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#### Research Paper

### Assessment of *Carthamus tinctorius* L. Variation for Yield Performance and Trait Associations under Semi-arid Conditions

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#### Abstract

A set of 36 safflower accessions was evaluated for grain yield ((GY)), capitula per plant ((CP)), seeds per capitulum ((SC)), capitula per branch ((CB)), harvest index ((HI)), flowering completion height ((FCH)), and thousand grain weight ((TGW)) under field conditions across two years. The polygon-view of the accession-by-trait ((AT)) biplot model revealed significant genotypic variation among accessions, with distinct groups forming based on trait performance. In the first year, accession 13 (C-47) exhibited superior performance for GY, HI, and FCH, while accession 18 excelled in CP, CB, and SC. In the second year, similar trends were observed, with accession 13 maintaining its high GY, demonstrating low genotype-by-environment interaction across two years. The perfect accession plot confirmed these results, identifying accessions 13, 16, 23 (Saffire), and 29 (Lesaf-486) as optimal candidates for selection due to their proximity to the ideal trait coordinate. Trait analysis indicated that HI was the most influential determinant of yield performance across both years, followed by TGW in the second year. In contrast, CP and SC did not contribute to yield, suggesting that indirect selection should be approached cautiously, while the vector-length revealed that CB and CP were highly representative and stable across environments, making them reliable indicators. Finally, accession 13 (C-47) was identified as the best accession for yield performance, and could be released as a new cultivar for semi-arid regions.

**Keywords:** accession-by-trait interaction, harvest index, plant breeding, safflower

#### Introduction

Among old domesticated crops, safflower (*Carthamus tinctorius* L.) is identified as an important oilseed from the Compositae family. It is a self-pollinating plant, with a small percentage of cross-pollination, and there are numerous reports of the cross-pollination rate in different species. The seeds are rich in iron, phosphorus, calcium, and vitamin A, and it has been recognized for its drought tolerance and high oil quality, with the average oil content being about 25–35% (Tonguc et al., 2023). Also, the medicinal and industrial uses of safflower are prominent in Western Asia due to its origin, while it can be cultivated in all regions with a long cultivation background in the Middle East. Therefore, Iran, as the primary origin, has a rich germplasm reserve (Gholami et al., 2018). Investigating the genetic diversity in cultivated and wild species is one of the works conducted to identify the genetic capacity of traits related to the purposes of protecting genetic resources. Exploring genetic variation and management of genetic resources in various crops makes it possible to use them in different breeding programs. The destruction of native populations and the production of uniform cultivars result in a reduction in genetic diversity and an increase in genetic erosion. Therefore, it is vital to evaluate the diversity of plant species for the

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maintenance of genetic resources and the scientific and practical use of these materials (Pathirana & Carimi, 2022). Estimating the genetic diversity of lines in different geographical regions provides valuable information about the preservation and use of intact germplasm available in each region, allowing researchers to use this diversity to increase the efficiency of qualitative and quantitative traits and to increase yield. Safflower has a direct root system that can penetrate the soil up to a depth of one and a half meters and can withstand drought stress (Sabaghnia et al., 2024a). The stem of the plant has primary, secondary, and tertiary branches, each of which has a flowering end called a capitulum, which contains a very large number of flowers (Yılmaz et al., 2021). The color of the flower may be white, yellow, orange, or red, and it produces a fruit in the form of an achene containing oil.

The economic yield of safflower is determined by seed production and oil content, while high oil quality cultivars that have drought tolerance, early maturity, and adaptability to plantation regimes are low-yielding. The yield of safflower seeds in Iran is about 1.3 t ha<sup>-1</sup>, and its global average production is one ton per hectare, while the highest yield in Mexico is reported as two tons per hectare (FAOSTAT, 2022). The first step in safflower breeding is to have a population with high diversity so that an appropriate selection can be made from within it. The selection of desirable genotypes and the determination of relationships between traits are important issues that give breeders the ability to choose the most suitable ratio between components that leads to higher performance (Sabaghnia et al., 2023). The success of safflower cultivation will depend on breeding programs that lead to increased yield and oil content, which are controlled by additive, dominance, and epistatic effects. Some safflower researchers have tried to identify and use these traits by focusing on the agronomic, morphological, and phenological traits of safflower.

It has been proven that there is a direct or indirect relationship between many morphological traits and seed yield in safflower, so by adopting appropriate breeding methods, it is possible to increase the yield of safflower (Shahsavari et al., 2023). Gholami-Baseri et al. (2022) introduced some important traits, such as capitulum diameter, capitula per plant, and thousand seed weight, for a useful selection process for yield improvement efforts in safflower. Minnie et al. (2020), in the evaluation of genetic diversity among some safflower accessions, found a high positive correlation between seed yield and seeds per capitulum, as well as days to flowering and maturity. Rahimi (2021), in studying 30 safflower accessions under warm-arid conditions, found that evaluation of germplasm by morphological traits can provide useful information to breeders, and accessions with high seed yield had moderate days to flowering and maturity traits. Ebrahimi et al. (2023) evaluated 81 safflower accessions and reported a positive correlation of yield with seeds per main capitulum and identified three accessions as the most favorable ones regarding yield performance. The target of this investigation was to determine the amount of variability in the accessions in terms of some morphological traits under semi-arid upland climatic conditions for use in breeding programs, as well as identifying the interrelationships among morphological traits and grouping the accessions by the graphical accession-by-trait biplot method.

## Materials and Methods

In the current study, 36 safflower accessions from the gene banks of Canada and Iran were selected from different origins (Table 1). These genotypes were selected from 100 available accessions by cluster analysis. They were planted in a two-replicated lattice order over two years at the farm of the University of Maragheh (37°23'N, 46°14'E). Accessions were cultivated in four rows with 2 m length, with 0.25 m spacing, and 10 cm between individuals. The trials were irrigated one day after cultivation, followed by 10 days for the subsequent irrigation. NPK (60:30:20 kg ha<sup>-1</sup>) was applied. During crop growth, local management practices like weed and pest control were applied. The dataset was recorded for different morphological traits based on Sabaghnia et al. (2024b), from ten randomly selected plants of each plot, including branches per plant (BP), capitula per branch (CB), capitula per plant (CP), diameter of stem (DS), the first lateral branch height (HFL), the first capitulum height (HFC), and seeds per capitulum (SC). After the maturity stage, plants of the central rows of experimental units were harvested and weighed to determine biological yield and then used for determining grain yield (GY). However, the ratio of GY to biological weight was calculated as harvest index (HI) and the thousand grain weight (TGW), which was measured by three-time sampling. Dataset normality was assessed by the Shapiro–Wilk normality procedure, and for exploring the structure of accession-by-trait interaction as well as graphical presentation of outputs, the accession-by-trait interaction biplot method (Yan, 2024) was used. This method is based on principal component (PC) analysis and symmetrical scaling of obtained scores of accessions and traits via the following equation:

$$\frac{a_{ij} - \alpha_j}{D_j} = \sum_{n=1}^2 \lambda_n \theta_{in} \psi_{jn} + R_{ij}$$

where  $a_{ij}$  is the value of accession  $i$  for trait  $j$ ,  $\alpha_j$  is the average of accessions for trait  $j$ ,  $D_j$  is the square root of variance for trait  $j$ ,  $\lambda_n$  is the eigenvalue for  $PC_n$ ,  $\theta_{in}$  is the value for accession  $i$  on  $PC_n$ ,  $\psi_{jn}$  is the value for trait  $j$  on  $PC_n$ , and  $R_{ij}$  is the error term. Scaling = 1, Centering = 2, and Singular Value Decomposition (SVD) = 2 were employed. Also, SVD = 1 was performed to obtain the singular scores, which were categorized into the accession eigenvectors based on Yan (2024).

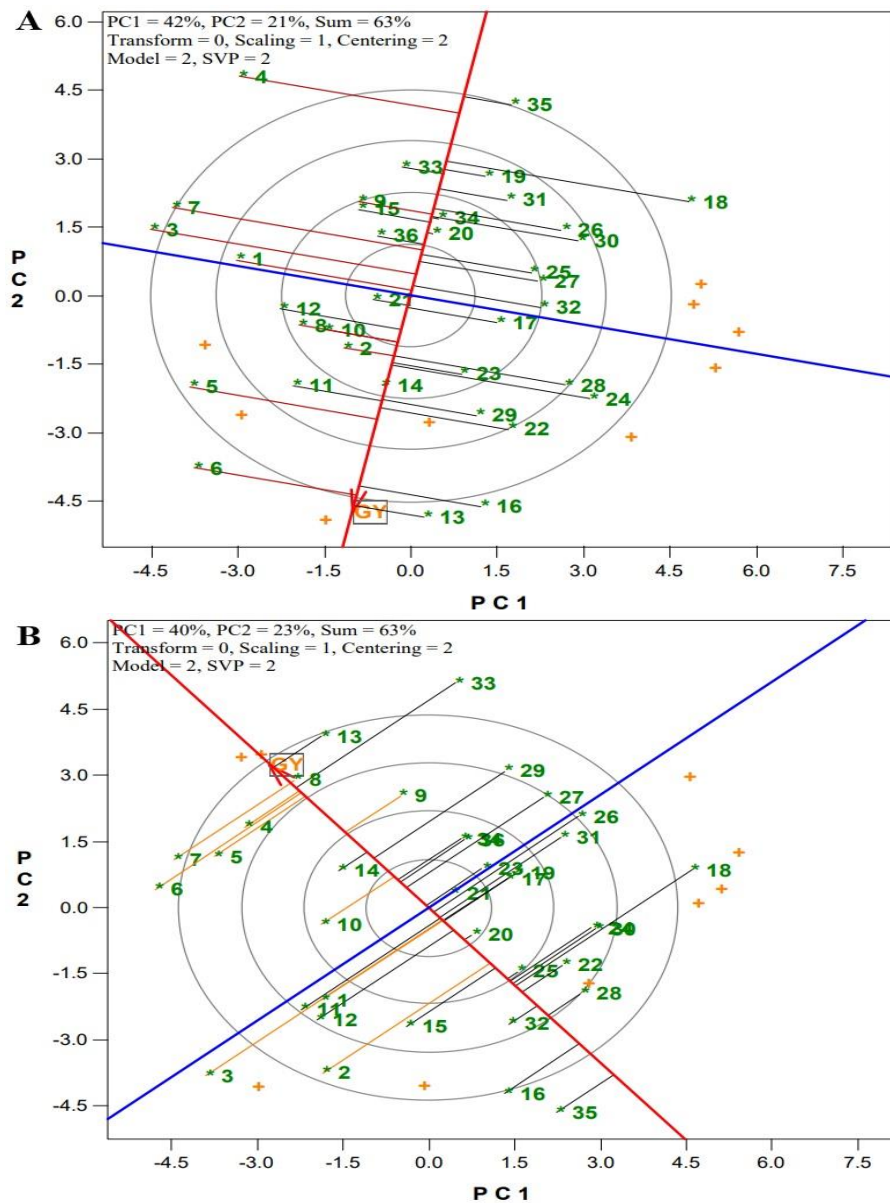


**Table 1.** The names and countries of origin of the 36 safflower accessions.

| #  | Name        | Country   | #  | Name        | Country |
|----|-------------|-----------|----|-------------|---------|
| 1  | IR-00101    | Unknown   | 19 | 307-S6-697  | Unknown |
| 2  | IR-00102    | Unknown   | 20 | Bhima       | Canada  |
| 3  | Zargan      | Iran      | 21 | 301055      | Turkey  |
| 4  | Dincer      | Turkey    | 22 | Kurdistan-3 | Iran    |
| 5  | IR-00103    | Unknown   | 23 | Saffire     | Canada  |
| 6  | C-111       | Iran      | 24 | CW-4440     | USA     |
| 7  | IR-00104    | Unknown   | 25 | N-6         | Canada  |
| 8  | Yimice      | Turkey    | 26 | Lesaf-493   | Canada  |
| 9  | PI-253384   | Palestine | 27 | Kurdistan-8 | Iran    |
| 10 | PI-537636-S | USA       | 28 | AC-Sterling | Canada  |
| 11 | Bregon      | Cyprus    | 29 | Lesaf-486   | Canada  |
| 12 | LRV-51-51   | Iran      | 30 | Lesaf-488   | Canada  |
| 13 | C-47        | unknown   | 31 | Lesaf-492   | Canada  |
| 14 | Marand      | Iran      | 32 | Lesaf-496   | Canada  |
| 15 | PI-537636-S | USA       | 33 | IR-00107    | Iran    |
| 16 | Isfahan-4   | Iran      | 34 | IR-00110    | Iran    |
| 17 | Hartman     | USA       | 35 | IR-00111    | Iran    |
| 18 | Lesaf-491   | Canada    | 36 | IR-00114    | Iran    |

## Results and Discussion

The applied accession-by-trait biplot model elucidated 63% of the dataset variation for both years (Figure 1), indicating a relatively complicated pattern of interactions among the safflower accessions and traits. The accession-by-trait biplot model can explore the overall pattern of accession-by-trait interaction effectively (Yan, 2024). ANOVA is a needed option for deciding how a variable has to be launched for the target statistical analysis or not, so the significance of the interactions emphasizes data analysis by the accession-by-trait biplot model, while non-significant interactions indicate that applying the accession-by-trait biplot model is not essential (Sabaghnia et al., 2024a). Results of ANOVA for safflower traits confirmed the launching of the AT-biplot due to the remarkable variability present among accessions and traits. Upon examining the grain yield (GY) across the accessions, it was evident that accessions 6, 13, and 16, followed by 5, 11, 14, 22, and 29, demonstrated high levels of yield performance in the first year (Figure 1A). However, regarding the low distance of accessions 13 and 14 from the vertical axis, their performance had low variability. Also, accessions 4 and 35 had the lowest grain yield in the first year. Testing of GY in the second year indicated that accessions 4, 5, 6, 7, 8, 13, and 33, followed by 9, 14, and 29, had high levels of performance, while accessions 16 and 35 had the lowest yield performance. However, regarding the results of both years, it can be concluded that accessions 6 (C-111 from Iran), 13 (C-47 from unknown origin), 14 (Marand from Iran), and 29 (Lesaf-486 from Canada) maintained their good potential across two years, so they are good candidates for further analysis in order to proceed with the cultivar release process. Two identified accessions (6 and 14) were from Iran, so it seems that these local landraces or cultigens had good adaptability to the climatic conditions of the semi-arid upland regions of Iran, showing low accession-by-environment interaction. Landraces were identified as an important resource of adaptability and resistance/tolerance to biotic/abiotic stresses (Broccanello et al., 2023), while breeders follow short-term targets, so they work on elite plant materials, which may not have proper adaptability (Snowdon et al., 2021). Thus, breeders did not have the desire to test exotic plant materials due to the loss of adaptability genes. In contrast, landraces or cultigens have enough adaptability potential, and using them in breeding programs is desirable.



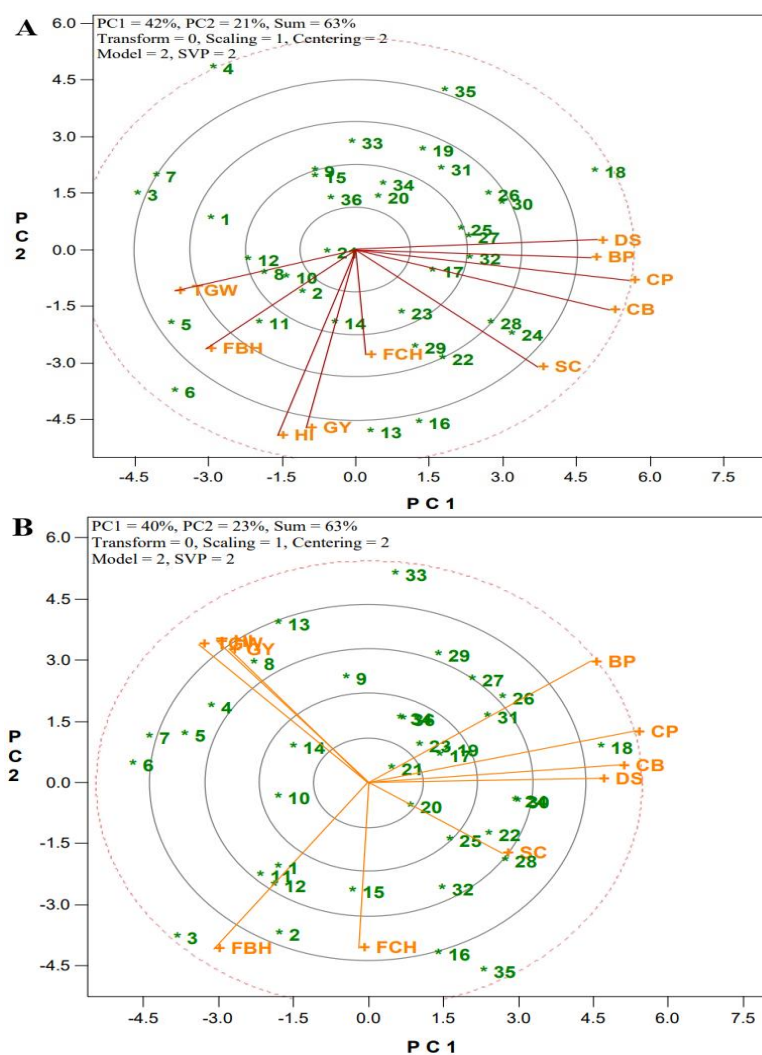
**Figure 1.** Testing grain yield (GY) performance using the accession-by-trait (AT) interaction biplot model for the first year (A) and the octagon view for the second year (B).

To explore the basic structures among traits visually, some vectors are created from the origin to the traits, facilitating the presentation of associations, provided that the fitted model covers an acceptable amount of variation. The most prominent associations of the first year unveiled include: (i) positive associations between grain yield (GY) and harvest index (HI); and among branches per plant (BP), capitula per branch (CB), capitula per plant (CP), and diameter of stem (DS), as depicted by acute angles with cosine equal to unity (Figure 2A). Also, regarding the obtuse angle with cosine equal to minus unity for thousand grain weight (TGW) with BP, CB, CP, and DS, it had a negative relation with the mentioned traits in the first year (Figure 2A). Additionally, relatively near-zero associations (with cosine equal to zero) were observed between GY and HI with BP, CB, CP, and DS, as evidenced by the near-perpendicular vectors in the first year (Figure 2A). Thus, the AT-biplot model visually delineated trait associations in safflower, aligning with findings from other researchers, such as Koç (2021), who reported a positive association between seed yield and harvest index of safflower.

In the second year (Figure 2B), positive associations among grain yield with TGW and HI, and among CB, CP, and DS were identified, as shown by acute angles. Considering the obtuse angle of BP with the first branch height (FBH), as well as the obtuse angle of seeds per capitulum (SC) with GY, TGW, and HI, it had a negative association with the mentioned traits in the second year (Figure 2B). Also, relatively near-zero correlations were seen between FBH and SC; between BP and SC; and between BP with TGW, GY,



and HI, as evidenced by the near-perpendicular vectors in the second year (Figure 2B). Similarly, Fattahi et al. (2023) noted high positive associations between capitula per branch and seeds per capitulum. A near-zero correlation between TGW and capitula per plant, between grain yield and TGW, and between the number of capitula per plant and grain yield has been reported in safflower (Sabaghnia et al., 2024b). In contrast, capitula per plant and TGW are the main characteristics of safflower due to their relation with yield performance, as indicated (Sadighfard et al., 2022), while such positive relationships have not been identified in this study across both years. Most of the associations can be confirmed from the correlations across both years, while exact parallels should not be expected because the AT-biplot explicates associations among traits based on the structure of the data, whereas correlations elucidate the association between two traits.

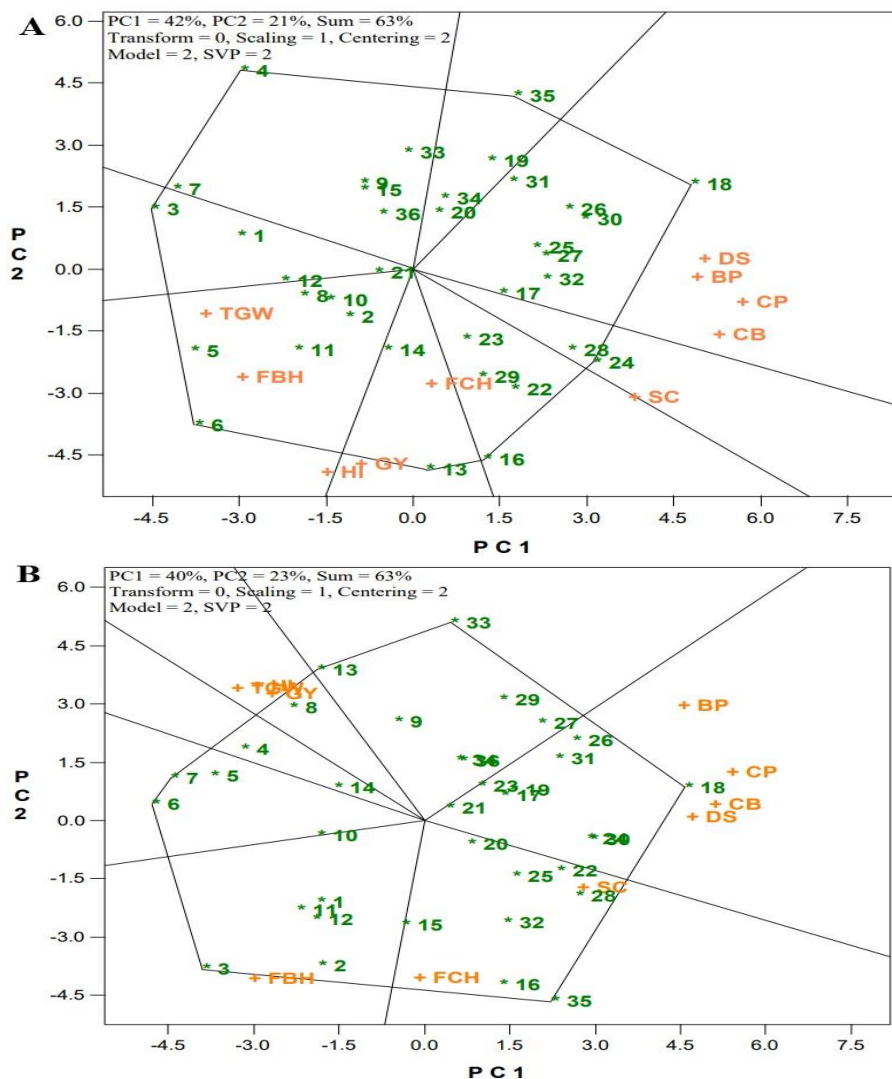


**Figure 2.** The arrow-view of the accession-by-trait (AT) interaction biplot model for the first year (A) and the octagon view for the second year (B). Traits are: branches per plant (BP), capitula per branch (CB), capitula per plant (CP), diameter of stem (DS), first lateral branch height (HFL), first capitulum height (HFC), seeds per capitulum (SC), grain yield (GY), harvest index (HI), and thousand grain weight (TGW).

The polygon-view tool demonstrates how the AT-biplot model can facilitate the comparison of accessions based on the traits and identify those accessions that excel in specific aspects (Yan, 2024), thus serving as candidates for future works like use in the breeding process or recommendation as the best cultivars to safflower producers. An octagon shape was constructed in the first year, with perpendicular lines to the nonagon sides aiding in the comparison among vertex accessions 3, 4, 6, 13, 16, 18, 24, and 35 (Figure 1A). Accession 6 exhibited superior performance for FBH and TGW; accession 13 showed the best performance for GY, HI, and FCH; accession 18 indicated the best performance for DS, BP, CP, and CB; and accession 24 exhibited superior performance for SC in the first year (Figure 1A). Although the AT-biplot model may not precisely depict the averages of traits for accessions, as it does not encompass all variance of the dataset, it provides overall insights into the underlying properties of the data structure (Güngör et al., 2024). The four remaining vertex accessions (3, 4, 16, and 35) did not perform optimally for any of the measured traits because the octagon of the AT-biplot model delineated these sections in the first year (Figure 3A). The main components of safflower performance, such as capitula per plant, seeds per capitulum, and thousand seed weight, had negative relations, so the indirect selection of yield components is suggested

(Pasban-Eslam et al., 2024). Thus, yield components of safflower would influence independently, and attempts to increase one component would decrease the other components. Moreover, under stress conditions, shortening the safflower life cycle reduces the yield component (sink), which leads to reduced seed yield (Yilmaz et al., 2021).

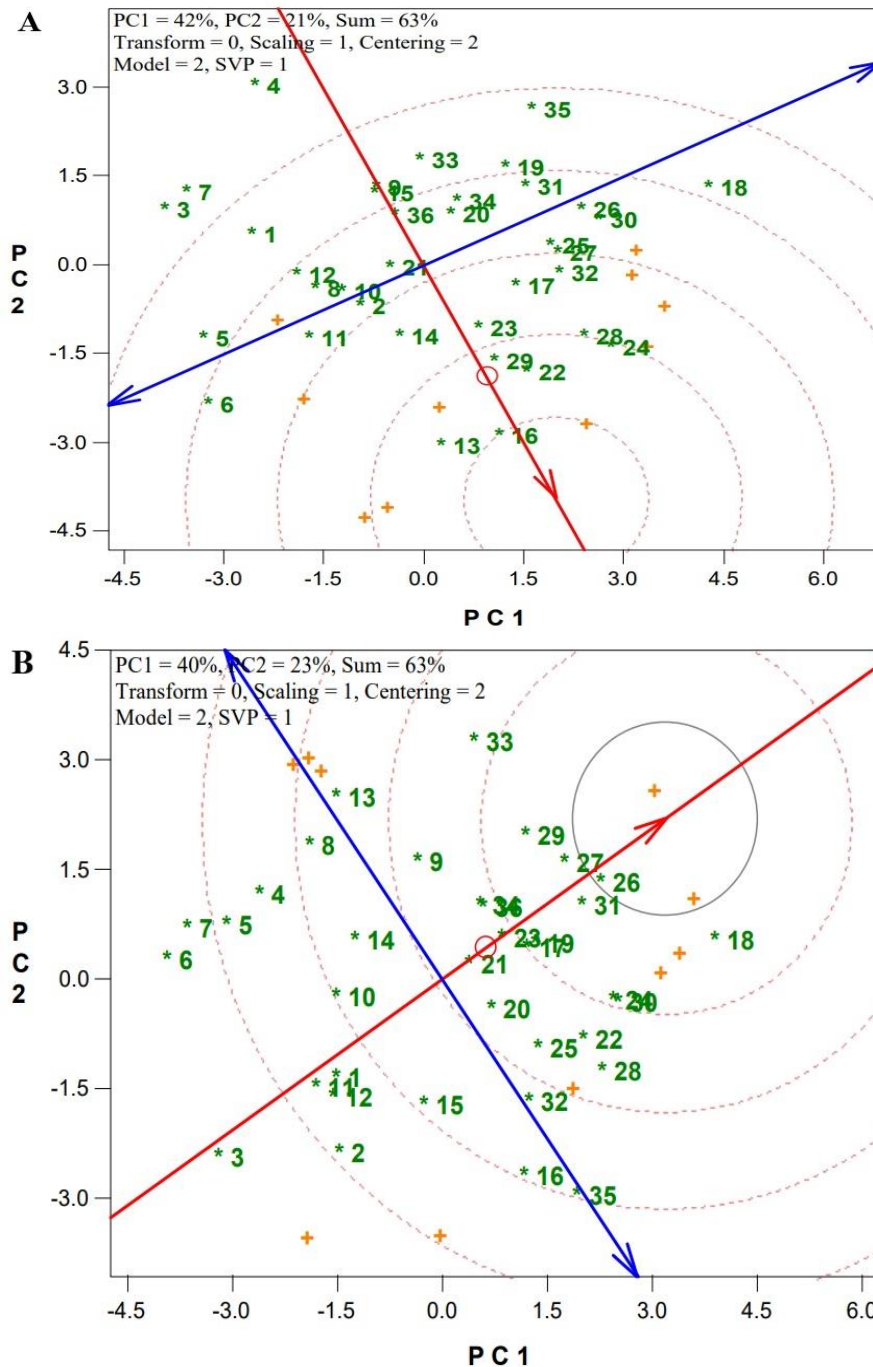
The polygon-view of the AT-biplot model indicated an octagon shape for the second year (Figure 3B), with 3, 6, 7, 13, 18, 33, and 35 as the vertex accessions. In the second year, accession 3 had the highest amounts of FBH; accession 13 exhibited high performance for GY, HI, and TGW; accession 18 showed the best performance for BP, CP, CB, and DS; and accession 35 indicated the best performance for FCH and SC (Figure 1B). However, in the second year, three vertex accessions (6, 7, and 33) were situated in unfavorable sectors or undesirable positions within favorable sectors (Figure 1B), rendering them unsuitable candidates for recommendation for any measured traits of safflower. Regarding the results of both years, it is obvious that two vertex accessions (13 and 18) were common with relatively similar traits, so these accessions had relatively low genotype-by-environment (GE) interaction, and their responses to yearly variations were relatively constant. According to the AT-biplot model, if it adequately estimates the variation in the dataset, accessions falling on the same side of the perpendicular line as any target trait (like grain yield) should perform above the mean, whereas those on the opposite side should perform below the mean. Thus, regarding both years, accession 13 (C-47 from unknown origin) had higher grain yield than the other safflower accessions, with little or no GE interaction effects. Sabaghnia et al. (2025) fitted a genotype-by-trait biplot model on 100 safflower genotypes with 60% and 66% explanations and identified several vertex genotypes, while the important sections of traits were similar to the current research, with grain yield, thousand grain weight, capitula per plant, and seeds per capitulum placed in distinct sections.



**Figure 3.** Polygon view for the first year (A) and octagon view for the second year (B) based on the accession-by-trait (AT) interaction biplot model. Traits are: branches per plant (BP), capitula per branch (CB), capitula per plant (CP), diameter of stem (DS), first lateral branch height (HFL), first capitulum height (HFC), seeds per capitulum (SC), grain yield (GY), harvest index (HI), and thousand grain weight (TGW).

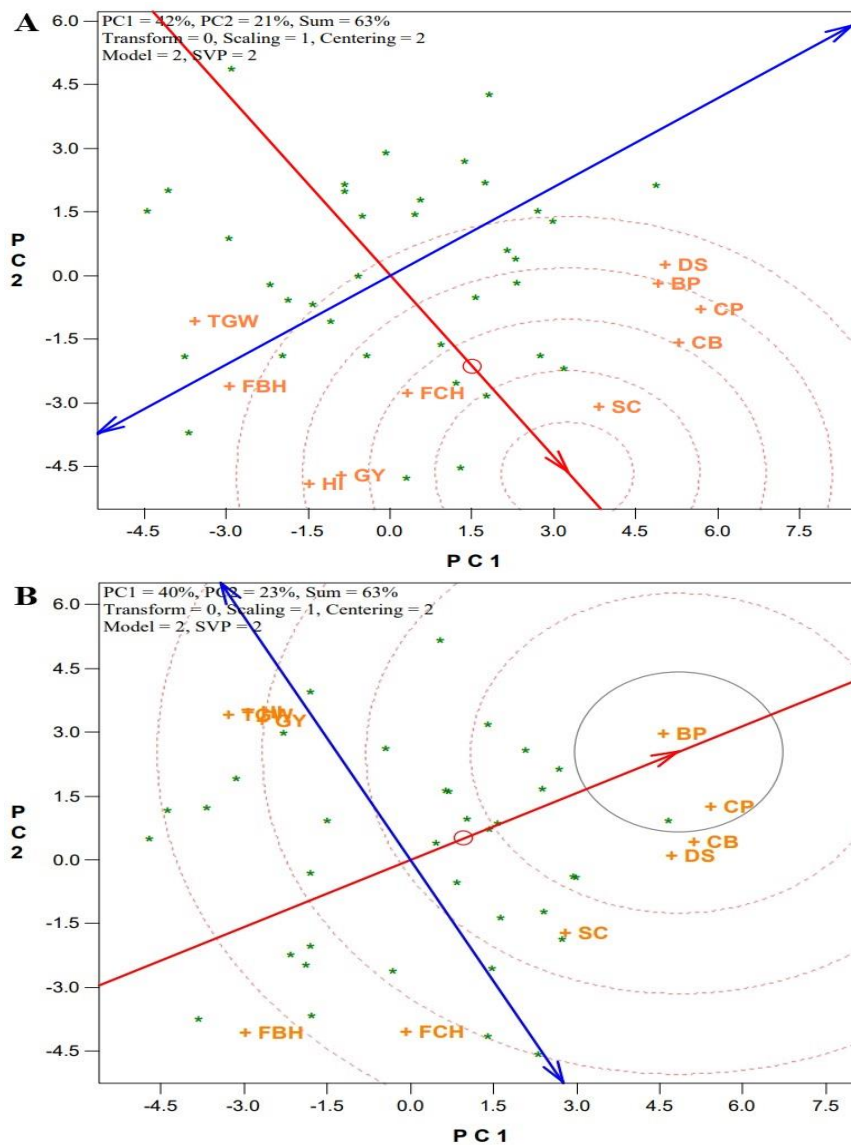


In Figure 4A, the center of the circles denotes the location of a perfect accession, with its projection on the vertical axis of the mean trait coordinate set to be equivalent to the largest vector among all accessions, while its projection on the horizontal axis of the mean trait coordinate is zero, indicating low variability and higher reliability. Thus, the closer an accession's interval is to this hypothetical accession, the more optimal the accession, so accession 13 and 16, followed by accessions 22, 23, 24, 28, and 29, were closest to the position of the perfect accession in the first year. The worst accessions were the farthest from the center circles, so accessions 3, 4, and 7 were not suitable and were not capable of discriminating the differences among the measured traits of safflower in the first year (Figure 4A). The perfect accession in the second year (Figure 4B) confirmed the results of the first year and determined accessions 26 and 27, followed by 17, 18, 19, 23, 29, and 31, as the best accessions. In contrast, accessions 3, 6, and 7 were identified as the unfavorable accessions in the second year. Comparison results of the two years indicated that accessions 23 (Saffire) and 29 (Lesaf-486) from Canada were repeated across both years.



**Figure 4.** The perfect accession view of the accession-by-trait (AT) interaction biplot model for the first year (A) and the octagon view for the second year (B).

Figure 5A illustrates the representative and discrimination potential of the traits, with vector length serving as a scale of discrimination potential, where a longer vector indicates a greater potential for discriminating a trait. Additionally, the stretch of a trait's projection onto the mean trait coordinate signifies its representative potential, with a shorter distance indicating a higher potential for the representation of a trait. Notably, SC, followed by FCH and CB, exhibited the highest potential for both representative and discrimination capabilities, positioned at the perfect trait location in the first year (Figure 5A). Following these traits, traits such as CP and GY also demonstrated strong representative and discrimination potentials. In the second year, BP and CP, followed by CB and DS, showed the highest ability for representative and discrimination properties (Figure 5B). Across both years, traits CB and CP indicated their good ability, ignoring accession-by-environment interaction, so screening safflower accessions based on these two traits results in reliable outputs. The number of capitula per branch and plant are less affected by environmental conditions (Sajid et al., 2024), so it is recommended to use this component in the genetic improvement of grain yield. Also, controlled selection could be applied in the breeding process, which influences yield performance via capitulum number while maintaining the other yield components without any changes (Sabaghnia et al., 2024b). Thus, accessions with a high number of capitula, having more seeds, are more ideal, especially in semi-arid regions, as capitula per plant is more influenced by the environment (Licata et al., 2023).



**Figure 5.** The perfect trait view of the accession-by-trait (AT) interaction biplot model for the first year (A) and the octagon view for the second year (B). Traits are: branches per plant (BP), capitula per branch (CB), capitula per plant (CP), diameter of stem (DS), first lateral branch height (HFL), first capitulum height (HFC), seeds per capitulum (SC), grain yield (GY), harvest index (HI), and thousand grain weight (TGW).



In the current investigation, a significant correlation between yield performance and harvest index was found, which is in accordance with the research of Ebrahimi et al. (2023), who found that utilization of arrow-view, perfect accession, and trait biplots indicated that the selection of the most favorable accessions for yield performance will be done by harvest index. Also, the variation of height properties, like the capitulum, found in this investigation was supported by the reports of Rahimi (2021), shorter plant height, as well as higher lateral branches and capitulum in safflower accessions, are suitable for mechanical harvest operation. Although, according to Sadighfard et al. (2022), higher yield of safflower is related to the components of yield (capitula per plant, seeds per capitulum, and thousand grain weight), no significant association was found between them and seed yield except for thousand grain weight. However, for genetic improvement of yield, it is logical to emphasize seeds per capitulum instead of capitula per plant or thousand grain weight (Baljani et al., 2015; Sajid et al., 2024). Also, accession 13 was identified as the best accession for yield performance, while accession 18 was detected as the best accession for some yield components, namely capitula per branch and capitula per plant. Thus, they can be used as breeding materials in genetic improvement programs, while capitula per branch and capitula per plant can be utilized for the exploration of reliable accessions due to their representative potential. The best safflower accessions need to be selected according to indices to ensure their performance, and the AT-biplot is a good model for visual data analysis (Ebrahimi et al., 2023). This visual model provides breeders with the facility to grasp the data structure, and it is interpretative and easy for grouping accessions and traits.

The present study employed the AT-biplot model to analyze the interaction between safflower accessions and agronomic traits over two years, revealing key patterns in yield performance and trait associations. The biplot analysis elucidated 63% of the dataset variation, highlighting a moderately complex interaction among accessions and traits. This substantial proportion of explained variance underscores the efficacy of the AT-biplot model in visually interpreting genotype-by-trait relationships and providing insights into trait selection for safflower breeding programs (Sabaghnia et al., 2024c). One of the primary findings of this study was the identification of stable, high-yielding accessions across both years. Accessions 6 (C-111, Iran), 13 (C-47, unknown origin), 14 (Marand, Iran), and 29 (Lesaf-486, Canada) demonstrated consistent performance across environmental conditions, making them promising candidates for cultivar development. Notably, accessions 6 and 14, which originated from Iran, exhibited strong adaptability to semi-arid upland environments, reinforcing the significance of local landraces in breeding programs. Landraces have been widely recognized for their genetic diversity and resilience to biotic and abiotic stresses, making them valuable resources for improving crop adaptability and yield stability (Janmohammadi et al., 2016; Adhikari et al., 2022). Trait associations revealed through the AT-biplot model were largely consistent with previous reports (Ebrahimi et al., 2023). Grain yield displayed a strong positive correlation with harvest index in both years, confirming the importance of HI as a key determinant of safflower yield potential. Additionally, in the first year, capitula per branch and capitula per plant were positively correlated, suggesting their collective contribution to safflower productivity. However, thousand grain weight exhibited an inverse relationship with these traits, indicating potential trade-offs in yield component selection. In the second year, positive associations were detected among GY, TGW, and HI, emphasizing the role of seed weight in determining yield under varying environmental conditions. These results align with findings from previous studies that identified capitula per plant and seeds per capitulum as critical yield components in safflower breeding programs (Ebrahimi et al., 2023; Sabaghnia et al., 2024c).

The polygon-view of the AT-biplot model effectively visualized the performance of accessions for specific traits, demonstrating that accession 13 consistently excelled in grain yield and HI across both years. Similarly, accession 18 performed well in key yield components such as capitula per branch and capitula per plant, reinforcing its potential as a genetic resource for breeding high-yielding safflower cultivars. The perfect accession analysis further confirmed the superior performance of accessions 13 and 16 in the first year and accessions 26 and 27 in the second year, while accessions 23 (Saffire, Canada) and 29 (Lesaf-486, Canada) were identified as consistently favorable across both years. Conversely, accessions 3, 4, and 7 were consistently classified as unfavorable due to their poor trait performance. The ability of the AT-biplot model to integrate multiple trait relationships into a visual framework provides safflower breeders with an efficient tool for identifying promising accessions and selecting traits that contribute to yield improvement (Koç, 2021). The observed lack of significant associations between yield components such as capitula per plant and seeds per capitulum suggests that direct selection for these traits may not significantly enhance overall yield. Instead, targeted selection for HI and TGW, coupled with indirect selection for capitula per branch and capitula per plant, may provide a more effective breeding strategy.

## Conclusions

The obtained results from the current investigation could be beneficial for safflower breeders concerning yield increment. The trait identified as influencing yield performance was harvest index across two years, followed by thousand grain weight in the second year, while the other components of yield, like capitula per plant and seeds per capitulum, did not indicate significant influence. Also, accession 13 (C-47) was identified as the best accession for yield performance, which can be regarded for cultivar release in semi-arid regions.

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