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Estimation of Yield Potential, Oil Content and Fatty Acid Composition of Safflower in Different Ecological Zones

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Abstract

Unfavorable temperatures threaten global crop productivity and sustainability to a significant extent under changing climate scenarios. Drastic impact of climatic variability demands suitable solutions including adaption through climate-proof cropping system. Similar intervention was focused through the subject study conducted during winter 2019 to assess cultivation of exotic USDA safflower accessions under various environments of Punjab, Pakistan. Four locations i.e. Bahawalpur, Faisalabad, Kasur and Rawalpindi were selected for cultivation of previously screened six safflower candidate lines in a randomized complete block design with factorial arrangements. Seed yield, oil quality and contents was calculated. Results revealed that the performance of safflower accessions of exotic origin perofmred variably under variety of climates. Safflower accession PI-198990 exhibited the highest seed yield at Kasur whereas, PI-199907reflected the least yield at Bahawalpur. High oil contents were estimated at Faisalabad when compared withother locations under study. However, the maximum accumulation of oleic acid was recorded in safflower planted at Bahawalpur. On the other hand, Rawalpindi sown safflower exhibited the maximum content of linoleic acid. As far the morpho-physiological attributes are concerned, positive and significant relationship of seed yield with number of branches, number of heads and thousand seed weight were recorded whereas, linoleic acid showed strongly negative correlation with oleic acid content. Therefore, it is concluded that environmental variation had significantly influenced safflower yield, oil and fatty acids contents.

Keywords: environments, spatial variation, agro-eclogy, oilseed, quality, productivity

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Introduction

Safflower (*Carthamus tinctorius* L.) is xerophytic oilseed crop with considerable use in pharmaceutical, edible, paint and textile industries of its growing countries. Composition of safflower seeds comprised of 24-37% oil, 32-34% crude fiber, 14-15% protein, 2-7% ash and 2-7% moisture (Golkar et al., 2011). It is rich in linoleic acid (polyunsaturated) followed by oleic acid (monounsaturated) (Matthaus et al., 2015) . Oil of safflower is an exceptional source of antioxidant (α-tocopherol) that ranges between 192-716 mg kg^{-1} (Zheng et al., 2018). Safflower is less input requiring crop with extraordinary drought tolerance and withstands frost with no trouble while, it possesses moderate salt tolerance across the globe (Hussain et al., 2016). Quality of oilseeds and their productivity is signficanlty reported for impact of prodctuion practices and climatic variability. Similarly, timely input availability and their application affected yields to a greater extent (Zemour et al., 2021). Climate-resilient crops are the one which can help ensure economic reliance of the groweres on farming especially under biotic and abiotic stressfull conditions (Jaleel et al., 2009; Zanjare et al., 2020). Rising water scarcity due to unprecedented climatic and weather patterns as well as extent of adverse stressful conditions resulted from climatic uncertainties and geopolitical regional limitations (Eckstein, 2009). Unpredictable river flow and variability in rainfall pattern as well as temporal fluctuations are resulted consequently and signify the adoption of resilient genetics in field crops or selection of crops for local husbandry with endogenous potential to sustain productivities under stressful conditions particularly drought, salinity, frost etc. (Raza et al., 2019).

Crops with such potential are admired as resilient and help originate climate resilient cropping systems. Safflower is a one of such selections for local crop husbandry as it is a xerophyte and exhibits high resilience to drought. In addition, it moderately withstands salt-affected environments hence, suitability as an oilseed under diversity of climatic conditions attracts interventions for improved productivity (Hussain et al., 2016). Very less water requirement for maturity and swift growth behavior with short life cycle highlights safflower as a preference while comparing with in-practiced crops in the local cropping systems with permanent features of drought, low rainfall, salinity, frost or multiple stresses (Singh et al., 2016).Variability in environmental impact on crop growth, physiology and metabolism indicate the potential of crop genetics. . Climatic factors such as temperature, rainfall and humidity majorly influence plant physiological process including photosynthesis under different environments (Shabana et al., 2013). The current study was executed to test the exotic safflower accessions for seed yield, oil and oil quality under four locations of Punjab Pakistan to evaluate the stability and possible resilience of studied accessions in diversity of climates.

Materials and Methods

A study trial was performed at four locations of Punjab Pakistan i.e. Bahawalpur (canal and tube well irrigated hot dry climate 29.4535°N and 72.2044°E), Faisalabad (canal irrigated semi-arid climate 31.2537°N and 73.0438°E), Kasur (tube well irrigated semi-arid climate 31.1202°N and 74.6195°E) and Rawalpindi (rainfed arid climate 33.1126°N and 73.0836°E). In each location, six safflower candidate lines were grown on ridges with45 cm and 15 cm distances between the rows asn the plants respectively. Diammonium phosphate (DAP) and urea fertilizers were applied @ 123 kg ha^{-1} whereas, pre-emergence herbicide Topmix (mixture of pendimethalin and S-metolochlor) was sprayed after 12 hours of sowing. Soil analysis and weather data of respective locations are given in Table 1 & Fig.1. Growth, yield, oil traits were measured using standard procedures. Contamination through crossing and birds was avoided by covering plants with nylon nets. Safflower was harvested and threshed manually whereas drying of seeds was done in shade to determined seed yield at 12% seed moisture content. Soxhlet apparatus was used to extract oil and to determine seed oil content where 10 g clean safflower seeds were ground and loaded for 24 h using n-hexane as solvent. Decrease in weight was measured using analytical balance to determine seed oil content (%)using formula as described by Velioglu et al. (2017).

$$\text{Oil Contents} = \frac{\text{Initial Weight of Sample} - \text{Final Weight of Sample}}{\text{Intial Weight of Sample}} \times 100$$

However, manual oil extractor was used to extract a small quantity of oil for fatty acid profile where 1.5 g of oil was collected from selected plant sample in Eppendorf tube. The extracted oil (50 µL) was methylated using 4 mL KOH for 1 h at room temperature. Methylated fatty acids were extracted using n-hexane and fatty acid profile was analyzed through gas chromatography (M-3900, Varian, USA) at Nuclear Institute of Agriculture & Biology (NIAB). Analysis was done by using the fused capillary column, flame ionizing detector and nitrogen gas carrier @ 3.5 mL min^{-1}. Injector and detector temperatures were kept at 260°C while column oven temperature was at 222°C. Methylated esterified fatty acid was injected manually while fatty acid was identified through peak retention time compared with standards.

The experiment was laid out under randomized complete block design with factorial arrangements and treatment mean was compared by employing Tukey's Honestly Significant Difference test at 5% level of probability by using OriginPro-2021 software. However, stability analysis was performed by online STABILITYSOFT software (Pour-Aboughadareh et al., 2019) to rank cultivars based on their stability using Wricke's ecovalence (W_i^2), Shukla's stability variance (σ_i^2), regression coefficient ($*b_i$), deviation from regression (S^2_{di}) and Kang's rank-sum (KR) (Wricke ,1962; Shukla, 1972; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Kang, 1988).

Table 1. Soil and weather traits of experimental sites

Soil & weather parameters	Experimental sites			
	Bahawalpur	**Kasur**	**Faisalabad**	**Rawalpindi**
Sample depth (cm)	0-30	0-30	0-30	0-30
Soil Type	Loam	Loam	Loam	Sandy loam
Soil saturation (%)	34.0	34.0	32.0	40.0
EC (dS $^{-1}$)	2.64	2.16	2.41	0.43
pH	7.6	7.4	7.7	8.0
Organic matter (%)	1.14	1.21	1.01	0.52
N (%)	0.30	0.28	0.24	0.22
P (mg kg^{-1})	15.8	12.3	10.6	3.0
K (mg kg^{-1})	268.0	89.0	169.0	80.0
Max. Temperature (℃)	41.40	40.00	38.52	31.68
Max. av. Temperature (℃)	25.95	24.64	23.82	20.97
Min. Temperature (℃)	1.44	1.19	1.08	-0.60
Relative humidity (%)	50.45	55.45	56.80	66.08
Rainfall (mm)	208.46	233.32	331.86	995.99

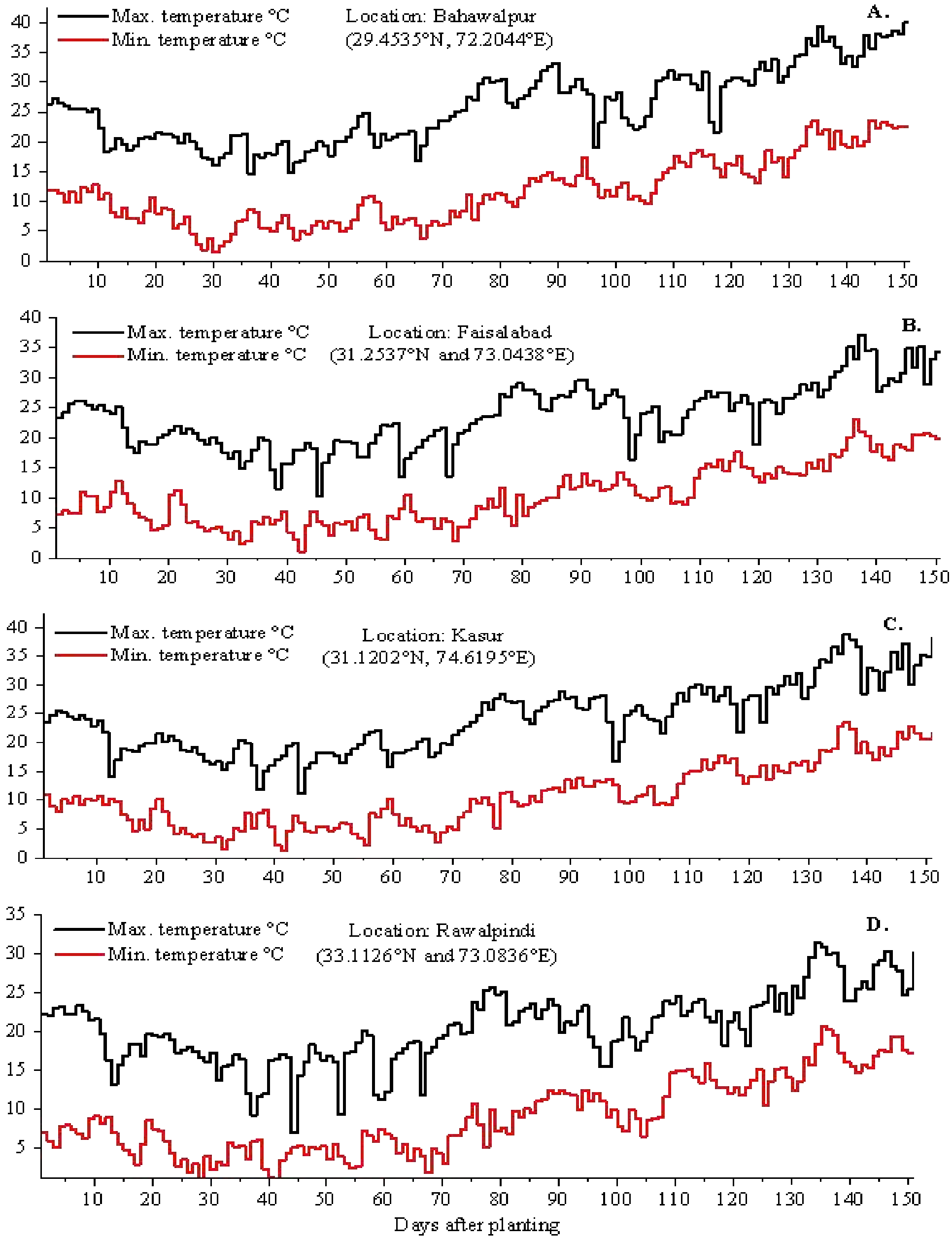


Figure 2. Maximum and minimum temperature (°C) of four experimental locations

Results

Phenological, agronomic and oil traits were studied under this investigation as depicted by their ANOVAs in table 1a & 1b. Accessions × locations was found significant (P≤0.05) for all traits except days to maturity and number of seeds per head.

Phenological traits

Comparsion for phenological traits exposed that the maximum days to flowering were recorded in Rawalpindi followed by Kasur and Faisalabad whereas, safflower took the least days to flowering in Bahawalpur (Fig. 2). However, accession PI-314650 emerged with the longest period of time to flower followed by PI-210834 and PI-199907. On the contrary, the least days were noted in PI-250187 and it emerged as early flowering accession. Moreover, accession PI-314650 took the maximum days for attaining maturity followed by accessions PI-210834 and PI-199907. Accession PI-250187 took the least time to become mature only in 148.33 days. Similarly, Rawalpindi grown safflower life cycle was the longest one followed by Kasur grown safflower. Shortest life span was recorded in safflower grown under Bahawalpur conditions..

Agronomic traits

Agronomic traits of safflower accessions studied across the locations are given inFig. 2&3. Tallest safflower plants were recordedin Kasur followed by Faisalabad and Bahawalpur whereas, Rawalpidin grown safflower was recorded with short stature plants. Similarly for safflower accessions, PI-314650 and PI-198990 were exposed with the highest plant height in Kasur and the least plant height was measured in PI-250187 when grown in Rawalpindi . Faisalabad grwon afflower accessions PI-198990, PI-199907 and PI-250187 borne the maximum number of branches . but for Rawalpindi, PI-198990, PI-199907 and PI-208677 were the leading branched accessions.Least number of branches were recorded in Bahawalpur wherePI-199907 accession had the maximum branching while the minimum branches were in PI-314650. Safflower heads were recorded with maximum number in accession PI-198990 followed by PI-210834 and PI-250187 in Faisalabad while, the minimum heads were recorded in PI-314650 whereas, the least number of heads were collected in PI-199907 when exposed to Bahawalpur. Similarly, maximum seed count per head was recorded in PI-208677 accession followed by the rest of all the accessions and , the least seed count was recorded in PI-314650. For einvironmental response, safflower seed count was similar under Rawalpindi and Faisalabad conditions whereas, the least seed count was recorded in Bahawalpur. Furthermore for thousand seed weight, maximum values were recorded for PI-198990 in Kasur sowing with similar response under Faisalabad for PI-210834 and the least thousand seed weight was recrded in PI-250187at Bahawalpur. Kasur was emerged as the highest seed yielder when compard across the locations. For Kasur, accession PI-198990 was the highest yielder with at par response of PI-210834 and the least seed yield was collected from PI-314650. But for Bahawalpur, accession PI-198990 was the highest seed yielder and accession PI-199907 yielded the least seed. Faisalabad was emerged as the highest biomass yielder followed by Kasur whereas as the least biological yield was quantified at Bahawalpur. For safflower accessions PI-198990 was the leading biomass accumulator in Faisalabad and the least yield was exhibited by PI-314650 there. For Bahawalpur, accession PI-198990 gahered the maximum biomass and the leastbiological yield was obtained from PI-250187. Maximum harvest index was calculated at Kasur followed by Rawalpindi whereas the minimum harvest index was observed at Faisalabad. At Kasur safflower accessions PI-210834 and PI-199907 had the highest harvest index and the least harvest index was observed in PI-208677. For Faisalabad, the highest harvest index was exposed in PI-314650 and PI-198990 accessions and the lowest harvest index was calculated in plants of PI-199907.

Oil traits

Data analysis regarding oil traits showed significant ($P \leq 0.05$) variation for locations and safflower cultivars in this study (Fig.4). Safflower accession PI-198990 had the leading oil content among all other accession when exposed to Faislabad locality whereas, the least oil content was expelled out from PI-208677 and PI-314650 however, at Rawalpindi site the maximum oil content was accumulated from PI-198990 with similar response of other employed safflower accessions. . For all locations, Kasur was emrged for variation in oil content. Moreover, the least oil content in this study was determined by PI-199907 when executed at Bahawalpur. Moreover, significant variation was recorded during comparison for oleic acid character ofsafflower accessions across the four locations. Bahawalpur site had the highest oleic acid content as compared to other locations and PI-198990 was emerged as the leading accession with identical oleic acid content in PI-210834, PI-314650 and PI-199907. However at Faisalabad, accession PI-314650 was found with the maximum oleic acid content and the minimum content was found in safflower accession PI-250187. Correspondingly, PI-198990 had significantly higher linoleic acid content when tested at Kasur and Rawalpindi sites while, the minimum linoleic acid content was determined in PI-210834 and PI-314650, respectively. The highest linoleic acid content was observed in safflower accession PI-314650 with statistically similar results of rest of all safflower accessions across the locations.

Table 1a. Analysis of variance for days to flowering (DF), days to maturity (DM), plant height (PH, cm), branches (Bran), heads plant^{-1}, seeds head^{-1} and thousand seed weight (TSW, g)

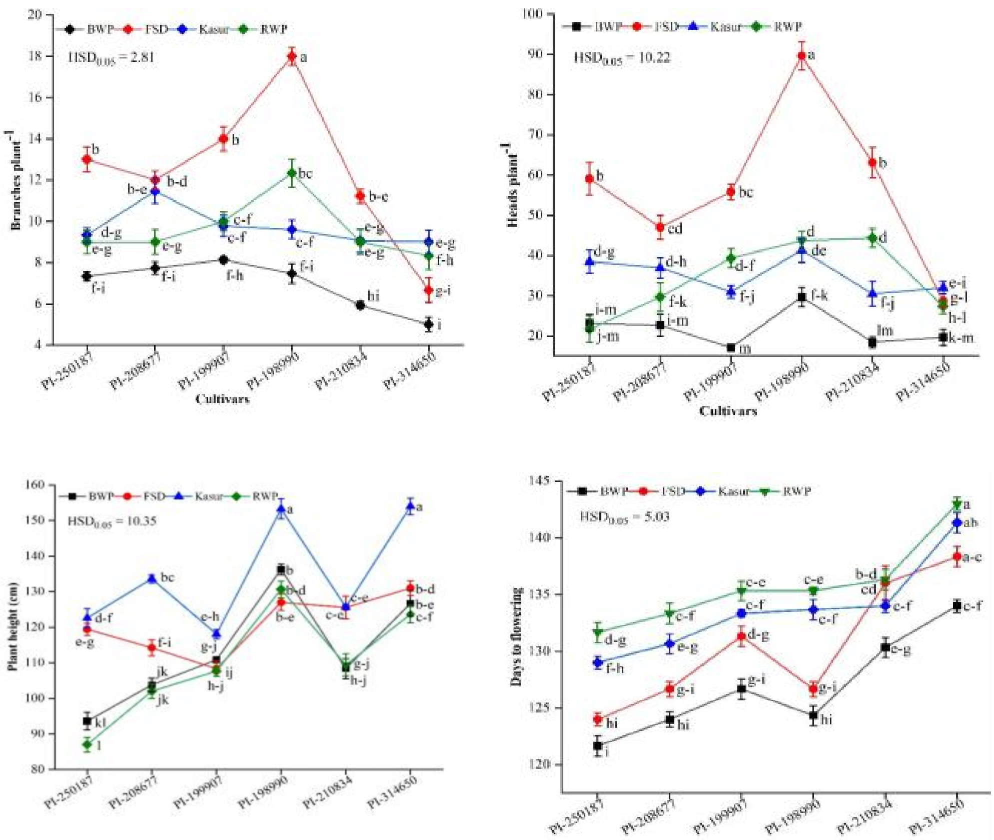
SOV	DF	Mean square						
		DF	DM	PH	Bran	Heads	Seeds	TSW
Block	2	3.9^{NS}	5.1^{NS}	90.9^{NS}	14.7*	27.4^{NS}	13.1^{NS}	8.7^{NS}
Cultivars (C)	5	240.3**	80.1**	1935.7**	29.2**	759.1**	146.7*	496.8**
Locations (L)	3	276.5**	371.7**	2134.3**	92.4**	3909.8**	341.6**	702.3**
C × L	15	6.7*	2.1^{NS}	157.9**	8.4**	279.0**	77.6^{NS}	68.6**
Residual	46	2.6	2.4	39.7	2.9	38.7	57.6	11.2
Total	71							

NS (non significant) ≥ 0.05; * (significant) ≤ 0.05; ** (highly significant) ≤ 0.01

Table 1b. Analysis of variance for seed yield (SY, kg ha^{-1}), biological yield (BY, kg ha^{-1}), harvest index (HI), oil content (Oil%), oleic acid content (OA%) and linoleic acid content (LA%)

Mean square							
SOV	DF	SY	BY	HI	Oil%	OA%	LA%
Block	2	249340.7^{NS}	8183934.3^{NS}	0.025^{NS}	20.8**	0.5^{NS}	0.8^{NS}
Cultivars (C)	5	5163166.2**	54536523.3**	0.034*	5.7**	8.6*	9.3*
Locations (L)	3	10488092.9**	254614582.8**	0.269**	3.0*	10.1*	12.0*
C × L	15	382574.3**	14378373.7**	0.084**	2.9**	9.8**	9.2**
Residual	46	134122.0	2877856.5	0.012	0.9	2.9	3.3
Total	71						

NS (non significant) ≥ 0.05; * (significant) ≤ 0.05; ** (highly significant) ≤ 0.01



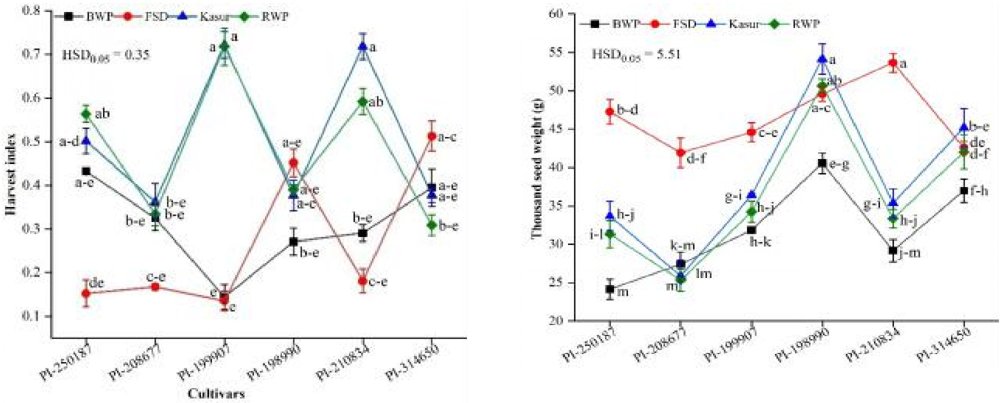
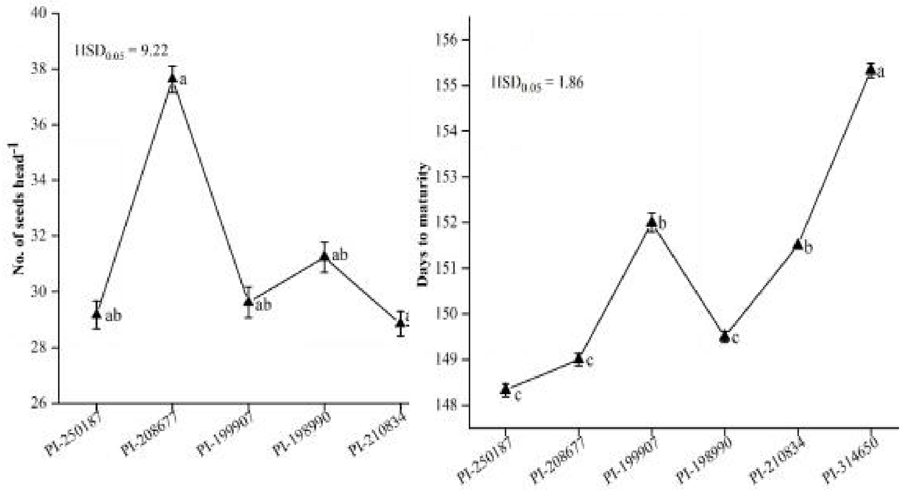


Figure 2. Phenological and agronomic traits of safflower under four locations of Punjab i.e. BWP = Bahawalpur (29.46°N, 72.24°E), FSD = Faisalabad (31.25°N, 73.04°E), Kasur (31.1202°N,74.6195°E), RWP = Rawalpindi (33.19°N, 73.08°E)



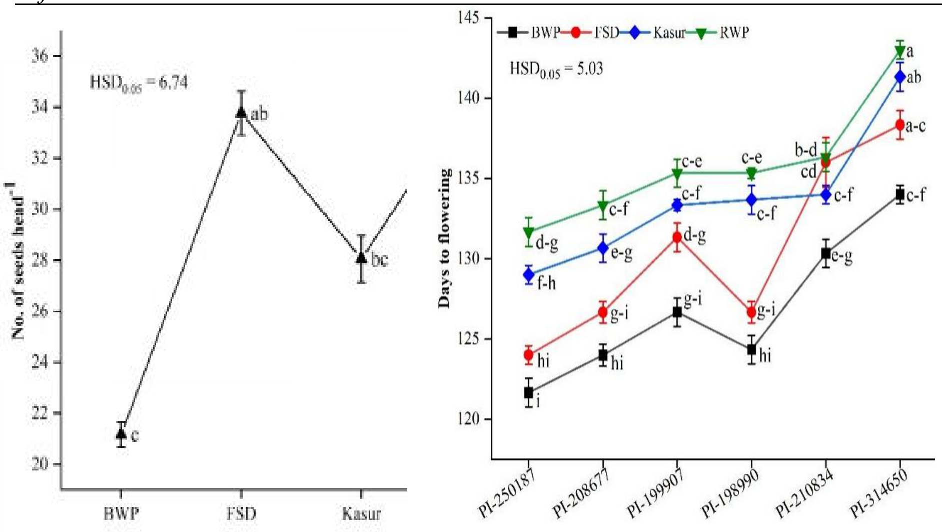


Figure 3. Agronomic traits of safflower under four locations of Punjab i.e. BWP = Bahawalpur (29.46°N, 72.24°E), FSD = Faisalabad (31.25°N, 73.04°E), Kasur (31.1202°N,74.6195°E), RWP = Rawalpindi (33.19°N, 73.08°E)

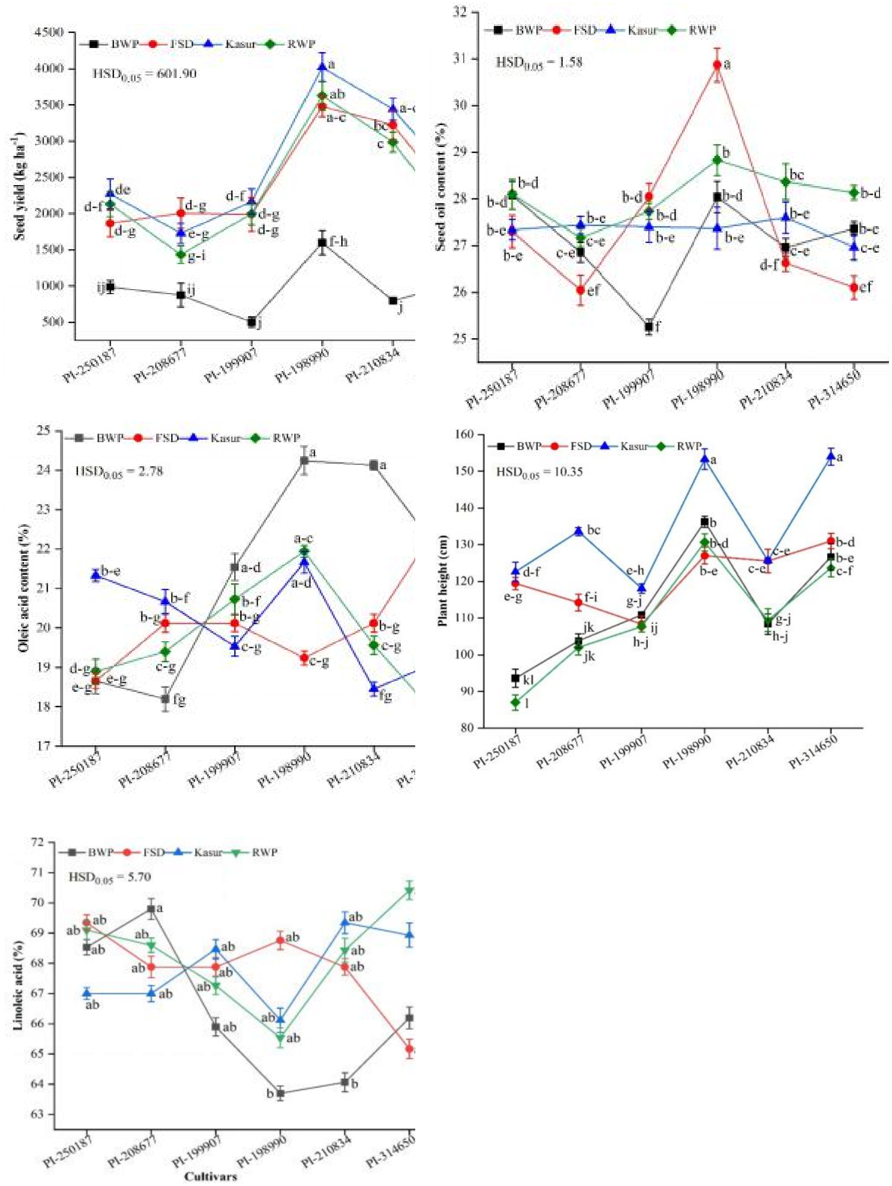


Figure 4. Oil contents and fatty acids of safflowerunder four locations of Punjab i.e. BWP = Bahawalpur (29.46°N, 72.24°E), FSD = Faisalabad (31.25°N, 73.04°E), Kasur (31.1202°N,74.6195°E), RWP = Rawalpindi (33.19°N, 73.08°E)

Correlation and regression analysis

Correlation analysis was done to check the association among all studied traits in this investigation (Fig.5). Correlation analysis described significant relationship between days to maturity (DTM) and days to flowering (DTF) as well as number of heads also had highly significant association with number of branches (Bran) thus showed that accessions had the higher number of branches had the higher number of heads. Seed yield ha^{-1} (SYH) and thousand seed weight (TSW) exposed highly significant correlation among plant height (PH), branches (Bran) and heads illustrated that safflower accessions had the higher heads, and thousand seed weight had the higher seed yield. However, oil content revealed significant rapport between branches, heads and seed yield consequently accessions had the higher seed yield had produced the higher seed oil content. Linoleic acid content had strong negative correlation with oleic acid content thus proved that safflower accessions depicted the higher linoleic acid content had the lower oleic acid content. Dependency of seed yield and oil related traits over maximum average temperature of studied locations was estimated through scatter plot diagram show in Fig. 6. R^2 value for all traits i.e. oil content, linoleic acid and oleic acid content was very high but the temperature had a positive influence over the oleic acid content while temperature had a negative influence over seed yield, oil and linoleic acid content. Above mentioned results showed the negative impact of temperature excepting on oleic acid content. Moreover, at Bahawalpur (BWP) experimental site had a higher temperature that significantly increased the oleic content as compared to all other locations whereas oil content and linoleic acid content had significantly increased with decrease in temperature among subject experimental sites and Rawalpindi (RWP) site showed maximum oil and linoleic acid content among other locations.

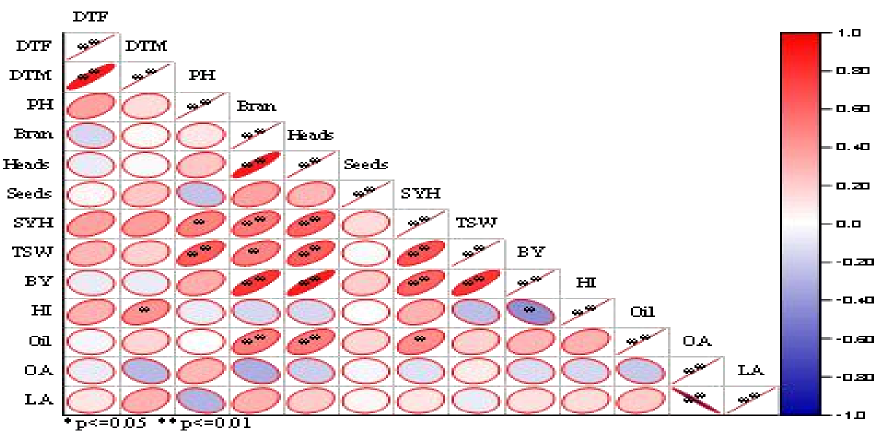


Figure 5. Correlations analysis among morphological, yield and oil parameters comprising such as days to flowering (DTF), days to maturity (DTM), plant height (PH, cm), number of branches palnt^{-1} (Bran), number of heads palnt^{-1} (Heads), number of seeds head^{-1} (Seeds), seed yield (SYH, kg ha^{-1}), thousand seed weight (TSW, g), biological yield (BY, kg ha^{-1}), harvest index (HI), oil content (Oil%), oleic acid content (OA%) and linoleic acid content (LA%).

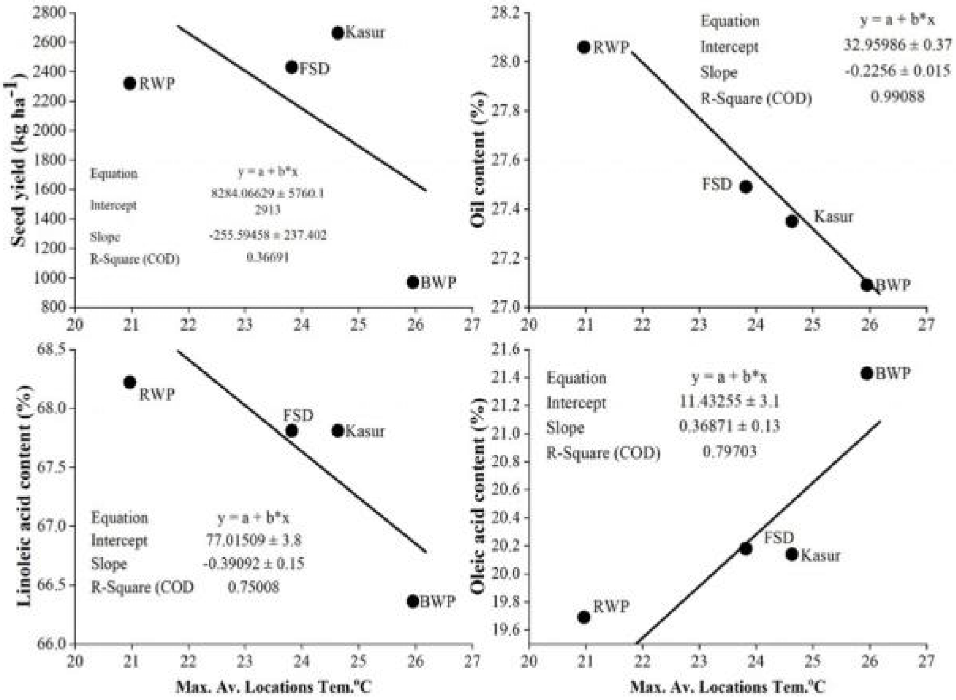


Figure 6. Regression analysis between temperature, seed yield, oil content, linolic acid and oleic acid among four locations i.e. BWP = Bahawalpur (29.46°N, 72.24°E), FSD = Faisalabad (31.25°N, 73.04°E), Kasur (31.1202°N,74.6195°E), RWP = Rawalpindi (33.19°N, 73.08°E)

Table 3. Stability analysis of selected safflower accessions across tested experimental locations

Accessions	Stability parameters						
	Yield	**W_i^2**	**σ^2_i**	**s^2d_i**	**b_i**	**CVi**	**���**
PI-250187	1815.	188862. 7	62550.16	9055.1	0.7	31.8	6
PI-208677	1511.	477512. 7	206875.2	20795.	0.5	32.0	10
PI-199907	1664.	17914.1	-22924.1	2503.9	1.0	46.7	6

PI-198990	3182.	334565	135401.3	7008.9	1.4	33.9	7
PI-210834	2612.	647057. 6	291647.6	1679.7	1.6	46.8	7
PI-314650	1785.	246959. 5	91598.54	10000.	0.6	30.3	6

Stability analysis

Stability of safflower accessions was measured across four experimental locations having wide range of agro-ecological conditions (Table 3). Highest mean yield was observed for safflower accession PI-198990 across four locations followed by PI-210834. Various stability traits were assessed to select stable safflower accessions in this multilocation study. Wricke (1962) projected 'ecovalence' to rank accessions. Safflower accessions with the lowest ecovalence value had the highest stability across the locations. As per ecovalence (Wi^2), PI-199907 had the lowest estimated value and emerged as stable. Shukla (1972) estimated 'Shukla variance' across environment after main effects of environment removed. Safflower accessions with the lowest Shukla variance (σ^2_i) were considered stable. Again, accession PI-199907 had the lowest value and was counted as stable followed by PI-314650. Finlay and Wilkinson (1963) estimated co-efficient of regression to rank accessions for stability and accession with slope of regression close to unity may be considered stable. However, deviation from regression (S^2_{di}) should be insignificant ($P \geq 0.05$). As per estimates PI-199907 has co-efficient of regression close to unity with insignificant deviation from regression. Accession PI-198990 significantly deviated from slope of regression and high b_i value and thus, safflower accession PI-198990 was emerged as adaptable to high yielding environment. Safflower accession PI-250187 had significantly lower value of *bi* than unity and have the tendency for being adaptable to stress and low yielding environment. Kang ranking (Kang, 1988) is done based on stability and seed yield of accessions with good yield potential and higher stability are given lower value of ranking and thus considered as desirable. Accession PI-199907, PI-314650 and PI-250187 were ranked lower thus, had good stability and acceptable yield. On the other hand, safflower accessions PI-198990 and PI-210834 had relatively better yield but lesser stability than accession mentioned above due to higher rank.

Discussion

Accessions showed significant interaction with locations for days to flowering which showed that accessions revealed relative ranking for days to flowering and days to maturity (Nadeem et al., 2020). The highest days to flowering at Rawalpindi compared to other location followed by Kasur while the accessions sown at Bahawalpur showed the lowest days to flowering, showing relatively early maturing at Bahawalpur location. Days to flowering is responsive trait in safflower accessions which was shown to be affected by the environmental factors such as photoperiod and temperature (Torabi et al., 2020). Daily temperature affects the degree days accumulation (Hertel, 2019). Location

Bahawalpur is relatively warmer than the other locations along with the relatively higher photoperiod and significant. The days to flowering as an important index of adaptability to environment earlier flowering with longer reproductive period under double cropping system (Guo et al., 2020). Different studies have shown the relative importance of photoperiod and degree days accumulation indicating the days to flowering. Several authors working on various crop species such as soybean, canola, sesame safflower have demonstrated the contribution of day length for days to flowering. However, safflower is day neutral plant and early flowering may be affected by higher degrees days accumulation may have induce early flowering (Mohammadi et al., 2018). As identified in our study where warmer location induced early flowering. However, early at Bahawalpur site was not beneficial in term of seed yield that was the lowest when compared with the other sites. The highest seed yield was obtained at Kasur by accession PI-198990 followed by Faisalabad and this accession have the best adaptability at these locations. Seed yield in safflower is contributed by several components such as number of heads per plant, number of seeds per head and thousand seed weight (Mohamed & El Fadl, 2018). Seed yield is equally contributed by environment and genotype however, genotypes with better allelic combination response to environment and farm inputs in more successful and efficient way such as some accessions may have better harvest index and seed yield when compared with other accessions (Subasi & Basalma, 2021). The improvement in yield potential may only be achieved when a particular genotype release as variety utilized farm resources with the highest efficiency. Farm inputs such as fertilizer, irrigational water and plant protection measures are applied in best combination to achieve profitable yield (Gitanjali et al., 2017). Moreover, seed yield is also affected by the temperature. High temperature generally harmful for the sustainable yield and accessions which shown better resilience to abiotic factors may able to show higher yield than the other accessions. Rising temperature and carbon dioxide are the key index of climate change that drastically affect the adaptability of cultivated materials that influences the yield and yield contributing traits negatively and posing threat to food security.

Under varying climatic conditions safflower growth and development are affected by uncontrolled environmental factors however, its oil content is generally influenced by temperature fluctuations. Temperature variations are induced by sowing of safflower at different locations that influence oil content and fatty acid profile at greater extent. However, safflower under warmer location considerable change was observed on fatty acid profile particularly on oleic content that increase with the increase of temperature at expense of linoleic acid and our results are supported by (Ozturk, 2019). In our study there was significant positive correlation among number of heads per plant, thousand seed weight, biological yield and economic yield. This investigation indicating that heads per plant, thousand seed weight and seed yield can be taken as yield components. Reportedly positive correlation thousand seed weight, number of heads per plant, biological yield, harvest index, oil content, days to harvest maturity and seed yield (Karimi et al., 2013). Pushpavalli & Kumar (2017) also stated that seed yield of safflower was positively correlated with number of heads per plant, thousand seed weight, oil content and biological yield. However, positive correlation effect of yield traits was also confirmed by (La Bella et al., 2019) with number of heads per plant thousand seed and biological yield and similar findings in this study was also support our

results (Raju et al., 2019). Shakeri-Amoughin et al., 2015 concluded that positive correlation of safflower seed yield with plant height, number of heads and thousand seed weight. Even though yield components are genetically controlled, they respond to plant density in a variety of ways (Bouchet et al., 2014).
Stability is the performance of genotypes across a range of environment (Tabrizi, 2018). Accessions with the highest stability were more predictable for their performance over the year. Higher stability is preferred trait and generally varieties are determined for their stable performance under advanced yield trial as well as accession with higher stability may have greater buffering capacity against environment vagaries (Taherian & Najjar 2018). Stability by the various factors including its adaptability resilience to the abiotic stress of nutrients, irrigation, photoperiod and temperature. Genotype with highest stability and seed yield are generally considered to be highly successful cultivars to the unstable and high seed yield cultivar.Research trial was executed under different locations and stability parameters (W_i^2, σ^2_i, s^2d_i, b_i, CVi, ���R) were used to find out stable genotypes and our study is supported by (Hasan, 2021), also conduct experiment to test stability of safflower genotypes. Accession PI-199907, PI-314650 and PI-250187 are ranked lower thus, may have good stability and acceptable yield. On the other hand, PI-198990 and PI-210834 had relatively better yield but may be lesser stable than accession mentioned above and thus rank higher.

Conclusion

Concluding the results of current study, the better performer safflower accessions at Bahawalpur conditions are PI-198990 and PI-314650 whereas accessions PI-198990 and PI-210834 are optimized for Faisalabad site. Moreover, accession PI-198990, PI-314650 and PI-199907 indicated for better yield and may recommend for Kasur and Rawalpindi locations. However, concerning oil content% the accessions PI-250187 and PI-198990 have higher oil content and suggested for Bahawalpur region while accessions PI-198990 and PI-199907 for Faisalabad and PI-210834, PI-198990, PI-199907 and PI-208677 for Kasur locality while accessions PI-198990 and PI-210834 and PI-250187 are recommended for Rawalpindi area. However, stability analysis exposed accessions PI-199907, PI-314650 and PI-250187 are categorized lower thus, may have good stability and acceptable yield across the locations.

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