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Genetic variability and divergence studies in Finger millet [*Eleusine coracana* (L.) Gaertn] germplasm

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Abstract
A total 158 finger millet accessions were evaluated to study the genetic diversity with the nature and magnitude of genetic divergence using Mahalanobis (1936) D^2 statistics. Genotypic and phenotypic variances, coefficient of variation, heritability and genetic advance were estimated and cluster analysis was performed. The data was recorded on fifteen traits. The one hundred fifty eight genotypes were grouped into XIII clusters. Clusters I was the largest with 58 genotypes. Maximum heritability was observed for iron content (99.8%) followed by calcium content (99.7%), days to maturity (98.6%), days to 50% flowering (97.2%), seed yield per plant (93.7%), finger number per panicle (92.7%) and flag leaf sheath width (91.8%). Genetic advance as per cent of mean ranged from 5.425 to 137.52. Since there is significant variability observed in all the finger millet genotypes, this could be used for genetic improvement through selection and hybridization.

Keywords: Finger millet, genetic divergence, D^2 statistic, coefficient of variation, heritability and genetic advance

Introduction

Finger millet [*Eleusine coracana* (L.) Gaertn.] also known as African millet or *Ragi*, belongs to family Graminae or Poaceae and common name 'Finger millet' is derived from the finger-like branching of the panicle. It is a self pollinated, tetraploid (2n = 36) crop. It the fourth most important crop in the world among the millets after sorghum, pearl millet and foxtail millet (Ganapathy, 2017) [12]. The crop is native to the Ethiopian highlands of Central Africa and was introduced into Indian sub continent approximately 3000 years ago. There is a long history of cultivation of finger millet in India under diverse agro-climatic conditions and the associated human and natural selection has resulted in generation of large variability giving India the status of secondary centre of diversity. Finger millet is an important staple food in India. It is particularly high in the minerals calcium, iron, magnesium, phosphorous and potassium. The first advance estimated area, production and productivity in Maharashtra *kharif* 2017-2018 total area 0.864 lakh ha, production 0.932 lakh tones and productivity 1078 kg/ha (Directorate of Agriculuture, Government of Maharashtra).

The achievement in plant breeding programme largely depend upon the genetic variability available in breeding population and the efficiency of selection technique. The importance of genetic diversity in plant breeding is obvious from results obtained in different crops. The recognition and measurement of such diversity, its nature and magnitude are beneficial, perhaps crucial to any breeding programme. This is particularly important in a crop like finger millet where hybridization is difficult, there being limited scope for making large number of crosses by random mating and hence, the information regarding the nature of genetic diversity of the parents to be used in the hybridization, is of paramount importance to finger millet improvement. The D^2 statistic is useful tool to assess the genetic divergence among population. It also provides a quantitative measure of association between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936) [20]. Analysis and utilization of available genetic diversity is a short-term strategy for developing improved cultivars for meeting immediate requirement of the farmers and the end users.

Keeping this view a genetic variability and divergence study was carried out to know the extent of variation and diversity for different traits in the germplasms accessions.

Materials and Methods

The field experiment was conducted on Agricultural Botany Experimental Farm, College of Agriculture, Badnapur. Experimental material comprises of 150 germplasm lines received from ICAR- NBPGR Regional station, Akola and eight checks grown in two replications with randomized block design during *Kharif*, 2017. Each entry was represented by two rows of 3 meter length. The spacing of 30 cm within rows and 10 cm between the plants was followed. All recommended agronomical cultural practices were carried out to raise a good crop. Observation were recorded based on five randomly selected plants in each genotype in each replication for fifteen important morphological characters *viz.*, days to 50 per cent flowering, plant height (cm), productive tillers per plant, flag leaf sheath length (cm), flag leaf sheath width (cm), flag leaf blade length (cm), flag leaf blade width (cm), finger number per panicle, finger Length (cm), finger width (cm), days to maturity, thousand grain weight (g), seed yield per plant (g), calcium content (mg/100g) and iron content (mg/100g). The statical analysis was carried out using Windowstat software.

Results and Discussion

Variability estimates

The estimates of variability (Genotypic and Phenotypic coefficients of variation), heritability (broad sense), genetic advance and genetic advance as per cent of mean for fifteen characters in one hundred fifty eight genotypes of finger millet were worked out (Table 1). Phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits this indicated large effect of environment on characters. However, GCV estimates were closer to PCV estimates for most of the characters indicating high contribution of genotypic effect for phenotypic expression of such characters. Although range can provide a preliminary idea about the variability, coefficient of variation is reliable, as it is independent unit of measurement. The extent of variability as measured by GCV and PCV also gives information regarding relative amount of variation in different populations. The GCV and PCV showed wide variation for most of the characters. As expected the PCV was invariably higher than GCV for all the characters. GCV and PCV values were categorized as low (0-10%), moderate (10-20) and high (20% and above). The value for GCV ranged from 4.82 to 31.38 per cent. The highest value of GCV and PCV were recorded for characters iron content (GCV=66.84%; PCV= 66.92%), seed yield per plant (GCV=31.38%; PCV= 32.41%), calcium content (GCV=22.20%; PCV=22.23%) and finger number per panicle (GCV=21.81%; PCV=22.65%) indicating presence of large variability among the genotypes and the possibilities of improvement of these traits through selection. Similar observations were observed by Bothikar *et al*., (2014) [3] for iron content, Wolie, (2013) [28], Lule *et al*., (2012) [19], Bendale *et al*., (2002) [2] for seed yield per plant. Kassahun and Solomon (2017) [16] for finger number per panicle.

The low estimates of PCV and GCV observed for days to 50% flowering (GCV=7.59%; PCV=7.70%) and days to maturity (GCV=5.37%; PCV=5.41%), these results are in accordance with Lule *et al*., (2012) [19], Ganapathy *et al*., (2011) [11] and Kebere Bezaweletaw *et al*. (2006) [17]. In case of plant height recorded low GCV (4.82%) and PCV (8.82%) similar results recorded by Karad and Patil (2013) [15], Srilakshmi (2013) [23] and Wolie (2013) [28].

The medium GCV and PCV observed for finger length (GCV=18.61%; PCV=19.75%), productive tillers per plant (GCV=16.47%; PCV=19.88%), flag leaf blade length(GCV=13.78%; PCV=14.95%), flag leaf sheath width (GCV= 12.54%; PCV= 13.08%), flag leaf sheath length (GCV=11.47%; PCV=12.99%), flag leaf blade width (GCV=11.38%; PCV=12.00%) and finger width (GCV=10.08%; PCV=12.43%) indicated moderate genetic variability for these traits in the material. Similar results were recorded by Bothikar *et al*., (2014) [3] for productive tillers per plant. for finger length, flag leaf blade length, flag leaf sheath width, flag leaf sheath length and flag leaf blade width (Ulaganathan and Nirmalakumari, 2014) [26]. Moderate to low variability of these characters indicated the need for improvement of base population. Test weight recorded moderate (GCV=18.92%) and High (PCV=20.57%). These results are in close agreement with Dhamdhere *et al.,* (2011) [8].

Heritability and Genetic advance

Genotypic coefficient of variation alone does not indicate the proportion of total heritable variation. However, the heritability estimates are better indicator of heritable portion of the variation. The broad sense heritability includes the contribution of additive gene effects and allelic interaction due to dominance and allelic due to epistasis. Burton (1952) [4, 5] suggested that the genetic coefficient of variation and heritability estimates together give better idea about the amount of genetic advance expected through selection. Johnson *et al.* (1955) [14] pointed out that in a selection programme, heritability values as well as genetic advance were more useful than heritability alone. According to them heritability is categorized like, less than 30% as low, 30-60% as moderate and more than 60% as high heritability. In the present study, estimate of heritability were ranged from 29.8% for plant height to 99.8% for iron content. High heritability was also exhibited by iron content (99.8%) followed by calcium content (99.7%), days to maturity (98.6%), days to 50% flowering (97.2%), seed yield per plant (93.7%), finger number per panicle (92.7%), flag leaf sheath width (91.8%), flag leaf blade width (89.9%) finger length (88.7%), flag leaf blade length (84.9%), thousand grain weight (84.6%), flag leaf sheath length (77.9%), productive tillers per plant (68.6%) and finger width (65.7%) indicating scope for selection on the basis of heritable performance. Similar results were observed for finger length by Kumari and Singh (2015) [18], Nishit (2013) [23], Karad and Patil (2013) [15] and Ulaganathan and Nirmalakumari (2012). Number of fingers per panicle similar result recorded by Priyadharshini *et al*., (2011), Nishit (2013) [23], Karad and Patil (2013) [15], Kumari and Singh (2015) [18] and Lule *et al*., (2012) [19]. For days to maturity Satish *et al*., (2007) [24], Karad and Patil (2013) [15], Nishit., (2013) [23], Wolie *et al*., (2013) [28] and Kumari and Singh (2015) [18] observed similar findings.

Calcium content (99.7%) recorded high broad sense heritability. Similar results recorded by Vadivoo *et al*., (1998) [27] and Srilakshmi *et al*., (2013) [23]. Days to 50% flowering (97.2%) also showed high heritability, which is supported by the findings of Dhagate *et al*., (1972) [7] and Ganapathy (2011) [13]. For seed yield per plant Karad and Patil (2013) [15] and Nishit (2013) [23] reported similar results. The character flag leaf sheath width, flag leaf blade width, flag leaf blade length, thousand grain weight, flag leaf sheath length, productive tillers per plant, and finger width, similar results were observed by Ulaganathan and Nirmalakumari (2014) [26]. The iron content (99.8%) showed high heritability which is supported by the findings of Bothikar *et al*., (2014) [3].

Genetic advance as per cent of mean ranged from 5.42 to 137.52 per cent. Iron content (137.52%) recorded highest genetic advance as per cent mean followed by seed yield per plant (62.59%), calcium content (45.66%), finger number per panicle (43.25%), finger length (36.11%), thousand grain weight (35.86%), productive tillers per plant (28.12%), flag leaf blade length, (26.16%), flag leaf sheath width (24.75%), flag leaf blade width (22.23%) and Flag leaf sheath length (20.85%). High genetic advance indicated that these characters are governed by additive genes and selection will be rewarding for improvement of these traits. Similar results were observed by Ulaganathan and Nirmalakumari (2014) [26], Ganapathy *et al*. (2011) [13], Kassahun and Solomon (2017) [16] and Kebere *et al*., (2006) [17]. Moderate genetic advance mean was recorded for finger width (16.82%), days to 50% flowering (15.43%) and days to maturity (10.98%), and lowest for plant height (5.42%) indicated these characters are governed by non additive genes and selection may not be efficient on this traits. Similar results were observed by Anuradha *et al*. (2017) [1], Ulaganathan and Nirmalakumari (2014) [26] for days to 50% flowering and finger width, days to maturity for Ulaganathan and Nirmalakumari (2014) [26], Kebere *et al*., (2006) [17] and Anuradha *et al*. (2017) [1].

Diversity analysis

The estimates of D^2 values ranged from 50073.01 to 9231753.02 clearly indicated the presence of adequate diversity between genotypes studied. Negi *et al*. (2017), Kumari and Singh (2015) [18] and Jadhav *et al*., (2015) [13] also reported wide genetic diversity in finger millet germplasm.

Cluster formation

The aim of cluster formation and measuring inter and intra cluster divergence is to provide the basis for hybridization programme. The theoretical concept behind such grouping is that, the genotypes grouped into the same cluster presumably are less diverse from each other than those belonging to the different clusters and will not give expected desired heterotic response and segregants in further generations. In the present investigation, the cluster I was with the highest number of genotypes (58) followed by cluster IV (43), clusters II (40), cluster V (8), and cluster III, VI, VII, VIII, IX, X, XI, XII, XIII had single genotype. The cluster formation in finger millet reported Jadhav *et al*. (2015) [13], Kumari and Singh (2015) [18], Devaliya *et al*. (2017) [6] and Mahanthesha *et al*. (2017) [21, 22].

The intra cluster distance (D) range from 223.77 to 3038.38. The maximum inter cluster distance (D =3038.38) was observed between cluster XI and cluster V, followed by cluster XII and IV (D = 2882.83), cluster X and cluster V (2759.73), cluster XI and cluster IV (D = 2723.03), cluster XIII and cluster IV (D = 2684.68), indicating that the genotypes falling in these clusters were highly divergent from each other implying large amount of diversity within and between groups, which could be exploited in breeding programmes. The minimum inter cluster distance (D = 223.77) was between IX and VII, indicating that this cluster is less divergent. The cluster means revealed high variability among the clusters for the traits, the cluster mean for days to 50 per cent flowering varied from 54 (XI) to 78 days (I) and (II). The cluster means for plant height ranged between 102.70 (XI) to 135.80cm (XIII). The cluster mean for productive tillers per plant ranged between 2.70 (X) to 4.50 (III). The cluster mean for flag leaf sheath length ranged from 8.69 (cluster X) to 12.55 (cluster III). The cluster mean for flag leaf sheath width ranged between 0.71 (cluster III) and 0.99 (cluster XIII).

The cluster mean for flag leaf blade length was maximum in cluster (VI) 35.22 and it was minimum in cluster (IX) 24.74. The cluster mean for flag leaf blade width was maximum in cluster (XIII) 1.08 and it was minimum in cluster (XI) 0.73. The cluster mean for finger number per panicle was minimum in cluster IX (4.2) and it was maximum in cluster XIII (17.7). The cluster mean for finger length ranged between 4.59 (cluster VIII) and 8.24 (cluster XIII). The cluster mean for finger width ranged between 0.81(cluster VI) and 0.95 (cluster XI). The cluster mean for days to maturity was maximum in cluster (I) 110 and minimum in case of cluster (XI) 87. The cluster mean for thousand grain weight was maximum in cluster (VIII) 2.85 and it was minimum in cluster (X) 1.5. The cluster mean for seed yield per plant was maximum in cluster (XIII) 5.51 and it was minimum in cluster (IX) 2.42.The cluster mean for calcium content was minimum in cluster (VI) 208.5 and it was maximum in cluster (XIII) 406.5 The cluster mean for iron content was maximum in cluster (V) 46.36 and it was minimum in cluster (XIII) 1.62. It was observed that, iron content (47.68%) contributed highest for divergence, followed by calcium content (39.77%), days to maturity (9.63%), seed yield per plant (0.73%), flag leaf sheath width (0.53%), finger length (0.53%), finger number per panicle (0.49%), flag leaf blade width (0.2%), flag leaf blade length (0.17%), days to 50% flowering (0.1%), thousand grain weight (0.07%), flag leaf sheath length (0.05%), productive tillers per plant (0.02%), finger width (0.01%) and Plant height (0%). Similar results were observed by Kumari and Singh (2015) [18] for days to maturity, plant height, seed yield per plant.

The utility of D^2 analysis was enhanced by its application to estimate the relative contribution of the various plant characters to genetic divergence. The per cent contribution of fifteen characters studied, towards total divergence is presented in Table 5. It was observed that, iron content (47.68%) contributed highest for divergence. It was followed by calcium content (39.77%), days to maturity (9.63%), seed yield per plant (0.73%), flag leaf sheath width (0.53%), finger length (0.53%), finger number per panicle (0.49%), flag leaf blade width (0.2%), flag leaf blade length (0.17%), days to 50% flowering (0.1%), thousand grain weight (0.07%), flag leaf sheath length (0.05%), productive tillers per plant (0.02%), finger width (0.01%) and plant height (0%).

Table 1: Estimates of variability parameters for fifteen quantitative characters in finger millet

Sr. No.	Name of the characters	Range	Mean	σ^2g	σ^2p	σ^2e	GCV (%)	PCV (%)	h^2 (b.s.) (%)	G.A.	G.A. as % of mean
1.	Days to 50% flowering	54-87	77	33.96	34.94	0.97	7.59	7.70	97.2	11.83	15.43
2.	Plant height (cm)	102.7-144.3	125.37	36.52	122.43	85.90	4.82	8.82	29.8	6.80	5.42
3.	Productive tillers per plant	1.6-5.5	3.78	0.33	0.55	0.17	16.47	19.88	68.6	1.06	28.12
4.	Flag leaf sheath length (cm)	7.2-12.96	10.23	1.37	1.768	0.39	11.47	12.99	77.9	2.13	20.85
5.	Flag leaf sheath width (cm)	0.64-1.18	0.86	0.012	0.013	0.001	12.54	13.08	91.8	0.21	24.75
6.	Flag leaf blade length (cm)	17.27-38.98	29.32	16.33	19.22	2.89	13.78	14.95	84.9	7.67	26.16
7.	Flag leaf blade width (cm)	0.65-1.24	0.91	0.011	0.01	0.001	11.38	12.00	89.9	0.20	22.23
8.	Finger number per panicle	4.2-17.7	7.00	2.07	2.24	0.16	21.81	22.65	92.7	2.86	43.25
9.	Finger length (cm)	4.25-12.47	6.19	1.33	1.49	0.16	18.61	19.75	88.7	2.23	36.11
10	Finger width (cm)	0.51-1.20	0.90	0.008	0.012	0.004	10.08	12.43	65.7	0.15	16.82
11	Days to maturity	87-120	109	34.02	34.51	0.48	5.37	5.41	98.6	11.93	10.98
12	Thousand grain weight (g)	1.3-3.7	2.28	0.18	0.22	0.034	18.92	20.57	84.6	0.82	35.86
13	Seed yield per plant (g)	1.94-9.18	3.54	1.23	1.31	0.083	31.38	32.41	93.7	2.21	62.59
14	Calcium content (mg/100g)	197.5-453.5	295.52	4305.39	4318.99	13.59	22.20	22.23	99.7	134.95	45.66
15	Iron content mg (mg/100g)	0.57-57.83	22.69	230.03	230.58	0.55	66.84	66.92	99.8	31.20	137.52

Table 2: Grouping of one hundred fifty eight finger millet genotypes into different clusters by Tocher's method.

Cluster No.	No. of genotypes	Genotypes included in the cluster
I	58	IC71408, 12-3, IC50015-A, IC65696-B, IC71342, IC87494-A, IC45866 IC87504, IC49940, IC51458, IC49983, IC50000, IC45863-A, IC87526 IC49999-A, IC203975, IC49999-B, IC361118, IC50000-B,I C45865, IC87471, IC87522, IC49956, IC44840,IC49979-B, IC66235, IC45852 IC43276-A, IC87498, IC87478, IC71411-B, IC49992, IC65595, IC87500 IC45850, IC45876, IC50013, IC45859, IC49995-A, IC71413, IC50006 IC71377-C, IC45845-A, IC45864, IC45844-A, IC45841-A, IC87483 IC45847, IC87485, IC49947-A, IC73541-A, IC87518, IC71380 IC340116, IC71581, IC340138, IC71420-A.
II	40	IC71381, IC71411-A, IGPM-14-3, IC71395-A, IC71330-A, IC71378-B LS-5L, IC203978, IC49985, IC45844, IC50011, IC49947, IC49990-B IC340116, IC45862, IC49992-A, IC203970, IC87486, IC69596-A, 17-3 IGPM-20-3, IC66588, IC71395, IC49949-A, IC87497-A, IC49999 IC87458-A, IC71418-A, IC50013-B, IC87472, IC65558-B, IC71399 IC87470, IC50009, IC50001, IC71400-A, VL-149, IC206167, IC50019 IC65559.
III	1	IC49988.
IV	43	IC44032-A, IC45863, IC71379-A, IC87490, IC87487, IC50004, IC45878-A IC87514-A, IC87565-B, IC49981-A, IC50002, IC49998-A, IC71410 IC71340, IC66172, IC49953, IC71420, 14-3, IC49942, IC66048-A, IC87469 IC71382-B, IC87488, IC87519-B, RDV-10, IC340136, IC65632-A, JK-439 IC87529-A, IC71413-A, IC49965, IC71419-A, IC49946-A, IC204141 IC87517, IC69598, IC71378-C, IC87494-B, IC87530, IC45867, IC87502 GPU-28, IC71418-B.
V	8	IC50012-A, IC66337, IC87519, GPU67, HR-374, GPU45, Phule Nachani IC66255.
VI	1	IC204143
VII	1	IC206171
VIII	1	IC340142
IX	1	IC49944-B
X	1	IC395842
XI	1	IC45861
XII	1	BR-708
XIII	1	IC87476

Table 3: Average intra and inter cluster distance (D) values in finger millet.

Cluster No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	341.62	850.04	549.69	1122.11	1867.38	720.36	807.35	651.23	1499.76	699.7	1478.58	1936.78	2308.03
II		356.64	689.74	1631.99	1299.46	1601.79	676.12	659.6	739.6	1278.23	1518.43	1098.24	1413.05
III			0.00	452.14	710.03	577.14	401.92	1021.87	779.01	1028.11	1559.11	1583.11	1591.32
IV				483.26	1036.59	915.97	1176.98	2098.58	1755.25	1874.56	2723.03	2882.83	2684.68
V					476.36	1988.28	1207.69	2385.3	1112.81	2759.73	3038.38	2209.83	1844.74
VI						0.00	556.32	991.15	1420.43	446.34	977.18	1782.72	2010.94
VII							0.00	484.4	223.77	494.15	513.85	507.27	903.35
VIII								0.00	924.35	332.77	485	727.72	1378.88
IX									0.00	1204.35	883.72	353.77	772.49
X										0.00	323.89	1114.49	1863.5
XI											0.00	464.66	1261.23
XII												0.00	494.22
XIII													0.00

Table 4: Cluster means of different characters to genetic diversity in finger millet.

SN	Days to 50% flowering	Plant height (cm)	Productive tillers per plant	Flag leaf sheath length (cm)	Flag leaf sheath width (cm)	Flag leaf blade length (cm)	Flag leaf blade width (cm)	Finger number per panicle	Finger length (cm)	Finger width (cm)	Days to maturity	Thousand grain weight (g)	Seed yield per plant (g)	Calcium content (mg/100gm)	Iron content (mg/100g)
I	78	126.2	3.76	10.06	0.84	29.04	0.90	6.46	6.00	0.89	110	2.24	3.35	257.52	12.45
II	78	128.1	3.75	10.20	0.86	29.21	0.93	6.59	6.16	0.90	109	2.20	3.50	372.03	15.61
III	77	119.2	4.50	12.55	0.71	29.53	0.85	6.70	5.91	0.87	106	1.90	3.51	296.50	30.41
IV	77	124.1	3.89	10.43	0.87	29.72	0.90	6.58	6.39	0.92	109	2.37	3.66	255.53	39.84
V	76	119.5	3.90	10.29	0.94	29.36	0.99	7.05	6.82	0.93	109	2.64	4.80	377.13	46.36
VI	65	118.9	3.50	11.48	0.87	35.22	0.77	6.90	6.30	0.81	97	2.65	3.09	208.50	23.12
VII	64	124.4	3.00	10.07	0.85	27.68	0.85	5.50	5.25	0.93	97	2.25	2.54	321.50	22.64
VIII	70	110.5	2.80	10.45	0.94	29.34	0.93	7.30	4.59	0.94	102	2.85	2.62	311.00	1.62
IX	61	115.6	4.00	9.73	0.76	24.74	0.85	4.20	6.16	0.88	97	2.40	2.42	389.00	27.39
X	62	120.1	2.70	8.69	0.77	26.4	0.83	5.80	6.02	0.93	96	1.50	2.46	241.50	5.96
XI	54	102.7	4.10	10.32	0.77	30.15	0.73	5.50	5.99	0.95	87	2.50	3.58	297.50	5.78
XII	55	119.4	2.80	10.28	0.96	31.53	0.91	7.27	6.80	0.88	90	2.35	3.89	399.00	14.01
XIII	58	135.8	3.80	11.14	0.99	32.35	1.08	17.70	8.24	0.91	90	2.30	5.51	406.50	24.03

Table 5: Per cent contribution of different characters to genetic diversity in finger millet

Sr. No.	Characters	No. of times appearing Ist in ranking	% contribution
1.	Days to 50% flowering	13	0.1
2.	Plant height (cm)	0	0
3.	Productive tillers per plant	2	0.02
4.	Flag leaf sheath length (cm)	6	0.05
5.	Flag leaf sheath width (cm)	66	0.53
6.	Flag leaf blade length (cm)	21	0.17
7.	Flag leaf blade width (cm)	25	0.2
8.	Finger number per panicle	61	0.49
9.	Finger length (cm)	66	0.53
10.	Finger width (cm)	1	0.01
11.	Days to maturity	1195	9.63
12.	Thousand grain weight (g)	9	0.07
13.	Seed yield per plant (g)	91	0.73
14.	Calcium content (mg/100g)	4933	39.77
15.	Iron content mg (mg/100g)	5914	47.68
	Total	12403	100

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