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Oil yield determinant of sunflower in climatically different regions of Iran

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Abstract

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In order to determine the most important determinants of sunflower oil yield using path analysis 36 sunflower hybrids were evaluated for agronomic traits as a simple lattice experiment in three regions with different climate (Karaj, Gonbad and Khoy) in 2015. According to the results, seed yield had the highest correlation with oil yield in all three locations. Seed number per head in Karaj, seed number/head plus oil content in Khoy and all three components of oil yield along with stem and head diameter in Gonbad had positive correlation with oil yield. The highest positive direct effects were imposed by achene number per head, achene weight and oil content respectively in all locations. The highest indirect effects on oil yield were imposed by achene number per head in Karaj and Khoy and by achene weight in Gonbad. Stem and head diameter, days to flowering and plant height had positive indirect effect on oil yield through seed number per head in Karaj. Majority of the indirect effects on oil yield were imposed through seed weight in Gonbad. In this location stem and head diameter, days to maturity, plant height and oil content had positive effect on oil yield through achene weight while stem and head diameter and oil content through seed number per head. Plant height, achene weight, days to flowering, stem and head diameter had negative and oil content had positive effect through achene number on oil yield in Khoy. The results of this study revealed achene number per head as the main determinant of oil yield in sunflower, beside that stem and head diameter and plant height were also the next important determinants.

Keywords: sunflower; oil yield components; correlation; path analysis

Introduction

Sunflower (*Helianthus annuus* L.) with an annual production of about 26 Mha, following rapeseed and soybean, is one of the most important oil crops worldwide (FAO, 2014). Production of sunflower in Iran has been started since 1967 and increased to a growing area of 105000 ha in 1990s. Due to the expansion of drought as a main factor growing area of sunflower has been reduced in Iran recently (Iranian Ministry of Agriculture Jihad, 2016). There are many efforts to develop single cross sunflower hybrids in Iran and three first hybrids were produced in 1990 and after that five other hybrids were commercially released; the latest one is Shams which released in 2016.

Understanding the nature of relationships between plant characteristics is a prerequisite for screening programs in plant breeding. Due to low heritability of yield, direct selection for this trait has a lower efficiency so indirect selection using yield components may improve achene and oil yield of sunflower. Correlation coefficient has been used for displaying the interrelationship of sunflower characteristics by many researchers. Fick et al. (1974) reported the relationship between achene yield and its components and among yield components, achene size was the most important yield-related character (Miller and Fick, 1997; Hladni et al., 2006). Shankar et al. (2006) reported positive correlations of plant height, head diameter, stem diameter, achene numbers and achene weight with achene yield per plant. Habib et al. (2007) reported higher correlations of stem and head diameter, achene weight and achene number per head with achene yield. Because of higher correlation of achene and oil yield Mijic et al. (2009) indicated that direct selection for achene yield will be efficient for improvement of oil yield.

Path analysis partitioning the overall correlation coefficients into direct and indirect effects, make it possible to determine the relative contribution of each trait to the oil yield and has been used extensively to exhibit the associations between sunflower characteristics (Marinkovic, 1992; Shankar et al., 2006; Darvishzadeh et al., 2011). Lal et al. (1997) reported that plant height and 1000 achene weight has positive direct effect on achene yield of sunflower. Shankar et al. (2006) revealed that achene number had the highest positive direct effect on achene yield followed by achene weight, plant height and stem diameter. Hladni et al. (2006) and Kaya et al. (2007) indicated a positive direct effect of head diameter and plant height on achene yield of sunflower. According to the results of Ghaffari and Haji Hosseinlou (2013) achene number, achene weight and head diameter had the highest direct effect on achene yield of sunflower. Patil et al. (1996) indicated that the highest indirect effect was imposed on achene yield through achene number per head. Alba et al. (1979) and Marinkovic (1992) showed that the highest negative effects were imposed by head diameter on achene yield.

Due to environmental effects interrelationships among sunflower traits could be variable in different locations. Because of importance of oil yield in sunflower this trait assigned as dependent variable in path analysis. So the objective of this study was to investigate the nature of relationships among oil yield related characters of sunflower in different geographical areas of Iran.

Materials and Methods

In this study agronomic performance of 36 sunflower single cross hybrids were evaluated in a simple 6×6 lattice experiment in research fields of Seed and Plant Improvement Institute (SPII) in Karaj and Khoy (irrigated condition), and in Gonbad (rainfed condition). Each plot consisted of three rows, 4-meter long with a between and within row spacing of 60 cm and 25 cm respectively. Treflan at a rate of 2 L/ha was applied to eradicate weed plants. Fertilizers (NPK) were applied before planting according to the soil test in each region. One top dressing with 30 kg N/ha was performed in the course of growing season in Karaj and Khoy. Planting was performed in the first half of April in Gonbad and first half of May in Karaj and Khoy.

Plant characteristics including phenological and agronomic traits were measured after flowering stage and achene yield and its components were measured after physiological maturity. Phenolgical traits were measured according to the descriptive of Schneiter and Miller (1981). Oil content was measured using NMR method. Achene yield was determined by harvesting of all plants in middle row except border plants. Oil yield obtained by multiplying of achene yield by oil content. For other traits mean of six measures in each plot were used. After calculation of correlation coefficient regression analysis was used to estimating regression coef-

Table 1. Correlation between different agronomic traits of sunflower in Karaj

Traits	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content	Achene yield
Days to maturity	0.370*								
Plant height	0.266	0.080							
Head diameter	0.117	0.030	0.277						
Stem diameter	0.228	-0.125	0.637**	0.333					
1000 achene weight	0.036	0.291	0.010	-0.063	-0.042				
Achene number head^{-1}	0.172	-0.052	0.146	0.181	0.200	-0.611**			
Oil content	0.091	0.317	-0.067	0.078	-0.323	0.164	-0.103		
Achene yield	0.250	0.119	0.164	0.173	0.198	-0.123	0.848**	0.053	
Oil yield	0.252	0.171	0.135	0.185	0.138	-0.078	0.794**	0.250	0.978**

* and ** are denote to the significant differences at probability of 5 and 1% respectively

ficients and path analysis was used for estimating direct and indirect effects of traits.

Results and Discussion

According to the results, achene yield had the highest correlation with oil yield in Karaj (Table 1). Achene number per head also had positive and significant correlation with oil yield. These are in agreement with the reports of Tahir et al. (2002), Shankar et al. (2006) and Goksoy and Turan (2007). There was negative correlation between 1000 achene weight and achene number per head. Achene weight, achene number per head and oil content are three main components of oil yield in sunflower and based on results of Hladni et al. (2006) achene weight had more importance than the two other components. There was positive correlation between days to flowering and days to maturity means that early flowering genotypes reach to physiological maturity earlier than late flowering genotypes.

Same as Karaj achene yield had the highest correlation with oil yield in Khoy. The two other components – oil content and achene number per head – had positive and significant correlation with achene and oil yield (Table 2). These correlations are in accordance with Mijic et al. (2009) and suggest the possibility of using the achene or oil yield components as selection criteria in screening of sunflower genetic materials. Plant height had positive correlation with achene weight but negative correlation with achene number; so genotypes with lower plant height are more suitable because of having more achene in head. There were more significant correlations between the studied traits in Gonbad, which means that relationships among traits could be affected by environmental condition. Stem and head diameter, 1000 achene weight, achene number per head and oil content had significant correlation with achene and oil yield in Gonbad (Table 3). Shankar et al. (2006) and Goksoy and Turan (2007) also reported positive correlation of achene weight and achene number with achene yield.

Path analysis was carried out to understanding the nature of correlations among studied traits in three locations separately. In all of these locations the highest positive direct effect on oil yield were imposed by achene number per head,

Table 2. Correlation between different agronomic traits of sunflower in Khoy

Traits	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content	Achene yield
Days to maturity	0.585**								
Plant height	0.499**	0.367*							
Head diameter	0.048	0.285	0.178						
Stem diameter	0.142	0.275	0.271	0.612**					
1000 achene weight	-0.075	0.169	0.348*	0.426**	0.218				
Achene number head^{-1}	-0.170	0.093	-0.371*	-0.113	-0.131	-0.385*			
Oil content	-0.170	0.109	-0.187	-0.104	-0.143	-0.065	0.558**		
Achene yield	-0.207	0.171	-0.293	0.060	-0.073	-0.048	0.937**	0.579**	
Oil yield	-0.195	0.178	-0.284	0.040	-0.092	-0.056	0.921**	0.722**	0.980**

* and ** are denote to the significant differences at probability of 5 and 1% respectively

Table 3. Correlation between different agronomic traits of sunflower in Gonbad

Traits	Days to flowering	Days to maturity	Plant height	head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content	Achene yield
Days to maturity	0.350*								
Plant height	0.184	0.245							
Head diameter	0.137	0.411*	0.277						
Stem diameter	0.045	0.412*	0.530**	0.745**					
1000 achene weight	-0.069	0.521**	0.448**	0.501**	0.532**				
Achene number head^{-1}	0.078	0.097	0.111	0.574**	0.446**	0.044			
Oil content	-0.188	0.122	-0.087	0.303	0.356*	0.444**	0.341*		
Achene yield	0.038	0.337*	0.303	0.751**	0.655**	0.528**	0.866**	0.506**	
Oil yield	-0.013	0.313	0.233	0.738**	0.650**	0.534**	0.841**	0.645**	0.983**

* and ** are denote to the significant differences at probability of 5 and 1% respectively

1000 achene weight and oil content respectively. Shankar et al. (2006) and Ghaffari and Haji Hosseinlou (2013) also indicted the highest positive impact of achene number on achene yield. However, Marinkovic (1992) and Darvishzadeh et al. (2011) reported the higher effect of 1000 achene weight and head diameter on achene yield respectively. This could be resulted from the variability of the environments and plant materials which have been used by different researchers. Traits with higher positive direct effect on oil yield can be used as direct criteria for selection of desirable genotypes (Sadras et al., 1993), so the results express the three components of oil yield as the main determinant of sunflower oil yield. The results of this study indicated that achene number per head is an efficient direct criterion for this purpose in all three regions of this study.

Beside higher positive direct effect on oil yield the most of indirect effects were imposed by achene number per head too in Karaj (Table 4) which is in accordance with the results of Patil et al. (1996). Head and stem diameter, days to flowering and plant height had positive indirect effect on oil yield through achene number in Karaj. The considerable effect of stem reservoirs on achene filling has been emphasized previously by Sadras et al. (1993). Days to maturity and oil content had positive indirect effect on oil yield through 1000 achene weight, however, the indirect effect of achene number through achene weight and vice versa which could be resulted from negative correlation between these traits.

Achene number along with achene weight were the main route for transmission of the effect of the other traits on oil yield in Khoy, but the most of effects through achene number were negative (Table 5). Achene weight had negative, while oil content had positive indirect effect on oil yield through achene number. Because of the negative correlation between achene number and achene weight it seems that achene weight decreases as achene number increases, which in turn causes an increase of oil content, knowing that lower hull content in small achene causes an increase of oil content. As achene number increased, plant height and head diameter negatively affected oil yield indirectly through 1000 achene weight.

Unlike the results of Karaj and Khoy, achene weight was the main route for transmitting of indirect effects on oil yield however achene number per head had the highest positive direct effect on oil yield in Gonbad (Table 6). Stem and head diameter, days to maturity, plant height and oil content achene weight and stem diameter and oil content through achene number had positive indirect effect on oil yield. As indicated previously stems are the main reservoirs for achene filling. Sadras et al. (1993) and Elizondo-Barron (1991) reported the critical role of partitioning of photosynthetic assimilates on achene filling in drought stressed condition. Higher correlation of stem diameter with oil yield components in Gonbad shows the crucial role of this trait in achene filling in rainfed condition.

Table 4. Direct and indirect effects of agronomic traits on sunflower oil yield (Karaj)

Traits	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content
Days to flowering	**0.014**	-0.012	-0.015	-0.002	0.013	0.022	0.205	0.027
Days to maturity	0.005	**-0.032**	-0.005	-0.001	-0.007	0.179	-0.063	0.094
Plant height	0.004	-0.003	**-0.058**	-0.005	0.036	0.006	0.174	-0.020
Head diameter	0.002	-0.001	-0.016	**-0.019**	0.019	-0.039	0.216	0.023
Stem diameter	0.003	0.004	-0.037	-0.006	**0.056**	-0.026	0.239	-0.096
1000 achene weight	0.001	-0.009	-0.001	0.001	-0.002	**0.615**	-0.730	0.049
Achene number head^{-1}	0.002	0.002	-0.008	-0.003	0.011	-0.375	**1.196**	-0.030
Oil content	0.001	-0.010	0.004	-0.001	-0.018	0.101	-0.123	**0.296**

Table 5. Direct and indirect effects of agronomic traits on sunflower oil yield (Khoy)

Traits	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content
Days to flowering	**0.043**	-0.004	-0.015	0.003	-0.006	-0.022	-0.153	-0.041
Days to maturity	0.025	**-0.006**	-0.011	0.020	-0.012	0.051	0.084	0.026
Plant height	0.022	-0.002	**-0.029**	0.013	-0.012	0.104	-0.334	-0.045
Head diameter	0.002	-0.002	-0.005	**0.072**	-0.027	0.128	-0.102	-0.025
Stem diameter	0.006	-0.002	-0.008	0.044	**-0.045**	0.065	-0.118	-0.035
1000 achene weight	-0.003	-0.001	-0.010	0.031	-0.010	**0.300**	-0.346	-0.016
Achene number head^{-1}	-0.007	-0.001	0.011	-0.008	0.006	-0.115	**0.901**	0.135
Oil content	-0.007	-0.001	0.005	-0.007	0.006	-0.020	0.503	**0.242**

Table 6. Direct and indirect effects of agronomic traits on sunflower oil yield (Gonbad)

Traits	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter	1000 achene weight	Achene number head^{-1}	Oil content
Days to flowering	**-0.006**	-0.003	-0.005	0.011	0.001	-0.026	0.055	-0.038
Days to maturity	-0.002	**-0.010**	-0.007	0.032	0.009	0.197	0.068	0.025
Plant height	-0.001	-0.002	**-0.028**	0.022	0.012	0.170	0.078	-0.018
Head diameter	-0.001	-0.004	-0.008	**0.078**	0.017	0.190	0.404	0.062
Stem diameter	0.000	-0.004	-0.015	0.058	**0.023**	0.202	0.314	0.072
1000 achene weight	0.000	-0.005	-0.013	0.039	0.012	**0.379**	0.031	0.090
Achene number head^{-1}	-0.001	-0.001	-0.003	0.045	0.010	0.017	**0.705**	0.069
Oil content	0.001	-0.001	0.002	0.024	0.008	0.168	0.240	**0.203**

Conclusion

The results of this study embossed achene number per head as the most important component of oil yield which affected directly oil yield and was the main route for transmitting the effect of the other traits on oil yield. However, in drought condition in Gonbad achene weight had more importance for transmitting of indirect effects. The results indicated that depending on the target area, stem and head diameter and plant height are main determinant of sunflower oil yield and could be used as selection criteria in sunflower breeding programs.

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