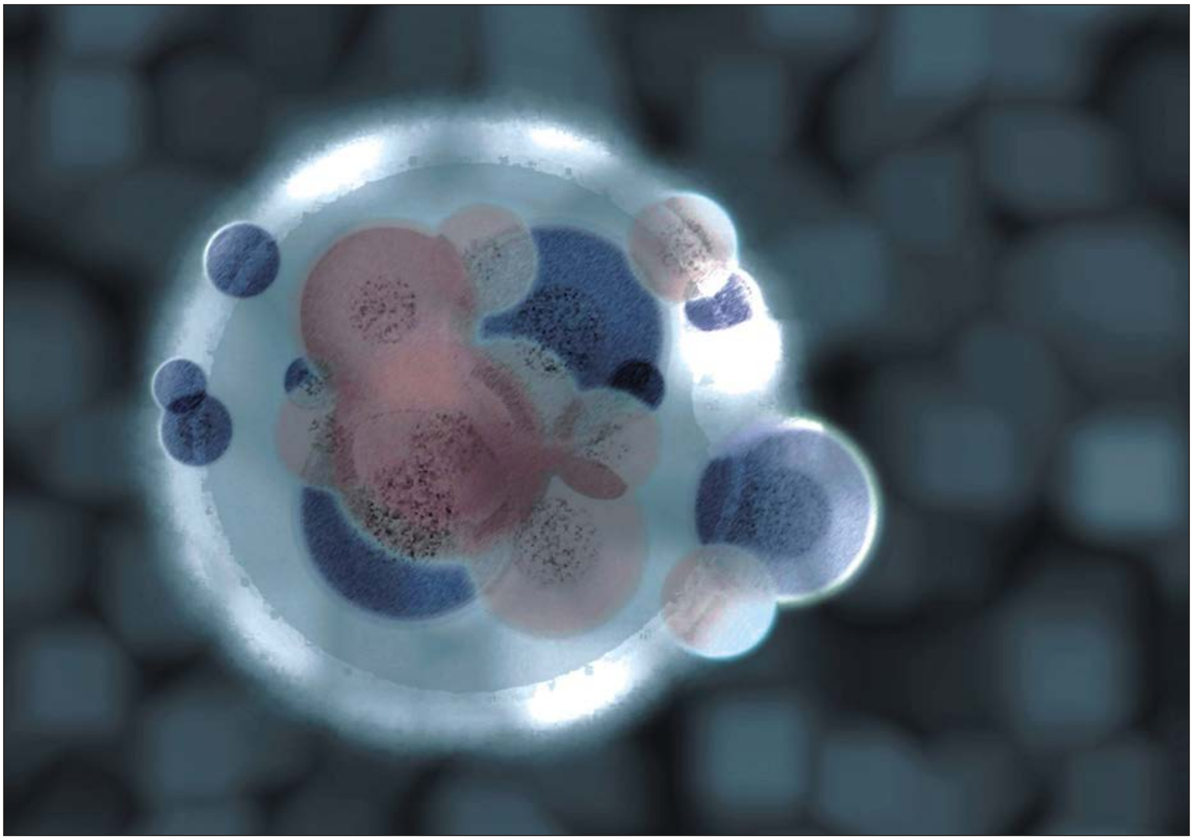

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The Path Analysis of Yield and its Components in Safflower (*Carthamus tinctorius* L.)

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Abstract: This study was aim to determine the relations among yield and some characters of safflower using correlations and path coefficient analysis. Fifteen safflower genotypes were grown at Van ecological conditions (eastern of Turkey) in 2000 and 2001 in randomized complete block design with three replications. Simple correlation analysis and path analysis were applied to the means of 15 genotypes in order to determine the relationships between agronomic characters and estimate the direct and indirect effects of agronomic characters on seed yield. Based on the results, positive and significant correlations were found between seed yield and all investigated traits except primary branches/plant (r = -0.466**) and 1000-seed weight (r = -0.220*). According to the path analysis, it can be also that seed yield was determined by head diameter, heads/plant and seeds/head since these characters had highly positive significant direct effects on seed yield.

Key words: Correlations, path analysis, yield, agronomic characters, safflower

INTRODUCTION

Safflower has a strong capacity to adapt to varying environmental conditions. Besides it is tolerant to cold, drought and salt and alkali, it does not demand fertilizer very much. This is one of the reasons of the reasons why safflower is distributed almost all over the world.

Safflower has long been widely cultivated for different aims in India, the Near East, the Middle East and China. It has been grown for centuries, primarily for its colorful petals used as a food coloring and flavoring agent, for vegetable oil and also for preparing textile dye in the Far East, Central and North Asia, America, North Africa, Europe and Caucasia (Esendal, 2001). In 2005, total production of safflower seed was 717,778 mt in the world. The highest amount of production was in Mexico with 212,765 mt; 210,000 mt in India; 87,340 mt in the USA, 75,000 mt in Kazakhistan and 51,000 mt in Argentina. Also, the production of safflower seed was 150 mt in Turkey (Anonymous, 2005).

Safflower is grown as a rainfed crop in Turkey. Therefore the farmers produce it on the marginal land areas (poor soils), usually ignore irrigation for supplementary water and refuse to use plant nutrients and pesticides in safflower fields. Although pests and diseases are few their influence on yield and quality is considerable. And, safflower can be grown as a winter crop. The high yields produce up to 2.000-2.500 kg ha•1 with no irrigation (Esendal, 2001).

Genetic variation among traits is important for breeding and in selecting desirable types. A wide variety of agronomic traits have been examined in safflower germplazm collections for their possible use in the improvement of the productivity of safflower cultivars. Expression of various traits is oftenly changed as the changing breeding material and environment. Therefore, the information of character associations between the traits themselves and with the traits themselves and with the yield is important for the breeding material subjected to selection for high yielding genotypes. Considerable emphasis has been given placed upon the inter relationships between yield and yield components in safflower. Correlation coefficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in safflower yield (Iqbal *et al.*, 2006). However, path coefficient analysis helps to determine the direct effect of traits and their indirect effects on other traits (Yücel *et al.*, 2006).

The seed yield and oil content are the primarily selection criteria for safflower breeding (Gencer *et al.*, 1987). Evaluating yield components and their interrelationships and detecting suitable selection indexes is very important in safflower breeding programme, especially the direct components of yield that are related to the various morphological characters regarded as indirect components of yield.

Selection is one of the important methods in safflower breeding. The importance of selection for a particular trait depends upon the extent of director or indirect effect of trait on seed yield (Mahasi *et al.*, 2006).

Plant height, branch height, branches/plant, heads/plant, seeds/head, head diameter, stem diameter, 1000-seed weight and oil content are the most important characters in safflower improvement for increasing seed yield (Ashri *et al*., 1976; Abel and Discroll, 1976; Dingming *et al*., 1993; Hudge *et al*., 1993; Yuhai *et al*., 1993; Corleto *et al*., 1997; Gupta and Singh, 1997; Patil, 1998; Rudra Naik *et al*., 2001; Hamadi *et al*., 2001; Omidi Tabrizi, 2005; Alizadeh and Carapetian, 2006) because of direct and indirect correlation with seed yield (Ghongade *et al*., 1993; Patil, 1998; Omidi Tabrizi, 2001; Sing *et al*., 2004; Çama• and Esendal, 2006; Mahasi *et al*., 2006). Some of these characters are more affected from one environment than another one due to environmental and genotypical differences.

The objective of the study reported in this research was to evaluate safflower yield components and their interrelationship by path coefficient analysis.

MATERIALS AND METHODS

The investigation was conducted under irrigation conditions between 2000 and 2001 years on the experimental area of the Department of Field Crops, Faculty of Agriculture, Yüzüncü Y•l University in Van, Turkey. The soil of the experimental area was clay-loam, pH was 7.7, low in organic matter (1.0%), poor in available nitrogen (0.080 mg L•^{1}) and phosphorus content (27.5 kg ha•^{1}), rich in potassium and lime contents (524 kg ha•^{1} and 12%, respectively) and at least in salt content (0.080%). The total rainfall was 234.60 and 137.5 mm in the experimental years, compared with the long-term (1965-1995) mean of 412.5 mm. The monthly average temperature (first year 10.3°C and second year 10.9°C) and relative humidity (first year 59.4% and second year 60.1%) means were similar to the long-term average (8.3°C; 65.1%).

Fifteen safflower cultivars were sown in a randomized complete block design with three replications. The plot size for each treatment during 2000 and 2001 was 11.25 m•^{2} (5.0×2.25 m) and sown with 45×15 cm row spacing (app.13.3 plant m•^{2}) in the midts of May in the experiment years. Nitrogenous fertilizer (ammonium sulfate 21% and 150 kg ha•^{1}) and phosphorus fertilizer (triple super phosphate 42% and 100 kg ha•^{1}) were applied before sowing and all standard agronomic practices were applied. Samples were obtained in the second week of October during both the years. Agronomic characters were determined on ten plants randomly selected in the mid-rows all of plots. Seed yield (kg ha•^{1}), plant height (cm), primary branches/plant), heads/plant), branch height (cm), stem diameter (mm); head diameter (mm), seeds/head), 1000-seed weight (g), oil content (%) were measured. The collected data was analyzed through computer TARIST statistical package. In order to determine the relationships between seed yield and the other examined characters simple correlation coefficients were calculated. The path coefficients were separated by using seed yield as a dependent variable (Wright, 1960).

RESULTS AND DISCUSSION

Positive significant relationships were found between seed yield and plant height (r = 0.389**), heads/plant (r = 0.212*), Branch height (r = 0.355**), stem diameter (r = 0.355**), head diameter (r = 0.819**), seeds/head (r = 0.670**), (Table 1). These results showed that any positive increase in such characters will suffice the boost in seed yield. These findings were in similar with the results of Dingming *et al*. (1993), Omidi Tabrizi, (2005), Patil *et al*. (2004), Mahasi *et al*. (2006) and Alizadeh and Carapetian (2006). On the other hand, negative significant relationships were determined between seed yield and primary branches/plant (r = -0.466**), 1000 seed weight (r = -0.220*), oil content (r = -0.428**). On the contrary, Hamadi *et al*. (2001) reported that seed yield in safflower was a strong positive association between the primary branches. Zheng *et al*. (1993) stated that the high-yielding safflower varieties have taller individuals lower branches, more effective heads, fewer ineffective heads, lower weight of seeds, higher average heads/plant and longer flowering. Present results confirm the findings of Zheng *et al*. (1993). The results indicated that improvement of seed yield in safflower could be decrease oil content and 1000-seed weight due to negative association between these traits (Pahlavani, 2005). Bagawan and Ravikumar (2001) stated that oil content and seed yield are negatively correlated and thus an attempt to improve one results in the reduction of the other. These findings were in accordance with the results of our study.

The highest positive correlations were determined between plant height and stem diameter (r = 0.823**), seed yield and head diameter (r = 0.819**), plant height and branch height (r = 0.728**) and head diameter and seeds/head (r = 0.720**). Similarly, Johnson *et al*. (2005), Omidi Tabrizi (2005), Çama• *et al*. (2005) and Yuhai *et al*. (1993) determined that positive and significant relationships between these components. The results indicated that among all traits that correlated with head diameter, the highest correlation was observed for seed yield (r = 0.819**) and seeds/head (r = 0.720**).

Seeds/head showed positive and considerable correlation with seed yield (r = 0.670**), plant height (r = 0.328**) and branch height (r = 0.508**) and considerable negative correlation with oil content (r = -0.423**), primary branches/plant (r = -0.403**) and 1000-seed weight (r = -0.254**). These results showed

Table 1: Correlation coefficients among ten characters of safflower

Traits[1]	SY	PH	PBN	HN	BH	SD	HD	SN	SW	OC
SY	1.000	0.389**	-0.466**	0.212*	0.355**	0.355**	0.819**	0.670**	-0.220*	-0.428**
PH		1.000	-0.063ns	0.234*	0.728**	0.823**	0.488**	0.328**	-0.139ns	-0.389**
PBN			1.000	0.515**	-0.279**	0.017ns	-0.363**	-0.403**	0.240*	0.343**
HN				1.000	-0.038ns	0.318**	0.249*	0.062ns	0.012ns	0.068ns
BH					1.000	0.618**	0.490**	0.508**	-0.073ns	-0.457**
SD						1.000	0.502**	0.283**	-0.090ns	-0.276**
HD							1.000	0.720**	-0.258*	-0.440**
SN								1.000	-0.254*	-0.423**
SW									1.000	0.142ns
OC										1.000

ns: Not significant, *p<0.05, **p<0.001 [1]SY: Seed yield (kg ha•[1]), PH: Plant Height (cm); PBN: Primary Branch No. (No./plant); HN: Head No. (No./plant); BH: Branch Height (cm) ST: Stem Diameter (mm); HD: Head Diameter (mm), SN: Seed No. (No./head); SW: 1000-Seed Weight (g); OC: Oil Content (%)

that head diameter or seeds/head or both traits could be responsible for high seed yield in safflower (Corleto *et al.*, 1997; Zheng *et al.*, 1993; Abel and Driscol, 1976).

Plant height exhibited a significant and positive correlation with heads/plant (r = 0.234*), but a significantly negative correlation with oil content (r = -0.389**). Present results confirm the findings of Çama• *et al.* (2005) for oil content. Seeds/head reveled a insignificant association with heads/plant but expressed a highly negative correlation with 1000-seed weight (r = -0.254*). Mahasi *et al.* (2006) reported that negatively and significant correlation between seeds/capitulum and 100-seed weight.

Gencer *et al.* (1987) stated that seed yield and oil content are the primarily selection criteria for safflower breeding. Among the all traits that correlated with oil content, the lowest correlation was observed for heads/plant (Table 1). The oil content was negatively correlated with seed yield, plant height, branch height, stem diameter, head diameter and seeds/head whereas it was positively correlated with primary branches/plant. Pahlavani (2005) found the similar results for seed yield and oil content. Also, Çama• *et al.* (2005) found similar results for plant height, branch height and primary branches/plant.

In order to get a clear picture of the interrelationships between different traits, the direct and indirect effects of different characters were worked out using path coefficient analysis in respect of seed yield (Sing *et al.*, 2004). The path coefficient analysis based on seed yield as a dependent variable revealed that all traits, except primary branches/plant and oil content, showed positive direct effects (Table 2). Compared to the simple correlation analysis, path analysis of seed yield and its traits demonstrated that head diameter, heads/plant, branch height and seeds/head evolved the highest direct influence, 46.0, 34.2, 27.4 and 21.8%, respectively. Conversely, primary branches/plant had a negative and high direct effect (43.3%) with an indirect effect via head diameter (21.5%) and seeds/head (9.8%) on seed yield, but a positive indirect effect via heads/plant and branch height. On the other hand, the indirect effects of branch height and seeds/head via head diameter were stronger than its direct effects. These analyses indicated that head diameter, heads/plant, branch height and seeds/head were the main characters to seed yield. For this reason, these traits could be used more significantly for safflower improvement. The present findings of the importance of the direct effects on seed yield are not in agreement with the findings of Patil (1998), who showed the importance of the direct effect of 100-seed weight, heads/plant and primary branches/plant. Singh *et al.* (2004) also reported the importance of the direct effect of seed weights/head and oil percent. Similar research results with present study were published by others (Patil, 1998; Gupta and Singh, 1997; Iqbal *et al.*, 2006; Hamadi *et al.*, 2001; Corleto *et al.*, 1997; Abel and Driscol, 1976; Omidi Tabrizi, 2001; Mahasi *et al.*, 2006; Ashri *et al.*, 1976).

Although stem diameter and plant height had small positive direct effects on seed yield with 20.1 and 5.2%, respectively, but a great indirect effect via head diameter (respectively, 34.4 and 32.6%). In addition to, the direct effect of 1000-seed weight (10.7%) was positive and small, the indirect effect of this trait, via head diameter (34.5%) and primary branches/plant (23.5%), was negative and high on seed yield. Conversely, oil content had a negative and small direct effect on seed yield, but a great indirect effect through head diameter, primary branches/plant and seeds/head. Similar results were published by Çama• *et al.* (2005), Dingming *et al.* (1993) and Zheng *et al.* (1993).

It was analyzed that a higher indirect effect was exhibited on head diameter, heads/plant and seeds/head by most of the yield traits. And these traits correlated to seed yield could be given the primarily selection criteria for safflower breeding. Our results are consistent with Patil (1998), Gupta and Singh (1997), Gencer *et al.* (1987), Ghongade *et al.* (1993) and Omidi Tabrizi (2005).

Table 2: The direct and indirect effects of nine yield components to seed yield in safflower (path analysis)[1]

Traits[2]	Direct effect	PH	PBN	HN	BH	SD	HD	SN	SW	OC	Correlation
PH	0.0383		0.0229	0.0477	0.1677	0.1194	0.2409	0.0667	0.0076	0.0284	
	(5.2)		(3.1)	(6.4)	(22.7)	(16.1)	(32.6)	(9.0)	(1.0)	(3.8)	0.389**
PBN	-0.3619	-0.0024		0.1049	0.0642	0.0024	-0.0179	-0.0819	0.0132	-0.0250	
	(43.3)	(0.3)		(12.5)	(7.7)	(0.3)	(21.5)	(9.8)	(1.6)	(2.9)	-0.466**
HN	0.2036	0.0090	-0.1864		0.0088	0.0461	0.1227	0.0127	0.0007	-0.0049	
	(34.2)	(1.5)	(31.3)		(1.5)	(7.7)	(20.6)	(2.3)	(0.1)	(0.8)	0.212*
BH	0.2303	0.0279	0.1009	-0.0077		0.0897	0.2420	0.1033	-0.0040	0.0333	
	(27.4)	(3.3)	(12.0)	(0.9)		(10.6)	(28.8)	(12.3)	(0.5)	(3.9)	0.355**
SD	0.1450	0.0315	-0.0061	0.0648	-0.1424		0.2480	0.0576	-0.0049	0.0201	
	(20.1)	(4.3)	(0.8)	(8.9)	(19.7)		(34.4)	(7.9)	(0.7)	(2.8)	0.414**
HD	0.4936	0.0187	0.1315	0.506	-0.1129	0.0729		0.1462	-0.0142	0.0320	
	(46.0)	(1.7)	(12.3)	(4.7)	(10.5)	(6.8)		(13.6)	(1.3)	(2.9)	0.819**
SN	0.2032	0.0126	0.1458	0.0127	-0.1170	0.0411	0.3552		-0.0140	0.0308	
	(21.8)	(1.3)	(15.6)	(1.3)	(12.5)	(4.4)	(38.1)		(1.5)	(3.3)	0.670**
SW	0.0549	-0.0053	-0.0870	0.0024	0.0168	-0.0131	-0.1272	-0.0517		-0.0103	
	(14.9)	(1.4)	(23.5)	(0.6)	(4.5)	(3.5)	(34.5)	(14.0)		(2.8)	-0.220*
OC	-0.0728	-0.0149	-0.1241	0.0138	0.1051	-0.0400	-0.2171	-0.0860	0.0078		
	(10.7)	(2.2)	(18.2)	(2.0)	(15.4)	(5.9)	(31.8)	(12.6)	(1.1)		-0.428**

*p<0.05, **p<0.01, [1]values in parenthesis show percentage, [2]SY: Seed yield (kg ha•^{1}), PH: Plant Height (cm); PBN: Primary Branch No. (No./plant); HN: Head No. (No./plant); BH: Branch Height (cm) ST: Stem Diameter (mm); HD: Head Diameter (mm), SN: Seed No. (No./head); SW: 1000-Seed Weight (g); OC: Oil Content (%)

CONCLUSIONS

The relationships were determined between the seed yield and some agronomic components of safflower with simple correlation coefficients and path analysis. According to the results of the correlation analysis, seed yield was significantly correlated that all traits. Improvement of some characters can increase safflower seed yield., In this study, path analyses of seed yield showed that head diameter, head number/plant and seed number/head have the highest direct effect. This components had main components to seed yield.

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