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Research Article

Variability for Oil Content and Fatty Acid Composition in Diverse Accessions of Niger (*Guizotia abyssinica* L.f. Cass)

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Niger is a minor oilseed crop primarily grown in Ethiopia and India. The oil content in niger seeds ranges from 32% to 47%. Niger oil has several nutritional and therapeutic benefits. Despite these benefits, the crop has been widely neglected by breeders due to its low productivity. Therefore, understanding the extent of genetic variability within the niger germplasm is a prerequisite for selecting superior genotypes and enhancing productivity. The present experiment was conducted at the ICAR-Indian Institute of Oilseeds Research, Hyderabad, Telangana, during the kharif seasons of 2022 and 2023. The study used an augmented randomized complete block design (ARCBD) with 111 accessions and four checks to assess variability in oil content and fatty acid composition. The analysis of variance showed significant differences among the accessions. Oil content ranged from 26.1% to 44.8%, with the highest oil content recorded in IC260240 (44.8%). Unsaturated fatty acids, such as linoleic and oleic acids, constituted the major portion of fatty acids among the accessions. The presence of a higher amount of unsaturated fatty acids indicates low susceptibility to autoxidation and confers a therapeutic advantage to niger oil. The accessions IC260250 and IC211053 exhibited high levels of linoleic and oleic acid content, respectively. Based on the Euclidean distance matrix method, the accessions were grouped into six hierarchical clusters. Cluster II had the highest number of accessions (34), followed by Cluster IV with nine accessions. The maximum genetic distance was observed between Clusters III and VI. Palmitic and stearic acids showed a significant positive correlation, whereas linolenic acid and oleic acid exhibited a significant negative correlation. No discernible variations were observed in the fatty acid composition among the accessions during the two seasons. The elite accessions identified from this study can be utilized as donors in the niger oil quality improvement program.

Keywords: clustering; fatty acid composition; genetic variability; *Guizotia abyssinica*; oil content

1. Introduction

Oilseed crops are a major source of nutrients for humans. The major oilseeds that dominate world markets are soybean, rapeseed and mustard, groundnut, and sunflower. However, as the world population continues to rise, these major oilseeds may not be able to meet the growing demands. This has renewed interest in newer sources of edible

oils [1]. Most niche crops, such as sesame, niger, safflower, and linseed, have low productivity levels. Hence, increasing the production of these edible oilseed crops is crucial to meet market demands [2].

Niger (*Guizotia abyssinica* Cass L.; $2n = 30$) is a minor oilseed crop that originated in the highlands of Ethiopia and has spread to other parts of the world. It belongs to the family Asteraceae, which includes other economically important crops such as sunflower, safflower, lettuce, and chrysanthemum. The niger crop is erect and stout, primarily grown for its edible oil and seeds. The small, black-colored seeds have an adherent seed coat and can be stored for long periods without deterioration. Niger seeds, called achenes, contain 32%–47% oil, 10%–25% protein, 12%–18% sugar, and 10%–20% crude fiber [3]. The oil is pale yellow or orange, with a nutty taste and sweet odor. Niger oil is rich in linoleic acid (45.5%–65.8%), oleic acid (13.4%–39.3%), stearic acid (5%–7.5%), and palmitic acid (5.8%–13%) [4]. Ethiopian niger genotypes are reported to have more than 70% linoleic acid content, whereas Indian niger genotypes have less than 70% [4]. Mono- and polyunsaturated fatty acids account for over 90% of the fatty acids in niger, which are highly valued for their role in reducing the risk of coronary heart diseases. Oleic acid has reported to decrease atherosclerosis [5]. Despite these benefits, niger crop production is limited due to its cultivation on marginal lands with minimal inputs, lack of improved cultivars suitable for diverse agroclimatic conditions, Cuscuta infestation, shattering nature, low harvest index, and the presence of self-incompatibility and nondeterminant types. Additionally, it is challenging for breeders to create high-yielding cultivars due to a lack of exploitable genetic diversity.

Even though the large number of niger accessions are available in India, limited or no research has been done to determine their oil content and fatty acid composition. This will be the first report on the study of oil content and fatty acids in a large set of niger accessions. The primary goal of the current study is to assess the oil content and fatty acid composition of the 111 potential niger accessions, including four checks.

2. Materials and Methods

2.1. Plant Materials. A total of 107 diverse niger accessions augmented from the Project Coordinating Unit for Sesame and Niger, Jabalpur, India. These accessions were collected from different parts of India by PC unit, Jabalpur (Table 1).

2.2. Experimental Design. A field experiment was conducted using an augmented randomized block design along with four checks (JNS-9, JNS-28, JNS-30, and IGPN-2004-1) during the kharif seasons of 2022 and 2023 at the Indian Institute of Oilseeds Research, Hyderabad, Telangana, India (latitude 17° 15′ 16″, longitude 78° 18′ 30″, and altitude 536 m). Two years of weather data for this location are presented in Figure 1. Plants were sown in well-drained red soil, with rows planted 45 cm apart and seeds placed 10 cm apart along each row. To evaluate oil content, seeds were harvested from five plants from each accession at physiological maturity and dried.

2.3. Fatty Acid Determination. The first step is to convert the fatty acids to their methyl ester forms. 0.1 g of individual oil samples was mixed with 0.5 mL of 2N methanolic potassium hydroxide and 3 mL of hexane. The mixture was vortexed and allowed to settle. The supernatant containing hexane was then separated, and 1 mL of it was injected into a gas chromatograph (Agilent 7860A, Santa Clara, California, the United States of America). A capillary column was used with nitrogen as the carrier gas at 1 mL/min, and detection was done with a flame ionization detector (FID). The injector, detector, and oven were maintained at 230°C, 250°C, and 210°C, respectively [6]. The fatty acid composition was determined by identifying and calculating relative peak areas using ChemStation software.

2.4. Seed Oil Determination. The seed oil analysis was done using the Soxhlet extraction method. Niger oil was obtained by chemical extraction, where 10 g of decoated seeds were crushed and extracted with hexane solvent for 4 h using a Soxhlet extractor. The oil extract was then dried under low pressure at 70°C in a rotary evaporator until the solvent was eliminated [6]. The weight of the oil was recorded, and the oil content was calculated using the following formula:

$$\text{Oil content (\%)} = \frac{(\text{weight of flask with oil} - \text{weight of empty flask})}{\text{weigth of ground seeds}} \times 100. \quad (1)$$

2.5. Statistical Analysis. Statistical analysis of the data was performed using packages in R v4.3.2 software. As the experiment was conducted using an ARCBD, the analysis was done using the R package version 0.1.7 "augmentedRCBD" [7]. The cluster analysis used the R package version 4.2 "Biotools" [8]. Pearson's correlation coefficient was used to analyze the correlation between the oil and fatty acid contents using the R package "metan" [9].

3. Results

3.1. Analysis of Variance. Two years of analyses of variance revealed significant differences in the mean sum of squares ($p < 0.05$) for all the biochemical traits studied in the experiment (Tables 2a and 2b). Significant differences were found in genotype and environment interactions. The effect of the environment on fatty acid composition is presented in Table 2c.

Table 1: The list of niger accessions and their passport data.

S. No	Acc. No	Acc. Name	Place of collection/passport data
1	5	IC864	Gwalior, Madhya Pradesh
2	9	IC15794	Amrapara, Pakur, Jharkhand
3	10	IC15795	Littipara, Hiranpur, Pakur, Jharkhand
4	11	IC15796	Littipara, Hiranpur, Pakur, Jharkhand
5	13	IC15798	Lathiar, Palamau, Jharkhand
6	14	IC15799	Netarhat, Latehar, Jharkhand
7	19	IC16395	Tuppa, Nanded, Maharashtra
8	22	IC16398	Pali Bhir, Raigad, Maharashtra
9	23	IC16399	Bownepangia, Maharashtra
10	25	IC16401	Umarkot
11	41	IC23674	Kondagaon, Jagdalpur, Madhya Pradesh
12	43	IC25629	Karjat, Raigad, Maharashtra
13	45	IC26295	Guralin, Dharwad, Karnataka
14	46	IC26296	Hubli, Dharwad, Karnataka
15	52	IC33557	Bawada, Kolhapur, Maharashtra
16	53	IC33674	Hattangi, Hukkeri, Belgaum, Karnataka
17	58	IC33774	Undale, Karad, Satara, Maharashtra
18	60	IC33804	Alsuli, Khandala, Satara, Maharashtra
19	66	IC34026	Chikalohal, Malegoan, Nashik, Maharashtra
20	67	IC34084	Chandigarh, Kolhapur, Maharashtra
21	76	IC42077	Thapa, Betul, Madhya Pradesh
22	80	IC42082	Singanama, Hoshangabad, Madhya Pradesh
23	89	IC49569	Asgani, Khed, Ratnagiri, Maharashtra
24	105	IC53563	Bagicha, Jushpimga, Raigarh, Chattisgarh
25	115	IC53573	Dahikinga Kondagaon, Bastar, Chattisgarh
26	121	IC55395	Khed, Osmanabad, Maharashtra
27	128	IC55410	Bhulai, Darwha, Yavatmal, Maharashtra
28	136	IC58622	Gorubathan, Darjeeling, West Bengal
29	142	IC59052	Selga, Ranchi, Bihar
30	153	IC59067	Morangi, Hazaribagh, Jharkhand
31	154	IC59068	Morangi, Hazaribagh, Jharkhand
32	155	IC59069	Morangi, Hazaribagh, Jharkhand
33	158	IC59072	Miantu, Hazaribagh, Jharkhand
34	169	IC74953	Tarpal,Udaipur, Rajasthan
35	177	IC74961	Bhagpura, Dholpur, Rajasthan
36	183	IC74967	Samod, Jaipur, Rajasthan
37	185	IC74969	Jaswantgarh, Nagaur, Rajasthan
38	187	IC74971	Jakra, Jaipur, Rajasthan
39	188	IC74972	Bhanpura, Udaipur, Rajasthan
40	189	IC74973	Kaithana, Rajasthan
41	215	IC75008	Deogarh, Rajsamand, Rajasthan
42	221	IC75014	Rampura, Bhilwara, Rajasthan
43	222	IC96247	Thambong, West Sikkim, Sikkim
44	228	IC96263	Dohana, Sarguja, Madhya Pradesh
45	235	IC96272	Akola, Maharashtra
46	237	IC96274	Malwada, Thane, Maharashtra
47	242	IC105288	Sujua, Hazaribagh, Jharkhand
48	248	IC105634	Banda, Ranchi, Bihar
49	252	IC110527	Bangalore, Bengaluru, Karnataka
50	267	IC119801	Akola, Maharashtra
51	270	IC119911	Raigad, Maharashtra
52	275	IC119921	Parbhani, Maharashtra
53	281	IC119935	Gulbarga, Karnataka
54	282	IC119938	Meelak, Karnataka
55	285	IC203172	Kathara, Sundergarh, Odisha
56	288	IC203177	Bindisahi, Akola, Maharashtra
57	292	IC211050	Banguruguda, Ranchi, Jharkhand
58	294	IC211053	Maliput, Akola, Maharashtra
59	298	IC211066	S. Bilaput

Table 1: Continued.

S. No	Acc. No	Acc. Name	Place of collection/passport data
60	304	IC267555	Ranchi, Jharkhand
61	306	IC267558	Akola, Maharashtra
62	310	IC268287	Akola, Maharashtra
63	313	IC268292	Akola, Maharashtra
64	330	IC274989	Akola, Maharashtra
65	331	IC274990	Ranchi, Jharkhand
66	332	IC274991	Odisha
67	334	IC274995	Geedam, Odisha
68	343	IC275006	Tokapal, Andhra Pradesh
69	345	IC275010	Tokapal, Rajasthan
70	348	IC275014	Parli, Bastar, Chattisgarh
71	354	IC298407	Badabandha, Kandhamal, Odisha
72	359	IC298468	Rupakana, Rayagada, Odisha
73	360	IC298483	Khilaguda, Koraput, Odisha
74	369	IC320979	Lurgami/Mahuatand, Palamau, Jharkhand
75	370	IC321671	Lahabadi, Kandhamal, Odisha
76	379	IC342806	Majrahi/Tandwa, Hazaribagh, Jharkhand
77	385	IC343126	Dorma/Torpa, Khunti, Jharkhand
78	387	IC343128	Kanijadi/ Mander, Ranchi, Jharkhand
79	391	IC344153	Mau, Ratnagiri, Maharashtra
80	403	IC353792	Kombai, Vellore, Tamil Nadu
81	409	IC385811	Bhelpur/Mihijam, Jamtara, Jharkhand
82	410	IC385901	Lowermanjhiara, Dumka, Jharkhand
83	411	IC400169	Keonjhar, Odisha
84	426	IC413089	Harichand Naik thanda, Zaheerabad, Medak, Telangana
85	434	IC413101	Papdiyalathanda, Zaheerabad, Medak, Telangana
86	435	IC413103	Papdiyalathanda, Zaheerabad, Medak, Telangana
87	437	IC413113	Magdampally, Jarasangham, Medak, Telangana
88	439	IC413120	Zaheerabad, Zaheerabad, Medak, Telangana
89	449	IC413148	Raipally, Zaheerabad, Medak, Telangana
90	453	IC413156	Peyalaram, Jarasangham, Medak, Telangana
91	461	IC417196	Anusona, Denkanikota, Dharmapuri, Tamil Nadu
92	475	IC499210	Unknown
93	477	IC499212	Unknown
94	478	IC499213	Balipurva, Mirzapur, Uttar Pradesh
95	481	IC499216	Unknown
96	483	IC499218	Unknown
97	484	IC499219	Unknown
98	486	IC499222	Unknown
99	495	IC499232	Unknown
100	505	IC0203170	Khamandih, Sundergarh, Odisha
101	515	IC0210976	Tamarada, Akola, Maharashtra
102	532	IC0259385	Hyderabad, Rajendernagar, Andhra Pradesh
103	537	IC260240	Hyderabad, Rajendernagar, Andhra Pradesh
104	541	IC260245	Hyderabad, Rajendernagar, Andhra Pradesh
105	546	IC260250	Jabalpur, Madhya Pradesh
106	567	IC0262481	Akola, Maharashtra
107	569	IC0262483	Akola, Maharashtra
108	*C1	JNS-9	Jabalpur, Madhya Pradesh
109	*C2	JNS-28	Jabalpur, Madhya Pradesh
110	*C3	IGPNC-2004-1	Maharashtra
111	*C4	JNS-30	Jabalpur, Madhya Pradesh

* indicates the four genotypes used as "checks" in the experiment.

3.2. Oil Content. The seed oil content of 107 accessions and four checks are listed in Table 3. The accessions showed significant variations in oil content ($p < 0.05$). The mean oil content was 37.1%, ranging from a minimum of 26.1% in accession IC413156 to a maximum of 44.8% in accession IC260240 (Table 3). The average oil content in 2022 and 2023 was 39.9% and 34.3%, respectively.

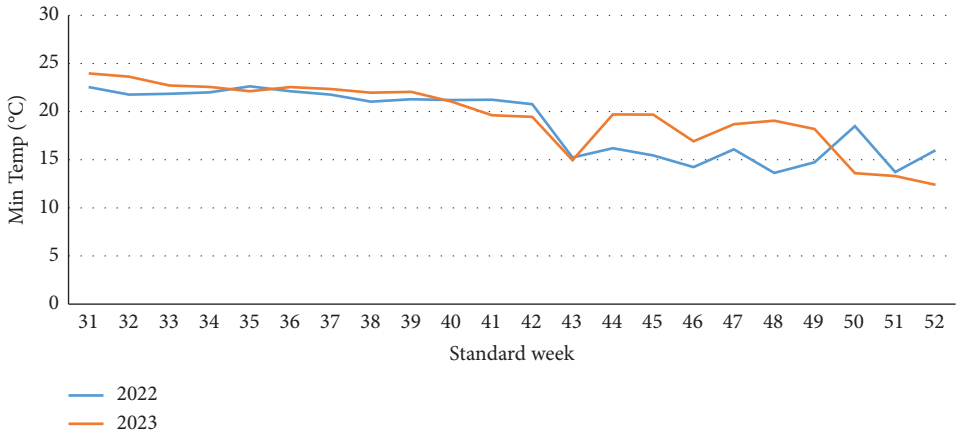


Figure 1: Average minimum temperature during crop period.

Table 2a: Analysis of variance for various biochemical traits during the year 2022.

Source	Df	Mean. Sq					
		OC	PA	SA	OA	LL	LLNIC
Treatment Adjusted							
Blocks (ignoring treatments)	4	11.60*	1.76**	0.49**	17.50**	17.59*	0.07**
Treatments (eliminating blocks)	110	13.63**	0.94*	0.84**	22.28**	25.08**	0.07**
Treatment: Checks	3	18.09**	1.58*	1.69**	11.21*	9.88^{ns}	0.02**
Treatment: Test and test vs. check	107	13.50**	0.92*	0.82**	22.59**	25.51**	0.08**
Residuals	12	2.64	0.30	0.06	2.64	5.01	0.00
Blocks Adjusted							
Treatment (ignoring blocks)	110	13.68**	0.98*	0.86**	22.75**	25.66**	0.08**
Treatment: Check	3	18.09**	1.58*	1.69**	11.21*	9.88^{ns}	0.02**
Treatment: Test	106	13.68**	0.97*	0.84**	20.94**	24.26**	0.08**
Treatment: Test vs. check	1	0.00^{ns}	0.01^{ns}	0.09^{ns}	248.66**	221.27**	0.25**
Blocks (eliminating treatments)	4	10.23*	0.63^{ns}	0.12^{ns}	4.48^{ns}	1.68^{ns}	0.00^{ns}
Residuals	12	2.64	0.30	0.06	2.64	5.01	0.00

Abbreviations: Df, degrees of freedom; LL, linoleic acid; LLNIC, linolenic acid; OA, oleic acid; OC, oil content; PA, palmitic acid; SA, stearic acid.
$^{ns}p > 0.05$.
$^{*}p \leq 0.05$.
$^{**}P \leq 0.01$.

Table 2b: Analysis of variance for various biochemical traits during the year 2023.

Source	Df	Mean.Sq					
		OC	PA	SA	OA	LL	LLNIC
Treatment Adjusted							
Block (ignoring treatments)	4	15.4*	0.4**	0.2^{ns}	37.2**	53.7**	0.1**
Treatment (eliminating blocks)	110	26.6**	0.7**	0.9**	32.9**	30.1**	0.1**
Treatment: Check	3	1.4^{ns}	1.1**	0.4*	3.1^{ns}	3.8*	0.02**
Treatment: Test and test vs. check	107	27.3**	0.7**	0.9**	33.8**	30.8**	0.1**
Residuals	12	2.9	0.08	0.1	2.1	0.8	0.00
Block Adjusted							
Treatment (ignoring blocks)	110	26.7**	0.7**	0.9**	33.9**	30.1**	0.1**
Treatment: Check	3	1.4^{ns}	1.1**	0.4*	3.1^{ns}	3.8*	0.02**
Treatment: Test	106	25.3**	0.7**	0.7**	30.3**	28.5**	0.1**
Treatment: Test vs. check	1	247.3**	0.1^{ns}	18.9**	510.2**	281.2**	1.4**
Block (eliminating treatments)	4	13.7*	0.12^{ns}	0.04^{ns}	9.6*	52.2**	0.00^{ns}
Residuals	12	2.9	0.1	0.1	2.1	0.8	0.00

Abbreviations: Df, degrees of freedom; LL, linoleic acid; LLNIC, linolenic acid; OA, oleic acid; OC, oil content; PA, palmitic acid; SA, stearic acid.
$^{ns}p > 0.05$.
$^{*}p \leq 0.05$.
$^{**}P \leq 0.01$.

Table 2c: Combined analysis of variance for genotype and environment interaction with various biochemical traits.

Source	Df	OC	PA	SA	OA	LL	LLNIC
ENV	1	1640.210	0.451	20.956	161.404	69.854	0.194
GEN	110	26.475**	1.055**	1.183**	45.810**	45.635**	0.118**
GEN:ENV	110	13.907**	0.606**	0.572**	10.904**	10.172**	0.032**
Residuals	24	2.772	0.187	0.076	2.370	2.929	0.001

Note: GEN: ENV, genotype × environment.
Abbreviations: Df, degrees of freedom; ENV, environment; GEN, genotype; LL, linoleic acid; LLNIC, linolenic acid; OA, oleic acid; OC, oil content; PA, palmitic acid; SA, stearic acid.
ns $p > 0.05$.
* $p \leq 0.05$.
** $p \leq 0.01$.

3.3. Fatty Acid Composition. The average fatty acid content for 2 years is presented in Table 3. The predominant fatty acids in the niger accessions were linoleic (C18:2) and oleic (C18:1), averaging 61.4% and 26.2%, respectively. Linoleic acid content ranged from 45.4% in IC211053 to 69.0% in IC260250. Oleic acid content varied from 16.8% in IC260250 to 42.1% in IC211053. As the minimum temperature decreased, oleic acid content decreased, while linoleic acid content increased (Table 3 and Figure 1). The lowest palmitic acid content was observed in IC0262481 (6.6%) and the highest in IC16398 (9.7%), with an average of 8.1%. The average stearic acid content was 3.9%, ranging from 2.6% in IC55410 to 6.9% in IC16398 (Table 3). Stearic acid content increased in 2023 compared to 2022 (Figure 2).

3.4. Cluster Analysis Using Euclidean Distance Matrix. The dendrogram generated using the Euclidean distance matrix method classified the 111 niger genotypes (107 accessions and 4 checks) into six hierarchical clusters based on biochemical traits. Cluster II had the highest number of accessions (34), followed by Clusters III and V (20 accessions each). Cluster IV had fewer accessions (9) than the others (Table 4 and Figure 3).

3.5. Cluster Mean Values for Biochemical Traits. The cluster means for different biochemical traits are presented in Table 5. A wide range of mean values between the clusters were recorded for biochemical traits. Cluster I manifested the highest mean values for linoleic acid while Cluster III showed high mean values for oleic acid content. Cluster V had a high mean for palmitic and stearic acid content. Highest mean oil content was observed in Cluster IV. There was no significant difference between Clusters II, IV, and VI for oil content trait, and these three clusters varied significantly with remaining clusters.

3.6. Average Inter- and Intracluster Distances Among the Clusters. The average intercluster and intracluster distances are shown in Table 6. Clusters III and VI had the greatest intercluster distance (4.72), while Clusters I and III had the smallest intercluster distance (2.79). The intracluster distance ranged from 1.95 (Cluster III) to 2.71 (Cluster VI).

3.7. Correlation Among the Biochemical Traits Analyzed. Analysis of correlation coefficients showed a significant ($p < 0.05$) positive correlation between palmitic acid and stearic acid (Figure 4). Additionally, there was a significant negative correlation between linoleic and oleic acid content, as well as between stearic acid and oil content.

4. Discussion

The success of an oilseed is often measured by the quantity and quality of its seed oil content. Seed oil content is reported to be medium to highly heritable [10]. A high diversity of seed oil content has been observed among plant species, ranging from 4% of dry weight in wheat to over 60% in castor [11]. A significant amount of diversity was observed among the genotypes for oil content in the present study. Niger seed has previously been reported to have an oil content of 27%–47% of dry seed weight [12].

4.1. Analysis of Variance. The statistical analysis of fatty acid content revealed significant differences among the studied accessions ($p < 0.05$) for all traits. The results suggest that a sufficient variation exists among the accessions for the studied biochemical traits, indicating a scope for effective selection. Similarly, significant variation was observed for oil content and fatty acid composition in a study of niger genotypes [13]. As the minimum temperature increased during the second year, fatty acid accumulation also increased, showing significant variation due to genotype and environmental interaction. Similar results were observed in a study of oilseed rape varieties [14].

4.2. Oil and Fatty Acid Content. The oil content ranged from 26.08% to 44.75%, with an average of 37.08% over both years. In India, 27 niger cultivars have been released so far, with the highest observed oil content being about 38%. The accession IC260240, with an oil content of 44.75%, can serve as a potential donor for the high oil content trait. Additionally, transgressive segregants for the oil content trait could be recovered by crossing the low oil content accession IC413156 (26.08%) with a high oil content genotype. The results from the present study suggest the possibility of enhancing niger's oil output volume without expanding the cultivation area by substituting low oil content populations with high oil content genotypes.

Table 3: Oil and fatty acid composition of the Niger accessions used in the study.

S.No	Acc. No	Acc. Name	Oil content			Palmitic			Stearic			Oleic			Linoleic			Linolenic		
			2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
1	5	IC864	36.7	34.5	35.6	6.7	7.0	6.9	4.6	5.4	5.0	27.2	24.6	25.9	61.2	62.7	61.9	0.3	0.4	0.3
2	9	IC15794	39.6	33.1	36.3	7.0	8.2	7.6	2.2	5.0	3.6	29.5	24.1	26.8	61.2	62.6	61.9	0.1	0.2	0.2
3	10	IC15795	41.1	37.6	39.4	7.6	7.7	7.6	4.5	4.9	4.7	25.4	21.2	23.3	62.3	66.0	64.2	0.3	0.3	0.3
4	11	IC15796	38.1	36.4	37.3	8.7	8.4	8.5	3.5	3.8	3.6	27.8	24.7	26.2	59.4	62.5	61.0	0.7	0.8	0.7
5	13	IC15798	37.6	37.0	37.3	9.3	8.0	8.6	4.1	4.0	4.0	21.7	23.3	22.5	64.6	64.2	64.4	0.3	0.5	0.4
6	14	IC15799	34.4	33.5	34.0	7.2	7.4	7.3	3.6	3.3	3.4	22.0	21.7	21.9	67.0	67.4	67.2	0.2	0.3	0.2
7	19	IC16395	37.8	36.5	37.1	8.3	7.7	8.0	3.9	4.3	4.1	21.7	21.5	21.6	65.7	66.0	65.9	0.5	0.5	0.5
8	22	IC16398	45.5	26.8	36.1	9.8	9.6	9.7	7.4	6.5	7.0	25.2	23.2	24.2	57.3	60.1	58.7	0.3	0.6	0.5
9	23	IC16399	38.6	36.5	37.6	8.0	7.4	7.7	2.8	3.0	2.9	25.1	23.2	24.1	64.1	66.2	65.1	0.2	0.2	0.2
10	25	IC16401	36.3	34.3	35.3	7.8	7.0	7.4	4.6	5.1	4.9	27.6	25.6	26.6	59.0	61.5	60.2	1.1	0.8	0.9
11	41	IC23674	35.5	33.9	34.7	9.0	8.2	8.6	4.2	4.7	4.5	23.2	22.6	22.9	63.3	64.2	63.7	0.3	0.4	0.4
12	43	IC25629	36.8	34.3	35.5	9.6	8.5	9.0	3.5	4.4	3.9	29.8	27.7	28.7	56.9	59.2	58.1	0.3	0.3	0.3
13	45	IC26295	35.5	29.7	32.6	7.8	9.2	8.5	4.0	5.1	4.6	24.1	20.8	22.5	63.7	64.6	64.2	0.4	0.3	0.3
14	46	IC26296	41.1	38.6	39.8	7.4	7.1	7.2	3.5	3.7	3.6	22.2	22.1	22.1	66.8	66.9	66.9	0.2	0.3	0.3
15	52	IC33557	42.0	38.7	40.3	8.6	7.7	8.2	2.9	3.5	3.2	23.3	22.7	23.0	64.9	65.8	65.4	0.2	0.3	0.3
16	53	IC33674	40.2	37.9	39.0	7.9	7.5	7.7	3.7	4.0	3.9	27.9	25.9	26.9	59.7	61.8	60.7	0.9	0.8	0.8
17	58	IC33774	38.0	36.4	37.2	9.0	8.2	8.6	4.5	4.8	4.6	23.5	23.0	23.3	62.7	63.6	63.1	0.4	0.4	0.4
18	60	IC33804	40.6	37.8	39.2	8.5	8.0	8.2	4.4	4.8	4.6	31.4	27.5	29.4	55.6	59.4	57.5	0.2	0.3	0.3
19	66	IC34026	38.9	34.9	36.9	7.0	6.6	6.8	3.4	4.0	3.7	27.2	24.2	25.7	61.0	64.2	62.6	1.4	1.0	1.2
20	67	IC34084	43.1	42.4	42.8	7.0	7.3	7.2	2.9	3.0	3.0	26.8	24.6	25.7	63.0	64.8	63.9	0.2	0.4	0.3
21	76	IC42077	42.1	25.7	33.9	8.9	8.6	8.8	2.1	5.0	3.6	24.3	25.2	24.7	64.6	60.3	62.4	0.2	1.0	0.6
22	80	IC42082	43.9	40.3	42.1	7.8	7.5	7.6	3.4	3.7	3.5	19.0	22.2	20.6	69.7	66.5	68.1	0.2	0.2	0.2
23	89	IC49569	38.6	36.7	37.6	9.1	7.8	8.4	3.4	4.4	3.9	25.4	24.2	24.8	61.8	63.4	62.6	0.3	0.2	0.3
24	105	IC53563	40.6	36.6	38.6	8.2	7.5	7.8	3.0	3.3	3.1	28.7	26.5	27.6	59.9	62.4	61.2	0.2	0.4	0.3
25	115	IC53573	44.6	27.6	36.1	7.5	10.0	8.8	3.7	4.3	4.0	30.0	19.7	24.9	58.7	65.4	62.1	0.1	0.5	0.3
26	121	IC55395	38.5	36.5	37.5	8.2	7.5	7.8	4.4	4.8	4.6	25.2	23.5	24.3	61.7	63.6	62.7	0.5	0.6	0.6
27	128	IC55410	39.5	38.5	39.0	6.4	6.8	6.6	2.3	2.8	2.6	32.2	29.4	30.8	58.8	60.7	59.8	0.2	0.3	0.2
28	136	IC58622	40.1	25.6	32.9	7.9	8.6	8.2	4.1	3.9	4.0	32.4	17.1	24.7	55.2	69.8	62.5	0.5	0.7	0.6
29	142	IC59052	37.8	33.6	35.7	8.6	7.7	8.1	3.7	4.0	3.9	28.8	26.7	27.8	58.0	60.8	59.4	0.9	0.9	0.9
30	153	IC59067	39.5	29.0	34.2	7.2	9.2	8.2	3.7	5.0	4.4	30.7	29.3	30.0	58.3	55.8	57.1	0.2	0.7	0.5
31	154	IC59068	43.2	36.3	39.8	7.7	8.5	8.1	4.7	5.7	5.2	25.2	21.4	23.3	62.0	64.3	63.2	0.4	0.2	0.3
32	155	IC59069	34.9	23.6	29.3	7.7	10.0	8.8	3.4	5.8	4.6	27.6	22.3	25.0	61.0	61.2	61.1	0.3	0.7	0.5
33	158	IC59072	40.9	28.1	34.5	7.3	7.9	7.6	2.6	5.3	4.0	29.3	26.9	28.1	60.6	59.7	60.1	0.2	0.2	0.2
34	169	IC74953	41.6	39.0	40.3	9.0	8.3	8.6	3.3	4.3	3.8	22.8	22.3	22.6	64.7	64.8	64.7	0.3	0.3	0.3
35	177	IC74961	39.6	36.7	38.1	7.3	7.5	7.4	3.4	3.6	3.5	27.9	26.3	27.1	60.5	61.8	61.1	0.9	0.9	0.9
36	183	IC74967	39.2	36.5	37.9	7.6	7.4	7.5	3.6	3.9	3.7	22.3	22.0	22.2	66.3	66.5	66.4	0.3	0.3	0.3
37	185	IC74969	33.5	33.0	33.3	8.0	9.0	8.5	4.7	5.5	5.1	31.7	17.1	24.4	55.1	68.2	61.7	0.4	0.3	0.3
38	187	IC74971	40.8	38.8	39.8	7.0	7.1	7.1	3.3	3.5	3.4	28.7	26.9	27.8	60.8	62.0	61.4	0.3	0.4	0.3
39	188	IC74972	37.6	30.1	33.9	8.2	7.0	7.6	4.4	5.0	4.7	32.0	18.5	25.3	55.2	69.5	62.3	0.1	0.0	0.1
40	189	IC74973	42.4	41.3	41.9	8.5	7.9	8.2	4.4	4.8	4.6	31.4	28.7	30.0	55.6	58.4	57.0	0.2	0.3	0.3
41	215	IC75008	35.1	32.6	33.8	6.8	7.0	6.9	3.3	3.7	3.5	23.8	22.7	23.3	65.4	65.9	65.6	0.7	0.8	0.8
42	221	IC75014	41.5	39.5	40.5	8.3	7.9	8.1	2.6	3.8	3.2	26.6	24.1	25.4	62.1	64.0	63.0	0.3	0.3	0.3

Table 3: Continued.

S.No	Acc. No	Acc. Name	Oil content			Palmitic			Stearic			Oleic			Linoleic			Linolenic		
			2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
43	222	IC96247	34.3	32.5	33.4	9.8	8.4	9.1	3.8	4.3	4.1	24.7	23.6	24.2	61.4	63.2	62.3	0.3	0.4	0.4
44	228	IC96263	42.1	41.3	41.7	9.5	8.4	9.0	4.1	4.7	4.4	23.6	22.9	23.2	62.7	63.9	63.3	0.1	0.2	0.2
45	235	IC96272	40.0	36.3	38.1	8.1	7.9	8.0	3.9	4.2	4.1	21.8	21.4	21.6	66.0	66.3	66.2	0.2	0.3	0.2
46	237	IC96274	43.7	41.3	42.5	7.5	7.7	7.6	2.2	3.2	2.7	23.4	22.7	23.0	66.7	66.2	66.5	0.2	0.2	0.2
47	242	IC105288	45.5	30.5	38.0	6.4	8.0	7.2	4.7	6.0	5.3	28.2	20.9	24.6	60.4	64.8	62.6	0.3	0.4	0.3
73	360	IC298483	39.8	37.3	38.6	8.5	8.4	8.5	2.4	3.0	2.7	36.5	32.7	34.6	52.4	55.7	54.0	0.1	0.2	0.2
74	369	IC320979	41.0	30.4	35.7	7.8	8.7	8.2	2.5	5.6	4.1	30.2	27.1	28.7	59.3	58.0	58.6	0.2	0.6	0.4
75	370	IC321671	39.1	36.9	38.0	9.9	9.0	9.4	3.2	4.4	3.8	30.0	26.4	28.2	56.8	60.1	58.4	0.1	0.2	0.2
76	379	IC342806	35.5	32.0	33.8	8.5	8.2	8.3	3.4	4.5	3.9	20.5	19.5	20.0	67.5	67.6	67.5	0.2	0.2	0.2
77	385	IC343126	44.9	42.6	43.8	8.0	8.1	8.0	4.8	4.4	4.6	19.1	18.7	18.9	68.0	68.6	68.3	0.1	0.2	0.2
78	387	IC343128	33.1	30.1	31.6	9.0	8.7	8.8	3.3	4.1	3.7	35.8	32.2	34.0	51.8	54.8	53.3	0.3	0.3	0.3
79	391	IC344153	38.5	35.9	37.2	7.5	7.3	7.4	2.4	3.9	3.1	23.9	21.6	22.8	65.9	67.0	66.4	0.2	0.3	0.3
80	403	IC353792	45.6	43.1	44.4	9.5	8.7	9.1	2.3	4.2	3.3	20.9	18.3	19.6	67.1	68.4	67.8	0.2	0.4	0.3
81	409	IC385811	35.0	26.5	30.7	9.4	7.0	8.2	4.4	4.1	4.3	30.3	33.8	32.0	55.6	54.5	55.1	0.3	0.7	0.5
82	410	IC385901	45.5	43.9	44.7	8.9	8.2	8.6	2.8	3.2	3.0	34.0	29.1	31.6	54.0	59.1	56.6	0.3	0.4	0.3
83	411	IC400169	45.9	28.3	37.1	8.3	6.6	7.5	3.7	4.3	4.0	24.6	25.1	24.8	63.2	63.3	63.3	0.2	0.7	0.5
84	426	IC413089	44.2	32.2	38.2	9.3	8.0	8.6	6.6	4.1	5.4	28.6	27.7	28.1	55.4	59.6	57.5	0.2	0.7	0.4
85	434	IC413101	44.3	42.1	43.2	8.5	8.2	8.3	2.2	3.3	2.8	23.1	21.5	22.3	66.0	66.7	66.3	0.3	0.3	0.3
86	435	IC413103	39.4	27.9	33.7	7.6	7.0	7.3	4.1	3.7	3.9	29.6	32.6	31.1	57.7	55.7	56.7	1.1	0.9	1.0
87	437	IC413113	42.6	22.7	32.6	8.6	8.1	8.3	3.7	4.0	3.9	23.0	23.3	23.2	64.5	63.7	64.1	0.1	0.9	0.5
88	439	IC413120	41.6	38.5	40.0	9.9	8.5	9.2	3.0	4.0	3.5	27.2	24.1	25.6	59.6	63.1	61.4	0.2	0.3	0.3
89	449	IC413148	43.9	41.2	42.6	8.0	7.7	7.9	2.0	3.2	2.6	30.9	26.5	28.7	58.9	62.4	60.7	0.2	0.3	0.2
90	453	IC413156	26.5	25.6	26.1	8.9	8.2	8.5	3.0	3.1	3.0	21.3	21.1	21.2	66.8	67.4	67.1	0.1	0.2	0.2
91	461	IC417196	35.9	33.4	34.7	8.5	8.6	8.6	4.7	4.4	4.6	31.3	28.7	30.0	55.1	57.9	56.5	0.4	0.4	0.4
92	475	IC499210	44.3	35.7	40.0	8.1	8.2	8.1	3.1	3.9	3.5	26.6	19.9	23.2	61.4	67.7	64.6	0.8	0.4	0.6
93	477	IC499212	33.7	24.9	29.3	8.2	9.9	9.0	3.8	3.7	3.8	29.9	40.5	35.2	57.8	45.3	51.6	0.3	0.7	0.5
94	478	IC499213	40.1	24.7	32.4	9.0	7.0	8.0	2.9	3.7	3.3	32.6	38.6	35.6	55.3	50.5	52.9	0.2	0.2	0.2
95	481	IC499216	44.2	41.6	42.9	7.6	7.8	7.7	4.0	4.0	4.0	29.4	26.0	27.7	58.7	61.9	60.3	0.3	0.3	0.3
96	483	IC499218	41.3	32.5	36.9	8.0	9.7	8.8	4.0	6.2	5.1	21.7	15.2	18.4	64.9	68.6	66.8	1.4	0.4	0.9
97	484	IC499219	40.8	37.2	39.0	7.5	7.1	7.3	4.3	4.4	4.3	32.7	28.8	30.7	55.3	59.5	57.4	0.3	0.3	0.3
98	486	IC499222	45.2	28.7	36.9	8.7	9.5	9.1	2.8	4.1	3.5	22.7	35.6	29.2	65.6	49.8	57.7	0.2	1.0	0.6
99	495	IC499232	45.6	36.5	41.0	7.8	9.7	8.8	3.2	4.4	3.8	21.9	18.8	20.3	66.7	66.5	66.6	0.4	0.6	0.5
100	505	IC0203170	39.2	36.1	37.6	8.5	8.2	8.4	4.7	4.4	4.5	22.1	21.5	21.8	64.6	65.7	65.1	0.2	0.2	0.2
101	515	IC0210976	41.2	38.5	39.8	6.8	7.2	7.0	3.2	3.1	3.2	25.1	23.1	24.1	64.3	66.0	65.1	0.6	0.7	0.6
102	532	IC0259385	43.2	41.7	42.4	7.6	7.5	7.6	3.8	4.0	3.9	27.8	24.1	25.9	59.3	63.2	61.3	1.5	1.2	1.4
103	537	IC260240	45.9	43.7	44.8	9.1	8.7	8.9	2.3	3.2	2.8	30.1	27.1	28.6	58.0	60.5	59.2	0.5	0.6	0.5
104	541	IC260245	44.0	25.6	34.8	9.2	7.3	8.3	2.8	4.7	3.7	26.2	25.0	25.6	61.2	62.8	62.0	0.7	0.2	0.5
105	546	IC260250	36.7	32.8	34.7	8.4	8.9	8.7	2.7	7.7	5.2	19.8	13.8	16.8	68.9	69.2	69.0	0.2	0.5	0.4
106	567	IC0262481	43.4	41.1	42.2	6.3	6.9	6.6	3.7	3.9	3.8	33.1	29.4	31.3	56.2	59.2	57.7	0.7	0.7	0.7
107	569	IC0262483	34.8	31.6	33.2	8.7	8.1	8.4	3.5	3.7	3.6	27.1	23.5	25.3	60.6	64.7	62.7	0.1	0.1	0.1
108	C1*	JNS-9	39.7	37.7	38.7	8.2	7.9	8.0	3.5	3.5	3.5	32.7	31.6	32.2	55.4	56.8	56.1	0.2	0.2	0.2
109	C2*	JNS-28	40.8	38.6	39.7	8.6	8.5	8.5	4.3	3.0	3.7	29.4	30.4	29.9	57.4	58.0	57.7	0.3	0.1	0.2

Table 3: Continued.

S.No	Acc. No	Acc. Name	Oil content			Palmitic			Stearic			Oleic			Linoleic			Linolenic		
			2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
110	C3*	IGPNC 2004-1	37.2	37.4	37.3	7.3	7.4	7.4	3.3	3.5	3.4	31.1	30.5	30.8	58.1	58.5	58.3	0.2	0.1	0.1
111	C4*	JNS-30	41.6	38.2	39.9	8.4	8.3	8.3	2.9	3.0	3.0	29.9	29.7	29.8	58.5	58.8	58.7	0.3	0.2	0.2
Minimum			**26.5**	**22.7**	**26.1**	**4.8**	**6.5**	**6.6**	**2.0**	**2.8**	**2.6**	**19.0**	**13.8**	**16.8**	**42.0**	**40.3**	**45.4**	**0.1**	**0.0**	**0.1**
Maximum			**45.9**	**43.9**	**44.8**	**9.9**	**10.0**	**9.7**	**7.4**	**7.7**	**7.0**	**45.5**	**46.2**	**42.1**	**70.0**	**69.8**	**69.0**	**1.5**	**1.2**	**1.4**
Mean			**39.9**	**34.3**	**37.1**	**8.1**	**8.1**	**8.1**	**3.6**	**4.3**	**3.9**	**27.1**	**25.3**	**26.2**	**60.9**	**62.0**	**61.4**	**0.4**	**0.4**	**0.4**

Note: The bold values are the descriptive statistical results of the biochemical traits analyzed in this study.
*C, checks.

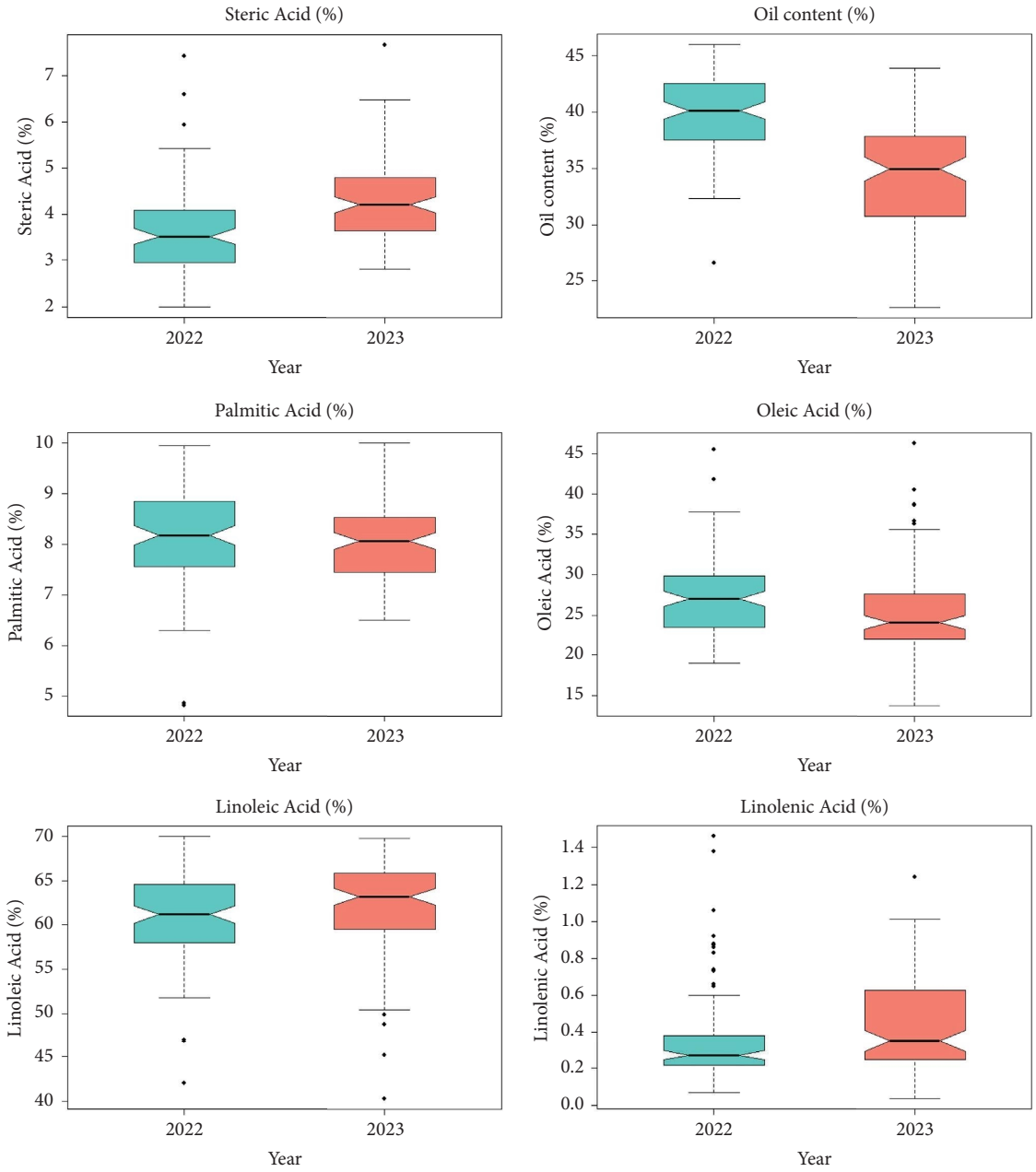


Figure 2: Box plot showing the distribution of biochemical traits in the years 2022 and 2023 ($n = 111$). The bold line (inside the boxplot) represents the median, box edges represent upper and lower quantiles, and outliers are shown as black circles.

Analysis of the fatty acid content in the niger accessions revealed that oil content was generally high in accessions with a high proportion of unsaturated fatty acids, likely due to the predominant presence of oleic and linoleic acids. A similar study of 153 niger accessions revealed a twofold variation in seed oil content and fatty acid composition. Double mutant maize genotypes also exhibited lower saturated fatty acid content (12.2%) and higher unsaturated fatty acid content (87.0%) [15]. The presence of higher amounts of unsaturated fatty acids leads to lower susceptibility to autoxidation [16]. Previous studies have reported that a deficiency of unsaturated fatty acids in the human body can cause neurological disorders, cardiovascular diseases, and inflammation [17, 18], as they are essential components of cell membranes and precursors for signaling molecules. Thus, the high amount of unsaturated fatty acids confers a therapeutic advantage to niger oil.

The proportion of oleic and linoleic acids in the current study is noteworthy and unique among all the biochemical traits. Linoleic acid was the predominant fatty acid in the studied accessions, followed by oleic acid in both years. These findings align with the research of Kostik, Memeti, and Bauer [19] and Hernández et al. [20], who also identified oleic acid and linoleic acid as the predominant fatty acids in the oils of various plant species. Breeders may find these attributes valuable for improving oil quality. Additionally,

Table 4: Distribution of 111 Niger genotypes based on genetic diversity.

Cluster no.	No. of accessions	Name of the accessions
I	16	IC268287, IC119935, IC274995, IC274991, IC400169, IC16395, IC55395, IC75008, IC0210976, IC74972, IC119921, IC864, IC105288, IC343126, IC15795, and IC59068
II	34	IC413089, IC413156, IC15794, IC59072, IC211066, IC0262483, IC59069, IC96247, IC74969, IC23674, IC26295, IC58622, IC413113, IC42077, IC260245, IC15796, IC499222, IC499218, IC260250, IC342806, IC96272, IC0203170, IC15798, IC119801, IC119938, IC33774, IC274989, IC96263, IC203172, IC268292, IC49569, and IC53573
III	20	IC353792, IC413101, IC75014, IC33557, IC119911, IC499210, IC74953, IC499232, IC42082, IC26296, IC74967, IC15799, IC16399, IC344153, IC74971, IC53563, IC211050, IC413148, IC34084, and IC96274
IV	9	IC34026, IC0259385, IC267558, IC413103, IC33674, IC74961, IC16401, IC59052, IC275006
V	20	IC25629, IC321671, IC275014, IC298468, IC413120, IC385901, IC260240, IC298483, JNS-9 (check), JNS-28 (check), IGPNC-2004-1 (check), JNS-30 (check), IC110527, IC33804, IC74973, IC499216, IC499219, IC0262481, IC55410, and IC274990
VI	12	IC320979, IC59067, IC417196, IC267555, IC385811, IC499213, IC343128, IC499212, IC203177, IC211053, IC105634, and IC298407

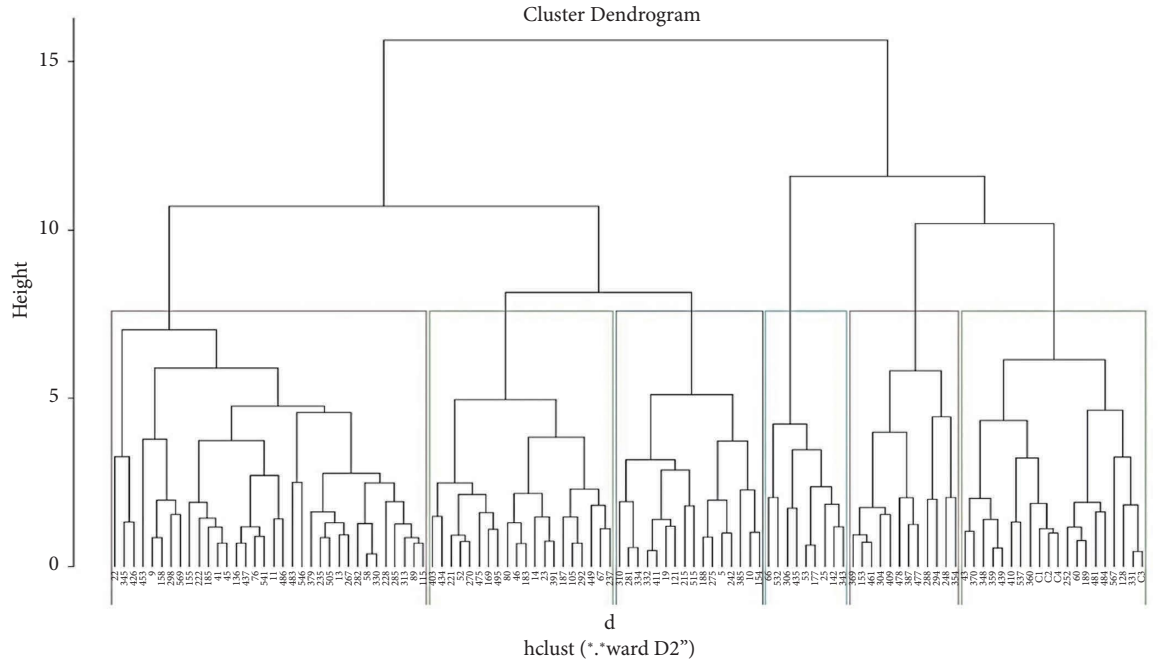


Figure 3: Dendrogram of hierarchal clustering showing the relationship among the 107 accessions along with four checks based on the various fatty acid components in niger.

the statistical analysis of fatty acid content revealed significant effects on genotypes ($p < 0.05$) for the investigated traits, likely due to the genotypic features of the accessions studied. The ratio of fatty acids could be utilized as a marker for varietal differentiation and categorization of oils [21, 22].

4.3. Cluster Analysis. Cluster analysis is a crucial method for classifying data, as it helps divide the germplasm into different homogeneous groups based on biochemical traits. This method minimizes variance within groups while maximizing variance between groups and aids in identifying outliers. Intracluster distances are typically lower than intercluster distances, resulting in less variation among genotypes within a cluster. Genotypes from clusters separated by high genetic distances could be used in hybridization programs to obtain a broad spectrum of variation among the segregants [23]. In the present study, the dendrogram was constructed using the Euclidean distance matrix method, grouping the 111 niger genotypes into six hierarchical clusters, providing crucial information. The maximum intercluster distance was found between Clusters III and VI, while the minimum intercluster distance was observed

Table 5: Cluster means of different biochemical traits in cluster analysis.

	Oil content	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Cluster I	35.60^{bc}	7.62^{bc}	3.97^{bc}	23.21^{c}	64.92^{a}	0.28^{b}
Cluster II	40.02^{a}	8.56^{a}	3.54^{cd}	23.38^{c}	64.23^{ab}	0.29^{b}
Cluster III	32.97^{c}	8.17^{ab}	4.21^{ab}	34.30^{a}	52.84^{c}	0.46^{b}
Cluster IV	40.45^{a}	7.87^{bc}	3.44^{d}	29.70^{ab}	58.72^{b}	0.26^{b}
Cluster V	35.39^{bc}	8.64^{a}	4.50^{a}	24.65^{bc}	61.73^{ab}	0.48^{b}
Cluster VI	37.69^{ab}	7.27^{c}	3.80^{bcd}	26.97^{bc}	61.05^{ab}	0.91^{a}

Note: Different letters indicate significant difference at $p < 0.05$.

Table 6: Variation in the average inter- and intracluster distances in cluster analysis.

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	2.20	2.88	2.79	3.62	3.54	4.43
Cluster II	2.88	2.43	3.05	3.83	3.26	3.90
Cluster III	2.79	3.05	1.95	4.10	2.96	4.72
Cluster IV	3.62	3.83	4.10	2.32	4.05	4.01
Cluster V	3.54	3.26	2.96	4.05	2.44	3.56
Cluster VI	4.43	3.90	4.72	4.01	3.56	2.71

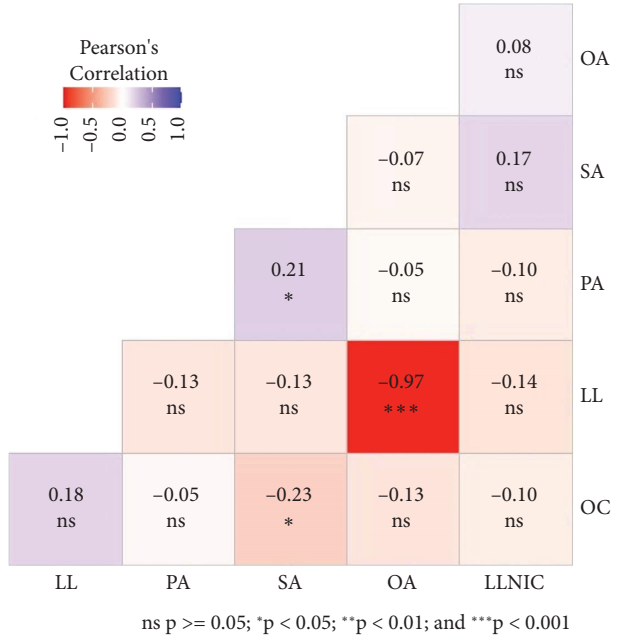


Figure 4: Association between different biochemical traits in niger. LL, linoleic acid; LLNIC, linolenic acid; OA, oleic acid; OC, oil content; PA, palmitic acid; SA, stearic acid. $^{ns}p \geq 0.05$, $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$.

between Clusters I and III. This indicates that genotypes from Clusters III and VI could be used in future hybridization programs to obtain useful segregants. For improving the oil content trait, accessions from Clusters II, IV, and VI can be selected for hybridization, as these clusters have high mean values for oil content. The accessions used in the current study were collected from 12 different states of the country. The accessions IC96272, IC119801, IC267558, IC268287, IC268292, IC274989, IC0262481, and IC0262483 were collected from the Akola region of Maharashtra state. Despite sharing the same geographical location, these accessions clustered into different groups: IC96272 (Cluster II), IC119801 (Cluster II), IC267558 (Cluster IV), IC268287 (Cluster I), IC268292 (Cluster II), IC274989 (Cluster II), IC0262481 (Cluster V), and IC0262483 (Cluster II). This could be due to the highly cross-pollinating nature of the crop, resulting from the presence of sporophytic self-incompatibility.

4.4. Correlation Analysis. Designing a successful breeding program requires understanding the correlation between different traits. In the present study, a negative correlation was observed between linoleic acid and oleic acid. A similar strong negative correlation between oleic and linoleic fatty acids was observed in a study conducted using safflower core germplasm [24]. In a study where safflower genotypes were evaluated for fatty acid composition under saline and

nonsaline conditions, a similar negative correlation was observed for oleic and linoleic acid accumulation in both conditions [25]. It can be inferred that the linoleic acid content of niger increases with a reduction in oleic acid and vice versa. Therefore, when undertaking a genetic improvement program in niger, breeders should consider these biochemical characteristics.

5. Conclusion

Deciphering the biochemical traits of an oilseed is crucial for understanding its role in human diet and health. This study was conducted to evaluate the variation in oil and fatty acid content among 111 genotypes, including checks. A significant amount of variability was observed among the genotypes tested. The accession IC260240 was found to have a high oil content of 44.75%. Similarly, the accessions IC260250 and IC211053 showed high amounts of unsaturated fatty acids, such as linoleic acid and oleic acid, respectively. These accessions can be used in future niger improvement programs to enhance oil content and desirable fatty acids. Based on the results of the current study, it is possible to leverage this significant biochemical variability in breeding programs that target the seed oil quality of niger germplasm.

Data Availability Statement

The data generated or analyzed in this study are included within this manuscript.

Ethics Statement

The authors have no relevant financial or non-financial interests to disclose.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Pushpa H.D. conceptualized the idea, augmented the germplasm, conducted the experiment, and did the statistical analysis; Helan Baby Thomas analyzed the data, compiled the results, and wrote the manuscript; Sujatha M. revised the manuscript; Ramchander L. compiled the data and did the statistical analysis; Sravanthi J. and Praduman Yadav did the biochemical analysis; Rajani Bisen, Prashanth Jagtap, Rajkumar S., and Sunil Gomashe, evaluated and maintained the stock germplasm; Mathur R.K. reviewed the manuscript.

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