,000	279,5	-6,0	0,1
Husk content	24	3	18-50	0,004	1817	3,4	0,034	275,1	-5,6	0,1
Flowering period	70	6	60-91	0,075	3065	123,4	0,000	-811,9	30,6	-0,2
Physiol. maturity	107	7	89-132	0,015	3038	23,2	0,000	-869,5	20,4	-0,1
Plant height	136	21	86-222	0,274	3095	584,0	0,000	136,6	-0,2	0,0
Head diameter	16	3	8-26	0,195	3096	374,7	0,000	127,4	2,4	0,2

R^2 = The determination coefficient, b0, b1 and b2 = Regression coefficients, DF = Degree of freedom, SdD = Standard Deviation.

The TSW was one of the three most important yield components along with seed number in the head and plant number in the field in determining sunflower yield (Miller & Fick, 1997; Kaya *et al*., 2003 and 2005). A quadratic relationship was observed between SY and TSW in the study. As expected, while TSW were increasing, sunflower seed yield increased too in parallel up to 70 g seed weight (Fig. 1). Most probably, sunflower seed yield augmentation was stopped and started to drop after 70 g because of declining seed numbers in the head (Miller & Fick, 1997).

Based on regression analysis in the research, there a nearly linear relationship between oil content and seed yield (positive) was found opposite to the path and correlation results (Fig. 2). Most probably, higher oil contents in the seed increased seed yield due to giving extra weight and also tougher seeds. Another approach could be increasing yield due to oil content by lowering husk contents (Miller & Fick, 1997).

On the other hand, husk content was generally negative in determining seed yield in oil type sunflower because of the negative relationship between oil and husk content (Miller & Fick, 1997). The husk content had the lowest R^2 and 5% significance statistically in the research but these HC values belonged only two years (1999-2000). Fig. 3 illustrated that reducing husk content until 27% decreased seed yield in this study. However, seed yield increased while husk content increased after 28% due to the existence of the some confectionery type of sunflower cultivars in the experiments. The best confectionery type should have the oil content lower than 30 % and generally husk content up to 50%. Therefore; husk content was augmenting seed yield for confectionery type sunflower.

Phenological components were also limiting factors in sunflower yield based on regression analysis in the study. Quadratic relationships were detected in both flowering and physiological maturity periods so earlier hybrids exhibited higher seed yield in the hybrids (Figs. 4 and 5).

Physiological maturity had the 2nd lowest R^2 in the study. Earlier hybrids exhibited generally higher yield performances in Edirne conditions because of not being affected by high temperatures in the summer (Kaya & Atakisi, 2003, Kaya *et al*., 2003). While seed yields were increasing in earlier hybrids up to 68 days in flowering period and 107 days in physiological maturity duration, the decrease in seed yield started after these days in later hybrids. However, the slope was sharper in physiological maturity period than flowering period.

Linear relationships were observed in both plant height and head diameter and seed yield in the research (Figs. 6 and 7). These two factors had the highest R^2 after plant height in the study. Both plant height and head diameter affected seed yield positively and played an important role in determining seed yield in sunflower.

The plant height, 1000 seed weight and head diameters were other valuable components affecting seed yield positively. However, flowering period, oil content, and husk content exhibited negative effects on seed yield based on the path analysis results. On the other hand; days to physiological maturity had smaller effect on seed yield according to the path analysis. Based on indirect effects, yield components affected seed yield in sunflower mostly through plant height in this study.

These regression results illustrated in the figures confirmed the importance of these components in determining seed yield in the path and correlation analysis in the study. The role of head diameter has been observed in many studies (Kaya *et al*., 2003, Joksimovic *et al*., 2004; Sridhar *et al*., 2005, Farhatullah & Khalil, 2006; Goksoy & Turan, 2007; Amorim *et al*., 2008), but interestingly, the importance of plant height was confirmed in many recent correlation and path analysis reports in sunflower (Dagustu, 2002, Kaya & Atakisi, 2003, Kaya *et al*., 2003; Hladni *et al*., 2004; Dusanic *et al*., 2004; Kaya *et al*., 2005).

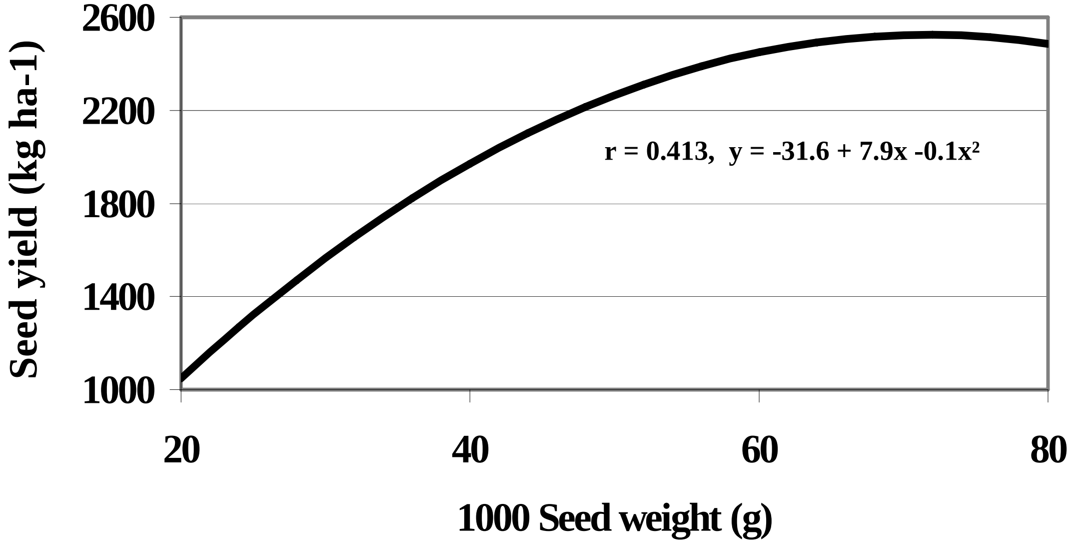

Fig. 1. The relationship between seed yield and 1000 seed weight.

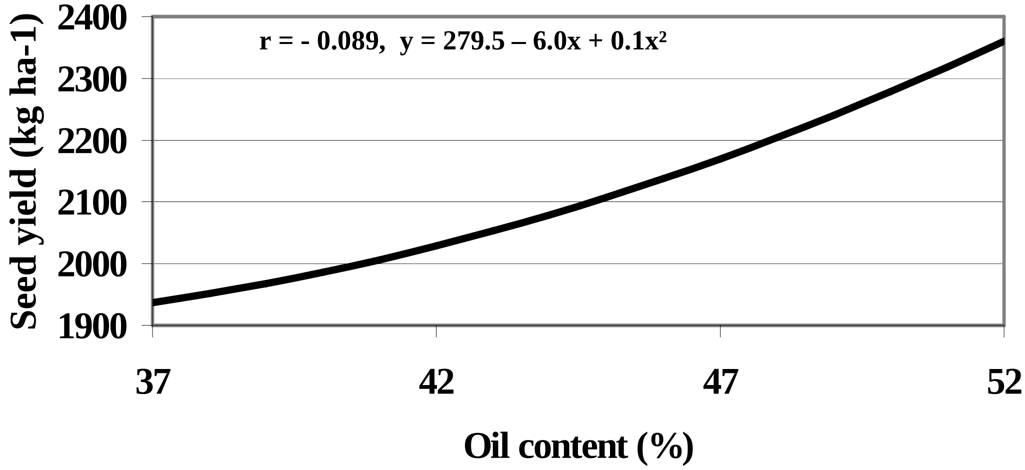

Fig. 2. The relationship between seed yield and oil content.

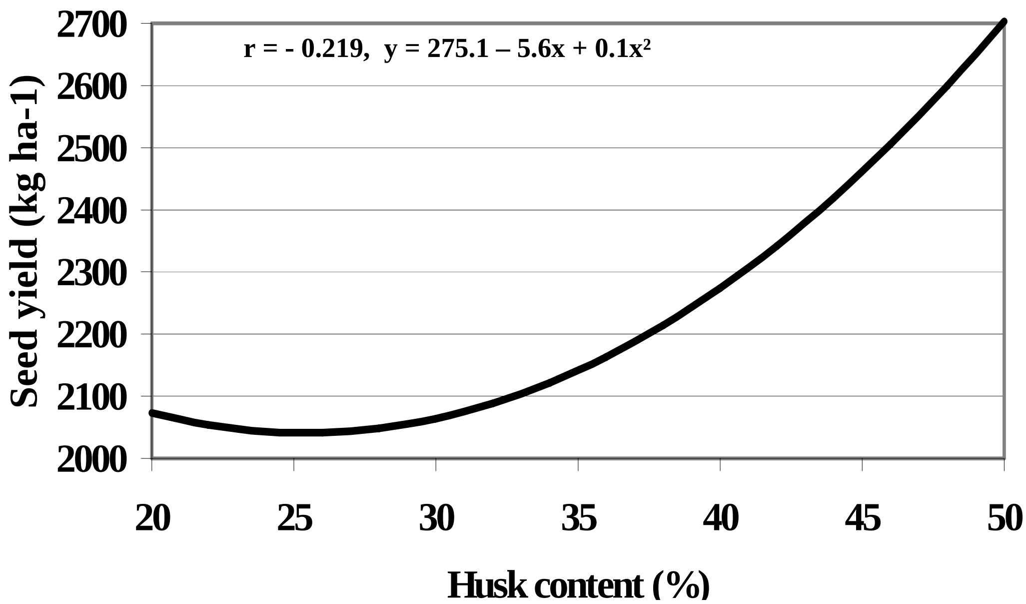

Fig. 3. The relationship between seed yield and husk content.

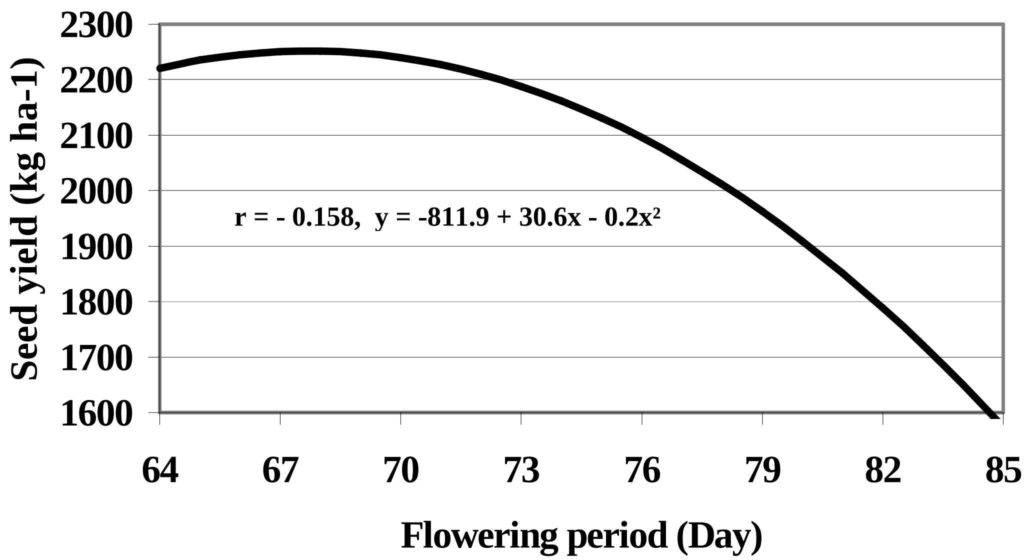

Fig. 4. The relationship between seed yield and flowering period.

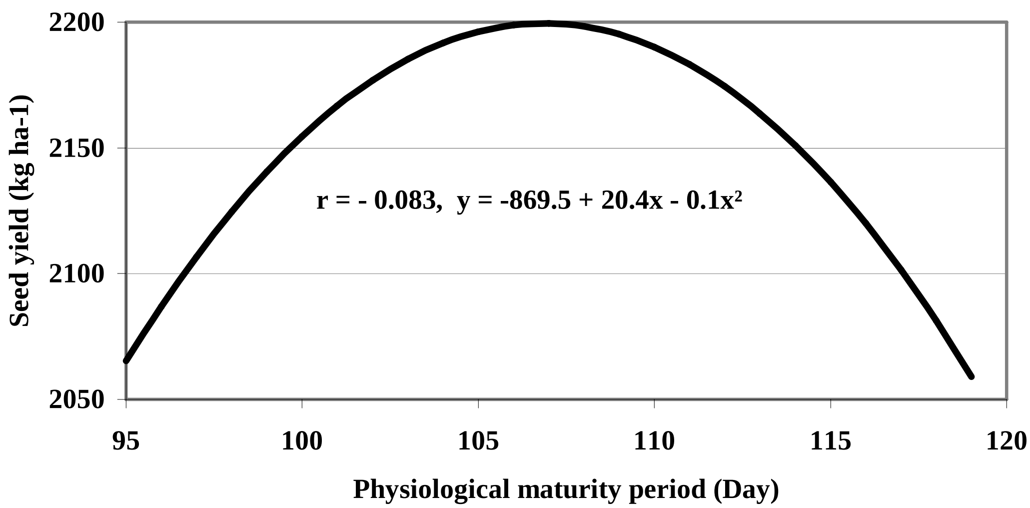

Fig. 5. The relationship between seed yield and physiological maturity.

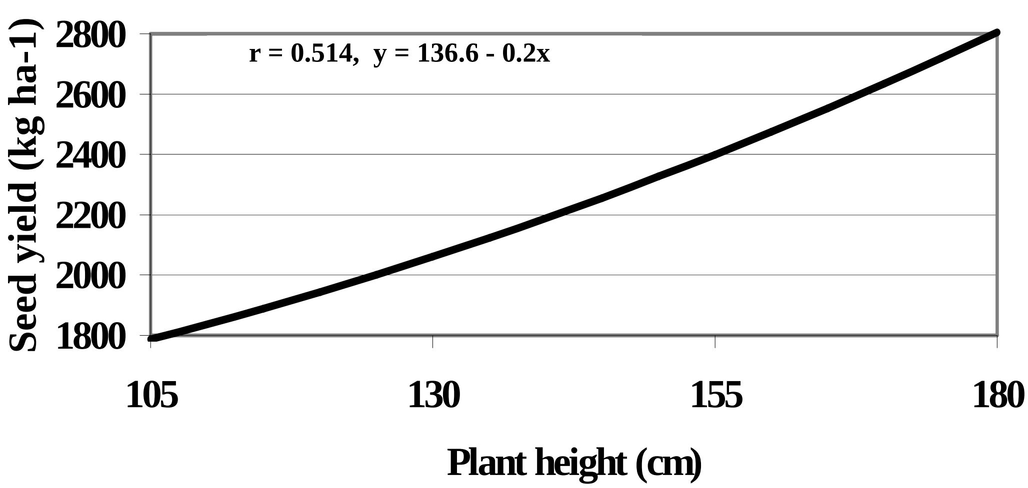

Fig. 6. The relationship between seed yield and plant height.

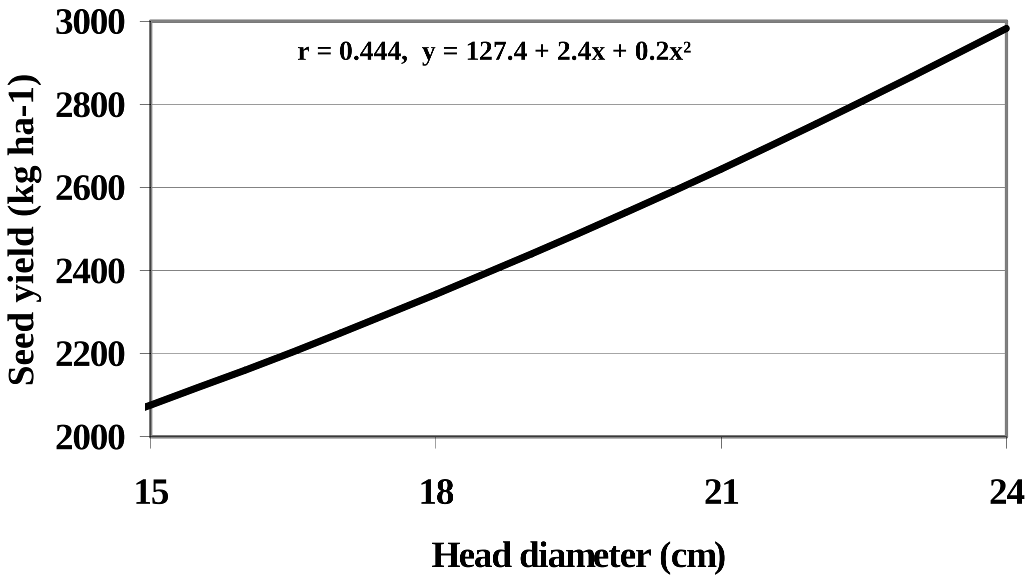

Fig. 7. The relationship between seed yield and head diameter.

Conclusions

Plant height and other yield components such as 1000 seed weight and head diameter played an important role in determining seed yield in sunflower. Earlier sunflower hybrids generally demonstrated higher yield performance in the study. Therefore, new oil type hybrids developed in the breeding program, should have about 58 days flowering period and less than 107 day period from planting to physiological maturity. Lower husk content, higher plant height, higher seed weight, higher oil contents and larger heads are other important yield components increasing sunflower yield. However, there were no upper limits in these traits so newly developed hybrids should have much higher yield potential in the future.

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