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Correlation and path coefficient analysis for seed yield and yield contributing components, phenological and some morphological traits in Safflower (*Carthamus tinctorius* L.)

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Abstract

The purpose of this study has been to determine the selection criteria for plant breeders using correlation and path analyses of the safflower plant. The experiment was carried out at the University of Ondokuz Mayıs, Faculty of Agriculture, Fields Crops Department during the season 2017-2019 under winter and summer growing seasons. A randomized complete block with three replications was adopted. The results of our study showed a strong positive significative correlation of seed yield per plant with head weight (0.916), head number (0.908), seed number (0.886), root dry weight (0.841), branch number (0.833), stem dry weight (0.783), plant height (0.704), thousand seed weight (0.485). Days to maturity (0.927), days to rosette (0.670), head number (0.402), stem dry weight (0.359), and head weight (0.343) had the most important positive direct effect on seed yield indicating that these characters will be effective in safflower breeding.

Keywords: safflower, correlation, path analysis, seed yield, yield components

Introduction

Safflower is a very important xeric oilseed crop mainly cultivated in dry climate conditions (Geçgel *et al*., 2007) [10]. It was less selective than many oil plants in terms of climate and soil requirements. It can grow easily in any type of soil, it needs deep, fertile soils without drainage problems to obtain the high yield (Emongor, 2010) [9]. Safflower oil is considered a high-quality oil due to its low saturated fatty acids and high unsaturated (90%) fatty acids mainly oleic and lineoleic acids, used as cooking oil and in the production of biodiesel (Baydar and Erbaş, 2016) [3].

The primary goal of plant breeding was to create varieties with desirable characteristics such as higher yield, disease resistance, drought resistance, early maturity, and better oil quality. Grain yield is a complex quantitative trait depending from the interaction between different yield components and environmental effects. It was very important to choose the appropriate selection criteria to improve grain yield (Samonte *et al*., 1998) [16]. Correlation has been used by plant breeders to identify characters that are useful as selection criteria to improve crop yield.

Significant positive association was indicated between safflower seed yield and some yield components such as plant height (Tünçtürk and Çiftçi, 2004; Pavithra *et al*., 2016) [19, 15], number of secondary branch (Omidi *et al*., 2009) [13], number of head per plant(Tünçtürk and Çiftçi, 2004; Omidi *et al*., 2009; Beyyavas *et al*., 2011; Pattar and Patil, 2020) [19, 13, 4, 14], number of seeds per capitulum (Pavithra *et al*., 2016) [15], biomass (Omidi *et al*., 2009) [13], thousand seed weight (Omidi *et al*., 2009; Beyyavas *et al*., 2011; Pattar and Patil, 2020) [13, 4, 14], harvest index (Pavithra *et al*., 2016) [15], oil yield (Tünçtürk and Çiftçi, 2004; Omidi *et al*., 2009) [19, 13], oil content (Tünçtürk and Çiftci, 2004) [19].

Wright (1921) developed the path analysis technique which has been used in most cases to determine the direct effect of one variable on another and also partitioning the correlation coefficient into direct and indirect effects. Pavithra *et al* (2016) [15] observed positive direct effect of plant height, rosette period, days to 50% flowering, head number, seed number, test weight, and harvest index on safflower seed yield. Pattar and Patil (2020) [14] found that the direct effects of number of heads per plant and thousand seed weight on seed yield were greater than those of other traits; while plant height, number of seeds per head and oil content showed a negative direct effect on seed yield. Arslan (2007) [1] reported that safflower seed yield was directly affected by capitulum diameter, capitulum number, and seed number.

Days to maturity, harvest index, and number of seeds per head had the greatest direct positive effect on seed yield per plant, according to Jadhav *et al* (2018) [12]. Bidgoli *et al*. (2006) [5] conducted a path analysis on the safflower plant and discovered that total biomass, 1000 seed weight, and flowering duration all had a direct effect on seed yield.

Most previous studies focused on small number of yield components. Information about correlation between some morphological and phenological characters and the path analysis in safflower plant has been still very limited. In our study, in addition to investigating the yield contributing components, phenological, and some morphological traits were investigated. The purpose of our research was to determine yield contributing traits, phenological and some morphological traits through correlation and path coefficient analyses to facilitate the work of breeding to develop new safflower varieties with high yielding capacity.

Materıals and methods

Experimental area

The experiment was carried out in winter season during two consecutive growing season (2017-2018, 2018-2019) under rainfed conditions at Faculty of Agriculture, University of Ondokuz Mayıs, Samsun (41°37.49'N, 35°36'30"E) located in the Black Sea coast of Turkey which characterized by humid climate, short warm, humid summers and long cold cloudly winters. The data of the monthly average temperature and precipitation throughout the research period and long term are given in Figure 1. The average temperature in both years of the experiment (16.6 and 15.8 ^{0}C) is higher than the average of long terms (14.5 ^{0}C). While the amount of average precipitation in the experiment area is higher than the average of the first year (64.5 mm) for long terms (59.4 mm), the second year of the experiment (54.4 mm) is lower than the long terms average.

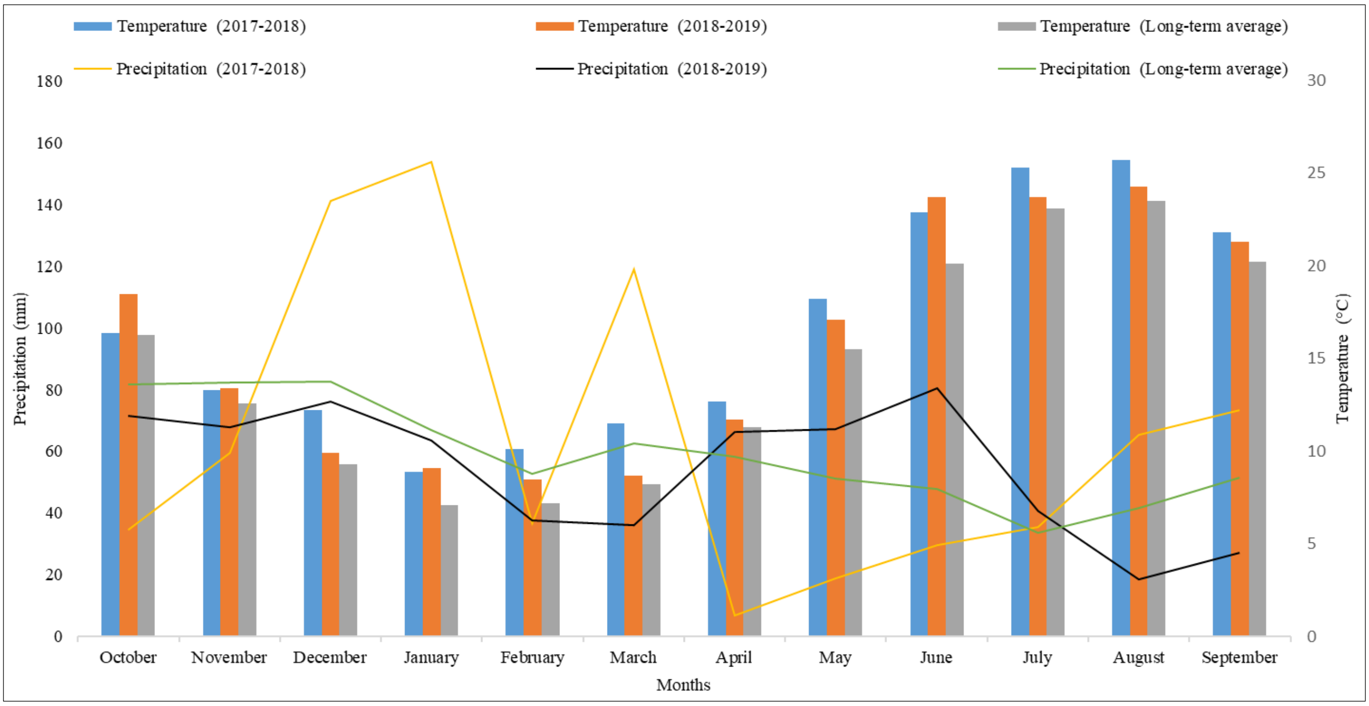


Fig 1: Some climate data of the experiment area (2017-2018, 2018-2019 and last 55 years)

According to the soil analysis, the experimental sit soils had a clay structure (%47.5 clay) with neutral pH (7). Moreover, the soil was rich in terms of phosphorus (293 ppm), potassium (10.3 ppm) contents, whereas the organic matter (%2.71) content was relatively medium.

Experimental material and method

The material for this study consist of two famous safflower genotypes Olas (oleic type) and Linas (linoleic type) provided by Trakya Agricultural Research Institute. The experiment was conducted according to a randomized complete block design with three replications. Each plot consisted of 5 rows, 3m in length and 40 cm between rows. The experimental plots were fertilized with the dose of 100 kg ha^{-1} by DAP (18-46) fertilizer in the first year and ammonium nitrate (33% N) fertilizer in the second year of the experiment. The fertilizer was applied at the stem elongation stage of the plant. Weed control in the experimental area was made manually in the row and using a hoeing machine in the inter-row. Cypermethrin and Thiacloprid active substances were applied on safflower plants with a dose of 400 ml ha^{-1} 2 and 3 times in the stem elongation, branching, and flowering stages against broad bean (*Tropinota hirta*), aphid (*Uroleucon Compositae*) and salivary beetle diseases. During the growing season, all phenological stages (days to emergence (E), days to rosette (R), days to stem elongation (SE), days to branching (B), days to flowering (F), days to maturity (M)) were followed and the number of days of each stage was recorded. At harvest, 10 plants were chosen at random from each plot, and some yield components such as plant height (PH), branch number (BN), head number (HN), head weight (HW), seed number (SN), thousand seed weight (TSW), root dry weight (RDW), stem dry weight (SDW), and seed yield (SY) were measured.

Statistical analysis

Amos SPSS was used to perform simple correlation and stepwise multiple regression analysis. The Pearson's correlation coefficient values among yield and yield compents, morphological and phenological traits were analysed according Dowdy *et al*. (2003) [8]. The path coefficient analysis was carried out using the Dewey and Lu method (1959) [7].

Results and discussion

Correlation coefficients

The correlation coefficient was regarded as an important statistical method for determining the direction and strength of the relationship between two traits or characters. The investigation of the relationship between seed yield and its constituents aids in breeding programs. The correlation coefficient for different traits in Safflower (*Carthamus tinctorius* L.) genotypes sown in winter season was represented in table 1 and figure 2.

Plant height was correlated positively with branch number (r=0.661**), head number (r=0.801**), head weight (r=0.766**), seed number (r=0.649**), thousand seed weight (r=0.838**), root dry weight (r=0.890**), and stem dry weight (r=0.927**), but negatively with days to rosette (r=-0.756**) and days to stem elongation (r=-0.392**). The positive correlation of plant height with seed yield and other yield related traits indicates that increase in plant height enhanced the allocation and translocation of photosynthates to the seed in safflower. It is evident that vigorous tall plants leads to increased yield compared to shorter plants. These findings are in corroborated with the investigations of Arslan (2007) [1] and Hussain *et al* (2014) [11]. Branch number was found to have a significant positive relationship with head number (r=0.841**), head weight (r=0.844**), seed number (r=0.848**), thousand seed weight (r=0.374**), root dry weight (r=0.751**), and stem dry weight (r=0.754**), but a significant negative relationship with days to rosette (r=-0.442**) and days to stem elongation (r=-0.355*).

Head number was correlated positively with head weight (r=0.950**), seed number (r=0.884**), thousand seed weight (r=0.581**), root dry weight (r=0.898**), and stem dry weight (r=0.844**), but negatively with days to rosette (r=-0.548**). Head weight had a significant positive relationship with seed number (r=0.923**), thousand seed weight (r=0.511**), root dry weight (r=0.903**), and stem dry weight (r=0.813**), but a significant negative relationship with days to rosette (r=-0.507**) and days to stem elongation (r=-0.327*). Similarly, there is a significant positive relationship between seed number and 1000 seed weight (r=0.354*), root dry weight (r=0.799**), and stem dry weight (r=0.692**), but a significant negative relationship with days to rosette (r=-0.371**).

Thousand seed weight showed a significant positive relationship with root dry weight (r=0.709**), and stem dry weight (r=0.733**); but it showed a significant negative relationship with days to rosette (r=-0.657**) and days to stem elongation (r=-0.419**). Days to emergence exhibited significant negative association with days to stem elongation (r=-0.529**), days to branching (r=-0.872**), days to flowering (r=-0.870**), days to maturity (r=-0.917**), and stem dry weight (r=-0.407**); but significant positive association with number of days to rosette (r=0.515**). Days to rosette recorded significant negative association with number of days to branching (r=-0.355**), number of days to flowering (r=-0.361*), number of days to maturity (r=-0.625**), root dry weight (r=-0.611**), and stem dry weight (r=-0.747**).

Days to stem elongation was correlated significantly positively with days to branching (r=0.726**), days to flowering (r=0.669**), and days to maturity (r=0.566**), but negatively with root dry weight (r=-0.367*), and stem dry weight (r=-0.327*). Days to branching correlated significantly with days to flowering (r=0.970**) and days to maturity (r=0.930**). Similarly, days to flowering and days to maturity had a significant positive correlation (r=0.928**). This implied that safflower plants with earlier stem elongation, branching, and flowering matured faster. Valli *et al*. (2016) [20] reported similar findings, indicating a significant positive correlation between days to flowering and days to maturity. Days to maturity had a significant positive relationship (r=0.376**) with stem dry weight, and root dry weight had a significant positive relationship (r=0.893**) with stem dry weight.

Seed yield which is considered such as an important economic trait in safflower plant due to its complex nature depending on yield components and environment exhibited significant positive correlation with plant height (r=0.704**), branch number (r=0.833**), head number (r=0.908**), head weight (r=0.916**), seed number (r=0.886**), thousand seed weight (r=0.485**), root dry weight (r=0.841**) and stem dry weight (r=0.783**).

This suggested that these characteristics could be used to select high-yielding safflower genotypes. Seed yield, on the other hand, had no significant correlation with days to emergence, days to branching, days to flowering, or days to maturity. Only the days to rosette (r=-0.413**) and the days to stem elongation (r=-0.313*) had a significant negative correlation with seed yield. Similarly, previous studies in safflower have found a strong positive relationship between seed yield and a variety of traits such as the number of heads per plant (Chaudhary, 1990; Tabrizi, 2000; Bagheri *et al*., 2001; Arslan, 2007; Beyyavas *et al*., 2011; Pavithra *et al*., 2016; Pattar and Patil, 2020) [6, 18, 2, 1, 4, 15, 14], thousand seed weight (Chaudhary, 1990; Bagheri *et al*., 2001; Beyyavas *et al*., 2011; Pattar and Patil, 2020) [6, 2, 4, 14], plant height (Chaudhary, 1990; Arslan, 2007; Pavithra *et al*., 2016) [6, 1, 15], number of seeds per plant (Bagheri *et al*., 2001) [2].

Our findings are consistent with those of Pattar and Patil (2020) [14], who discovered a non-significant relationship between seed yield and days to 50% flowering. Pavithra *et al*. (2016) [15], on the other hand, found that safflower seed yield was significantly negatively correlated with days to flowering and maturity.

Table 1: Correlation coefficient among agronomic traits of *Carthamus tinctorius*. L.

Traits	BN	HN	HW	SN	TSW	E	R	SE	B	F	M	RDW	SDW	SY
PH	0.661**	0.801**	0.766**	0.649**	0.838**	-0.244	-0.756**	-0.392**	-0.009	0.000	0.266	0.890**	0.927**	0.704**
BN		0.841**	0.844**	0.848**	0.374**	-0.157	-0.442**	-0.355*	-0.083	-0.054	0.128	0.751**	0.754**	0.833**
HN			0.950**	0.884**	0.581**	-0.273	-0.548**	-0.278	-0.001	0.006	0.233	0.898**	0.844**	0.908**
HW				0.923**	0.511**	-0.189	-0.507**	-0.327*	-0.070	-0.052	0.171	0.903**	0.813**	0.916**
SN					0.354*	-0.118	-0.371**	-0.269	-0.096	-0.084	0.101	0.799**	0.692**	0.886**
TSW						-0.185	-0.657**	-0.419**	-0.025	-0.030	0.182	0.709**	0.733**	0.485**
E							0.515**	-0.529**	-0.872**	-0.870**	-0.917**	-0.241	-0.407**	-0.205
R								0.172	-0.355*	-0.361*	-0.625**	-0.611**	-0.747**	-0.413**
SE									0.726**	0.669**	0.566**	-0.367*	-0.327*	-0.313*
B										0.970**	0.930**	-0.006	0.110	-0.022
F											0.928**	0.024	0.132	0.009
M												0.237	0.376**	0.180

RDW													0.893**	0.841**
SDW														0.783**

PH: Plant height, HN: Head number, HW: Head weight, SN: Seed number, TSW: Thousand seed weight, E: days to emergence, R: days to rosette, SE: days to stem elongation, B: days to branching, F: days to flowering, M: days to maturity, RDW: root dry weight, SDW: Stem dry weight, SY: Seed yield; * correlation coefficient significant at (P<0.05), ** correlation coefficient significant at (P<0.01)

Table 2: Estimates of path analysis direct (diagonal) and indirect (off diagonal) effect of different agronomic traits on seed yield

Traits	PH	BN	HN	HW	SN	TSW	E	R	SE	B	F	M	RDW	SDW	Correlation with seed yield
PH	-0.079	-0.005	0.322	0.235	0.188	0.122	-0.084	-0.507	0.151	0.001	0.000	0.247	-0.221	0.333	0.704**
BN	-0.052	-0.008	0.338	0.259	0.245	0.055	-0.054	-0.296	0.137	0.007	-0.001	0.119	-0.186	0.271	0.833**
HN	-0.063	-0.007	0.402	0.292	0.255	0.085	-0.094	-0.367	0.107	0.000	0.000	0.216	-0.223	0.303	0.908**
HW	-0.061	-0.007	0.382	0.307	0.267	0.075	-0.065	-0.340	0.126	0.006	-0.001	0.159	-0.224	0.292	0.916**
SN	-0.051	-0.007	0.355	0.283	0.289	0.052	-0.040	-0.249	0.104	0.008	-0.002	0.094	-0.198	0.248	0.886**
TSW	-0.066	-0.003	0.234	0.157	0.102	0.146	-0.063	-0.440	0.162	0.002	0.000	0.169	-0.175	0.263	0.485**
E	0.019	0.001	-0.110	-0.058	-0.034	-0.027	0.343	0.345	0.204	0.070	-0.022	-0.850	0.060	-0.146	-0.205
R	0.060	0.003	-0.220	-0.156	-0.107	-0.096	0.177	0.670	-0.066	0.028	-0.009	-0.579	0.152	-0.268	-0.413**
SE	0.031	0.003	-0.112	-0.100	-0.078	-0.061	-0.181	0.115	-0.386	-0.058	0.017	0.525	0.091	-0.117	-0.313*
B	0.001	0.001	-0.000	-0.021	-0.028	-0.004	-0.299	-0.238	-0.280	-0.080	0.024	0.862	0.001	0.039	-0.022
F	0.000	0.000	0.002	-0.016	-0.024	-0.004	-0.298	-0.242	-0.258	0.078	0.025	0.860	-0.006	0.047	0.009
M	-0.021	-0.001	0.094	0.052	0.029	0.027	-0.315	-0.419	-0.218	-0.074	0.023	0.927	-0.059	0.135	0.180
RDW	-0.070	-0.006	0.361	0.277	0.231	0.104	-0.083	-0.409	0.142	0.001	0.001	0.220	-0.248	0.321	0.841**
SDW	-0.073	-0.010	0.339	0.250	0.199	0.107	-0.140	-0.500	0.126	-0.009	0.003	0.349	-0.221	0.359	0.783**

PH: Plant height, HN: Head number, HW: Head weight, SN: Seed number, TSW: Thousand seed weight, E: days to emergence, R: days to rosette, SE: days to stem elongation, B: days to branching, F: days to flowering, M: days to maturity, RDW: root dry weight, SDW: Stem dry weight, SY: Seed yield. * correlation coefficient significant at (P<0.05), ** correlation coefficient significant at (P<0.01); Bold and diagonal values are the direct effects; Residual effect=0.270; R^2=0.927

Path coefficients

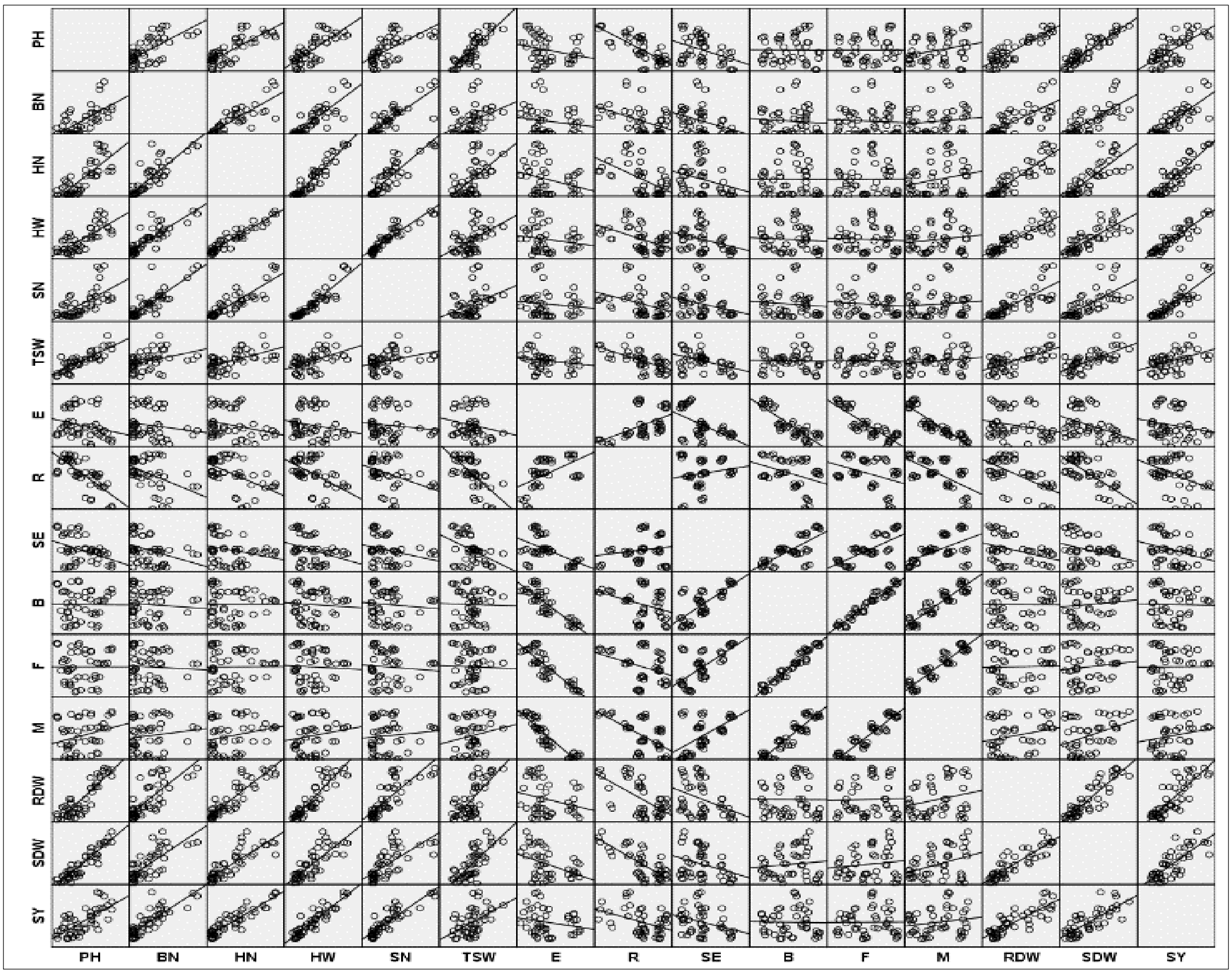
Path analysis is considered as one of statistical correlation method depending on regression and multi correlation and is used for putting probability relationship among variables. The main aim of finding path analysis is to know the direct and indirect effects of variables on the seed yield. The path coefficient analysis results revealed that the coefficient of determination (R^2) of path analysis was equal to 0.927, indicating that the variables used in this model explain 93 percent of the variation in seed yield.

As illustrated in Figure 2 and Table 2, the path coefficient was used to estimate the direct and indirect effects of the traits studied on seed yield (table 2; figure 2). Despite the fact that the significant association between yield contributing traits, the path analysis showed a non-significant values of some studied characters indicating that correlation studies is insiffucient for plant selection and breeding program.

Days to maturity (0.927), which had the greatest positive direct effect on seed yield, was followed by head number (0.402), stem dry weight (0.359), and head weight (0.343), which provides information about selection of these traits could be helpful in improving seed yield. On the other hand, days to rosette with negative and significant correlation had a positive direct effect (0.670) on seed yield indicating that the improvement of seed yield can be achieved through reducing the days to rosette.

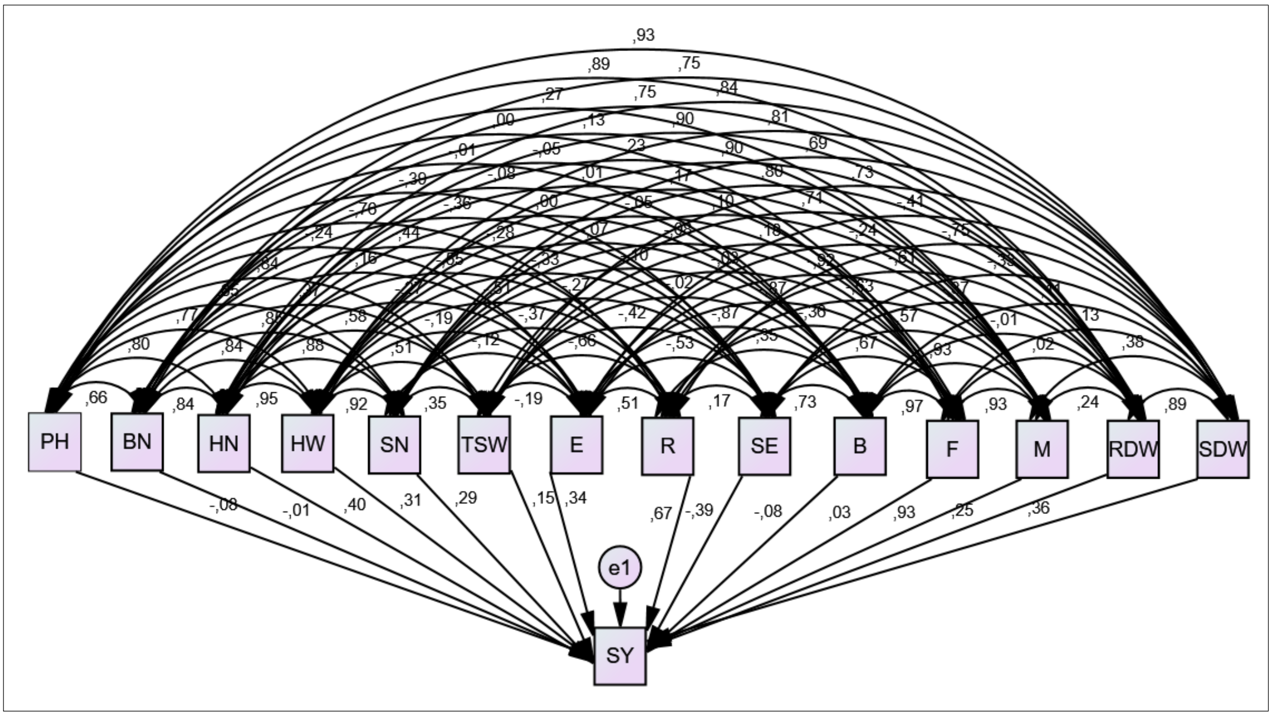
According to Sirel and Aytaç (2016) [17], safflower seed yield was determined by plant height, seed weight/head, and thousand seed weight, and according to Arslan (2007) [1], head diameter, head number, and seed number had a direct effect on safflower seed yield. Hussain *et al*. (2014) [11] stated that seed yield was directly affected by number of seeds per head followed by thousand seed weight and plant height. Valli *et al*. (2016) [20] indicated that thousand seed weight exhibited maximum direct effect followed by number of seeds per plant, days to flowering, number of head /plant, but days to maturity showed a negative direct effect on seed yield. Pattar and Patil (2020) [14] reported that the improvement of safflower seed yield will be efficient via selection for head number and 1000 seed weight.

Yield related characters not only directly affect seed yield, but also indirectly affecting other characters. Days to rosette, days to branching and days to flowering exhibited strong positive indirect effect via days to maturity (0.525, 0.862, 0.860 respectively) on seed yield (Table 2). Pattar and Patil (2020) [14] noticed that plant height, number of seeds per head contribute indirectly through number of heads per plant and 1000 seed weight on seed yield.



PH: Plant height, HN: Head number, HW: Head weight, SN: Seed number, TSW: Thousand seed weight, E: days to emergence, R: days to rosette, SE: days to stem elongation, B: days to branching, F: days to flowering, M: days to maturity, RDW: root dry weight, SDW: Stem dry weight, SY: Seed yield.

Fig 2: Graph of correlation of seed yield and some traits in *Carthamus tinctorius L.*



PH: Plant height, HN: Head number, HW: Head weight, SN: Seed number, TSW: Thousand seed weight, E: days to emergence, R: days to rosette, SE: days to stem elongation, B: days to branching, F: days to flowering, M: days to maturity, RDW: root dry weight, SDW: Stem dry weight, SY: Seed yield.

Fig 3: Schematic representation of the direct effects of some traits on the seed yield of *Carthamus tinctorius*. L.

Conclusıon

Our results showed that safflower seed yield was signficantly and positively correlated with head weight (0.916), head number (0.908), seed number (0.886), root dry weight (0.841), branch number (0.833), stem dry weight (0.783), plant height (0.704), and thousand seed weight (0.485). Days to maturity (0.927), days to rosette (0.670), head number (0.402), stem dry weight (0.359), and head weight (0.343) had the most important positive direct effect on seed yield. As a result, increasing safflower seed yield will be extremely efficient through selection for days to maturity, days to rosette, head number, stem dry weight, and head weight.

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