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ANALYSIS OF PRODUCTIVITY AND TRAIT INTERRELATIONSHIPS FOR SAFFLOWER GROWN IN DIFFERENT PLANT DENSITIES AND LOCATIONS

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ABSTRACT

Safflower is a promising oil crop and drought tolerant. Information on the proper plant population for optimum production is necessary for management systems which allow maximum expression of genetic potential. The objectives of this study were (1) evaluating the agronomic performance of adapted and available new safflower genotypes under non-stress and stress soil conditions, and (2) using a combination of statistical models to study variation and relationships among safflower traits. The field research was performed during the winter seasons of 2011/12 and 2012/13, using six safflower genotypes evaluated in two different locations (Wadi El-Natroon and Giza) and three plant densities (33600, 67200 and 100800 plant fed^{-1}) in a split-plot design of randomized complete block arrangement. The main plots were devoted to the plant densities and sub-plots to the six genotypes. The traits that most contribute to safflower yields were revealed by statistical procedures including; simple correlation, multiple linear regression, and stepwise regression. For justifying the block of linked traits, the multivariate statistical methods including factor analysis, principal component, and cluster analysis were used. Results showed that location, density and genotype had significant effects on seed and oil yields of safflower. The genotypes responses to the desert site produced nearly the same seed yield as non-stress growing site. Plant density of 100800 plants fed^{-1} recorded the highest values of plant height, seed and oil yield kg fed^{-1}. Meanwhile, the highest values of number of branches and capitula plant^{-1}, petal weight plant^{-1} and seed weight plant^{-1} were at 33600 plant fed^{-1}. Line-168 and Demo-137 surpassed the other genotypes in seed and oil yields fed^{-1} at both locations in both seasons. Seed oil content and oil yield fed^{-1} had significant and positive simple correlation and regression coefficients with number of capitula plant^{-1}, petal weight plant^{-1}, seed weight plant^{-1} and seed index, with r^2 > 64% in all cases. The stepwise regression showed that oil yield fed^{-1} was limited to the three variables seed yield fed^{-1}, seed oil% and seed index. The stepwise model was $\hat{OY}$/fed = -648.87 +0.30 SY/fed** +21.34 SO%** +3.30 SI** -0.45 SW/p (R^2 =99%). The eigenvalues above 1 were 3.56, 2.11 and 1.02 and their correspondent variance ratios were 39, 23 and 11% for the first, second and third principal components, respectively. The results across models showed that the most important variables contributing to safflower yield were seed weight/plant, seed index and percent of oil content. These variables can be used as selection criteria in the developing safflower genotypes in both stress and non-stress soil conditions.

Keywords: ***Safflower, Salinity, Stress, Seed-oil, Yield, Regression, Multivariable, Statistics.***

INTRODUCTION

Being native to the old world, found in the Egyptian king TUT tomb, and neglected thousands of years, Safflower (*Carthamus tinctorius* L.) cultivation seems opening a new window towards partial recovery of edible oil lack in developing countries of arid and semi arid zones. While Egyptian Pharaohs planted safflower for many purposes, their descendents suffering a vast gap of edible oils. The demand for edible oil increased up to 1.3 million ton in Egypt (FAO 2013). Recent studies documented a lot of potential to safflower oil when it comes to health benefits. Despite worldwide importance, safflower has received little research attention in Egypt.

An increasing effort has been made in recent years towards the choice of safflower genotypes appropriate for regular and poor soils or abiotic stress growing conditions (Hamza 2015). The Egyptian newly reclaimed soils which are about 2.5 million feddan (FAO 2005) offer a great oppottunity to expand safflower planting due to its capability to withstand stress conditions of these soils (Abu-Hagaza *et al* 2009, Hamza 2010 and Hamza 2014). Limited studies documented the effects of plant density on growth, development, yield and yield components, as well as, seed oil content of safflower especially under the conditions of poor soils in Egypt. There is significant variation in plant density recommended in the literature, depending on climactic conditions and countries (Vallantino *et al* 2013). Gonzalez and Schneiter (1994) reported that as plant density increased, seed yield plant^{-1} decreased with maximum seed yield plant^{-1} obtained at the lowest plant density. They also showed that the stability in yield across the plant populations was attributed to the compensatory effect produced by the changes in number of plants per unit area and the yield plant^{-1}. Moreover, the worldwide ability to sustain severe needs to edible oil will depend in some ways on the genotypes with superior potential. Safflower genotypes with low nutrient requirments would be an advantage (Abbadi *et al* 2008). Many promising characters in safflower genotypes were selected as an indicator for superior production, such as high yielding capacity (Dajue and Griffee 2001) and high oil levels (Bergman *et al* 2007). In newly reclaimed soils, there is a need for additional research examining the agronomic performance of safflower genotypes compared to non-stress conditions. This would be useful for both the agronomist and farmer.

On the other hand, various statistical techniques were used to study the safflower trait interrelationships and determine the characters aided selection for high yields of seed and oil. These procedures varied between uni-variable techniques that utilized to study the direct and indirect interrelationships among traits (Golparvar 2011, Abd El-Lattief 2012 and Katar 2013) and multivariable techniques that utilized to study a block of positively linked traits (Sharifmoghaddasi and Omidi 2010, Abd El-Latif 2014 and Bahmankar *et al* 2014). These techniques were adopted in the current study under pressure of divergent locations, population intensity, and different genotype backgrounds that may provide an accurate illustration about the direction and magnitude of cause and effect of these traits. Recent works indicated that these statistical procedures can be used as an efficient tool to determine the suitable selection criteria of related traits that positively influence safflower yield improvement. The objectives of the present study were to evaluate the agronomic performance of safflower genotypes under stress and non-stress soil conditions, and using a combination of statistical models to study interrelationships between safflower traits.

MATERIALS AND METHODS

Experimental sites and treatments

Six safflower genotypes were sown in yield trials under three plant densities (33600, 67200 and 100800 plant fed^{-1}) across two winter seasons (2011/2012 and 2012/2013) at two locations belonging to Agricultural Experiments Stations, Faculty of Agric., Cairo University. These two locations were Wadi El-Natroon (L1), El-Beheira governorate (located in 30º32' N and 29º57' E, with an altitude of 45.0 m) and Giza governorate (L2) (located in 30°02' N and 31°13' E, with an altitude of 22.5 m). Genotypes name and description are presented in Table (1).

Table 1. Genotype code, name, characteristic, origin and source of studied safflower genotypes.

Code	Genotype	Flower color		Spine	Oil content (%)	Origin	Source
		Before fertilization	After fertilization				
1	Line -168	Yellow	Red	Spiny	32.1	Turkey	The exotic seeds were kindly offered by Agricultural Research Center (ARC)
2	Demo-137 cv.	Yellow	Orange	Spiny	33.6	USA	
3	Line -1697	Orange	Red	Spiny	34.3	Cyprus	
4	Giza-1 cv.	Yellow	Orange	Very spiny	29.6	Egypt	ARC, Ministry of Agriculture, Egypt
5	Bani-Suef (middle Egypt)	Yellow	Red	Very spiny	30.6		Somosta zone (farmer's seed lots)
6	Aswan (upper Egypt)	Yellow	Orange	Very spiny	28.5		Daraw zone (farmer's seed lots)

Soil and water properties of the two experimental locations are presented in Table (2). Soil of Wadi El-Natroon site was sandy, saline and poor in nutrients (NPK), as well as, organic matter. Irrigation water was saline (4-4.2 Ec; dS/m). Soil of Giza site was clay loam and better in nutrients (NPK), as well as, organic matter.

Under Wadi El-Natroon conditions a mono super-phosphate fertilizer (15.5% P_2O_5) at the rate of 30 kg P_2O_5 fed^{-1} was applied uniformly before planting. Nitrogen was added at level of 60 kg N fed^{-1}, in the form of ammonium nitrate (33.5% N) through equal 5 doses. The first dose was added at 21 days from planting, and then the rest doses were applied at a 7-day interval. Potassium Sulphate (50% K_2O) at the rate of 50 kg K_2O fed^{-1} was added through five equal doses at a 7-day interval. Mixture of micronutrients was also sprayed, four times, as a foliar application after thinning at 21-day intervals.

On the other hand, flooding irrigation system was used at Giza location. Mono super-phosphate fertilizer (15.5% P_2O_5) at the rate of 15 kg P_2O_5 fed^{-1} was applied uniformly before planting.

Table 2. Physical and chemical properties of soil at experimental locations in 2011/12 and 2012/13 seasons.

Properties	Location			
	Wadi El-Natroon (L1)		Giza (L2)	
	2011/12	2012/13	2011/12	2012/13
Physical properties				
Sand %	95.16	94.85	36.5	33.2
Silt %	3.14	4.00	30.2	31.5
Clay %	1.70	1.15	33.3	35.3
Texture	Sandy	Sandy	Clay loam	Clay loam
Chemical properties				
Soil (pH)	8.23	7.89	7.5	7.7
Ec (dS/m)	7.08	7.23	1.85	1.93
Organic Matter (%)	0.20	0.30	2.33	2.15
Total $CaCo_3$ (%)	3.50	2.55	3.40	3.49
Available N (mg kg^{-1})	0.55	0.63	35.4	40.9
Available P (mg kg^{-1})	1.33	1.45	9.00	9.88
Available K (mg kg^{-1})	10	15	210	230
Ec of irrigation water (dS/m)	4.0	4.2	0.78	0. 86
Irrigation system	Drip		Flooding	

Nitrogen was added in three doses of rate of 30 kg N fed^{-1}, in the form of ammonium nitrate (33.5% N). The first dose was added 21 days after planting and the rest of doses were applied at 21-day intervals. Potassium sulphate (50% K_2O) at the rate of 25 kg K_2O fed^{-1} was added in two equal doses; before planting and flowering. A mixture of micronutrients was also sprayed twice as a foliar application after thinning and at the beginning of flowering stage.

At harvest, ten guarded plants were randomly sampled from the two inner rows of each sub-plot to record plant height (PH in cm), number of branches $plant^{-1}$(NB/p), number of capitula $plant^{-1}$(NC/p), petal weight $plant^{-1}$ (PW/p in g), seed weight $plant^{-1}$ (SW/p in g), seed index (SI, 100-seed weight in g). Seed oil percentage (SO%) was determined according to AOAC (2000). Seed yield fed^{-1} (SY in kg) was weighed from the whole area of each sub-plot and adjusted to yield per feddan. Oil yield fed^{-1} (OY in kg) was calculated by multiplying seed-oil percentage by seed yield fed^{-1}.

Experimental design

Experimental design was split-plot in randomized complete block arrangement using three replications. The main plots were devoted to the three plant densities. The sub-plots were allotted to the six safflower genotypes. Each sub-plot consisted of 5 rows of 4 m long and 0.60 m wide with an area of 12 m^2. Seeds were sown in hills 20, 10 and 7 cm apart on 15 October in L1 and 15 November in L2 in both seasons, thereafter were thinned to one plant $hill^{-1}$ to give three plant densities 33600 (D1), 67200

(D2) and 100800 (D3) plant fed^{-1}. The obtained data were statistically analyzed and means were compared by LSD test according to procedures outlined by Steel *et al* (1997). Test for homogeneity of variance was used to compare between error variances before deciding the validity of combined analysis.

Pair-wise matrix of simple correlation and simple regression between safflower seed yield and its components was computed to the data combined across seasons according to the formula given by Snedecor and Cochran (1981). Multiple linear regression (more than one predictor variable) and coefficient of determination (r^2) were estimated in order to evaluate the relative contribution and to develop the prediction equation for safflower seed and oil yields. Stepwise regression was used to identify the most important independent variables that significantly contributed to total dependent variables of seed and oil yields (Draper and Smith 1981). Factor analysis is a multivariate analysis method which aims to explain the correlation between a large set of variables in terms of a small number of underlying independent factors (Cattell 1965). The factor loadings of the non-rotated matrix, the percentage variability explained by each factor and the communalities for each variable were determined as suggested by Seiller and Stafford (1985).

Principal components analysis is a mathematical procedure used to classify a large number of variables (items) into major components and determine their contribution to the total variation. The first principal component is accounted for the highest variability in the data, and each succeeding component accounts for the highest remaining variability as possible (Everitt and Dunn 1992). The main advantage of principal component analysis is reducing the number of dimensions without much loss of information. Cluster analysis was used for arranging variables into different clusters to find the clusters that their variables are more similar and correlated to one another comparing to other clusters. This procedure was performed using a measure of similarity levels and Euclidean distance (Eisen *et al* 1998). Statistical analyses were performed using authentic versions of EXILE, IRRESTAT (2005), and Minitab-13.1.

RESULTS AND DISCUSSION

Analysis of variance

Results presented in Table (3) showed that location had highly significant effect on all traits except NC/p and PW/p in both seasons and NB/p and SW/p in season 2. Plant density had highly significant impact on all traits in both seasons. Location had little effect on plant density since L×D interaction was highly significant only for NB/p in both seasons, it was significant for PW/p and SW/p in both seasons and OY in 2^{nd} season. Genotypes affected deeply all traits in both seasons except for NB/p in season 2.

Table 3. Mean squares of combined analysis of variance across locations for all studied traits of six safflower genotypes evaluated under three plant densities in 2011/12 and 2012/13 seasons.

SOV	df	PH	NB/p	NC/p	PW/p	SW/p	SI	SO%	SY/fed ($\times10^3$)	OY/fed ($\times10^3$)
	Season 1 (2011/12)									
Location (L)	1	2130.67**	23.52**	23.71	0.02	328.27**	4.06**	300.07**	271.06**	94.34**
R(L)	4	689.09*	1.63	12.92	0.79*	47.73*	0.26	32.62*	6.14	4.54*
Densities (D)	2	1298.55**	70.83**	1164.15**	7.43**	653.26**	7.14**	56.90*	1209.28**	69.28**
L×D	2	6.99	12.15**	35.86	0.88*	84.74*	0.22	0.46	5.76	1.62
Error (a)	8	23.01	0.16	24.52	0.19	15.82	0.18	7.89	2.22	1.14
Genotype (G)	5	521.28**	3.62**	333.84**	1.06**	54.76**	2.41**	39.00**	69.69**	18.66**
L×G	5	654.49**	0.34	15.86	0.09	5.03	0.20	9.60**	60.20**	9.08**
D×G	10	157.90*	0.73	28.81	0.35**	19.95**	0.39	1.48	31.30**	2.87**
L×D×G	10	83.49	0.96	41.42*	0.24	9.37	0.71	1.39	24.66**	2.55**
Error (b)	60	70.33	1.01	19.37	0.12	5.98	0.42	2.74	6.89	0.94
TOTAL	107	188.74	2.75	58.73	0.38	28.71	0.66	9.76	40.80	4.79
	Season 2 (2012/13)									
Location (L)	1	8791.25**	4.44	60.30	0.00	18.85	7.81**	509.34**	449.29**	160.40**
R(L)	4	46.72	0.94	26.98	0.14	5.12	0.90	24.90*	1.13	1.97
Densities (D)	2	776.28**	126.8**	1006.29**	7.67**	572.45**	11.96**	44.57**	911.78**	50.56**
L×D	2	23.00	12.11**	23.16	0.50*	63.63*	0.05	0.14	37.40	5.16*
Error (a)	8	32.70	1.25	33.00	0.08	8.82	0.34	2.01	11.82	0.84
Genotype (G)	5	447.61**	1.51	166.95**	2.14**	62.64**	2.32**	52.04**	170.62**	33.55**
L×G	5	426.02**	0.31	8.70	0.19	6.75	0.37	11.41**	28.53*	5.35**
D×G	10	84.64*	1.34	13.82	0.31**	37.31**	0.76*	0.79	28.23**	2.93*
L×D×G	10	89.46*	0.66	30.83*	0.32**	21.54**	0.29	0.60	14.96	2.05*
Error (b)	60	40.82	0.85	12.22	0.10	6.46	0.33	2.51	10.21	1.02
TOTAL	107	181.28	3.52	42.51	0.39	25.28	0.77	11.18	41.93	5.53

*** and ** indicate significance at 5 and 1% probability levels, respectively. PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield/fed, OY/fed; oil yield/fed.**

The location had a great impact on genotype in both seasons with PH, SO%, SY/fed and OY/fed in both seasons. Obviously, each of location and genotypes behaved independently with the current components traits. The planting density affected the genotype behavior deeply with PH, PW/p, SW/p, SY/fed and OY/fed in both seasons and SI in season 2. Location × density × genotypes interaction was significant for NC/p, SY/fed and OY/fed in season 1, whereas it was significant for PH, NC/p, PW/p, SW/p and OY/fed in season 2. Similar trends were obtained by Ada (2013).

Performance of main effects

Mean performance of the two main effects (location and genotypes) for safflower traits is presented in Table (4). Locations significantly affected all traits, except for NC/p and PW/p in season 1 and NB/p, NC/p, PW/p and SW/p in season 2. Location 1 was significantly superior to location 2 in yield traits SI, SO%, SY/fed and OY/fed, whereas location 2 dominated location 1 in PH during both seasons.

Table 4. Effect of location and genotypes on safflower yields and its components in 2011/12 and 2012/13 seasons.

Trait	2011/12									
	Location			Genotype						
	L1	L2	$LSD_{(0.05)}$	G1	G2	G3	G4	G5	G6	$LSD_{(0.05)}$
PH (cm)	124.5	133.3	Sig.	137.0	131.8	130.7	126.3	121.8	125.7	5.6
NB/p	9	9.9	Sig.	10.0	9.8	9.6	9.3	9.1	8.8	0.7
NC/p	27.4	28.3	ns	35.8	28.5	27.6	26.4	25.5	23.3	2.9
PW/p (g)	1.4	1.4	ns	1.7	1.6	1.6	1.4	1.3	1.0	0.2
SW/p (g)	17.5	14.1	Sig.	18.1	17.2	16.6	15.0	14.1	13.9	1.6
SI (g)	6.3	5.9	Sig.	6.7	6.2	6.2	6.0	5.9	5.7	0.4
SO (%)	31.5	28.2	Sig.	31.7	31.4	30.1	28.9	29.0	28.0	1.1
SY/fed (kg)	908.8	808.8	Sig.	947.1	915.4	868.3	791.7	820.0	810.8	55.4
OY/fed (kg)	286.8	227.6	Sig.	300.9	289.0	261.8	226.8	238.9	225.8	20.4
	2012/13									
PH (cm)	123.5	141.6	Sig.	137.1	137.7	131.5	135.5	126.1	127.4	4.3
NB/p	9.8	9.4	ns	10.0	9.8	9.6	9.4	9.4	9.2	Ns
NC/p	29.4	27.9	ns	34.2	29.4	28.9	26.4	26.9	26.0	2.3
PW/p (g)	1.4	1.4	ns	1.9	1.5	1.5	1.3	1.1	0.9	0.2
SW/p (g)	15.8	16.6	ns	19.6	17.0	16.1	15.4	15.0	14.3	1.7
SI (g)	6.3	5.8	Sig.	6.4	6.2	6.2	6.1	5.9	5.4	0.4
SO (%)	31.3	27.0	Sig.	31.2	30.7	29.9	28.2	28.1	26.9	1.1
SY/fed (kg)	959.2	830.0	Sig.	1025.4	940.8	941.3	888.3	819.2	752.5	67.5
OY/fed (kg)	301.3	224.3	Sig.	322.1	289.3	281.3	248.6	233.1	202.2	7.5

L1; Wadi El-Natroon, L2; Giza, G1; Line-168, G2; Demo-137, G3; Line-1697, G4; Giza-1, G5; Bani-Suef, G6; Aswan, PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

The differences between the two locations were attributed the soil differences, since soil of Wadi El-Natroon site was sandy, saline and poor in nutrients (NPK), as well as organic matter (Table 2). However, Wadi El-Natroon site seemed to be a good competitor to Giza site. Abbadi *et al* (2008) reported the advantage of some safflower genotypes with low nutrient conditions.

Genotype 1 (Line-168) followed by genotype 2 (Demo-137) were significantly superior to all other genotypes in all traits in both seasons (Table 4). Significant differences among genotypes were reflecting their differences in genetic background. Genotype 6 (Aswan) was significantly the lowest in both seasons, except PH. The superiority of the exotic genotypes 1 and 2 was due to their increased values of yield attributes which reflecting their ability in accumulating more assimilates and dry matter content that help establishing strong plants with final superior yield potential. Therefore, these results explained that the current set of safflower genotypes can be grown successfully under stress conditions of soil and hot climate and also were influenced more or less by prevailing environmental conditions either locations or plant densities. Hamza (2015) reported that some introduced lines surpassed the commercial cultivar Giza-1 under drip irrigation system in sandy salt soils of Egypt. In contrast, Shabana *et al* (2013) found that two land races surpassed two introduced lines which were not statistically different from Giza-1.

Results revealed that all traits were significantly affected by plant densities. However, it is important to answer the question regarding whether the increased plant densities from the second to third density had the same effects either positive or negative on the studied traits. To answer this question, the response equations of the studied variables to increased plant densities across the two seasons were depicted and discussed. The highest plant density significantly recorded the tallest plant, the highest seed and oil yields. Increasing plant density from 33,600 to 100,800 plants fed^{-1} increased plant height linearly (r^2= 99) in season 1 and quadratically in the second season (Fig. 1). In general, plants grown in season 2 were shorter than plants grown in the first year. The lowest density significantly dominated the other two densities in NB/p, NC/p, PW/p, SW/p, SI, and SO% in both seasons (Fig. 2, 3, 4, 5, 6 and 7, respectively). In addition to PW/p, SO%, seed yield components of NB/p, NC/p, and SI significantly decreased linearly with increased plant density in both seasons. Seed weight $plant^{-1}$ recorded closer measurements in both seasons, however, SW/p significantly decreased quadratically in both seasons. Increasing plant density from 33,600 to 100,800 plants fed^{-1} significantly increased seed and oil yields/fed linearly (r^2=99) in the first season and quadratically in the second one (Fig. 8 and 9, respectively).

The linear decreasing in NB/p by increasing plant density may be due to decrease light intensity around plants that promoting branching. The linear decreasing in NB/p associated with increasing plant density pointed to linear decreasing in NC/p. Vallantino *et al* (2013) reported that the reduction in some yield components of safflower due to increase plant density was attributed to inter and intra-plant competition for light, nutrients and water necessary for growth and development. The lower plant density exhibited the higher seed oil%. Similar trends were obtained by Shahri *et al* (2013). Oil yield was significantly increased by increasing plant density. This increase was due to the increase in seed yield. Such increase in seed yield may be attributed to the increase in plant density. On the contrary, Shahri *et al* (2013) and Vallantino *et al* (2013) cleared that oil yield was depressed significantly by increasing plant density.

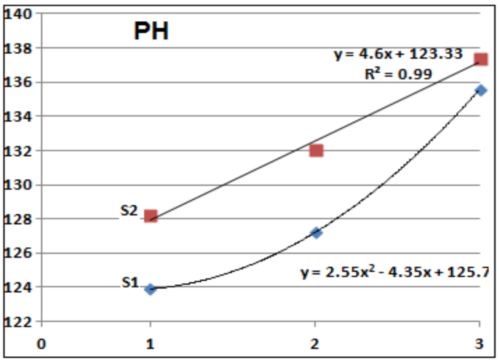

Fig. 1. Effect of plant density on safflower plant height (cm) in season 1 and 2.

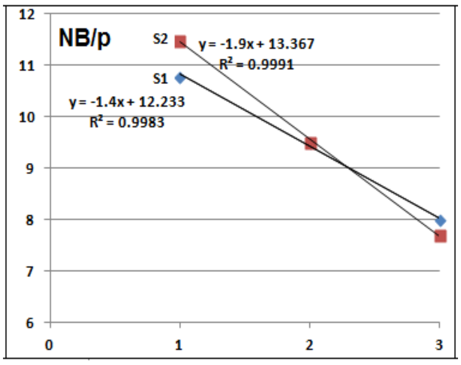

Fig.2. Effect of plant density on safflower number of branches per plant in season 1 and 2.

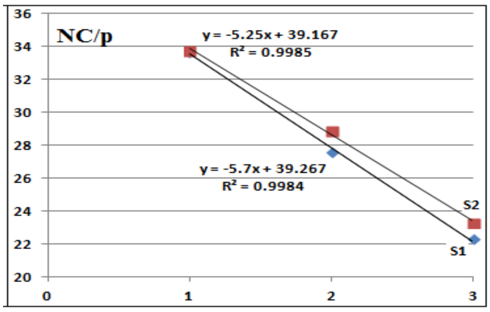

Fig-3. Effect of plant density on safflower number of capitula per plant in season 1 and 2.

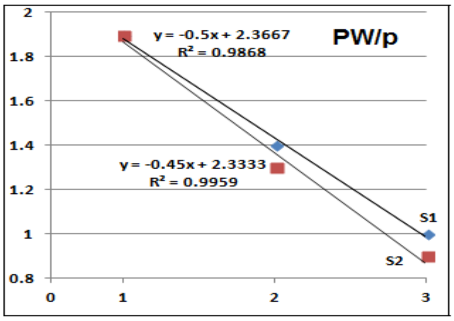

Fig. 4. Effect of plant density on safflower petal weight per plant (g) in season 1 and 2.

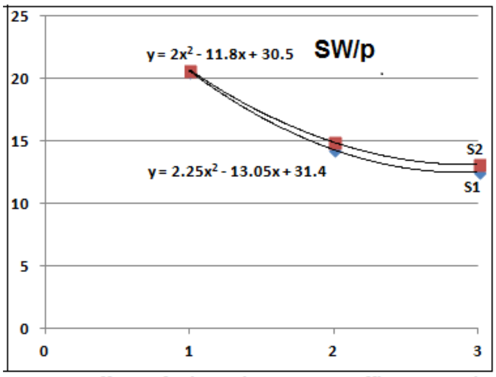

Fig. 5. Effect of plant density on safflower seed weight per plant (g) in season 1 and 2.

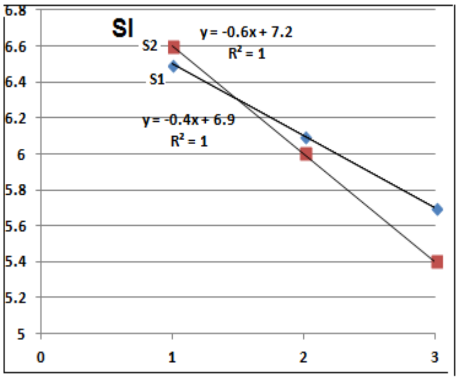

Fig. 6. Effect of plant density on seed index (g) in season 1 and 2.

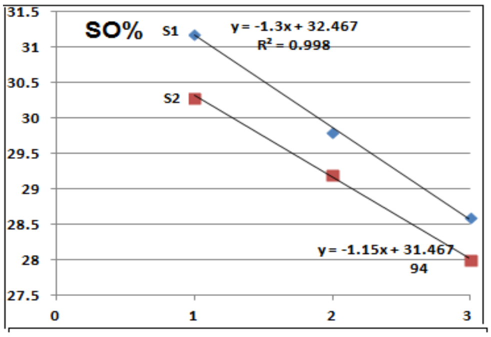

Fig. 7. Effect of plant density on safflower seed oil (%) in season 1 and 2.

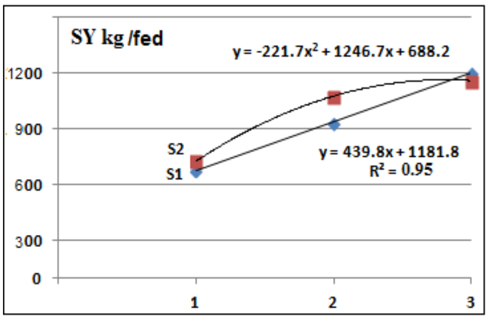

Fig. 8. Effect of plant density on safflower seed yield per feddan (kg) in season 1 and 2.

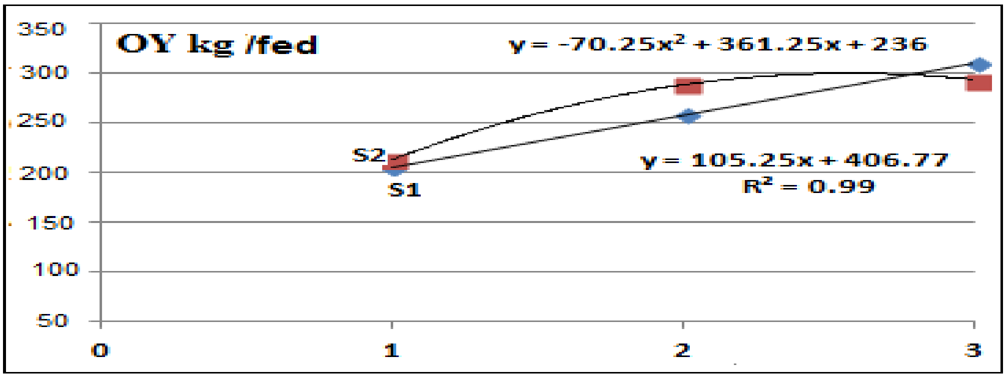

Fig. 9. Effect of plant density on safflower oil yield per feddan (kg) in season 1 and 2.

Interaction

Interaction between location and planting density (Table 5) showed that the locations and planting densities behaved independently for six and five out of the nine studied traits in season 1 and 2, respectively. The third planting density exhibited the tallest plants in both locations and seasons with insignificant interaction within each season. Same result was observed for SY and OY per feddan. Oil yield/fed showed significant interaction in season 2. Also, L×D interaction had significant effect on NB/p, PW/p, SW/p in both seasons.

Yield components (NB/p, NC/p, PW/p, SW/p and SI) were not affected by L×G interaction in both seasons (Table 6). This indicated that these two sources behaved independently regarding these traits. Moreover, these results explained that the current set of safflower genotypes were not much influenced by these two different locations. In other words, the current set of genotypes can be grown successfully under the two completely variant locations.

Table 5. Effect of the interaction of location and plant density on safflower yields and its components in 2011/12 and 2012/13 seasons.

Traits	2011/12						
	Wadi El-Natroon			Giza			LSD
	D1	D2	D3	D1	D2	D3	(5%)
PH (cm)	119.25	123.25	130.85	128.60	131.12	140.28	ns
NB/p	11.01	8.65	7.27	10.61	10.38	8.74	0.31
NC/p	34.12	26.05	21.93	33.18	29.09	22.64	ns
PW/p (g)	2.03	1.24	0.97	1.75	1.59	0.98	0.34
SW/p (g)	24.13	15.00	13.51	17.11	13.51	11.56	3.06
SI (g)	6.69	6.29	5.94	6.41	5.97	5.38	ns
SO (%)	32.69	31.54	30.37	29.62	28.06	26.92	ns
SY/fed (kg)	713.62	909.06	1104.33	641.87	800.43	984.13	ns
OY/fed (kg)	235.59	288.27	336.38	191.30	225.63	265.98	ns
	2012/13						
PH (cm)	120.02	122.92	127.67	136.38	141.13	147.22	ns
NB/p	12.23	9.12	7.96	10.71	9.91	7.48	0.86
NC/p	34.20	29.07	24.92	33.43	28.68	21.58	ns
PW/p (g)	2.00	1.19	0.90	1.72	1.35	1.00	0.22
SW/p (g)	21.47	13.07	12.90	19.95	16.79	13.21	2.28
SI (g)	6.90	6.31	5.67	6.29	5.78	5.21	ns
SO (%)	32.48	31.40	30.15	28.06	26.99	25.95	ns
SY/fed (kg)	744.12	1050.43	1082.67	683.56	861.87	944.79	ns
OY/fed (kg)	244.86	330.88	328.17	194.26	233.66	244.77	22.27

D1; 33600 plant fed^{-1}, D2; 67200 plant fed^{-1}, D3; 100800 plant fed^{-1}, PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

Table 6. Effect of the interaction of location and genotypes on safflower yields and its components in 2011/12 and 2012/13 seasons.

Trait	2011/12												
	Wadi El-Natroon						Giza						$LSD_{0.05}$
	G1	G2	G3	G4	G5	G6	G1	G2	G3	G4	G5	G6	
PH (cm)	134.60	126.53	135.20	124.57	112.73	113.07	139.43	137.13	126.17	127.97	130.90	138.40	7.91
NB/p	9.52	9.21	9.16	9.07	8.70	8.21	10.49	10.42	10.07	9.58	9.47	9.44	ns
NC/p	34.23	27.90	27.37	25.90	24.37	24.43	37.38	29.07	27.88	26.87	26.57	22.07	ns
PW/p (g)	1.67	1.58	1.43	1.43	1.25	1.12	1.69	1.63	1.68	1.38	1.33	0.93	ns
SW/p (g)	20.20	19.12	17.54	16.24	16.14	16.05	15.98	15.25	15.68	13.78	12.00	11.67	ns
SI (g)	6.83	6.36	6.29	6.24	6.08	6.04	6.66	6.04	6.03	5.77	5.73	5.28	ns
SO (%)	34.27	33.66	32.03	29.73	30.71	28.80	29.17	29.10	28.27	28.02	27.39	27.26	1.56
SY/fed (kg)	982.15	1007.60	961.97	745.70	922.94	833.67	912.04	823.09	774.47	837.97	716.93	788.36	77.92
OY/fed (kg)	335.25	338.43	306.32	219.03	282.76	238.70	266.58	239.53	217.14	234.63	195.06	212.87	28.75
	2012/13												
PH (cm)	136.97	126.13	124.73	124.47	112.70	116.20	137.27	149.17	138.27	146.57	139.53	138.67	6.02
NB/p	10.41	10.08	9.76	9.59	9.42	9.37	9.56	9.51	9.49	9.30	9.29	9.04	ns
NC/p	35.37	30.93	29.93	26.83	27.73	25.57	33.03	27.90	27.90	25.97	26.10	26.50	ns
PW/p (g)	2.09	1.50	1.45	1.27	1.08	0.77	1.73	1.46	1.46	1.30	1.18	1.03	ns
SW/p (g)	18.57	16.49	15.06	14.81	15.61	14.32	20.58	17.42	17.07	16.00	14.45	14.36	ns
SI (g)	6.79	6.52	6.42	6.41	5.88	5.76	5.96	5.96	5.88	5.88	5.86	5.00	ns
SO (%)	34.38	33.47	32.10	29.37	30.58	28.16	28.03	27.98	27.75	26.96	25.66	25.62	1.49
SY/fed (kg)	1109.13	980.82	992.39	905.88	951.39	814.81	941.53	901.13	890.41	870.39	687.17	689.81	95.00
OY/fed (kg)	381.20	327.02	317.11	263.85	290.45	228.21	263.04	251.60	245.45	233.39	175.70	176.21	30.00

G1; Line-168, G2; Demo-137, G3; Line-1697, G4; Giza-1, G5; Bani-Suef, G6; Aswan, PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

On the other hand PH, PW/p, SW/p, SY/fed and OY/fed were significantly affected by D×G interaction in both seasons and SI in season 2 only (Table 7). Results revealed that the genotypes (1 and 2), (1 and 3) and (2 and 3) were the highest performance in the densities 1, 2 and 3, respectively in the first season. Also, the genotypes (1 and 2), (2 and 3) and (1 and 3) were the highest performance in the densities 1, 2 and 3, respectively in the second one. The highest seed yield recorded by G3×D3 and G1×D3 in season 1 and 2, respectively, whereas the highest oil yield was recorded by G2×D3 and G1×D3 in season 1 and 2, respectively. Sharifi *et al* (2012) reported significant G×D interactions.

Table 7. Effect of the interaction of plant density and genotype on safflower yields and its components in 2011/12 and 2012/13 seasons.

Plant density	2011/12																		
	D1						D2						D3						$LSD_{0.05}$
Trait	G1	G2	G3	G4	G5	G6	G1	G2	G3	G4	G5	G6	G1	G2	G3	G4	G5	G6	
PH (cm)	125	129	124	120	118.0	128	141	129	125	124	121	123	146	138	143	135	127	126	9.7
NB/p	11.7	11.1	11.4	10.6	10.0	10.1	10.2	10.0	9.6	9.3	9.1	8.9	8.1	8.4	7.8	8.1	8.2	7.5	ns
NC/p	39.3	36.7	30.7	32.6	32.5	30.2	37.5	27.0	29.1	23.7	26.0	22.2	30.7	21.8	23.1	22.9	18.0	17.4	ns
PW/p (g)	2.1	2.3	1.9	2.2	1.4	1.5	1.6	1.5	1.6	1.5	1.3	1.0	1.3	1.0	1.2	0.6	1.2	0.5	0.4
SW/p (g)	25.0	21.7	19.8	20.7	18.0	18.6	15.7	14.5	15.6	12.5	12.3	15.0	13.6	15.4	14.5	11.9	11.9	7.9	2.8
SI (g)	6.9	6.4	6.8	6.2	6.5	6.4	6.8	6.3	6.0	6.0	6.0	5.7	6.6	5.8	5.6	5.8	5.2	4.9	ns
SO (%)	33.4	32.1	31.0	30.2	30.4	29.7	31.5	31.2	30.6	29.3	28.7	27.5	30.3	30.8	28.8	27.1	28.0	26.8	ns
SY/fed (kg)	858.8	767.5	575.8	633.3	662.1	568.8	952.1	901.3	931.7	736.3	771.7	835.4	1030.4	1077.5	1097.1	1005.8	1025.8	1028.8	95.8
OY/fed (kg)	286.1	250.8	179.9	190.4	204.2	169.3	301.7	283.6	286.0	215.2	224.8	230.4	314.9	332.5	319.3	274.9	287.8	277.7	35.3
	2012/13																		
PH (cm)	135	134	123	135	120	124	131	141	130	135	128	128	145	139	141	137	132	131	7.4
NB/p	12.2	12.3	11.1	11.3	11.2	10.8	10.1	9.4	9.2	9.4	9.7	9.2	7.7	7.7	8.6	7.7	7.2	7.6	ns
NC/p	37.9	35.7	34.1	31.4	31.9	32.1	37.1	28.9	27.3	26.7	28.2	25.2	27.7	23.7	25.4	21.2	20.7	20.9	ns
PW/p (g)	2.5	1.8	1.9	2.2	1.6	1.1	1.8	1.4	1.6	0.8	1.0	0.9	1.4	1.2	0.9	0.9	0.7	0.6	0.4
SW/p (g)	26.9	21.1	18.0	16.5	21.7	20.1	18.5	17.1	15.0	15.3	12.3	11.4	13.3	12.7	15.2	14.5	11.1	11.6	2.9
SI (g)	7.0	6.4	6.7	6.7	6.2	6.6	6.7	6.4	6.2	6.0	5.9	5.1	5.4	5.9	5.5	5.7	5.5	4.5	0.7
SO (%)	32.5	31.4	31.0	29.9	29.0	27.8	31.1	31.0	30.2	27.7	28.1	27.1	29.9	29.8	28.6	26.9	27.2	25.8	ns
SY/fed (kg)	980.8	763.8	684.6	690.8	622.1	541.3	982.9	992.9	1029.6	987.1	929.6	815.0	1112.1	1065.8	1110.0	986.7	906.3	901.3	116.7
OY/fed (kg)	324.2	239.6	212.9	206.3	183.8	150.4	308.3	309.6	312.9	274.6	266.7	221.3	333.8	318.8	317.9	265.0	248.8	235.0	36.9

D1; 33600 plant fed^{-1}, D2; 67200 plant fed^{-1}, D3; 100800 plant fed^{-1}, G1; Line-168, G2; Demo-137, G3; Line-1697, G4; Giza-1, G5; Bani-Suef, G6; Aswan, PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

Interrelationships between safflower traits

Simple correlation coefficient between each pair of variables is presented in Table (8). Seed oil content and oil yield has significant and positive correlation with NC/p, SW/p, and SI. These results that were matched with many previous reports indicated that any positive increase in such characters will reflected in increased seed and oil yields. Hajghani *et al* (2009) found that NC/p significantly correlated with SY. Golparvar (2011) found positive and significant correlation between SI and SW/p and between SW/p and OY.

Table 8. Pairwise correlation coefficients (r) for the estimated nine variables of safflower.

Variable	PH	NB/p	NC/p	PW/p	SW/p	SI	SO%	SY/fed
NB/p	0.38							
NC/p	0.29	0.68**						
PW/p	0.34	0.61**	0.78**					
SW/p	0.13	0.06	0.59**	0.64**				
SI	-0.09	0.39	0.69**	0.69**	0.60**			
SO%	-0.28	0.22	0.49**	0.52**	0.57**	0.80**		
SY/fed	-0.07	0.29	0.58**	0.55**	0.67**	0.72**	0.83**	
OY/fed	-0.15	0.28	0.58**	0.57**	0.65**	0.78**	0.94**	0.97**

PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1},OY/fed; oil yield fed^{-1}.

Karimi *et al* (2014) found positive and significant correlation between SI and SY. However, this adequacy needs to be quantified and grouped to determine the most important characters which possessed positive association with yield traits. This can be revealed through the regression relationship between each of these dependent variables and their attributed independent counterparts. Simple regression model, coefficients of determinate, and the probability of the estimated variables in predicting the safflower yields are presented in Table (9).

Table 9. Regression equation and relative contribution (R^2) for response of dependent variable (Y) and associated independent variable (X) of safflower data across seasons.

Independent var.	Dependent var.	Regression equations	P	R^2 (%)
PH	SY/fed	SY = - 1817 + 30 PH	0.01	68.7
	OY/fed	OY = - 1069 + 13 PH	0.01	61.9
NB/p	SY/fed	SY = - 2056 + 438 NB/p	0.00	70.7
	OY/fed	OY = - 1375 + 210 NB/p	0.00	79.0
NC/p	SY/fed	SY = 887 + 43.1 NC/p	0.00	64.2
	OY/fed	OY = 41 + 20.6 NC/p	0.00	71.2
PW/p	SY/fed	SY = 1318 + 562 PW/p	0.00	74.5
	OY/fed	OY = 244 + 271 PW/p	0.00	83.9
SW/p	SY/fed	SY = 508 + 99.6 SW/p	0.00	81.6
	OY/fed	OY = - 128 + 46.9 SW/p	0.00	87.6
SI	SY/fed	SY = - 846 + 486 SI	0.00	70.9
	OY/fed	OY = - 788 + 232 SI	0.00	78.5
SO%	SY/fed	SY = - 949 + 103 SO%	0.00	70.0
	OY/fed	OY = - 922 + 52.4 SO%	0.00	86.7
SY/fed	SY/fed	SY = 764 + 2.15 OY	0.00	95.4
$\widehat{SY}$ = -152 + 13.1** PH - 189 NB/p - 5 NC/p + 76 PW/p + 69* SW/p + 108 SI + 20.8* SO% (R^2=88.3%)				
$\widehat{OY}$ = - 596 - 1.2 PH + 8.37 NB/p + 0.64 NC/p - 25.7 PW/p + 4.8** SW/p - 7.49** SI + 21.5** SO% + 0.309 SY/fed (R^2=94%)				

P; probability, R^2; relative contribution, PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

Seed and oil yields increased linearly with various magnitudes with the studied traits. The coefficient of determination (r^2) described the degree to which the data clustered around regression line. The coefficient of determination (r^2=0.68%) revealed 68.7% variation in the safflower SY/fed, due to its relationship with PH. Regression coefficient (b=30) showed that a unit increase in plant height per plant resulted into a proportional increase of 30 kg/fed in safflower seed and 13 kg/fed oil yield, whereas the SW/p exhibited strong positive association with seed and oil yields (r=0.90 and r=0.94), respectively. The coefficient of determination (r^2=0.81 and r^2=0.87) revealed 81.6% and 87.6% of the total variation in safflower seed and oil yields, respectively, attributable to the variation in SW/p. The regression coefficient (b=99.6 and b= 46.9) indicated that for a unit increase in SW/p, there would be a proportional increase of 99.6 and 46.9 kg/fed in safflower seed and oil yields, respectively. Combined the effects of all data variables on the safflower seed and oil yields showed positive relationships with seed yield except for NB/p and NC/p with r^2=0.88, whereas PH, PW/p and SI were negatively associated with OY/fed (r^2=0.94). The obtained results showed that the prediction model equation for safflower seed and oil yields are formulated using the safflower plant variables as follows:

$\widehat{SY}$/fed = -152 + 13.1** PH - 189 NB/p - 5 NC/p + 76 PW/p + 69* SW/p + 108 SI + 20.8* SO% (R^2=88.3%).

$\widehat{OY}$/fed = -596 - 1.2 PH + 8.37 NB/p + 0.64 NC/p - 25.7 PW/p + 4.8** SW/p - 7.49** SI + 21.5** SO% + 0.309 SY/fed (R^2=94%).

These models are justifying significantly more than 88 and 94% changes in performance of the seed and oil yields, respectively. The remaining 12 and 6% perhaps are due to residual effects. The overall results reflect the importance of the abovementioned variables (SW/p, SI and SO%) in safflower seed yield selection. Similar trends were obtained by Katar (2013) who found that capitulum yield and SW/p are important variables. Besides, Karimi *et al* (2014) showed that SI and NC/p are the best criteria for genetic improvement of SY and SI and number of seeds/p for oil yield under drought stress condition and accounted for 92% of the total variation. However, the important question is that what is the most important variable(s) contributed in seed and oil yields? This question can be answered by analyzing the stepwise multiple regressions, which is a multiple statistical method that can screen or select the most important independent variables.

A stepwise regression is a useful way to identify promising predictors affecting a specific response. Based on this method, results of SY/fed presented in Table (10) showed that the overall 44.60% of the SY/fed variation could be explained by NB/p, PH, SO%, and NC/p. The unexplained variation, 55.40% of the total variance may be due to variation in the other yield components that did not included in the model.

Table 10. Regression coefficient, standard error and probability of the accepted variables by the stepwise routine to predict safflower seed and oil yields fed^{-1}.

	Seed yield fed^{-1}				Oil yield fed^{-1}				
Step	**1**	**2**	**3**	**4**	**Step**	**1**	**2**	**3**	**4**
Constant	**3543.30**	**2288.30**	**1006.80**	**983.90**	**Constant**	**-28.51**	**-634.86**	**-644.52**	**-648.87**
NB/p	**-157.00**	**-155.00**	**-169.00**	**-150.00**	**SY/fed**	**0.31**	**0.30**	**0.30**	**0.30**
P-Value	**0.00**	**0.00**	**0.00**	**0.00**	**P-Value**	**0.00**	**0.00**	**0.00**	**0.00**
PH		**9.60**	**11.00**	**10.50**	**SO%**		**21.30**	**21.03**	**21.34**
P-Value		**0.00**	**0.00**	**0.00**	**P-Value**		**0.00**	**0.00**	**0.00**
SO%			**41.00**	**47.00**	**SI**			**2.50**	**3.30**
P-Value			**0.00**	**0.00**	**P-Value**			**0.11**	**0.04**
NC/p				**-9.80**	**SW/p**				**-0.45**
P-Value				**0.07**	**P-Value**				**0.10**
S	**411.00**	**391.00**	**372.00**	**368.00**	**S**	**67.50**	**11.90**	**11.80**	**11.70**
R^2	**28.85**	**36.22**	**42.82**	**44.60**	**R^2**	**83.62**	**99.50**	**99.51**	**99.53**

SW/p; seed weight plant^{-1}, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

The positive regression coefficients of PH and SO% imply that good selection indexes for increasing SY/fed. Oil yield/fed were limited to the three variables SY/fed, SO%, and SI. The stepwise model was $\widehat{OY/fed}$ = -648.87 +0.30 SY/fed +21.34 SO% +3.30 SI -0.45 SW. This model justified significantly more than 99% in OY/fed performance. The positive and significant regression coefficient of SY/fed, SO%, and SI variables implies that a logical index selection with these variables, with considering their high coefficients of determination and correlation, they might be a good strategy for increasing OY/fed. Our findings are similar to the results illustrated by Karimi *et al* (2014) who found that stepwise regression analysis revealed that SI, seed number/p and NC/p are the most important components under stress conditions.

Principle component analysis and factor analysis

The previously studied models are depending mainly upon the direct relationships between a response and its predictors. However, the main drawbacks that are usually not confirmed with these models are the expected residual abnormality, variables multi-collinearly and expected increase the variance inflation factor especially if the collected data not tested for data quality (Abdalla 2015). The multivariate statistical procedures can provide a solution when the object is to select an array or block of biologically linked variables (Johnson and Wichern 1992). Figure (10) shows the scree plot of nine eigenvalues estimated for the 9 original variables, as well as, the cumulative percentage of variance explained. The eigenvalues (variances) above 1 were 3.56, 2.11 and 1.02 for the first, second and third principal components, respectively. The rest of the components were less than one.

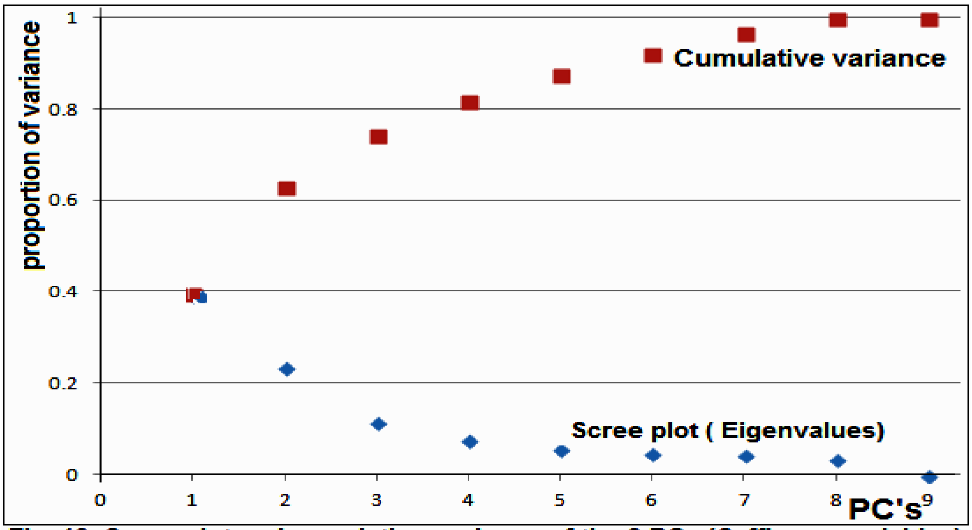

Fig. 10: Scree plot and cumulative variance of the 9 PCs (Safflower variables) based on principal components analysis

These components exhibited a maximum information of variance explained in the data set of 74% distributed as about 39.5, 23, and 11% for first, second and third principal component, respectively.

Table (11) shows the three principle components and factors loading based on both multivariable analysis. The array of communality is not presented herein because the factor analysis model is completely sufficient (Seiller and Stafford 1985).

Table 11. Loading of the first three principal components and factor analysis of the nine variables of safflower based on the average of the entire two seasons data.

Variable	Principle Component Analysis			Factor Analysis (no rotation)		
	PC1	PC2	PC3	Factor1	Factor2	Factor3
PH	-0.157	0.076	-0.914	-0.296	0.111	-0.924
NB/p	0.417	-0.087	-0.301	0.787	-0.126	-0.304
NC/p	0.391	0.116	-0.05	0.738	0.168	-0.051
PW/p	0.417	0.081	-0.048	0.786	0.118	-0.049
SW/p	0.391	0.228	0.01	0.738	0.331	0.01
SI	0.316	0.226	-0.149	0.595	0.329	-0.15
SO%	0.211	0.525	0.205	0.397	0.763	0.207
SY/fed	-0.355	0.459	-0.071	-0.67	0.667	-0.072
OY/fed	-0.227	0.614	0.016	-0.428	0.891	0.016
Variance explained (Eigenvalues)	3.5584	2.1105	1.0225	3.5584	2.1105	1.0225
%variance	0.395	0.234	0.114	0.395	0.234	0.114

PH; plant height, NB/p; number of branches plant^{-1}, NC/p; number of capitula plant^{-1}, PW/p; petal weight plant^{-1}, SW/p; seed weight plant^{-1}, SI; seed index, SO%; seed oil %, SY/fed; seed yield fed^{-1}, OY/fed; oil yield fed^{-1}.

The first principal component accounted for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. When we look at these components or factor loading, we are interested in the correlations above 0.3 or less than -0.3 (Dillon and Goldstein 1984). Based on both principle components and factor analysis, the first component had high positive loading on NB/p, PW/p, NC/p, SW/p and SI. The positive correlation indicates the positive direction of the relationship between the factor and the initial variable. The interesting note here is that factor can be named as yield component factor because of the high loading positive sign with these variables. This in turn shows that these traits may be influenced by the same genes and hence may be beneficial for screening desirable safflower characters or genotypes. Second factor explained 23% of the total genetic variance. The variables SO%, SY and OY per feddan highly loaded with positive sign. Obviously, this factor can be described as yield factor. The third factor explained 11% of the total genetic variation and has less important in safflower improvement program.

Katar (2013) reported that the maximum component number is determinate at three factors, and these components accounted for 93.6% of the total variation of safflower oil yield. PC1 correlated with capitula yield, SI and SO%. The PC2 correlated with SW/p and PC3 correlated with PH. The three PC1, PC2 and PC3 account for 53.8, 80.9 and 93.6% of the total variation, respectively. In order to see how the nine original variables actually lay in the component space, the without rotation first two component factors were presented on Figure (11).

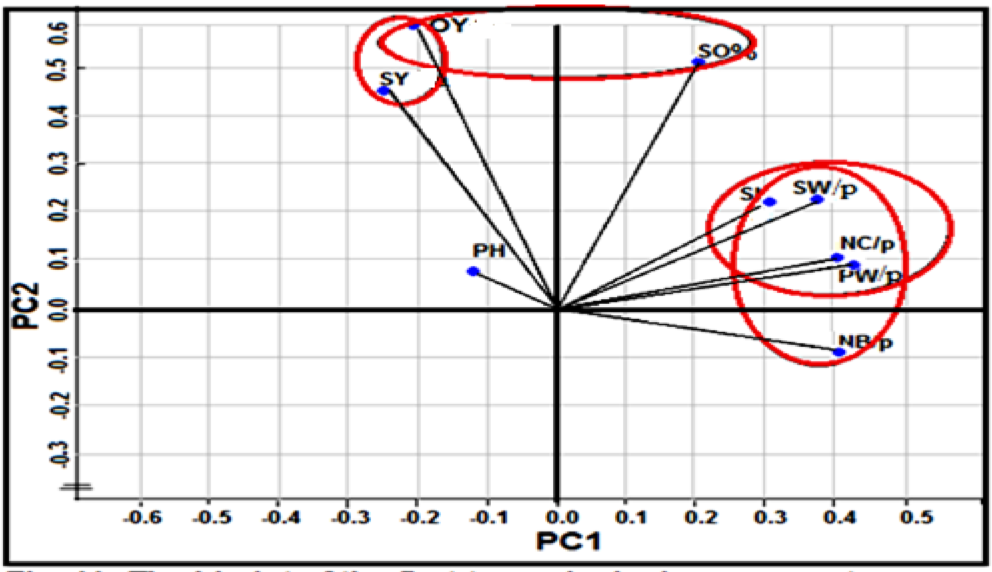

Fig. 11: The bi-plot of the first-two principal components among the nine safflowe variables.

The bi-plot accounted for 62.5% of the total variation. The variables SW/p, SI, NC/p, PW/p, as well as NB/p were closely linked and showed relatedness to PC1, whereas the variables SY/fed, OY/fed and SO% were closely linked and showed relatedness to PC2. Variables like SO%, OY/fed and SY/fed greatly affected by growing environment, since they exhibited a very long score, but plant height was the lowest factor affected by growing environments (very short arm). The investigated bi-plot indicated that germplasm is likely to be improved for late planting if selection for these traits practiced in either location. Moreover, selection for linked traits within the stressed conditions may be guide to develop safflower genotypes can be grown successfully under poor soil conditions.

Cluster analysis

Cluster analysis is used to arrange a set of variables into clusters so that objects within a cluster are more similar to each other than within other clusters. The current study aimed to sort cases (variables) into groups, or clusters, so the degree of association between members of the same cluster is stronger than members of different clusters. The cluster analysis was performed using a measure of similarity levels and Euclidean distance. The safflower yield and its contributing variables fell into five will-supported clusters that are consistent with abovementioned correlations (Figure 12).

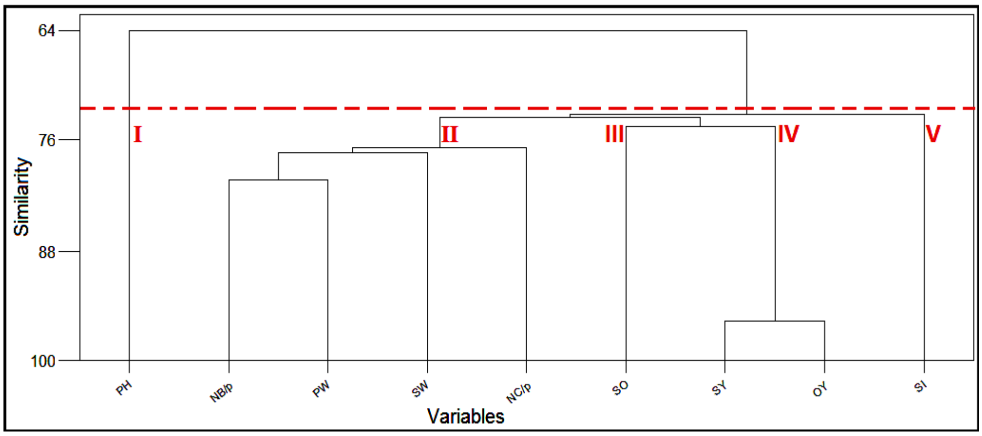

Fig. 12. Similarity levels of the estimated nine safflower variables using the hierarchical cluster analysis.

Plant height occupied a separate branch at 64% level of similarity. The second cluster included NB/p, PW/p, and SW/p at 78% level of similarity. At the same level, the SO% occupied individual position of cluster 3. At the highest similarity level (5%), cluster 4 incorporated the very dependent yield variables SY and OY per feddan, in kg. The fifth group was individual branch of SI. Our data reflected the tendency of each grouped variables in one cluster to relate closely to each other. Therefore, the traits like SO%, NC/p, SW/p and NB/p could be good indictors for direct selection to seed and oil safflower yields. Katar (2013) showed that capitulum yield, SI, SO% could be considered as important traits for high yielding in safflower breeding program according to multivariable procedures analysis.

In conclusion, the overall results showed that the genotypes responses to the desert site produced almost the same seed and oil yields as non-stress growing site. Plant density of 100800 plants fed^{-1} recorded the highest values of plant height, seed and oil yields kg fed^{-1}. The genotypes Line-168 and Demo-137 were the best in seed and oil yields kg fed^{-1} at both location and both season. The most important variables contributed to safflower yields were SW/p, SI, and SO%. These variables can be used as selection criteria to help in developing safflower genotypes that can be grown under both rich and poor condition soils. The multiple statistical procedures suggest that the final judgment of important yield contributing variables may need to be supported by using multivariable statistical methods for the best screening important traits in safflower.

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تحليل الإنتاجية والعلاقات بين الصفات للقرطم المنزرع تحت كثافات نباتية ومواقع مختلفة

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القرطم محصول زيت واعد ومتحمل للجفاف. وإن توفير المعلومات عن الكثافة النباتية المناسبة للإنتاج الأمثل ضروري لتحديد نظم إدارة المحصول التي تسمح بأفضل تعبير للتراكيب الوراثية عن امكاناتها. وتهدف هذه الدراسة الي (1) تقييم الأداء المحصولي لبعض التراكيب الوراثية الجديدة من القرطم ومدي تاقلمها تحت ظروف التربة العادية والمُجهَدة بالملوحة ونقص الخصوبة وكذلك (2) استخدام توليفة من الاساليب الإحصائية لدراسة التباين والعلاقات بين مكونات المحصول . تم إجراء البحث خلال الموسيمين الشتويين 2012/2011 و2013/2012، باستخدام ستة تراكيب وراثية من القرطم تم تقييمها في موقعين مختلفين هما محطتي البحوث والتجارب في كلا من وادي النطرون والجيزة التابعين لكلية الزراعة، جامعة القاهرة تحت ثلاثة كثافات نباتية (33600، 67200 و 100800 نبات/فدان) في تصميم القطع المنشقة مرة واحدة . خصصت القطع الرئيسية للكثافة النباتية والقطع المنشقة للتراكيب الوراثية. استخدمت اساليب إحصائية متنوعة بين الارتباط البسيط، الانحدار الخطي، الانحدار الخطي المتعدد، الانحدار المتعدد المرحلي وذلك بغرض التعرف علي المتغيرات الأكثر تأثيرا في محصول البذور والزيت. كما استخدمت الدراسة ايضا طرق الانحدار العاملي، تحليل المكونات الاساسية والتحليل العنقودي وذلك لتأكيد ارتباط مجموعة من الصفات تؤثر معا في محصول البذرة والزيت سواء بشكل مباشر او غير مباشر. وأظهرت أهم النتائج أن لموقع الزراعة، الكثافة النباتية والتركيب الوراثي تأثيرا معنوياً على مكونات المحصول ومحصول البذور والزيت. أعطي القرطم المنزرع بموقع وادي النطرون ما يقارب نفس محصول البذور بموقع الجيزة. سجلت الكثافة النباتية 100800 نبات/فدان أعلى قيم لصفات ارتفاع النبات ومحصول البذور والزيت كجم للفدان . وتحققت أعلى قيم من عدد فروع النبات، عدد الرؤوس الزهرية للنبات، وزن بتلات النبات، محصول البذور للنبات الفردي عند الزراعة بكثافة 33600 نبات/فدان. السلالة–168 والصنف ديمو– 137 تفوقتا علي التراكيب الوراثية الأخرى في محصول البذور والزيت كجم للفدان في كلا الموقعين وموسمي الدراسة. أظهرت معاملات الارتباط والانحدار البسيط ارتباطاً معنوياً موجباً بين نسبة ومحصول الزيت وبين عدد الرؤوس الزهرية للنبات، وزن بتلات النبات، وزن بذور النبات ودليل البذرة (r^2 > 64% في كل الحالات). أظهر الانحدار المتعدد المرحلي أن محصول الزيت للفدان يتحدد بثلاثة صفات هي وزن بذور الفدان، نسبة الزيت ودليل البذرة من خلال النموذج التالي

$$OY/fed= -648.87 +0.30\ SY/fed^{**} +21.34\ SO\%^{**} +3.30\ SI^{**} -0.45\ SW/p\ (R^2 =99\%).$$

كانت قيم التباين الأعلي من قيمة الواحد هي 3,56، 2,11 و 1,02 ونسبتها هي 39، 23 و 11% لكل من المكون الرئيسي الاول والثاني والثالث، علي التوالي. كما أظهرت النتائج أن أهم مكونات المحصول التي تساهم في محصول القرطم هي: وزن بذور النبات، دليل البذور ونسبة الزيت بالبذور . هذه المكونات يمكن أن تستخدم كصفات مساعدة للانتخاب بين التراكيب الوراثية من القرطم تحت ظروف التربة المُجهَدة وغير المُجهَدة .

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