

Comparative assessment of yield, oil content and fatty acid composition of spiny and non-spiny safflowers

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Abstract – Safflower (*Carthamus tinctorius* L.) is one of the edible oilseeds crops which is neglected due to its spiny nature that poses difficulties in field operations; however, this problem can be sorted out by introducing non-spiny safflower cultivars. Hence, a 2-year study (2020–2021 and 2021–2022) was planned to assess the production potential of spiny (5 accessions) and non-spiny (5 accessions) safflower germplasm and an experiment was laid out using randomized completed block design (RCBD) under semiarid conditions of Faisalabad (Pakistan). Agronomic and oil traits were targeted during study. In 2021, non-spiny safflower accession PI-198990 gave the highest seed yield and oil percentage as compared to spiny safflower. However, the highest linoleic concentration was noted in spiny PI-199829 accession whereas the greatest oleic acid percentage was determined in non-spiny PI-235660 accession. Principal component analysis unveiled two components accounting for 39.5% and 25.7% of total variation. Biplot graph indicated that seed oil content, seed yield and 1000-seed weight had the highest correlation in the 2nd group while in the 3rd group plant height, days to maturity and oleic acid were correlated. These targeted characters can be considered as suitable index for selection of safflower elite accessions for semi-arid conditions. In general, non-spiny safflower accession responded 19%, 4.3%, 10.7%, 21.6%, 6.2% and 77.9% greater in plant height, number of branches, number of heads (capitula), 1000-seed weight, seed yield and oleic acid respectively. From the data of this 2-year studies, we concluded that spiny safflower accessions exhibited 1.2% and 16.3% more oil and linoleic acid content respectively.

Keywords: Safflower / oil / fatty acid / traits / spiny nature

Résumé – Le carthame (*Carthamus tinctorius* L.) est une des cultures oléagineuses comestibles qui est négligée en raison de sa nature épineuse qui pose des difficultés durant les opérations agronomiques. Cependant, ce problème peut être résolu en introduisant des cultivars de carthame non épineux. Aussi, une étude sur deux ans (2020–2021 et 2021–2022) a été mise en place pour évaluer le potentiel de production du germoplasme carthame épineux (5 accessions) et non épineux (5 accessions). L'expérience a été menée dans les conditions semi-arides de Faisalabad (Pakistan) avec un design en *blocs randomisés complets* (RCBD). Des caractéristiques agronomiques et oléagineuses ont été ciblées au cours de l'étude. En 2021, l'accension PI-198990 de carthame non épineux a offert le plus haut rendement en graines et le meilleur taux d'huile par rapport au carthame épineux. Toutefois, la concentration en acide linoléique la plus élevée a été observée chez le carthame épineux PI-199829, tandis que le pourcentage d'acide oléique le plus élevé a été obtenu avec l'accension PI-235660 non épineuse. L'analyse en composantes principales a révélé deux composantes représentant 39,5 % et 25,7 % de la variation totale. Le graphique biplot indique que la teneur en huile des graines, le rendement en graines et le poids de 1000 grains présentent la corrélation la plus élevée dans le deuxième groupe, tandis que dans le troisième groupe, la hauteur des plantes, le nombre de jours à maturité et l'acide oléique sont corrélés. Ces caractères ciblés peuvent être considérés comme des indicateurs appropriés pour la sélection d'accensions élites de carthame pour les conditions semi-arides. Globalement, les accessions de carthame non épineux ont permis d'obtenir des résultats supérieurs de 19 %, 4,3 %, 10,7 %, 21,6 %, 6,2 % et 77,9 % pour la hauteur des plantes, le nombre de branches, le nombre de capitules, le poids de 1000 grains, le rendement en graines et l'acide oléique, respectivement. Les données de cette étude sur

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deux ans nous ont permis de conclure que les accessions de carthame épineux présentaient des teneurs en huile et en acide linoléique respectivement supérieures de 1,2 % et de 16,3 %.

Mots-clés : Carthame / Huile / Acide gras / Comparaison / Caractère épineux

Highlights

- This manuscript highlights the comparison of spiny and non-spiny safflowers yield, oil and fatty acids (Oleic acid linoleic acid).
- Studied safflower accessions were selected from screening trial and further tested across the years for consolidation of both years findings.
- Trial was executed under Faisalabad conditions using RCBD design with three replications.
- Abovementioned attributes were collected and this concluded that the non-spiny safflower accessions were identified for considerable yield and recommended to farmer community for ease cultural practices due to absence of spines on leaf.

1 Introduction

Safflower (*Carthamus tinctorius* L.) is an important but underutilized oilseed crop belonging to the *Asteraceae* family which is most commonly grown for nutritious edible oil extraction, dyes, and pharmaceuticals products (Nosheen *et al.*, 2018). Species being drought and salt tolerant have been found suitable for dry and salty environments where other oilseeds fail to survive (Culha and Cakırlar, 2011; Hussain *et al.*, 2016). Its deeper root system favors the capture of nutrients below the rootzone which are often left untouched by other crops (Sarto *et al.*, 2018). Oil concentration in safflower seeds ranges from 35 to 50%, having 90% of unsaturated fatty acids that proves it as excellent oil for dietary consumption (Tahmasebpour *et al.*, 2011; Kiprovski *et al.*, 2021).

Safflower germplasm has been characterized morphologically and the variability for traits such as seed size, oil content and fatty acid composition has been done. Germplasm resources of the safflower may also be characterized on the basis of spine character as it belongs to genus *Carthamus* (Wu *et al.*, 2021) which is characterized by intense spines on leaves of the plants. Although spiny trait may induce some tolerance against stress condition, yet farm labor often faces difficulties in handling and management of this crop species. Contrastingly, non-spiny accessions may provide an ease in the crop management practices such as overpopulation thinning, hoeing and harvesting.

Furthermore, studies reported higher petal yields from non-spiny than spiny safflower cultivars (Padmavathi and Yadav, 2020). Selection of non-spiny cultivars is found more profitable as they are not only grown for oil used for multiple benefits, but their petals are also economically beneficial for the growers as they can be used in making tea, coloring food

and textile and as health and cosmetic products. Non-spiny safflower has more fodder nutritional value when harvested during vegetative phase (prior to flowering) as compared to spiny safflower (Ochoa-Espinoza *et al.*, 2022). It is well understood that the safflower of spiny nature has better oil quality and content than that of non-spiny one (Yassein *et al.*, 2020). However, growing such spiny safflower is tedious in terms of agronomic practices such as weeding and harvesting of the crop which consequently induces annoyance in the handling farm labor in such operations leading to less acceptability at producer and business level due to increased labor costs and displeasure.

On the basis of these findings, a two-year study was formulated to compare non-spiny safflower accessions with the spiny ones for seed yield, oil content, and oil quality. The objective was to determine their suitability of accession for crop production.

2 Materials and methods

2.1 Trial execution

This investigation was set up at the Agronomic Research Farm of the University of Agriculture in Faisalabad (UAF), Pakistan to emphasize the yield, oil content and oil quality of spiny and non-spiny safflower accessions. Experiment was sown on 4th November of 2020–2021 and 7th November, 2021–2022. Safflower accessions were imported from United States Department of Agriculture (USDA). Research trial was accomplished using factorial designed comprising two factors *i.e.* spiny nature and safflower accessions and replicated thrice. Five accessions each of spiny and non-spiny nature were grown on microplots (6 m × 2.7 m) under semi-arid conditions of Faisalabad.

2.2 Selection criteria of safflower accessions

The selection of spiny and non-spiny safflower accessions was based on spine intensity seed yield, oil content and fatty acids composition. Therefore, a screening trial of 145 safflower accessions was executed and promising 5 spiny and non-spiny accessions were selected with respect to aforementioned studied traits. However, selected safflower accessions were grown over a period of two years to consolidate the results. Therefore, comparing spiny and non-spiny accessions allows for a thorough investigation into the potential differences in these traits. Secondly, the inclusion of both spiny and non-spiny accessions enables us to assess the impact of spine presence on safflower performance across different environments and over multiple years. By examining the yield, oil content, and fatty acid composition of both types of accessions, we aimed to provide insights into the potential agronomic advantages or disadvantages associated with spine presence in safflower cultivation.

Table 1. Soil attributes.

Soil variables	unit	2020–2021	2021–2022
Sample depth	cm	0–20	0–20
Nature of soil	–	Sandy Loam	Sandy Loam
Soil moisture at saturation	%	34.5	34.3
EC	dS m ⁻¹	1.99 ± 0.8	1.98 ± 0.7
pH	–	7.9 ± 0.1	7.8 ± 0.1
Organic matter	%	1.0	0.99
Nitrogen	µg g ⁻¹	295 ± 18	290 ± 19
Phosphorus	µg g ⁻¹	6.89 ± 0.25	6.61 ± 0.24
Potassium	µg g ⁻¹	234 ± 18	2229 ± 21

2.3 Crop husbandry

Sowing was completed on ridges having 20 cm and 45 cm plant to plant and row to row distances respectively using hand drill. Pre-emergence herbicide Dualgold 960 EC (S-Metolachlor 800ml/acre) after 8 hours of planting. A total 120 kg ha⁻¹ urea (46% N) fertilizer was applied in two splits. Half dose was applied at the time of sowing and left over was fertigated with first irrigation (40 days after sowing) whereas 120 kg ha⁻¹ diammonium phosphate (DAP) was used at the time of plantation. Soil and weather-related variables were observed with the help of Soil and Water testing Laboratory, Ayub Agriculture Research Institute of Faisalabad (AARI) and Agro-meteorological Cell of the University of Agriculture of Faisalabad respectively (Tab. 1 and Fig. 1).

2.4 Data collection

Data regarding agronomic, oil and oil quality attributes were targeted using standard procedure. At the time of head (or capitulum) initiation, selected safflower plants were swathed using polythene net to avert insect contamination in case of pollination. Safflower sampled plants were harvested and manually threshed to collect seeds and exposed to sunlight to maintain desired level of seed moisture content. 10-gram dried safflower seed was taken for determination of oil content, cleaned from inert matter and crushed with the help of an electric grinder. The ground sample was loaded on Soxhlet apparatus using n-hexane as solvent for overnight until the further oil was not recovered and dried in oven at 40 °C and weight reduction was measured on weighing balance then seed oil concentration was calculated (Velioglu *et al.*, 2017).

For fatty acids (oleic and linoleic acids) analysis, 1.5 g of safflower seed oil was placed in Eppendorf tubes by taking 50 µL of the oil added with methylated spirit using 4 mL KOH at room temperature for a period of 60 min. Processed fatty acids were determined using a Gas Chromatograph Varian 3900 (USA) at the Nuclear Institute of Agriculture and Biology (NIAB). Identification of fatty acids was done using nitrogen as gas carrier by deploying fused capillary column of FID (flame ionized detector) at 3.5 mL min⁻¹. The injector and detector were sustained at 260 °C whereas, column oven was set at 222 °C. Methylated esterified fatty acid was manually infused and the fatty acid was verified by contrasting peak

retention time to standards. The study data were analyzed using OriginPro 2024 software and mean comparison was drawn using group indexed columns index techniques as well as Principal Component Analysis (PCA) and heatmap dendrogram (hierarchical cluster) analysis. Statistically, data were analyzed using Fisher's analysis of variance techniques and means were compared using the Least Significant Difference test (LSD) at 5% level of probability.

3 Results

Statistical analysis reflected significant (** $P \leq 0.01$; * $P \leq 0.01$) variation of all targeted safflower traits along with mean sum of squares in 2020–2021 and 2021–2022 (Tab. 2).

3.1 Phenology and plant height

Mean comparison of interaction response of safflower traits is presented in graphi graphical form and showed that there was significant ($P < 0.05$) difference among the accessions for days to flowering. Generally non-spiny safflower accessions were about 2% and 1.2% later for flowering than spiny accessions during 2-year trials. Nonspiny (NS) safflower accession PI-253392 took the highest days for flowering and the least number of days to flowering was recorded in PI-198990 during 2020–2021. Alternatively, spiny safflower accession “PI-250187” was late maturing and accession PI-199873 was a short duration accession in both years (Fig. 2). Statistically, the maximum days were consumed for maturity in accessions PI-253392 as compared to other non-spiny safflower accessions in 2020–2021. In contrast to spiny safflower accessions, the highest days were taken by accession PI-250187 and identical effect was assessed during 2021–2022. However, overall maturity time was 1.7% more in non-spiny accessions as compared to spiny ones during both growing seasons. Plant height was significantly affected by comparing spiny and non-spiny safflower and the tallest plants were identified in accession PI-314650 (NS) and the shortest plants were observed from accession PI-235660 (NS) in 2020–2021. Conversely for spiny safflower, accession PI-250342 led for plant height and the short stature plants were observed from PI-220250 plants (Fig. 2). Moreover, similar plant height fashion was documented during 2021–2022 and non-spiny safflower resulted in 19% and 18.9% more plant height as compared to spiny one during 2020–2021 and 2021–2022 respectively.

3.2 Number of branches, heads and 1000-seed weight

In case of non-spiny safflower, the maximum number of branches per plant was recorded in accession PI-235660 (with a similar value for accession PI-253392) and the least branching habit was ensured in accession PI-314650 during 2020–2021. Spiny accession PI-220250 had the highest number of branches followed by accession PI-199829. On the other hand, the lowest number of branches was counted in accession PI-250187 (Fig. 3). Moreover, similar findings regarding number of branches per plant were assessed during 2021–2022. However, 4.3% and 2.4% more number of branches were revealed in non-spiny safflowers during 2020–2021 and 2021–2022 respectively. The highest head number was found for the accession PI-235660

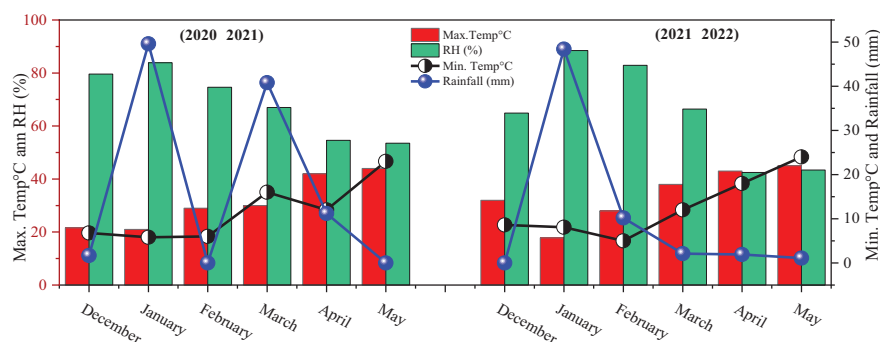


Fig. 1. Weather characteristics of the 2 growing seasons at the experimental site.

Table 2. Mean sum of square of agronomic, oil and oil quality traits.

Attributes	Mean sum of squares					
	2020–2021			2021–2022		
	Spiny nature	Accessions	Interaction	Spiny nature	Accessions	Interaction
DF	53.3**	24.6**	19.3*	17.6*	43.5*	28.3**
DM	124.0**	40.9**	15.4*	97.2*	46.4*	7.6**
PH	5483.7**	1466.0**	596.9**	5424.9*	1388.4*	521.1**
Branches	2.1 ^{ns}	29.7**	18.8*	0.7 ^{ns}	23.4**	13.6**
HPP	172.8**	1398.7*	969.5**	90.1**	1098.0*	832.1**
TSW	512.1**	472.3**	134.2**	584.3**	464.3**	105.9**
SYP	50.2*	572.5**	314.4**	34.1**	531.8*	250.9*
SOC	0.8 ^{ns}	23.7**	35.2*	0.9 ^{ns}	21.8**	37.9**
LA C18:2	1063.5*	71.9**	28.2**	1063.5*	71.9**	28.2**
OA C18:1	1016.3*	70.7**	19.2**	1017.1*	70.7**	20.0**

(NS) (with similar results for PI-181866) and the lowest head number was observed for PI-314650 in 2020–2021. In spiny accessions, significantly higher number of heads was found in accessions PI-199873 and PI-250187 and the lowest head number resulted in PI-250342 (Fig. 3). In addition, similar results regarding number of heads were observed during 2021–2022. However, 10.7% and 7.5% more heads were collected from non spiny safflower accessions as compared to spiny during 2020–2021 and 2021–2022 respectively. In non-spiny safflower accessions, the highest 1000-seed weight was recorded in accessions PI-198990 and PI-253392 and the minimum weight was accumulated in accession PI-220250 during 2021–2021. Similarly, spiny safflower accessions PI-199873 and PI-250187 had the highest 1000-seed weight, and the lowest weight was documented in accession PI-220250 (Fig. 3). However, 21.6% and 25% more 1000-seed weight were measured in non-spiny safflowers as compared to spiny ones when tested in 2020–2021 and 2021–2022 respectively.

3.3 Seed yield and seed oil content

Leading seed yield per plant in non-spiny accessions was recorded in PI-198990 followed by PI-314650 and the minimum yield was collected from accession PI-235660 when grown during 2020–2021. On the other hand, spiny safflower accessions PI-250187 and PI-199873 were considered high yielding whereas the lowest yield was produced from

accession PI-250342 (Fig. 4), whereas, during 2021–2022, a comparable yield was assessed in spiny and non-spiny safflowers. In brief, non-spiny safflower accessions exhibited 6.2% and 5.1% higher seed yield as compared to spiny ones when grown in 2020–2021 and 2021–2022 respectively. Highest seed oil content was extracted from non-spiny accession PI-198990 followed by PI-314650 and the minimum oil extraction was done in accession PI-253392 during 2020–2021. However, the highest oil in spiny safflower was collected from accession PI-250187 and the lowest seed oil content was analyzed in accession PI-250342. It was generally observed that the seed oil percentage was 1.2% and 1.3% more in spiny as compared to non-spiny safflowers when sown in 2020–2021 and 2021–2022 respectively.

3.4 Linoleic acid and oleic acid content

Non-spiny accession PI-235660 had the highest percentage of oleic acid followed by PI-314650 and the lowest oleic acid content was determined in PI-181866 during 2020–2021. However, spiny safflower accession PI-250187 showed the highest oleic acid content whereas, the lowest content was confirmed in accession PI-199829 (Fig. 5). Moreover, 77.9% and 68.3% more oleic acid percentage was recorded in non-spiny safflowers by comparing with spiny ones during 2020–2021 and 2021–2022 respectively. Furthermore, non-spiny

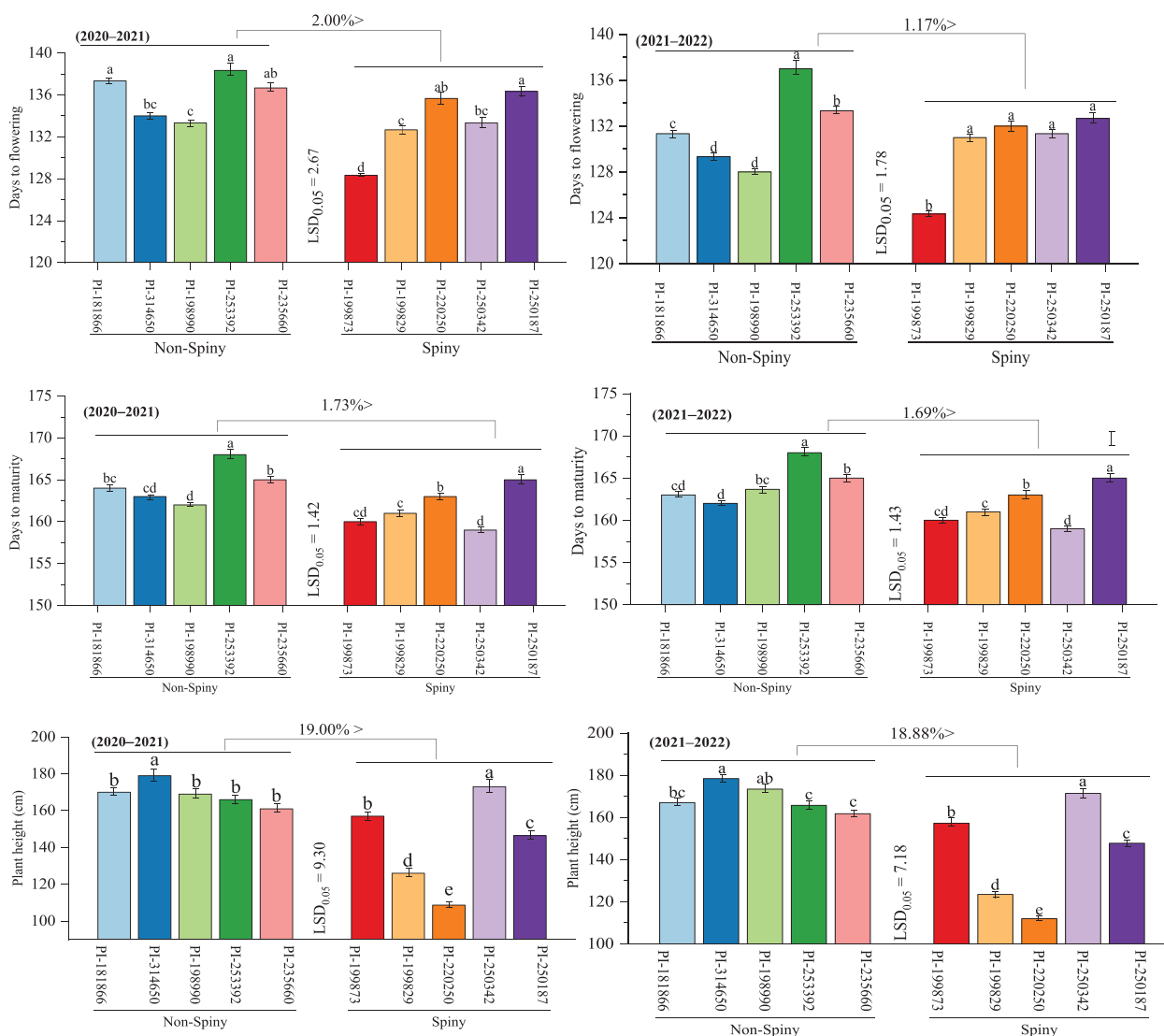


Fig. 2. Mean comparison of phasic duration and plant height of non-spiny vs. spiny safflower accessions. Similar letters mean non-significant ($P \leq 0.05$) differences as computed through LSD at 5% level of probability.

accession PI-181866 was found with leading linoleic acid content whereas, the minimum linoleic acid content was determined from PI-253660 when cultivated in 2020–2021. Similarly, spiny safflower accession PI-199829 exhibited greater linoleic acid content and the lowest linoleic acid concentration was observed in seeds of PI-250187 (Fig. 5). Generally, 16.3% and 20.1% more linoleic acid was determined in spiny as compared to non-spiny safflower.

3.5 Description of biplot and heat map with dendrogram

Biplot analysis of recorded traits for spiny and non-spiny safflower accessions was executed to select desirable safflower accessions based on their performance in 2020–2021 and 2021–2022 (Fig. 6). During 2020–2021 study, the graph explained the performance of the 10 accessions across PCA-1

(39.5%) and PCA-2 (25.7%). From the biplot diagram, four major groups were characterized in which seed yield per plant (SYP) and seed oil content were closely related in a 1st group whereas, plant height (PH), days to maturity (DM) and oleic acid (C18:1) were spotted in the 2nd group. Safflower accessions categorized in diagram segment could be simultaneously selected for these attributes. For instance, spiny safflower accession PI-199829 had the greatest linoleic acid concentration. However, the highest seed yield per plant (SYP) and seed oil content (SOC) were observed from non-spiny safflower accession PI-198990. Moreover, the highest oleic acid content and number of heads was observed from non-spiny accession PI-235660. Similar findings were recorded when experiment was replicated during 2021–2022 season.

Heatmaps show the outcomes of hierarchical clustering of their performance in this two-year trial (Fig. 7). The clustering result of 2020–2021 displayed as either the distance or the similarity between the clustered rows or

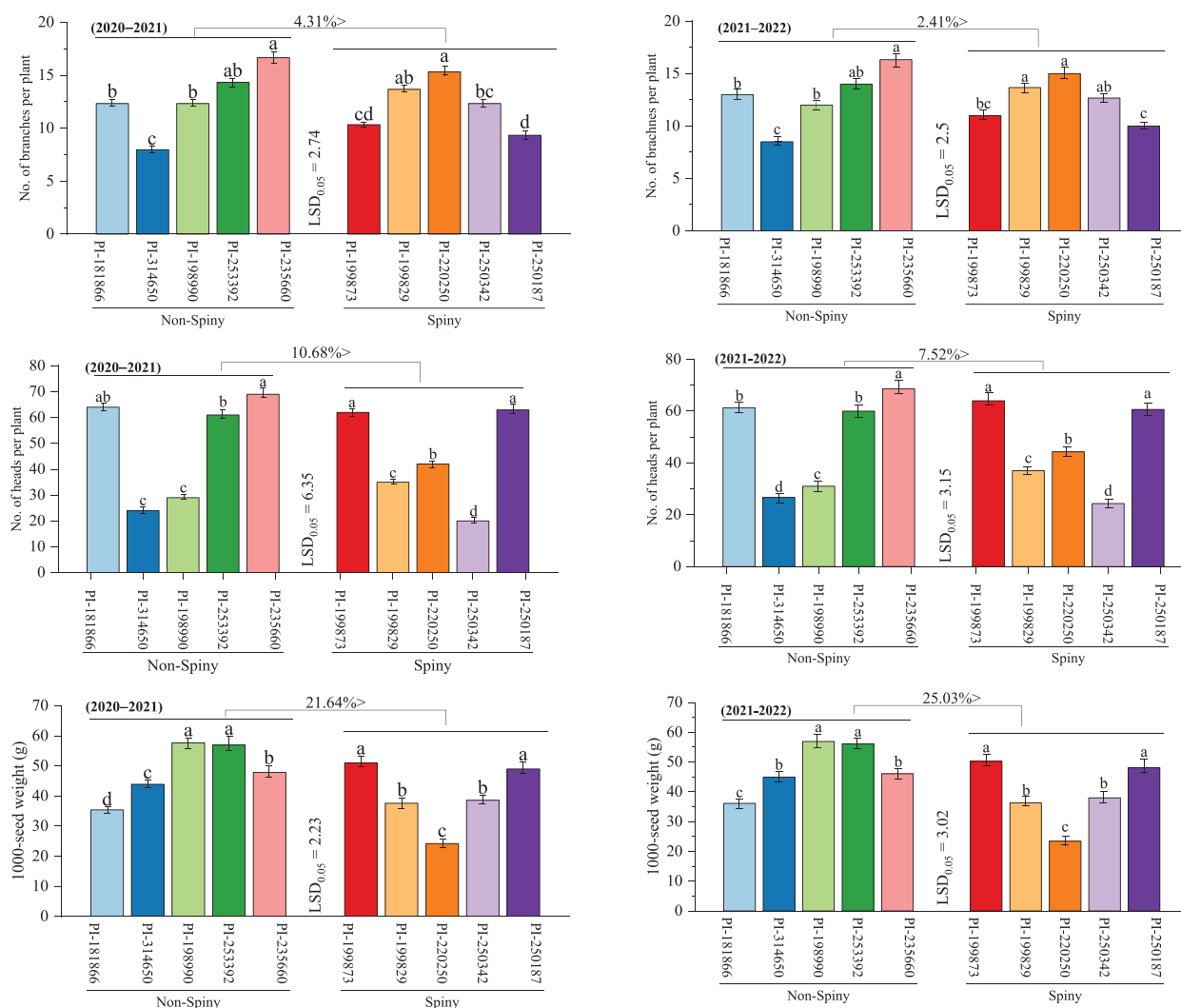


Fig. 3. Mean comparison of yield components of non-spiny vs. spiny safflower accessions. Similar letters mean non-significant ($P \leq 0.05$) differences as computed through LSD at 5% level of probability.

columns depending on the selected distance measured. Heatmap with dendrogram cluster analysis was performed to make cluster groups of spiny and non-spiny safflower accessions and mentioned attributes along with their ranges. Safflower accessions were distributed in 3 major clusters. First cluster consists of spiny accessions S=PI-220250 and S=PI-199829, 2nd one contains accessions S=PI-250342, NS=198990 and NS=PI-314650 and 3rd cluster comprises S=PI-250187, S=PI-199873, NS=PI-235660, NS=PI-253392 and PI-181866. However, safflower studied traits were also categorized into three major clusters. The first cluster contains phenological traits (DF, DM and PH), the 2nd cluster showed seed oil content branches and oleic acid (C18:1) and the 3rd cluster depicted heads per plant (HHP), thousand seed weight (TSW), seed yield per plant (SYP) and linoleic acid (C18:2). Days to flowering, heads per plant and C18:2 showed significant variation.

4 Discussion

Unexpected rise in population at alarming rate disclosed a lot of issues regarding food security. There is an urgent need to fulfil necessities of human including food, feed and shelter especially from agricultural sector. Among agricultural crops, oilseed crops are one of the major cultivations to cope up the edible oil demands of humans. Edible oil is one of the major food commodities which feed approximately 7 billion people across the world (Hussain and Bhat, 2018). In Pakistan, approximately 86% (2.8 million tons) edible oil is imported with crushing precious foreign exchange at cost of US\$3.681 billion whereas the local production of country is 0.46 million tons that poses serious food security risk in future (PES, 2022). Understanding such scenario of edible oil, there is need of much attention to reduce the import bill through introducing non-conventional oilseed crops including sunflower, canola,

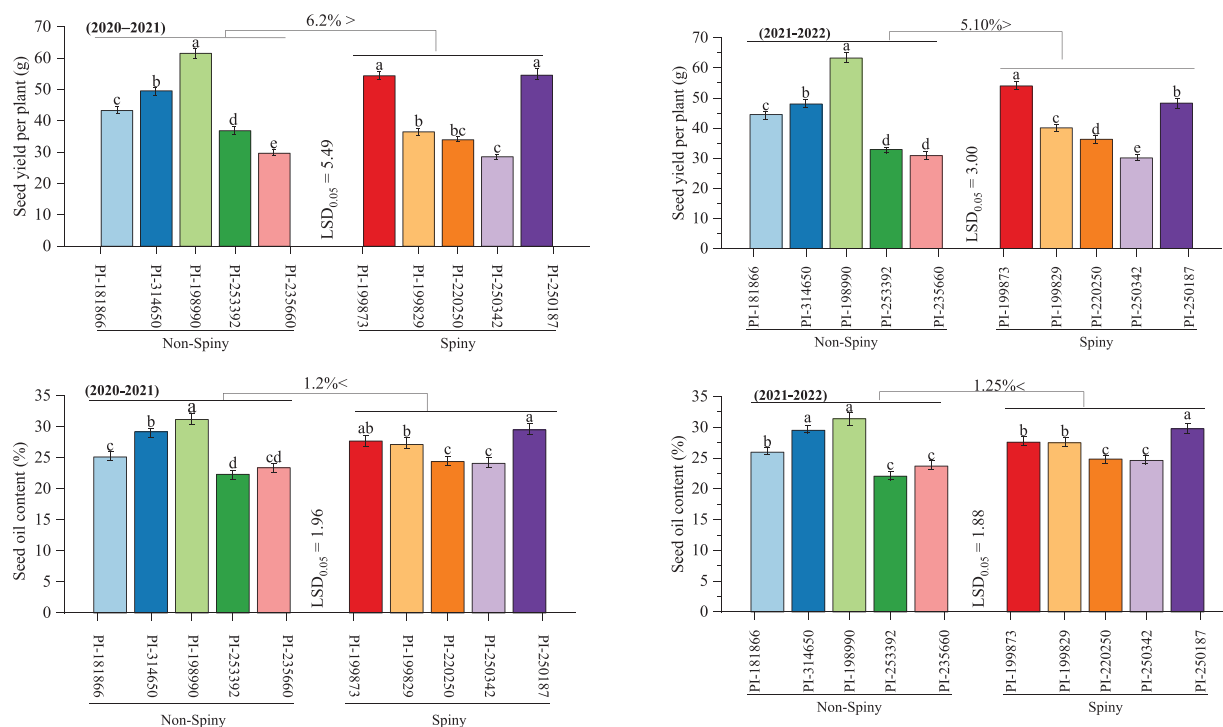


Fig. 4. Mean comparison of seed yield and oil concentration of non-spiny vs. spiny safflower accessions. Similar letters mean non significant ($P \leq 0.05$) differences as computed through LSD at 5% level of probability.

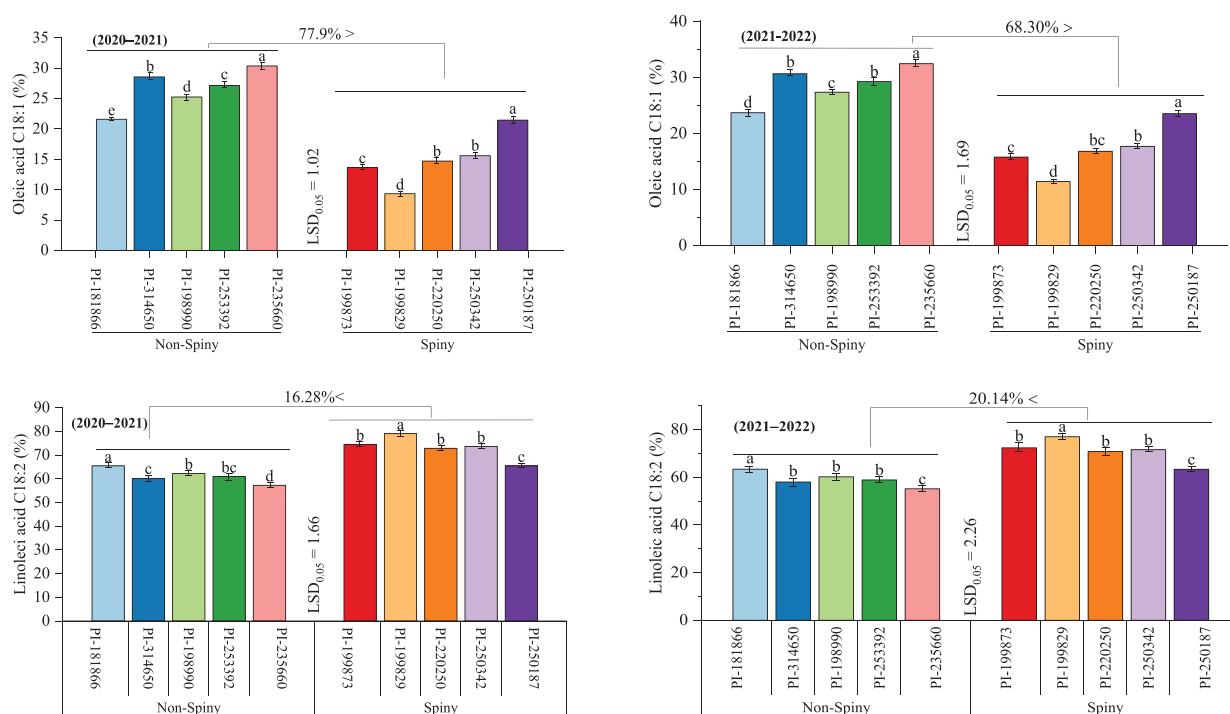


Fig. 5. Mean comparison of oil quality of non-spiny vs. spiny safflower accessions. Similar letters mean non significant ($P \leq 0.05$) differences as computed through LSD at 5% level of probability.

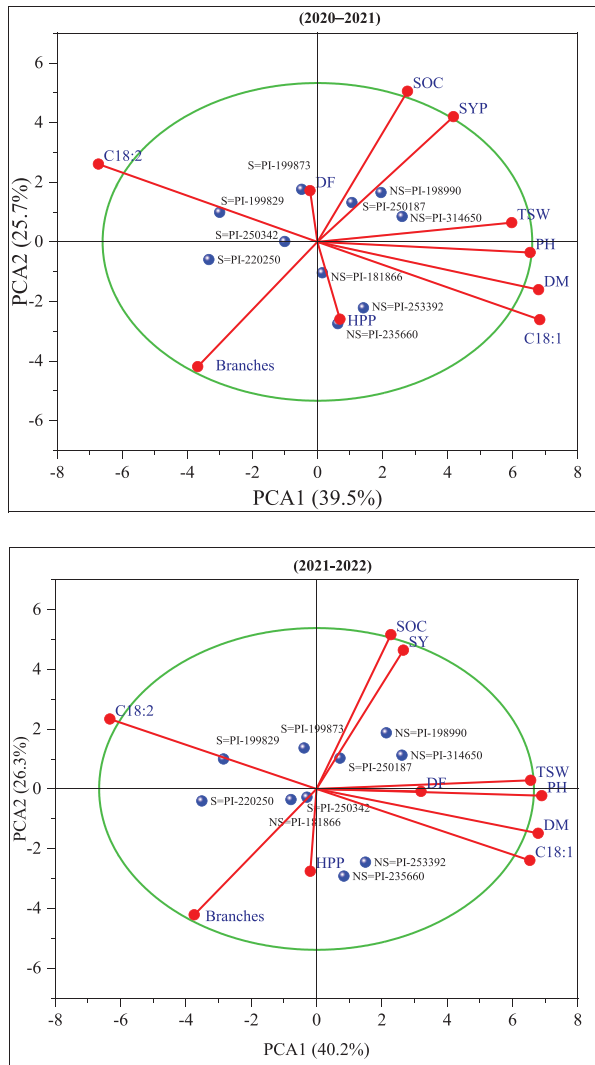


Fig. 6. Biplot analysis diagram of spiny and non-spiny safflower accessions traits *i.e.* DF = days to flowering, DM = days to maturity, PH = plant height (cm), Branches = branches per plant, HPP = heads per plant, TSW = 1000-seed weight, SYP = seed yield per plant (g), C18:2 = linoleic acid (%), C18:1 = oleic acid (%). NS symbolizes non-spiny safflower and S spiny safflower accessions.

soybean, and safflower. For instance, safflower cultivation in Pakistan is an unattended crop for sake of edible oil extraction which has great potential regarding its nutritional requirement as well as tolerance against less productive land particularly salinity and drought affected regions. Spiny safflower cultivation is foremost an undesirable practice ; due to cultivation (including foliar applications, hoeing, manual weeding), harvesting and threshing which are especially labor intensive practices, farmers cannot adopt this crop (Nimbkar, 2008). Spineless safflower accessions are a great innovation regarding such problems of cultural practices, and they have comparable seed and oil yield as well as quality of edible oil. In this study, spiny and spineless safflower accessions were grown to evaluate their agronomic and quality characteristics.

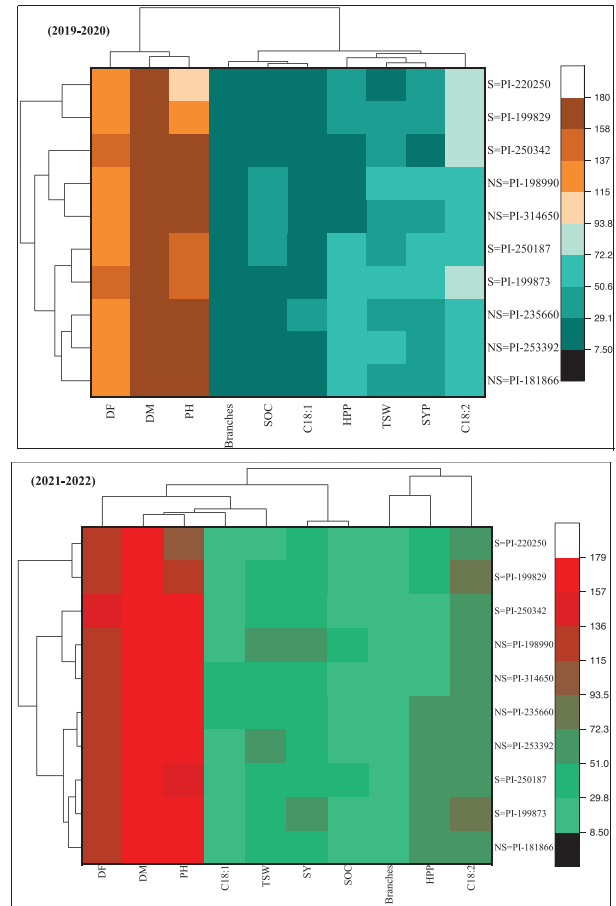


Fig. 7. Heat map showing expression of safflower accessions (NS = non-spiny; S = spiny) and linkage of their studied traits.

Studied characters comprising number of branches/plant, number of capitula/plant, thousand seed weight and seed yield were recorded to be higher from non-spiny safflower accessions as compared to spiny ones (Fig. 2). These results are also close to the findings of Naik *et al.* (2009). PCA analysis characterized 10 safflower accessions into two components PCA1 (25.7%) and PCA2 (39.5%) (Fig. 4). In this experiment, component one was designated as linoleic acid (C18:2) and days to flowering. The second component was seed oil content, seed yield and thousand seed weight. Moreover, the third component was nominated as plant height, days to maturity, oleic acid (C18:1) and heads per plant (Bahmankar *et al.*, 2017).

The non-spiny safflower accession PI-198990 (Fig. 3) gave the highest seed yield as compared to spiny safflower and these findings were also reported by Gobade *et al.* (2015), Ojaq *et al.* (2020) and Sajid *et al.* (2024). Oil content of oilseed crops varies under the influence of genotype and environment (Yousefzadeh and Ehsanzadeh, 2017). Seed oil content and 1000-seed weight were also recorded as maximum in non-spiny safflower accession PI-198990 as compared to spiny safflower and our results also matched with the findings of Davari *et al.* (2022). Additionally, higher oleic acid and less linoleic acid concentrations were reported in our study for non-spiny safflower accessions as was also reported by Sajid *et al.*

(2023). Keeping in view the above-mentioned findings of this study, the non-spiny safflower accession PI-198990 was identified as leading seed yield and oil percentage, significant linoleic concentration was observed in PI-199829 whereas PI-235660 had greater oleic acid percentage as compared to spiny safflower accessions.

5 Conclusion

The results of this trial suggested that non-spiny safflower accessions may be introduced for cultivation with comparable seed yield and quality edible oil advantage over non-spiny accessions. Non spiny safflowers exhibited 6.2% more seed yield as compared to spiny safflowers. Moreover, seed oil content was recorded 1.2% greater in spiny as compared to non-spiny accessions. Fatty acid acids including oleic acid was 77.9% during 2020–2021 and 68.3% in 2021–2022 higher in non-spiny instead of spiny safflowers. Overall results show that non spiny accessions may be preferred as they have better yield, comparable oil contents and also provide ease of farm operations over the spiny accessions.

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Conflicts of interest

The authors declare no competing interests.

Data availability statement

The data that support the findings of study are available from the corresponding author upon reasonable request.

Author contribution statement

Muhammad Sajid: conceptualization, Writing-original draft preparation, methodology.

Hassan Munir, supervision, validation, manuscript preparation.

Fahd Rasul: Investigation, visualization.

Muhammad Abu Bakar Hayat: Revision, formatting

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