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EFFECT OF DIFFERENTIAL NITROGEN REGIMES ON YIELD, OIL CONTENT AND AGRONOMIC EFFICIENCY OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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Abstract

Nitrogen is an essential nutrient for plant growth and development. It is an important component of chlorophyll which is essential for photosynthesis process that enables plants to convert sunlight into energy. Nitrogen is also a key element in amino acids, which are the building blocks of proteins and it essential for the formation of new cells and tissues in plants, as well as for various metabolic processes. Henceforth, this study was planned to optimize the nitrogen requirement for safflower accessions with respect to yield, oil and agronomic efficiency of nitrogen. Experiment was arranged using split plot design by possessing nitrogen in main plot and safflower accessions sub plot and replicated thrice. Concluding the results of this study the maximum seed yield was gathered under 90 kg N ha^{-1} followed by 60 kg N ha^{-1} while the least seed yield was gathered where no nitrogen was applied. Moreover, safflower accession PI-198990 had the leading genotypes regarding seed yield whereas, accession PI-199907 was found for maximum seed oil content. Similarly, the highest agronomic efficiency and partial factor productivity of nitrogen was calculated in PI-199907 and PI-198990 respectively along with 30 kg ha^{-1} nitrogen application. Moreover, seed yield positively correlated with days to flowering (DTF), days to maturity, Branches per plant, heads per plant and 1000-seed weight (TSW). However, agronomic efficiency (AE_N) of nitrogen had the significant correlation with heads, 1000-seed weight, seed yield and oil content.

Keywords: Accessions, Nitrogen, Agronomic efficiency of nitrogen, Oil, Amino acid, seed yield.

1. INTRODUCTION

Nitrogen is key element of the proteins that make up cell material and plant tissue. Inorganic forms of nitrogen found in plants include nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+). The concept of plant organic nitrogen with respect to nutrition is mostly based on amino acid research. The physiological process of nitrogen absorption into carbon skeletons is critical for plant growth and development. Inorganic nitrogen is assimilated to amino acids such as glutamate, glutamine and asparagine which are important nitrogen transport molecules in plants (Mokhele et al., 2012). In addition, availability of mineral nutrients, especially nitrogen has a substantial impact on the output

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of an agricultural crop (Sawan, 2006; Myrold, 2021). Because nitrogen is component of amino acid which essential to make proteins and plays a critical role in all metabolic activities of plants (Lasa et al., 2002; Imran et al., 2019). Nitrogen is considered single most important nutrient that limit crop growth (Shah, 2008) and mostly plants may use nitrogen as NO_3^- and NH_4^+ however, accessible inorganic forms of nitrogen taken by the roots from the soil solution, which subsequently undergo complicated systems of assimilation, transformation and mobilization inside plants (Wickert et al., 2007; Oh et al., 2008; Yan et al., 2020).

Management of nitrogenous fertilizer has remained focused in agriculture research and extension since long. Nitrogen play critical role in plant metabolism including synthesis of chlorophyll, protein, nucleic acid, enzymes etc. (Rehman et al., 2020). However, optimization of appropriate nitrogen doses for safflower enhanced its seed yield. Nitrogen deficiency decreased the amino acid content the building block for soluble and insoluble proteins (Mu and Chen, 2020). For optimum vegetative development, safflower demands higher amount of nitrogen than other nutrients (Bitarafan et al., 2011).

Consequently, it is important to apply adequate quantity of N to ensure the maximum seed yield and quality produce. Moradi et al. (2018) identified impact of significant nitrogen management for maximizing the safflower production and oil content. Nutrient management is a critical segment for maximizing safflower production in the recent years (Mundel et al., 2004). Janmohammadi et al. (2016) described the maximum yield potential of safflower requires optimum nutrients supply even grown under water deficit conditions.

Yield levels of safflower obtained in research farms demonstrate that its production can be enhanced significantly by adopting the proper production technology. However, mostly farmers are incapable to adopt recommended production plan as directed by agriculture research sector due to some difficulties beyond their control. Safflower crop shown higher response to nitrogen than the supplementary nutrients (Koutroubas et al., 2008). Singh et al. (2003) presented that nitrogen is critical element among other nutrients for crop growth, development and seed yield.

During vegetative growth stage safflower requires sufficient amount of nitrogen than other nutrients. Bitarafan et al. (2011) studied that optimum amount of nitrogen must be applied to achieve optimal yield and high-quality product. Sufficient dose of nitrogen increased the leaf area, which results in improved solar radiation interception and efficient utilization resulting in enhanced dry matter accumulation, seed yield and yield components (Abdel-Hafiz and Hassan, 2019; Al-Zubaidy and Al-Mohammad, 2021). Taking into consideration of aforesaid discussion this study was arranged to optimize the nitrogen requirement of exotic safflower accessions under Faisalabad conditions with respect to seed yield, oil and nitrogen efficiency traits.

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2. MATERIALS AND METHODS

Experiment was set up at Agronomic Farm University of Agriculture Faisalabad to optimize the nitrogen fertilizer for safflower crop during 2nd week of November 2019. Study was planned using Split Plot Design with three replications. Experiment was executed by consisting 4 nitrogen doses (0 kg ha^{-1}, 30 kg ha^{-1}, 60 kg ha^{-1} & 90 kg ha^{-1}) and six safflower accessions. Planting was done using line to line and plant to plant distances 45 cm and 20 cm respectively. Moreover, 120 kg DAP ha^{-1} was applied and nitrogen doses were used in two splits as well as two irrigations were applied during the whole crop cycle. Moreover, soil profile and weather attributes were recorded of experimental site (Table 1 & Figure 1). Agronomic, oil and nitrogen efficiency related traits were recorded in this study which given as under.

Table 1: Soil Profile of Experimental Site

Variables	Unit	Value
Sample depth	cm	0-30
Soil type	-	Loam
Soil saturation	%	34
EC	dS m^{-1}	2.39
pH	-	7.6
Organic matter	%	1
Nitrogen	%	0.23
Phosphorus	mg kg-1	8.9
Potassium	mg kg-1	163

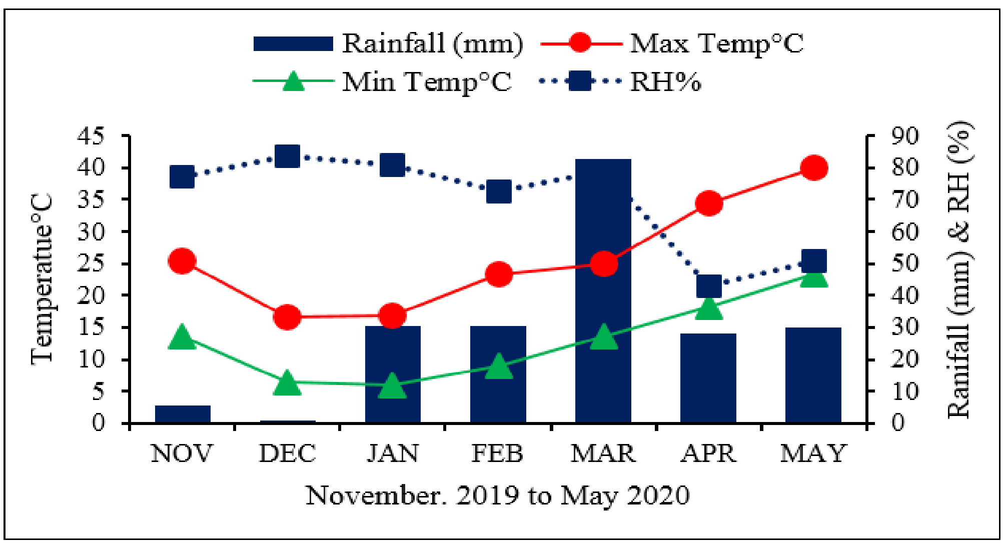

Figure 1: Weather Attributes of Experimental Site during November, 2019 to May 2020

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2.1. Oil Determination

For oil determination Soxhlet apparatus was facilitated for oil extraction of 10 g gram seed having 10% moisture content. Seed sample was crushed with the help of grinder and prepared sample was loaded on Soxhlet apparatus and left for 24 hours using n-hexane as solvent. Hereafter, for calculation of oil content the following equation of was used (Velioglu et al., 2017).

$$\text{Achene oil Content (\%)} = \frac{\text{Initial sample weight } - \text{Final sample weight}}{\text{Intial sample weight}} \times 100$$

2.2. Agronomic efficiency of Nitrogen (AE_N)

Agronomic use efficiency of nitrogen (AE_N) was determined according to following equation described by Craswell and Godwin (1984).

$$\mathbf{AE_N} = \frac{G_F - G_C}{N}$$

Where

G_F = Seed yield kg h^{-1} with fertilized plot

G_C = Seed yield kg ha^{-1} without fertilized plot

N = Amount of nitrogen kg ha^{-1}

2.3. Partial Factor of Productivity (PFP_N)

It is simplest way to measure nitrogen use efficiency and reveals units of yield per unit of nitrogen applied. Reliable statistics of nitrogen input used, and crop yields obtained, PFP_N can be calculated at the regional as well as national levels (Dua et al., 2007).

$$PFP_N = \frac{\text{Yield}}{\text{Amoutn of Nitrogen applied}}$$

2.4. Statistical Analysis

Studied data were analyzed using DSAASTAT excel extension and treatment mean compared though HSD test α 5% as well as OriginPro-2024 employed for Pearson correlation plot using two tail t-test (df-2).

3. RESULTS

Analysis of variance was executed under split plot design for assessment of safflower accessions to varying nitrogen doses on basis of their yield attributes. All studied traits were significantly ($P \leq 0.5$) influenced by nitrogen and accessions whereas interactive effects of subject parameters were also significant excluding oil content (Table 2).

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Table 2: F Value of Recorded Traits of Subject Factors Study

SOV	DF	F value									
		DF_L	DM	PH	Bran	Heads	TAW	SY	Oil	AE_N	PFP_N
Block	2	0.2	3.6	1.1	2.6	1.0	0.4	1.5	3.1	5.8	1.2
Nitrogen	3	101.7**	1082.2**	66.2**	25.3**	21.0**	9.0*	112.0**	7.3*	116.9**	2253.6**
Error a	6										
Accession	5	15.7**	80.5**	5.8**	2.8*	15.2**	42.6**	15.3**	3.0*	14.4**	32.8**
N × Acc	15	2.0*	2.2*	6.0**	2.2*	2.7**	1.9*	2.0*	1.0	3.3**	9.4**
Error b	40										
Total	71										

Here; DFL = days to flowering, DM = days to maturity, PH = plant height, Bran = branches per plant, TSW = 1000-seed weight, SY = seed yield, AEN = agronomic efficiency of nitrogen and PFPN = partial factor productivity of nitrogen

** = P≤0.01 & * = P≤0.05

3.1. Days to Flowering (days)

Interaction of nitrogen doses × accessions was also significant (Figure 2A). Nitrogen impacted the days to flowering by delaying it and extending the crop growth period. Moreover, under no external application of nitrogen, safflower accession PI-210834 took longest life cycle to flower with similar response of accession PI-198990 whereas, accession PI-199907 took the least time for flowering. At 30 kg N ha^{-1}, plants of PI-198990 took the longest duration for flowering that was not markedly different when compared with accession PI-210834 whereas, accession PI-199907 took the least days for flowering and considered as an early flowering genotype. Accessions PI-210834 and PI-198990 desired the maximum days for flowering whilst, the minimum days were counted in PI-199907 when used 60 kg N ha^{-1}. Additionally, nitrogen dose of 90 kg ha^{-1} greatly affected and safflower accessions PI-250187, PI-201834 and PI-198990 took the longest duration to flower whereas, PI-314650 was recorded with the least days to flowering.

3.2. Days to Maturity (days)

Interaction effect of differential nitrogen doses with accessions exposed that PI-314650 took the longer duration for physiological maturity with statistically at par performance of accession PI-250187 where no nitrogen was applied externally. Similarly, under control treatment, the minimum days to maturity were noted in accession PI-210834 (Figure 2B). However, at 30 kg N ha^{-1} treatment, accession PI-198990 took the longest duration to maturity and that was statistically at par with accessions PI-314650, PI-208677and PI-250187 while, the lowest number of days were recorded in accession PI-210834. At 60 kg N ha^{-1} level, safflower plants were strongly influenced for their time to maturity and accession PI-208677 had the maximum days for maturity of crop that was shown with similar response in accessions PI-2501187, PI-314650 and PI-198990 whereas, the minimum days were recorded in accession PI-210834. However, PI-208677 took the longest time to mature in response to 90 kg N ha^{-1} hence, proved late maturing when exposed to extreme nitrogen fertilization while, safflower accession PI-250187 also exhibited similar response. On the other hand, the least days were taken by accession PI-199907 to become mature hence, proved early maturing.

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3.3. Plant Height (cm)

Interaction regarding nitrogen doses and accessions was also highly significant (Figure 2C). Under control (no N application) conditions, plants of accession PI-199907 were the tallest with similar plant height of PI-250187 plants whilst the minimum plant was measured in PI-198990 accession. While comparison of accessions under 30 kg N ha^{-1} regime, emerged plant height was assessed in PI-210834 with at par response of accession PI-199907 whereas, least height was measured PI-198990. However, the longest plant was observed in PI-198990 when exposed to Under 60 kg N ha^{-1} that shown statistically at par recording in accessions PI-314650 and PI-199907 and the minimum plant height was measured by safflower accession PI-208677. At 90 kg N ha^{-1} dose, accession PI-250187 had the tallest plants followed by accession PI-208677 whereas, the least height was measured in plants of accession PI-314650.

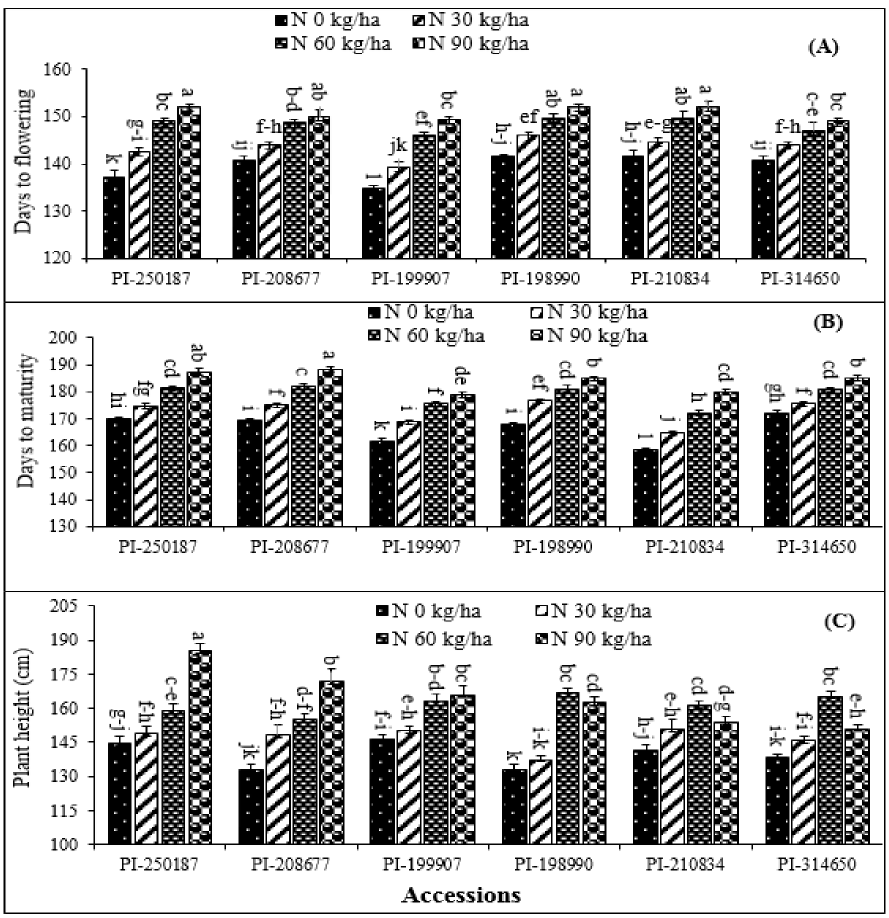

Figure 2: Effect of Nitrogen Doses on Days to Flowering (A), Days to Maturity (B) and Plant Height (C) of Safflower Accessions. Similar Alphabets on Histogram Indicated Insignificant Difference among Treatments

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3.4. Number of Branches per Plant

Nitrogen and accessions interactively affect the branching in safflower with highly significant impact, (Figure 3A). Moreover, at no external application of nitrogen, accession PI-250187 had the maximum branch count with similar trend in all other accessions excluding PI-314650 that was observed with the lowest branch count.

Whereas the maximum number of branches were collected in accession P198990 with similar and nonsignificant trend in all other accessions excluding PI-208677 in which the least number of branches were counted under both 30 and 60 kg N ha^{-1} treatments. Safflower accession PI-250187 had the maximum number of branches with statistically similar response of all other accessions when 90 kg N ha^{-1} used while, the least branches per plant were counted in accession PI-199907. Hence, accessions showed their performance according to the differential amount of nitrogen fertilizer and branches had strong influence of nitrogen treatment.

3.5. Number of Heads per Plant

Interactive effect was also observed significant (Figure 3B). Likewise, accession PI-198990 had the maximum number of heads under no application of nitrogen with similar effect of PI-199907 whereas, lowest performance regarding heads were scored in accession PI-208677. Under 30 kg N ha^{-1}, the maximum heads were counted in accession PI-250187 that was statistically at par with accession PI-198990 whereas, the least count of heads per plant was noted in accession PI-314650. Accession PI-250187 had the maximum heads under 60 kg N ha^{-1} that was statistically similar with accessions PI-198990, PI-208677 and PI-199907 and the minimum number of heads were found in accession PI-314650 under this regime. At 90 kg N ha^{-1} level, safflower accession PI-208677 was identified with the maximum heads while, the minimum heads counted was assessed in accession PI-314650.

3.6. 1000-seed Weight (g)

Analysis showed significant ($P \leq 0.5$) response for nitrogen levels and safflower accessions for 1000-seed weight. Moreover, the interactive effect was also observed as significant (Figure 3C). However, in plants with no applications of nitrogen, PI-198990 accession resulted the highest 1000-seed weight with similar value of accessions PI-210834, PI-314650 and PI-250187, while the least 1000-seed weight was measured in safflower accession PI-208677. Under 30 kg N ha^{-1} regime, the maximum value of 1000-seed weight was observed in accession PI-199907 that was statistically at par result of accessions PI-198990, PI-250187 and PI-314650 however, the minimum 1000-seed weight was observed in accession PI-208677. Furthermore under 60 kg N ha^{-1} dose, the maximum seed weight collected in accession PI-198990 that was statistically similar with accessions PI-199907 and PI-250187 and the least 1000 seed weight was observed in accession PI-208677. At 90 kg N ha^{-1}, accession PI-198990 had significantly more 1000-seed weight while, the minimum 1000-seed weight was gathered in accession PI-208677. Generally, accession PI-198990 had the higher 1000-seed weight under nitrogen

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amendments because it was bold seeded cultivar whereas, PI-199907 showed the least weight at all differential nitrogen doses due to small-seeded character.

3.7. Seed Yield (kg ha^{-1})

Generally, the maximum seed yield was gathered under 90 kg N ha^{-1} followed by 60 kg N ha^{-1} while the least seed yield was gathered where no nitrogen was applied (Figure 4). Moreover, the maximum seed yield was collected under no nitrogen application from PI-198990 followed by PI-314650 and PI-210834 whereas, the minimum seed yield was gathered in accession PI-208677. However, under 30 kg N ha^{-1} application accession PI-198990 obtained the maximum seed yield that was statistically at par with accessions PI-199907 and PI-210834 whereas, the least yield was observed in accession PI-208677. Under 60 kg N ha^{-1} strongly influenced the seed yield and accession PI-198990 exposed the maximum seed yield that was exhibited followed by accession PI-199907 while the minimum seed yield was collected in accession PI-314650. However, under 90 kg N ha^{-1} accession PI-198990 reflected the maximum yield followed by accession PI-199907 whereas, the lowest yield was accumulated in accession PI-208677.

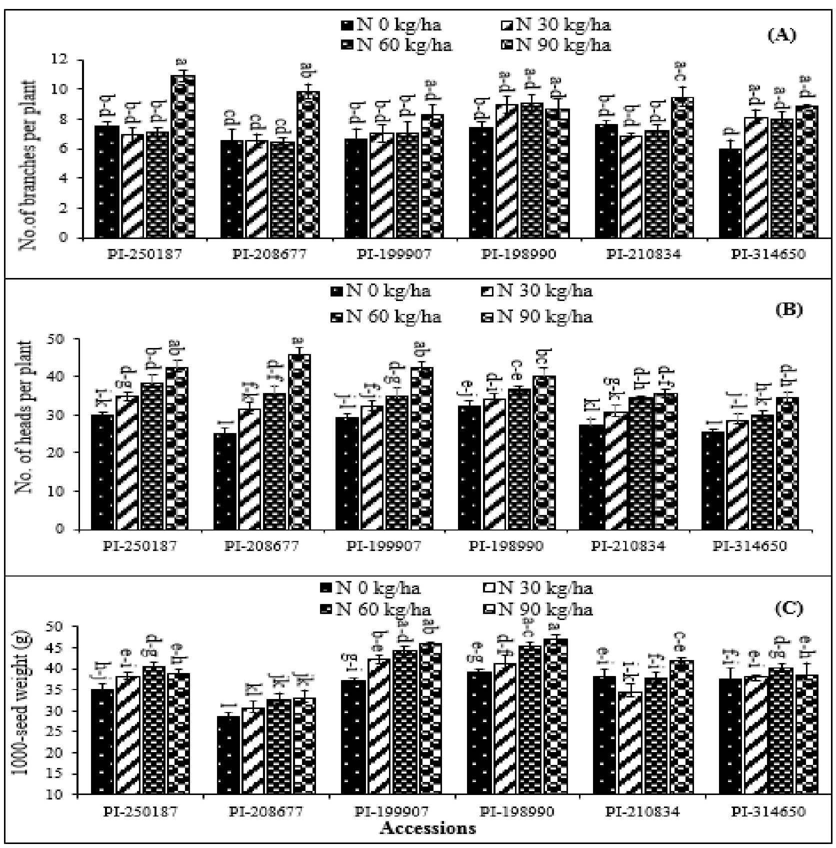

Figure 3: Effect of Nitrogen Doses on Branches per Plant (A), Heads per Plant (B) and 1000-Seed Weight (C) of Safflower Accessions. Similar Alphabets on Histogram Indicated Insignificant Difference among Treatments

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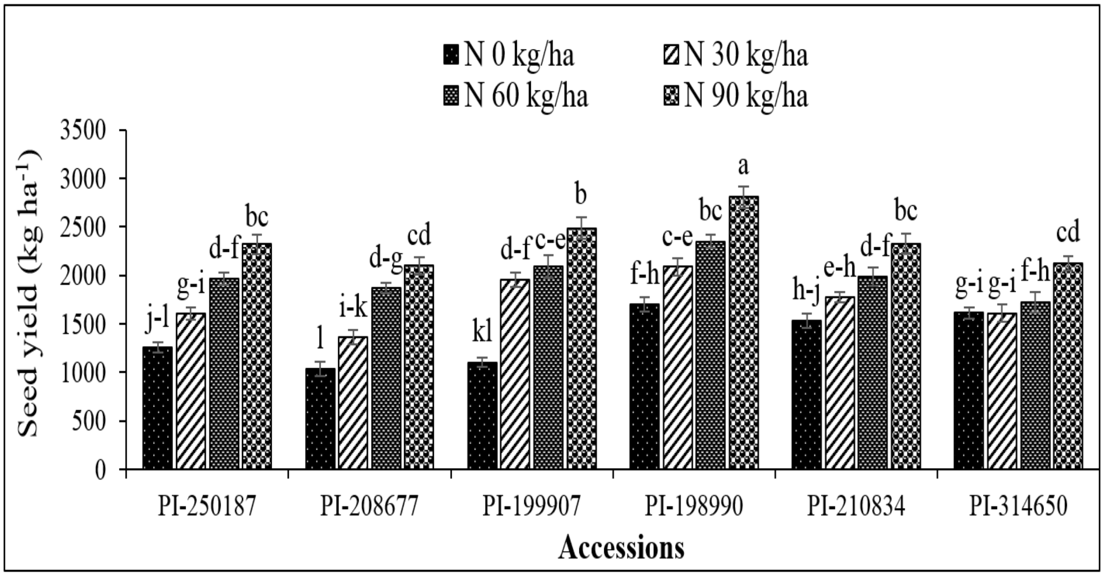

Figure 4: Effect of Nitrogen Doses Seed Yield of Safflower Accessions. Similar Alphabets on Histogram Indicated Insignificant Difference among Treatments

3.8. Seed Oil Content (%)

Data regarding oil content, safflower accession PI-199907 resulted the highest oil content followed by accessions PI-20677 and PI-210834 while, the minimum oil content was obtained from accession PI-314650 (Figure 5A). Conversely, the leading oil content was determined in plants grown under 90 kg N ha$^{-1,}$ that was resulted at par oil content from plants exposed to 60 kg N ha^{-1} whereas, the least content was collected where no nitrogen was used (Figure 5B).

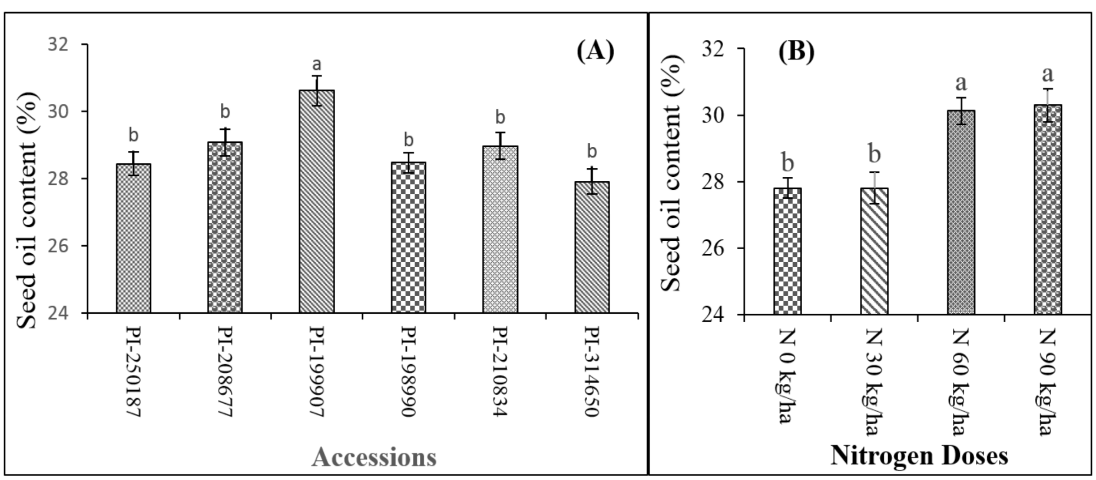

Figure 5: Effect of Safflower Accessions (A) and Nitrogen Doses (B) on Oil Content. Similar Alphabets on Histogram Indicated Insignificant Difference among Treatments

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3.9. Agronomic Efficiency of Nitrogen (AE_N)

Interaction of nitrogen doses × accessions was also found significant (Table 2). Agronomic efficiency of nitrogen in regime where no external nitrogen is applied (Control) could not be calculated for being the baseline for other subtractions and agronomic efficiencies for other doses employed. However, under 30 kg N ha^{-1} the maximum agronomic efficiency was calculated in respect of PI-199907 and the minimum agronomic efficiency was measured in accession PI-314650. Under 60 kg N ha^{-1} statistically, accession PI-199907 had the highest agronomic efficiency of nitrogen with similar response to accession PI-208677 while, the least efficiency was observed in accession PI-314650. Under 90 kg N ha^{-1}, the highest agronomic efficiency was calculated in accession PI-199907 which was statistically at par with PI-198990, PI-208677 and PI-250187 accessions while, the lowest agronomic efficiency was calculated in accession PI-314650.

3.10. Partial Factor Productivity of Nitrogen (PFP_N)

Interaction effect of nitrogen doses × accessions was also found significant (Table 3). As per its formula as mentioned in chapter 3, the PFP_N cannot be derived in respect of no application of N level i.e. control. However, for 30 kg N ha^{-1} regime, accession PI-198990 was having the highest PFP_N followed by accessions PI-199907 and PI-210834 whereas, the lowest value of PFP_N was determined in accession PI-208677. For 60 kg N ha^{-1} treatment, accession PI-198990 had the maximum PFP_N which was statistically at par with accessions PI-199907 and PI-210834 whereas, the minimum PFP_N value was calculated by accession PI-314650. Under 90 kg N ha^{-1}, the highest PFP_N was determined in safflower accession PI-198990 which was statistically similar with accession PI-199907 for PFP_N while the lowest PFP_N value was calculated in safflower crop belonging to PI-208677.

Table 3: Effect of Differential Nitrogen Doses on Agronomic Efficiency of Nitrogen (AE_N) of Safflower

Treatments	N 0 kg/ha	N 30 kg/ha	N 60 kg/ha	N 90 kg/ha
PI-250187	**-**	12.38 c-f	11.72 c-g	11.98 c-g
PI-208677	**-**	10.86 c-g	13.86 b-e	11.83 c-g
PI-199907	**-**	28.01 a	18.13 b	15.25 b-d
PI-198990	**-**	15.58 bc	10.80 c-g	12.28 c-f
PI-210834	**-**	8.02 f-h	10.21 d-h	8.84 e-h
PI-314650	**-**	6.69 gh	5.23 hi	6.74 gh

Similar alphabets on histogram indicated insignificant difference among treatments computed through HSD test.

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Table 4: Effect of Differential Nitrogen Doses on Partial Factor Productivity of Nitrogen (PFP_N) of Safflower Accessions

Treatments	N 0 kg/ha	N 30 kg/ha	N 60 kg/ha	N 90 kg/ha
PI-250187	**-**	54.28 d	32.67 gh	25.95 jk
PI-208677	**-**	45.31 e	31.09 hi	23.31 k
PI-199907	**-**	65.10 b	36.68 f	27.62 ij
PI-198990	**-**	72.25 a	39.13 f	31.16 hi
PI-210834	**-**	59.11 c	35.75 fg	25.87 jk
PI-314650	**-**	57.36 cd	30.57 hi	23.63 k

Similar alphabets on histogram indicated insignificant difference among treatments computed through HSD test.

3.11. Correlation Analysis

Pearson correlation was performed to estimate the association among phenological, morphological, yield, oil, and nitrogen efficiency traits (Figure 6**)**. In this study, traits such as number of heads (Heads) and branches (Bran) on individual plant basis were having high and positive correlation with plant height (PH) and days to maturity (DTM) and exposes those accessions with higher branches were having greater number of heads. Moreover, seed yield positively correlated with days to flowering (DTF), DTM, PH, branches per plant, heads per plant and 1000-seed weight (TSW) showing that these safflower accessions were having higher 1000-seed weight and branches which are yield contributing traits along with the highest seed yield. However, oil content (Oil) significantly positively correlated with number of DTF, plant height (PH), heads per plant (Head) and seed yield (SY) suggesting that safflower accessions were having higher seed yield were found with higher seed oil content. Agronomic efficiency (AE_N) of nitrogen had the significant correlation with heads, 1000-seed weight, seed yield and oil content.

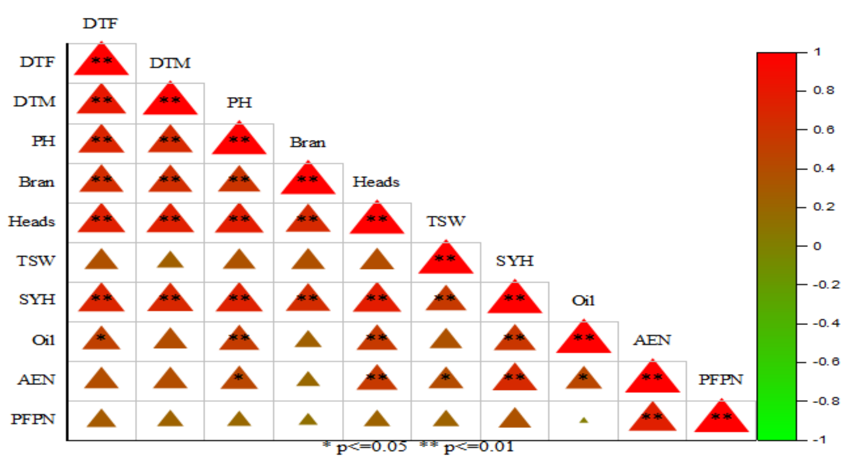

Figure 6: Pearson Correlation Analysis of Days to Flowering (DTF), Days to Maturity (DTM), Plant Height (PH), Branches Per Plant (Bran), Heads Per Plant (Heads), Seed Yield Per Hectare (SYH), 1000-Seed Weight (TSW, g), Oil Content (Oil%), Agronomic Efficiency (AE_N) and Partial Factor Productivity (PFP_N)

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4. DISCUSSION

Application of nitrogen considerably affected the plant height across the safflower accessions. Increasing trend in plant height was observed under increased nitrogen doses. Application of 90 kg N ha^{-1} significantly contributed in plant height whereas, the least plant height was measured in control plants where no nitrogen was applied. Results showed that nitrogen is important plant nutrient responsible for growth and phenological traits of field crops.

This increase in plant height in parallel to increased nitrogen doses may be attributed to nitrogen influence at cell and tissue level growth where basic building blocks such as amino acids and proteins desire nitrogen and hence contribute to the biomass according to its provision. In general, nitrogen is elementally ranked for support to the vegetative growth associated with other growth factors. Similar, the growth and prolonged vegetative impact on plant life is also reported by Eryigit et al. (2015) as well as by Katar et al. (2012) and Bitarafan et al. (2011). Nitrogen in higher doses have considerable increasing impact on number branches per plant.

Elfadl et al. (2009) opined that number of branches are significantly higher under excessive application of nitrogen which matches the aptitude of safflower plants in this study in response to excessive dose of 90 kg N ha^{-1} and found for setting highest branches per plant. Plant branching habit was equally found responding to the higher nitrogen doses under different studies too and proved a nitrogen responsive trait (Eryigit et al., 2021; Elfadl et al*.,* 2009; Mohammad et al., 2012).

Incremental effects of increased nitrogen doses progressively impacted the yield and yield contributing traits of safflower in this study. This could only happen due to the efficient response at plant level where physiological and biochemical processes were considered responsible for such nitrogen utilization.

Meaningfully, heads per plant were found the highest under the maximum nitrogen dose applied. However, nitrogen sufficiency, found from 60 kg N ha-1 onward and supports the finding of Bitarafan et al. (2011) who consistently observed the differential responses of the plant to the nitrogen levels and emphasized in detail regarding efficient use of nitrogen for getting more yields through setting of more heads per plant. Moreover, increased in yield refers to a strong correlation of other traits important for such contribution either directly or indirectly.

The strong correlation between seed yield and the number of heads and branches suggests that these factors significantly contribute to increased yield. Rastgou et al. (2013) quoted that increased use of nitrogen fertilizer was reflected in increased count of heads per plants. Ebrahimian and Soleymani (2013) opined that higher heads per plant was counted with the application of 150 kg N ha^{-1} for being increased nitrogen fertilizer dose.

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Similar to this, contribution of increased nitrogen dose to 1000-seed weight, biological and seed yield is well reported and confirmed by literature (Mohamed et al., 2012; Khalil et al., 2013 and Eryigit et al., 2014). In addition to the yield contribution traits, significant triggering of physiological activities including photosynthesis, respiration and gaseous exchange traits was observed leading to enhanced source sink relationship and statistics reflecting yield got improved. Increased nitrogen increased 1000-seed weight to a major extent and proved that the assimilation of photosynthates is getting efficiently done by means of supplying nitrogen in bulk (Mohamed et al., 2012).

Such addition to the biomass through better assimilation of photosynthates and improved source sink relationship is being reflected in the form of better seed yield. Safflower is found to be a nitrogen use efficient plant where meager amounts of fertilizer application robustly contribute to plant growth and development however, the economic threshold level is not reflected in this study as yield contributing traits were found increasing with increased nitrogen levels even to the maximum administered in this experiment and support the results of Sampaio et al. (2016).

Abd El-Mohsen and Mahmoud (2013) also found the response of safflower to nitrogen application for enhanced seed yield where positive significant correlation between plant height, number of heads and 1000-seed weight was framed that agrees with the outcomes of this experiment (Afzal et al., 2017).
Similarly, relationship resulted in this study showing significant positive correlation of oil content with plant height, heads number and seed yield is strongly endorsed by Sampio (2016) who exposed that the yield components positively contributed to oil yield of safflower.

5. CONCLUSION

Nitrogen is proved equally important macronutrient for safflower as for other field crops. Increased nitrogen uses improved growth, yield and yield contributing traits of safflower even up to 90 kg N ha^{-1} For safflower accessions exposed to no external N application, PI-199907 gathered the highest yield with similar response to accession PI-198990 whereas, under 30 kg N ha^{-1} level, accession PI-199907 was the best yielder followed by accession PI-198990 whereas, accessions PI-198990 and PI-199907 performed better when exposed to 60 kg N ha^{-1}. For 90 kg N ha^{-1} regime, safflower accession PI-250187 performed as leading genotype and the minimum yield was observed in accession PI-145650.

6. CONFLICT OF INTEREST

The Authors have no Conflict of Interest

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