Assessment of Phenotypic Variation and Agronomic Type based Distribution of Genotypes Associated with Oil Content in Groundnut (*Arachis hypogaea* L.)

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ABSTRACT: Groundnut (*Arachis hypogaea* L.) is a major contributor to global cultivation due to its rich source of good-quality vegetable oil in seeds. In the current investigation, 184 groundnut genotypes were evaluated across two seasons, season-1 (S1) and season-2 (S2) to study the subspecies level variation for oil content in the *Arachis* subspecies and agronomic types. Significant variability in oil content (39.6%–52.2%) was detected among the groundnut genotypes. The accessions with higher oil content were predominant in the Spanish Bunch/Valencia Bunch types, whereas the accessions with comparatively low oil content were more prevalent in the Virginia Bunch/Virginia Runner types. The genotypes ICG 4746 (S1- 52.2%, S2- 51.7%), ICG 12370 (S1- 51.6%, S2- 48.4%), ICG 4955 (S1- 51.1%, S2- 50.5%) demonstrated higher oil content across both the seasons. These genotypes with high oil content hold potential for their use in breeding programmes to develop groundnut varieties with increased oil quality.

Keywords: Oil content, Agronomic types, Subspecies level variation, Breeding programmes, Oil quality.

INTRODUCTION

Groundnut, also referred to as the "King of oilseeds" is an essential oilseed legume crop, known for its high oil content and economic significance. It is also referred to as peanut, wonder nut, earthnut, goobernut, and monkey nut (Nwokolo, 1996). It belongs to the family Leguminosae and subfamily Papilionoideae (Stalker and Wilson 2015). The cultivated groundnut is allotetraploid (AABB, 2n = 4x = 40), and includes the two cultivated subspecies, *hypogaea* and *fastigiata*, whereas the majority of the 80 species in the genus *Arachis* are diploid (2n = 2x = 20) (Krapovickas and Gregory 1994). The cultivated groundnut *A. hypogaea* was initially classified into two large botanical groups, Virginia and Spanish-Valencia on the basis of branching pattern (Krapovickas, 1973; Upadhyaya and Nigam 1999). Early-maturing Spanish-Valencia plants are usually erect, with pods formed around the base (Litzenberger, 1976). The seeds of late-maturity (Virginia-type) plants exhibit alternating branching patterns, and the pods are distributed along secondary and tertiary branches (Stephen, 2009). Early maturity promotes adaptation to a shorter growing season, however late maturation results in prolonged pod-filling and higher yield potential (Kunta *et al.,* 2025). Spanish groundnut cultivars, cultivated mainly in Africa and semi-arid regions of Asia, account for 60% of global groundnut production (Rani *et al.,* 2024).

Globally, it is cultivated in 29.92 million hectares with an annual production of 55.30 million tonnes and a productivity of 1851 Kg ha^{-1} (Sukrutha *et al.,* 2025). About 80% of total groundnut production in India is crushed for oil extraction, hence improving the oil content and quality, which is of benefit to plant breeders. The most important quality requirements of groundnut as a source of oil are high protein and oil content in the seed. Groundnut seed contains 10–20% carbohydrates, 48–50% oil, and 25–28% protein (Parmar *et al.*, 2023). It also contains antioxidants such as p-coumaric acid and resveratrol, bioactive

compounds such as polyphenols, flavonoids, isoflavones, and many B-complex vitamins, as well as monounsaturated and polyunsaturated fatty acids. It is used as animal feed (oil pressings, green and dry haulms) and as raw material in the manufacturing industry (oil cakes and fertilizers). The oilcake contains 7.3% nitrogen, 1.5% P_2O_5, and 1.3% potassium (Korale *et al.,* 2022).

The nutritional quality of oil is determined by its fatty acid composition. The major fatty acids found in groundnut are palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), arachidic (20:0), eicosenoic (20:1), behenic (22:0), and lignoseric (24:0) acids. Oleic acid, a monounsaturated fatty acid, and linoleic acid, a polyunsaturated fatty acid, account for 75-80% of total fatty acids in groundnut oil (Sarvamangala *et al.,* 2011). Regular groundnut consumption is linked with a reduced risk of cardiovascular disease, lower blood pressure, cancer, and may benefit those with type II diabetes (Vassiliou *et al.,* 2009). Groundnut consumption has also been associated with the maintenance of body weight.

Groundnut-based ready-to-use therapeutic food products (RUTP) like "Plumpy Nut" and peanut butter have saved the lives of thousands of malnourished children in Africa, where malnutrition is a severe issue. As a result, groundnut becomes increasingly important as a food nutritional source, in addition to an oil source. Because of its great nutritional value, it is often referred to as the "poor man's almond" and hence an important contributor to combat malnutrition (Parmar *et al.*, 2022).

Assessment of phenotypic and genetic diversity is essential before adopting effective and successful crop improvement approaches to ensure ideal selection (Ajmera *et al.,* 2017). The extent and nature of phenotypic and genotypic variability determine the effectiveness of selecting high-potential genotypes in plant breeding programmes (Yami and Abtew 2025).

Hence, the present study was carried out to assess the phenotypic variation and distribution of 184 groundnut accessions based on the different agronomic types.

MATERIALS AND METHODS

The experimental material used in this study comprised of 184 groundnut mini-core accessions. These mini-core accessions include six botanical varieties: *hypogaea*, *fastigiata*, *hirsuta*, *peruviana*, *vulgaris*, and *aequatoriana*.

A. Phenotyping for oil content

The oil content (%) of the groundnut accessions was estimated using Near-Infrared Spectroscopy (NIRS). The groundnut samples weighing 60 g were examined with a diode array analyzer at wavelengths ranging from 950 to 1650 nm. Each sample was scanned three times and absorbance readings were taken at 5 nm increments to ensure accuracy (Parmar *et al.,* 2023).
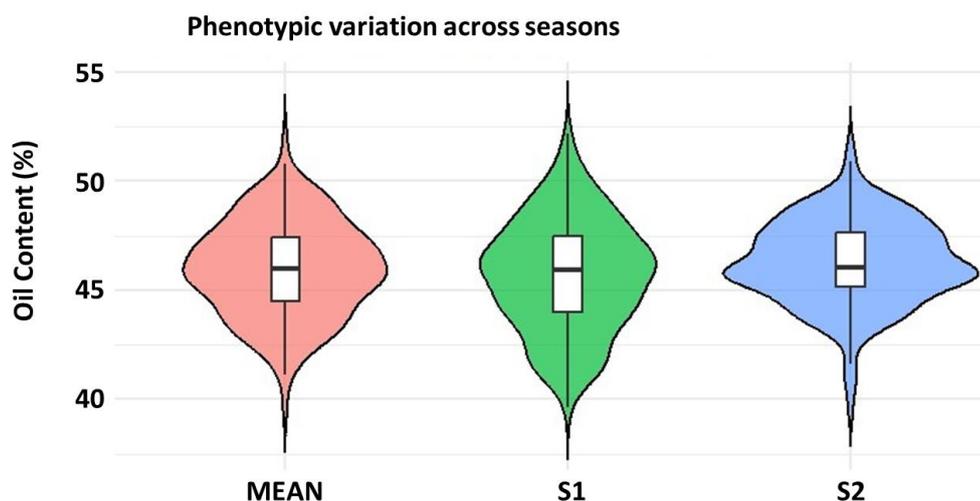
B. Phenotypic variability and distribution of the accessions based on agronomic types

The "SRplot" (Scientific and Research plot tool) (Tang *et al.,* 2023) was used to create frequency distribution graphs (violin plots) to study the range and mean of the accessions. The box plots were used to visualise the phenotypic distributions of the groundnut mini-core collection, which included 184 accessions from the two subspecies *fastigiata* and *hypogaea*, as well as the agronomic types Valencia bunch/Spanish bunch and Virginia bunch/Virginia runner. These box plots were generated using "ggplot" package in the "R" software (Xia *et al.,* 2018).

RESULTS AND DISCUSSION

A. Phenotypic variability for oil content

The phenotypic variation of 184 accessions for oil content across the two seasons were visualized using violin plots (Fig. 1).

Fig. 1. Phenotypic variation for oil content in the diverse 184 groundnut genotypes. This figure illustrates the violin plots showing the distribution of oil content (%) for various genotypes across S1 and S2, and mean of both the seasons. The box plot represents the average frequency of distribution of genotypes in a particular season.

The mean values of oil content varied among the seasons such as 45.7% in S1 and 46.3% in S2. The oil content ranged from 39.6% to 52.2% in S1, whereas the values ranged from a minimum of 39.6% to a maximum of 51.7% in S2 (Table 1).

Table 1: The oil content (%) of the 184 groundnut accessions across the two seasons and mean performance of the two seasons.

Sr. No.	Accession	Season 1	Season 2	MEAN
1.	ICG 10036	45.9	46.1	46.0
2.	ICG 10092	45.0	46.6	45.8
3.	ICG 10185	44.1	44.5	44.3
4.	ICG 10384	47.3	47.1	47.2
5.	ICG 10474	47.3	46.6	46.9
6.	ICG 10479	50.7	48.7	49.7
7.	ICG 10554	45.0	43.2	44.1
8.	ICG 10566	46.4	47.5	46.9
9.	ICG 10890	47.3	48.2	47.8
10.	ICG 11088	43.1	43.2	43.1
11.	ICG 111	41.9	44.6	43.3
12.	ICG 11109	46.3	46.3	46.3
13.	ICG 11144	48.8	48.9	48.9
14.	ICG 11219	43.6	45.5	44.6
15.	ICG 11249	45.9	47.3	46.6
16.	ICG 11322	45.1	45.4	45.3
17.	ICG 1137	47.0	48.0	47.5
18.	ICG 1142	48.9	49.0	49.0
19.	ICG 11426	46.1	45.6	45.9
20.	ICG 11457	44.7	46.4	45.6
21.	ICG 115	49.4	48.8	49.1
22.	ICG 11515	46.4	46.3	46.4
23.	ICG 11651	44.2	44.0	44.1
24.	ICG 11687	47.1	47.2	47.1
25.	ICG 118	46.6	47.1	46.9
26.	ICG 11855	45.7	45.9	45.8
27.	ICG 11862	44.5	45.9	45.2
28.	ICG 12000	47.3	49.2	48.3
29.	ICG 12189	42.5	45.0	43.8
30.	ICG 12276	46.5	47.8	47.2
31.	ICG 12370	51.6	48.4	50.0
32.	ICG 12625	45.6	45.0	45.3
33.	ICG 12672	46.3	45.5	45.9
34.	ICG 12682	44.4	47.6	46.0
35.	ICG 12697	43.0	45.5	44.3
36.	ICG 1274	43.0	43.4	43.2
37.	ICG 12879	44.1	46.5	45.3
38.	ICG 12921	47.8	47.1	47.5
39.	ICG 12988	47.7	47.3	47.5
40.	ICG 13099	45.7	45.6	45.6
41.	ICG 13491	47.2	47.3	47.3
42.	ICG 13603	48.2	48.1	48.2
43.	ICG 13723	41.4	43.4	42.4
44.	ICG 13787	44.3	45.2	44.7
45.	ICG 13856	50.0	49.1	49.5
46.	ICG 13858	49.3	49.0	49.2
47.	ICG 13982	44.2	45.6	44.9
48.	ICG 1399	47.7	48.4	48.1
49.	ICG 14008	46.4	45.8	46.1
50.	ICG 14106	48.5	47.6	48.1
51.	ICG 14118	46.7	47.2	46.9
52.	ICG 14127	45.1	45.5	45.3
53.	ICG 1415	49.2	48.7	49.0
54.	ICG 14466	46.3	45.7	46.0
55.	ICG 14475	44.0	43.5	43.8
56.	ICG 14482	46.6	45.5	46.1
57.	ICG 14523	49.6	48.9	49.2
58.	ICG 14630	47.8	47.9	47.9
59.	ICG 14705	47.1	46.9	47.0

60.	ICG 14710	49.9	49.9	49.9
61.	ICG 14985	48.1	46.8	47.4
62.	ICG 15042	46.7	46.0	46.3
63.	ICG 1519	47.9	48.5	48.2
64.	ICG 15190	44.1	45.3	44.7
65.	ICG 15287	45.5	45.6	45.5
66.	ICG 15309	46.8	46.8	46.8
67.	ICG 15419	44.0	44.6	44.3
68.	ICG 163	44.1	45.3	44.7
69.	ICG 1668	41.4	44.4	42.9
70.	ICG 1711	45.5	46.4	46.0
71.	ICG 188	46.2	47.6	46.9
72.	ICG 1973	48.0	48.7	48.4
73.	ICG 2019	46.6	47.7	47.1
74.	ICG 2106	48.1	48.3	48.2
75.	ICG 2381	39.6	39.6	39.6
76.	ICG 2511	43.6	44.2	43.9
77.	ICG 2772	41.1	44.3	42.7
78.	ICG 2773	41.4	44.6	43.0
79.	ICG 2777	41.6	44.5	43.1
80.	ICG 2857	45.5	45.7	45.6
81.	ICG 2925	44.0	45.5	44.8
82.	ICG 297	47.5	48.3	47.9
83.	ICG 3027	43.1	44.2	43.7
84.	ICG 3053	43.0	44.6	43.8
85.	ICG 3102	46.9	47.3	47.1
86.	ICG 3240	47.1	47.7	47.4
87.	ICG 332	47.7	46.1	46.9
88.	ICG 334	46.4	47.5	46.9
89.	ICG 3343	46.7	46.7	46.7
90.	ICG 3421	47.3	48.1	47.7
91.	ICG 3584	46.3	47.6	46.9
92.	ICG 36	49.4	49.2	49.3
93.	ICG 3673	49.2	49.3	49.2
94.	ICG 3681	48.4	48.8	48.6
95.	ICG 3746	46.2	47.4	46.8
96.	ICG 3775	44.4	47.4	45.9
97.	ICG 397	48.0	49.3	48.7
98.	ICG 3992	44.5	45.2	44.8
99.	ICG 4156	41.7	44.1	42.9
100.	ICG 434	46.1	48.0	47.1
101.	ICG 4343	42.7	43.6	43.2
102.	ICG 4389	44.5	46.5	45.5
103.	ICG 4412	45.0	46.0	45.5
104.	ICG 442	49.0	50.9	50.0
105.	ICG 4527	40.4	43.6	42.0
106.	ICG 4538	46.5	47.0	46.8
107.	ICG 4543	46.9	47.5	47.2
108.	ICG 4598	43.4	45.8	44.6
109.	ICG 4670	44.5	45.4	45.0
110.	ICG 4684	46.5	47.6	47.1
111.	ICG 4729	48.1	47.8	48.0
112.	ICG 4746	52.2	51.7	51.9
113.	ICG 4750	46.1	46.2	46.1
114.	ICG 4911	46.1	46.8	46.4
115.	ICG 4955	51.1	50.5	50.8
116.	ICG 4998	50.7	49.0	49.8
117.	ICG 5016	43.9	43.2	43.6
118.	ICG 5051	45.7	45.9	45.8
119.	ICG 513	43.0	46.0	44.5
120.	ICG 5195	45.6	45.8	45.7
121.	ICG 5221	44.9	45.6	45.3
122.	ICG 5236	46.3	45.8	46.0
123.	ICG 5286	41.5	42.2	41.9
124.	ICG 532	43.9	45.5	44.7
125.	ICG 5327	42.4	44.2	43.3

126.	ICG 5475	43.6	44.1	43.8
127.	ICG 5494	44.6	44.5	44.5
128.	ICG 5609	48.7	48.7	48.7
129.	ICG 5662	43.1	45.2	44.1
130.	ICG 5663	42.4	45.3	43.8
131.	ICG 5745	45.3	45.1	45.2
132.	ICG 5779	49.3	49.9	49.6
133.	ICG 5827	47.9	45.9	46.9
134.	ICG 5891	42.4	45.6	44.0
135.	ICG 6022	46.0	46.4	46.2
136.	ICG 6057	41.6	44.6	43.1
137.	ICG 6201	49.2	49.5	49.3
138.	ICG 6263	45.4	46.9	46.1
139.	ICG 6375	44.5	44.9	44.7
140.	ICG 6402	47.5	47.8	47.6
141.	ICG 6407	50.3	48.9	49.6
142.	ICG 6646	43.8	43.8	43.8
143.	ICG 6654	45.3	45.9	45.6
144.	ICG 6667	46.0	46.7	46.3
145.	ICG 6703	48.1	47.4	47.8
146.	ICG 6766	48.6	47.2	47.9
147.	ICG 6813	40.9	43.4	42.2
148.	ICG 6888	47.7	46.3	47.0
149.	ICG 6892	46.0	45.9	46.0
150.	ICG 6913	42.0	41.6	41.8
151.	ICG 6993	41.5	40.8	41.1
152.	ICG 7000	49.1	48.7	48.9
153.	ICG 7153	43.5	44.0	43.8
154.	ICG 7181	48.8	48.6	48.7
155.	ICG 7190	50.2	48.2	49.2
156.	ICG 721	43.8	45.8	44.8
157.	ICG 7243	44.8	46.0	45.4
158.	ICG 76	43.5	44.5	44.0
159.	ICG 7906	41.4	44.4	42.9
160.	ICG 7963	44.8	46.0	45.4
161.	ICG 7969	49.8	47.5	48.7
162.	ICG 8083	45.2	45.3	45.2
163.	ICG 81	48.1	48.1	48.1
164.	ICG 8106	46.5	47.0	46.7
165.	ICG 8285	45.1	45.8	45.4
166.	ICG 8490	41.2	43.8	42.5
167.	ICG 8517	42.1	45.0	43.6
168.	ICG 8567	48.4	47.6	48.0
169.	ICG 862	40.8	43.8	42.3
170.	ICG 875	42.2	45.1	43.7
171.	ICG 8760	46.4	45.6	46.0
172.	ICG 9037	45.4	45.9	45.7
173.	ICG 9157	41.4	40.8	41.1
174.	ICG 9249	46.1	45.5	45.8
175.	ICG 928	41.6	43.7	42.7
176.	ICG 9315	48.2	47.9	48.1
177.	ICG 9418	44.3	46.4	45.3
178.	ICG 9507	45.4	46.0	45.7
179.	ICG 9666	42.1	44.3	43.2
180.	ICG 9777	45.2	45.6	45.4
181.	ICG 9809	46.7	46.8	46.8
182.	ICG 9842	46.2	46.6	46.4
183.	ICG 9905	42.8	42.9	42.8
184.	ICG 9961	44.2	45.9	45.0

Previous studies also reported the variability for oil content in the range of 45% to 55% (Upadhyaya *et al.,* 2011; Upadhyaya *et al.,* 2003). Across both the seasons, oil content levels were consistently higher in S2 than S1. The genotypes ICG 4746 (52.2%), ICG 12370 (51.6%), ICG 4955 (51.1%), ICG 10479 (50.7%) and ICG 4998 (50.7%) demonstrated higher oil content in S1. Likewise, the genotypes ICG 4746 (51.7%), ICG 442 (50.9%), ICG 4955 (50.5%), ICG 14710 (49.9%) and ICG 5779 (49.9%) showed high oil content in S2. Groundnut varieties with high oil content particularly high oleic acid content are desirable due to their

potential health benefits and extended shelf life (Mozingo *et al.,* 2004; Norden *et al.,* 1987).

Similarly, phenotypic variability for oil content was previously reported in groundnut (Shasidhar *et al.* 2017; Pandey *et al.,* 2014; Sarvamangala *et al.,* 2011). In this study, the genotypes ICG 4746 and ICG 4955 showed high oil content across both the seasons. This stability indicates that these genotypes have developed specific genetic mechanisms that buffer against environmental variations while ensuring consistent oil production (Tang *et al.,* 2022). This inherent stability is beneficial as it reduces the unpredictability of oil content under various cultivation conditions, offering consistent product quality to consumers and processors.

In this study, the identified phenotypic variations and their stability across environments have major implications for breeding strategies. The varieties with stable phenotypic performance, irrespective of environmental changes, can be targeted in breeding programs for large-scale, diverse cultivation. On the other hand, varieties with specific adaptabilities to certain conditions can be utilised for cultivation in specific environments where those conditions prevail (Wang *et al.,* 2023).

B. *Phenotypic distribution for oil content based on agronomic types*

The box plots were used to demonstrate the phenotypic variations for oil content based on the different agronomic types. The agronomic types differed in their oil content; accessions with high oil content were identified in Spanish Bunch and Valencia Bunch, while the low oil content accessions were found in the Virginia Bunch and Virginia Runner (Fig. 2).
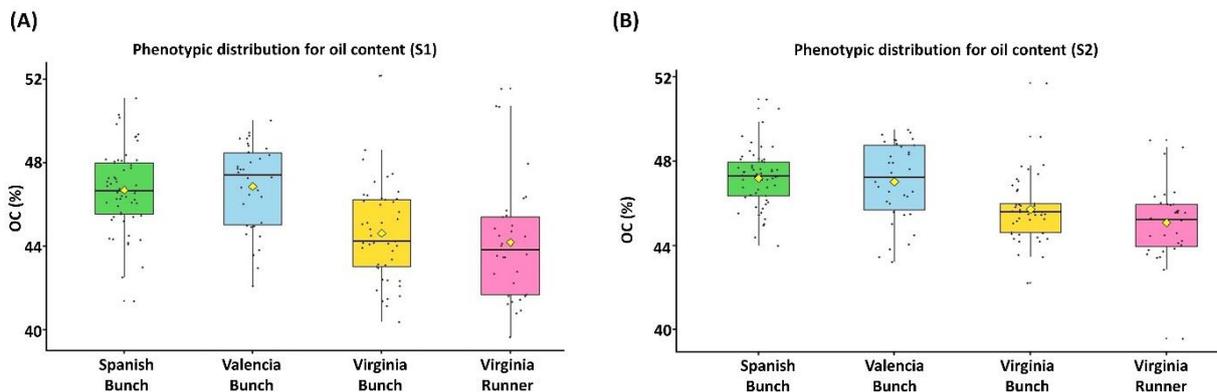
Fig. 2. Phenotypic distribution for oil content based on different agronomic types of the groundnut mini-core accessions across two seasons (A) Season-1, (B) Season-2. The mean values are depicted by the horizontal line in the box.

Previous studies indicated that population genetic and evolutionary factors such as selection, mutation, and recombination rates influence the distribution of genotypes (Joshi *et al.,* 2023; Magwa *et al.,* 2016; Zaitlen *et al.,* 2005). In a study the high blanchability trait was mostly identified in *fastigiata* subspecies, and the agronomic types like Valencia bunch and Spanish bunch, indicating the effect of genetic background and ecogeographic adaptation. However, low-blanchability was observed mostly in *hypogaea* subspecies and agronomic type: Virginia runner and bunch types, revealing genetic constraints (Shah *et al.,* 2025). Guo *et al.* (2026) demonstrated that iron content varied across different botanical types in groundnut and Valencia-type accessions exhibited higher iron concentration than other types.

Similar results were earlier reported in rice (Qian *et al.,* 2017). The accessions from the *aus* subgroup were found to be a rich source of micronutrients, and several high Zn donor accessions from this subgroup were discovered and are extensively used in the Zn biofortification program in rice (Calayugan *et al.,* 2021; Palanog *et al.,* 2019; Swamy *et al.,* 2016). In another study, the U.S. peanut germplasm including 83 accessions were evaluated for oil content and fatty acid composition (Wang *et al.,* 2010). The preliminary results indicated significant variability in oil content and fatty acid composition across botanical varieties.

The subspecies *hypogaea* var. *hypogaea* was helpful for identifying accessions with a high oil content and oleic acid. Further screening of U.S. peanut germplasm was focussed on this botanical variety for high oil content and oleic acid.

Yol *et al.* (2018) carried out a study using 256 groundnut genotypes and the significant variation among the genotypes was identified for oil content with a range of 35.1% to 55.3% in the subspecies *fastigiata*, and 31.1% to 57% in the subspecies *hypogaea*. Oil content varied significantly among genotypes, possibly due to genotypic effects and maturation (Sanders *et al.,* 1980). Oil content may vary depending on location, season, temperature, and environmental conditions (Dwivedi *et al.,* 1993). In this study, subspecies *fastigiata* had slightly higher oil content than subspecies *hypogaea*, and similar findings were obtained in the groundnut collections (Yol *et al.,* 2018; Wang *et al.,* 2013). Spanish types are more suitable for oil production because of their high oil content, compared to other market types (Liao *et al.,* 2007). This study identified some genotypes from different botanical types that had over 50% oil content, indicating the potential for oil marketing in groundnut. These high-oil content groundnut types can be utilised in various breeding programmes for the development of groundnut varieties with enhanced oil content. Groundnut oil remains less competitive than other crops

like rapeseed oil due to its higher market price (Liao, 2014), thus improving oil content in groundnut is crucial. Breeding for high oil content in various market types could increase the marketability of groundnut oil.

CONCLUSIONS

This study reports the phenotypic variation associated with oil content among the 184 groundnut accessions. Phenotypic distribution revealed that high oil content genotypes majorly belong to the subspecies *fastigiata*, and agronomic type, Valencia bunch/Spanish bunch, whereas the genotypes with the low oil content values belong to the subspecies *hypogaea*, and agronomic type, Virginia bunch/Virginia Runner. The accessions ICG 4746 (S1- 52.2%, S2- 51.7%), ICG 12370 (S1- 51.6%, S2- 48.4%), ICG 4955 (S1- 51.1%, S2- 50.5%) showed higher contents of oil across the two seasons. The superior oil content genotypes identified in the groundnut germplasm collection will serve as a potential resource in various breeding programmes for enhancing oil quality in groundnut.

FUTURE SCOPE

The genotypes which possess to have higher oil contents could serve as donors in breeding programme for the development for high oil content groundnut cultivars. The subspecies level variation for oil content provides the primary source of genetic variation for groundnut improvement to meet present and future demands.

Conflict of Interest. The authors declare no conflicts of interest for the research paper.

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