

A study on diversity and distribution of kokum (*Garcinia indica* (Choisy) Thouars) using DIVA-GIS in Goa with respect to fruit characters

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ABSTRACT

Kokum (*Garcinia indica* Choisy (Thouars), native to Western Ghat of India, is an important under-exploited fruit tree having culinary, pharmaceutical and industrial uses. It is a cross-pollinated species and of seedling origin, owing to which, there is heterozygosity and wide variability existing in the natural population. To know the spatial distribution and assessment of natural variability in *kokum*, grid maps were generated using DIVA-GIS version 5.2. Average fruit weight ranged from 6.80 to 47.60 g with a mean of 18.41 g, whereas, the average fruit diameter varied widely from 1.80 to 5.51 cm with a mean fruit diameter of 2.97 cm. Rind thickness varied from a minimum of 0.14 cm to a maximum of 0.48 cm, with mean of 0.26 cm. Fruit diameter expressed a highly significant and positive correlation with fruit weight (0.789) and rind thickness (0.203). Among the eleven taluks of Goa, Bicholim, Pernem, Ponda and Canacona were found to be promising zones of *kokum* diversity and are identified as the hotspots for its biodiversity by using various richness and diversity indices.

Key words: *Garcinia indica*, DIVA-GIS, diversity, fruit characters.

INTRODUCTION

Kokum (*Garcinia indica* Choisy) belongs to the genus *Garcinia*, which is a very large genus of polygamous evergreen trees and shrubs, native to Asia, South Africa and Polynesia (Anthony, 1). *Konkan* region of Western Ghats in general is known for its biodiversity. *Kokum* is one such native species, which is dioecious in nature. Cross-pollination coupled with seedling population of *kokum* has lead to large genetic diversity and wide adaptability. Presence of hydroxy citric acid (HCA) in *kokum* rind has enhanced the value of this species in the international market, owing to the anti-obesity factor of HCA. Other than these virtues, *kokum* also serves as a source of natural food colours, resins, tannins, etc.

In Goa, *kokum* trees are naturally distributed in the hill slopes, forest regions, rocky plateaus, roadsides, farm bunds and stream banks. The favoured habitats for the *kokum* trees are the secondary forests that are close to human habitation. Unfortunately, these are under serious threat due to rapid urbanization. *Kokum* therefore requires greater attention from conservationists. Till now, the tremendous genetic diversity of *kokum* existing in Goa state has not been scientifically documented. Systematic identification, documentation and conservation of genetic diversity of *kokum* either *ex situ* or *in situ* are the need of the

hour. Therefore, survey of the existing diversity and identification of ideal accessions for yield traits was attempted. The challenge lies in identification of potential areas and regions for collection of *Garcinia indica* germplasm for better utilization of the available diversity. DIVA-GIS, a Geographic Information System (GIS) is designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of species of interest (Hijmans *et al.*, 6). DIVA GIS supports the analysis of exploration, gene bank and herbarium databases to elucidate genetic, ecological and geographic patterns in the distribution of crops and wild species. GIS was successfully used by many researchers in identifying areas of high diversity in crops like *Phaseolus* bean (Jones *et al.*, 8); wild potatoes (Hijmans *et al.*, 6) and pepper (Parthasarathy *et al.*, 11). Considering the importance of *Garcinia indica*, we have mapped the distribution and diversity for exploration and conservation in the state of Goa.

MATERIALS AND METHODS

The study was conducted in the state of Goa located between 14°16" North latitude and 73°75" East longitude with the states of Maharashtra on the North and Karnataka on the East and South and Arabian Sea on the West side. As *Garcinia indica* is native to the Western Ghat of India, an extensive survey was conducted in all the eleven taluks of Goa during 2005 to 2010. A total of 268 trees were identified during extensive survey in Goa for *kokum* diversity. Various morphometric characters of fruits like

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fruit weight, polar diameter, equatorial diameter, fruit volume, fruit colour, rind thickness, number of locules per fruit, number of seeds per fruit, juice content (%), moisture content (%), total acids (%), sugars (%), hydroxy citric acid content (%) in dried rind and fat percentage in dried seeds were observed in all the accessions studied. Twenty five fully grown and ripe fruits /tree were used to record these observations. Among these, only three important fruit characters are discussed in this paper.

The latitude, longitude and altitude of the spot, where the accession is located were recorded using GPS (Garmin GIS12, made in USA, supported by twelve satellites). The values recorded in degrees/minute/second were decimalized by dividing minutes by 60 and seconds by 3600. These decimal values were used to plot the accessions on Goa map using software "DIVA-GIS" Version 5.2. Maps on the distribution pattern, diversity and richness were generated with the help of point-to-grid analysis using simple method.

RESULTS AND DISCUSSION

Based on the systematic study on natural variability of *kokum* in Goa and the analysis of diversity and distribution of *kokum* germplasm using Geographic Information System (DIVA-GIS) promising accessions in terms of fruit characters were identified. The results are hereunder discussed on two aspects, viz., horticultural significance as well as biodiversity of the crop in the state of Goa. Out of 268 accessions studied, average fruit weight ranged from 6.80 to 47.60 g (Table 1). The two most promising accessions are Borim-2 from Ponda taluk and Kasarpal-5 from Bicholim taluk (Priya Devi, 13).

When the accessions were mapped (Fig. 1), it was found that the trees with heavier fruits, i.e. above 40 g were located in Ponda (Acc. No.126) and Bicholim (Acc. No.69) taluks (red grids). The accessions that bore fruits weighing in the range of 32 and 40g were scattered in Pernem (Acc. Nos. 24, 6 and 7), Bardez (Acc. No.118), Bicholim (Acc. Nos. 97, 98 and 110), Ponda (Acc. Nos. 138,153 and 157) and Sanguem (Acc. Nos. 257 and 259) which were depicted by orange grids.

Accessions with fruits of medium weight ranging from 24 to 32 g (yellow grids) were distributed in almost all taluks except Mormugoa, Sanguem and Sattari. Accessions represented in light green grids having average fruit weight ranging from 16 to 24 g were scattered all over the taluks except Bicholim and Quepem. Trees with very small fruits weighing 10 g and below were noticed in taluks like Sattari (Acc. No. 173 and 168), Salcete (Acc. No. 188), Sanguem (Acc. Nos. 249 and 262), Canacona (Acc. Nos. 224 and 228), Ponda (Acc. No. 139), Tiswadi (Acc. No. 37) and Bicholim (Acc. Nos. 53, 60, 67 and 87) (Table 3)

When the data on fruit weight were subjected to diversity analysis (Shannon model), it was observed that the maximum diversity of 2.36 to 2.94 (red grid) (Fig. 2) was in Ponda, Bicholim and Pernem taluks, followed by an index range of 1.77 to 2.36 (orange grid) in Sattari, Bardez, parts of Bicholim and Canacona taluks. A medium diversity index of 1.18-1.77 (yellow grid) was noticed in parts of Pernem, Sattari, Bardez, Mormugoa, Sanguem and Quepem. Less diversity (index range of 0.59 to 1.18 in light green) and very low diversity (index range of 0.00 to 0.59 in dark green grids) were found scattered throughout the state of

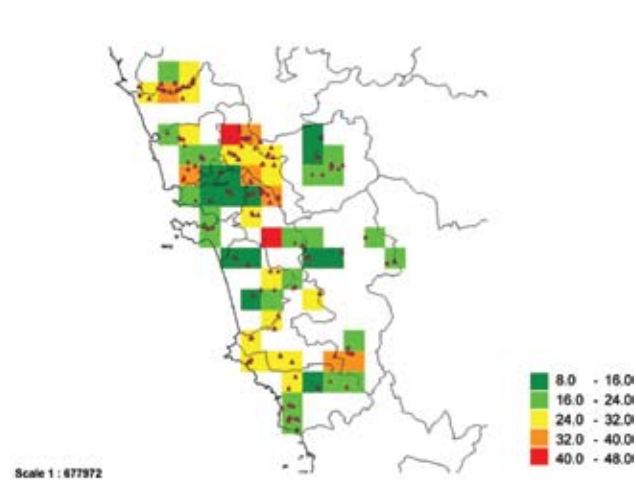


Fig. 1. Map of Goa showing distribution of accessions for fruit weight.

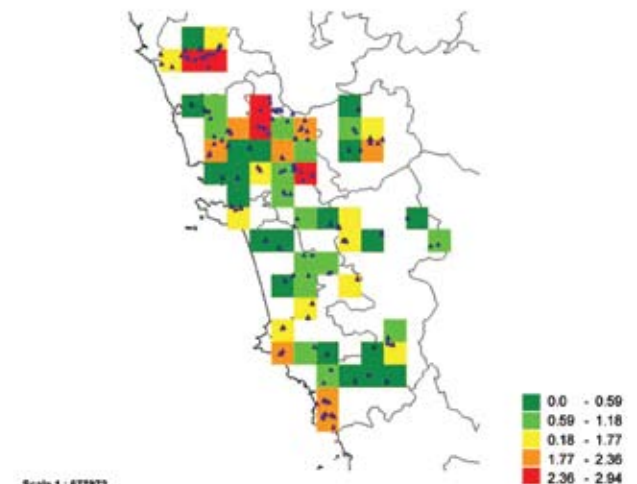


Fig. 2. Map of Goa showing diversity of *kokum* accessions for fruit weight.

Table 1. Statistics for fruit characters of *kokum* trees in Goa.

Statistical parameter	Variable		
	Fruit weight (g)	Fruit diameter (cm)	Rind thickness (mm)
Minimum	6.80	1.79	0.14
Maximum	47.60	5.51	0.48
Mean	18.41	2.97	0.26
Standard deviation	6.72	0.59	0.06
Variance	45.19	0.35	0.00
Range	2.22	3.72	0.34
Sum	4934.29	795.29	69.36
Coefficient of variation	36.51	20.05	24.65

Goa. Thus, the biodiversity richness estimators in DIVA-GIS showed Pernem and Bicholim taluks to have greater genetic diversity. These zones need further exploitation regarding crop improvement

Similar diversity index maps were made by Parthasarathy *et al.* (11) to show the density of species of *Piper* and found the two hot spots in south India with 7-8 species of *Piper* naturally occurring. Studies on genetic variation in *kokum* fruit characters were carried out by several workers in *konkan* tracts of Maharashtra. Rodrigues (14) recorded a fruit weight range of 22.10 to 33.80 g in some promising naturally occurring seedling in Goa. This range corroborates with the present study. Gawankar *et al.* (3) recorded a range of 19.15 to 40.80 g in nine seedling progenies of *kokum* evaluated under field condition in Maharashtra. All these trees were projected as promising accessions of the study. Gawankar *et al.* (4) reported a variation of 25.40 to 58.38 g in fruit weight of *kokum* types. In an evaluation study in clonal orchards on performance of grafts of promising types *kokum*, the average fruit weight ranged from 25.40 to 58.38 g (Shingre *et al.*, 15) under well managed conditions. In the present study also promising accessions recorded 47.60 and 41.25 g under natural conditions. Higher fruit weight may be obtained from these promising genotypes under well managed conditions.

The average fruit diameter varied widely from 1.80 (Acc. No. 188) to 5.51 cm (Acc. No. 194) with a mean fruit diameter of 2.97 cm (Table 1). The highest range of fruit diameter 4.80 to 5.50 cm (red grids) was found in Bicholim and Pernem taluks (Fig. 2), followed by orange grids (of range 4.00 to 4.80 cm) spotted over Pernem, Bicholim, Ponda and Canacona taluks. The accessions having medium diameter range of 3.30 to 4.00 cm (yellow grids) were also distributed in Bardez, Sattari, Bicholim, Salcete, Quepem and Canacona taluks. The accessions having lower range (light green grids) of fruit diameter (2.50 to 3.30 cm) were widely

distributed all over Goa, except Quepem taluk and the accessions having lowest range of 1.80 to 2.50 cm of fruit diameter were only seen in few trees found in Sattari, Bicholim and Canacona taluks (Fig. 3).

Highest diversity for fruit diameter was seen in Pernem, Bicholim, Ponda and Canacona taluks, followed by Sattari, Bardez, Bicholim and Quepem. Medium diversity was seen in Pernem, Sattari, Tiswadi, Mormugoa, Sanguem and Quepem. Low diversity found in Bardez, Sattari, Bicholim, Salcete, Quepem, Canacona and Sanguem and the lowest diversity range was in all taluks except Bicholim taluk (Fig. 4).

Fruits with diameter more than 4 cm are preferred by farmers as well as by the breeders. Accessions 126 and 69 recorded desirable fruit diameter as well as fruit weight (Table 3). Therefore, such accessions need further selection and propagation. Similar diversity studies for fruit traits were attempted earlier by Nair (10) who reported a range of 1.17 to 4.02 cm and 0.76 to 4.17 on for fruit length and diameter, respectively. Likewise, Gawankar *et al.* (5) also observed similar variation in fruit length (3.20 to 4.28 cm) and fruit diameter (3.30 to 4.75 cm) in *kokum* genotypes. In the present study, superior genotypes for fruit diameter were located in Canacona, Ponda and Bicholim taluks.

Rind is the most sought after part of the fruit. Dried rind is an important commercial product. Besides, fruit juice purely extracted from locules bear no colour. Only when juice is extracted from both rind and locules, it bears an appealing colour and flavour. Therefore, rind composition in fruit is very crucial. The thickness of fruit rind showed a wide variation among the accessions studied (Table 1). It varied from a minimum of 0.14 cm in Acc. No. 16 (Pernem taluk) to a maximum of 0.48 cm in Acc. No. 263 (Sanguem taluk). The rind thickness of 0.4 cm and above (up to a maximum of 0.48 cm) was noticed in several accessions from various taluks (Table 3). The mean rind thickness was 0.26 cm and 104 accessions had rind thickness above the mean value.

On mapping, it was observed that (Fig. 5), accessions with fruits having higher range of rind thickness (0.41 to 0.48 cm), represented by red coloured grids were seen in taluks like Pernem, Bardez, Sattari, Sanguem, Quepem and Canacona. Eight such elite accessions with superior rind thickness are furnished in Table 3. Accessions in next range of 0.35 to 0.41 cm, represented by orange coloured grids

Table 3. Accessions falling under range reported for fruit characters.

S. No.	Parameter	Range	Accessions Nos.	No. of accessions	
1.	Fruit weight (g)	i)	8-16	7, 8, 9, 12, 13, 14, 15, 22, 28, 31, 34, 37, 38, 39, 40, 41, 45, 46, 47, 50, 53, 54, 55, 56, 57, 60, 65, 67, 71, 73, 86, 87, 90, 95, 96, 102, 103, 114, 115, 117, 121, 123, 124, 125, 132, 139, 140, 141, 146, 154, 156, 160, 161, 162, 166, 168, 169, 170, 171, 172, 173, 175, 176, 177, 180, 181, 182, 183, 185, 186, 187, 188, 195, 196, 198, 199, 201, 204, 205, 207, 208, 213, 214, 216, 217, 218, 219, 220, 221, 222, 224, 226, 228, 230, 231, 232, 233, 236, 237, 242, 245, 246, 247, 248, 249, 250, 251, 258, 261, 262, 263, 266, 267	113
		ii)	16-24	1, 3, 5, 6, 10, 11, 17, 20, 21, 25, 29, 32, 35, 36, 42, 44, 48, 49, 51, 52, 58, 62, 63, 64, 68, 72, 77, 80, 81, 82, 83, 84, 85, 88, 91, 92, 93, 94, 99, 100, 101, 104, 105, 106, 107, 111, 112, 113, 119, 120, 122, 127, 128, 129, 130, 133, 134, 142, 143, 145, 147, 148, 149, 150, 151, 155, 158, 159, 163, 164, 165, 167, 174, 178, 179, 190, 191, 193, 197, 202, 206, 209, 210, 211, 212, 215, 223, 225, 227, 229, 234, 235, 238, 241, 243, 244, 252, 253, 254, 255, 256, 264, 265, 268	104
		iii)	24-32	2, 4, 16, 18, 19, 23, 26, 30, 33, 43, 59, 61, 66, 70, 74, 75, 76, 78, 79, 89, 108, 109, 110, 116, 135, 136, 137, 144, 152, 184, 189, 192, 194, 200, 203, 239, 240, 260	38
		iv)	32-40	24, 27, 97, 98, 118, 131, 138, 153, 157, 257, 259	11
		v)	40-48	69, 126	2
2.	Fruit diameter (cm)	i)	1.8-2.5	8, 9, 10, 12, 15, 45, 46, 47, 51, 56, 58, 60, 67, 76, 86, 87, 102, 114, 120, 125, 132, 139, 141, 154, 156, 160, 161, 168, 175, 177, 183, 186, 188, 198, 199, 207, 213, 219, 220, 224, 230, 232, 233, 244, 245, 247, 248, 249, 250, 251, 261, 262, 263, 267	54
		ii)	2.5-3.3	1, 3, 6, 7, 11, 13, 14, 18, 20, 21, 22, 25, 28, 29, 30, 31, 32, 34, 36, 37, 38, 39, 40, 41, 42, 44, 48, 49, 50, 52, 53, 54, 55, 59, 62, 63, 64, 65, 71, 72, 73, 78, 80, 81, 85, 88, 88, 90, 93, 94, 95, 96, 99, 100, 101, 103, 105, 106, 107, 108, 111, 112, 113, 114, 115, 116, 117, 119, 121, 122, 123, 124, 127, 128, 129, 130, 131, 133, 134, 140, 145, 146, 147, 155, 158, 159, 162, 163, 164, 165, 166, 169, 170, 171, 172, 173, 174, 176, 178, 179, 180, 181, 182, 185, 187, 190, 191, 195, 196, 201, 202, 204, 205, 206, 208, 209, 211, 212, 214, 216, 217, 218, 221, 222, 223, 225, 226, 227, 228, 229, 231, 234, 235, 236, 237, 238, 241, 242, 243, 246, 252, 253, 255, 258, 260, 264, 265, 266, 268	149
		iii)	3.3-4.0	2, 4, 16, 17, 19, 23, 43, 61, 66, 70, 74, 75, 77, 82, 84, 89, 91, 92, 97, 98, 104, 109, 110, 118, 135, 136, 142, 143, 144, 148, 149, 150, 151, 167, 184, 189, 192, 193, 197, 200, 203, 210, 215, 254, 256, 257, 259	47
		iv)	4.0-4.8	24, 26, 27, 33, 68, 69, 79, 83, 126, 137, 138, 152, 157, 239, 240,	15
		v)	4.8-5.5	35, 153, 194	3

contd...

Table contd...

S. No.	Parameter	Range	Accessions Nos.	No. of accessions
3.	Rind thickness (cm)	i) 0.162-0.225	1, 7, 8, 10, 12, 16, 17, 31, 32, 34, 36, 48, 50, 51, 52, 54, 56, 57, 63, 67, 68, 76, 77, 80, 87, 96, 97, 102, 105, 107, 108, 113, 115, 117, 118, 119, 124, 129, 132, 133, 134, 136, 139, 143, 145, 146, 148, 149, 153, 156, 158, 160, 168, 170, 172, 178, 180, 181, 186, 188, 191, 193, 194, 196, 198, 201, 202, 204, 206, 207, 208, 210, 213, 215, 219, 221, 222, 232, 233, 236, 237, 241, 242, 244, 245, 249, 252, 253, 258, 265, 266, 277	92
		ii) 0.225-0.287	2, 3, 5, 6, 11, 13, 14, 15, 18, 21, 25, 29, 33, 35, 40, 41, 46, 49, 53, 55, 58, 61, 62, 64, 66, 69, 70, 72, 73, 75, 79, 81, 82, 85, 86, 88, 90, 91, 93, 94, 95, 98, 99, 100, 101, 103, 104, 110, 122, 125, 128, 130, 131, 135, 137, 141, 142, 144, 147, 150, 151, 157, 159, 161, 162, 164, 166, 167, 169, 171, 174, 182, 184, 185, 187, 190, 199, 203, 205, 211, 212, 217, 218, 220, 223, 224, 225, 226, 231, 234, 235, 238, 239, 248, 250, 254, 255, 259, 261, 262, 264, 268	102
		iii) 0.287-0.349	9, 20, 22, 23, 24, 26, 37, 38, 39, 42, 43, 45, 59, 65, 71, 74, 78, 83, 84, 89, 92, 106, 109, 112, 114, 116, 120, 121, 123, 126, 140, 152, 154, 155, 165, 176, 179, 183, 227, 228, 229, 230, 246, 247, 251, 256, 260	47
		iv) 0.349-0.412	19, 30, 44, 47, 60, 111, 127, 138, 163, 173, 175, 189, 192, 195, 197, 209, 214, 216, 257	19
		v) 0.412-0.475	4, 27, 28, 177, 200, 240, 243, 263	8

was shown over Pernem, Bardez, Bicholim, Sattari, Ponda, Quepem and Canacona taluks. The accessions with fruits having medium rind thickness of 0.29 to 0.35 cm (yellow grids) were spread over taluks like Pernem, Bardez, Bicholim, Ponda, Salcete, Sanguem and Canacona. The accessions having less rind thickness ranging from 0.23 to 0.29 cm were shown as light

green grids, found in Pernem, Bardez, Sattari, Tiswadi, Mormugoa, Ponda, Salcete, Sanguem, Quepem and Canacona taluks. The minimum range under classification, i.e. 0.16 to 0.23 cm projected as dark green grids were spread over Bardez, Tiswadi, Sattari, Sanguem, Salcete and Canacona taluks of Goa.

Similarly, maximum diversity (Fig. 6) of 60.00

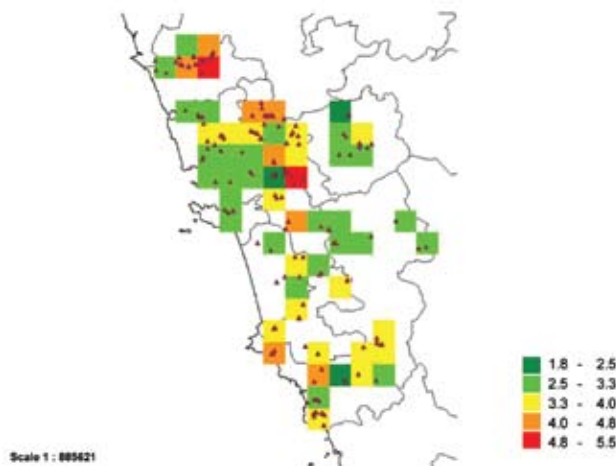


Fig. 3. Map of Goa showing distribution of kokum accessions for fruit diameter

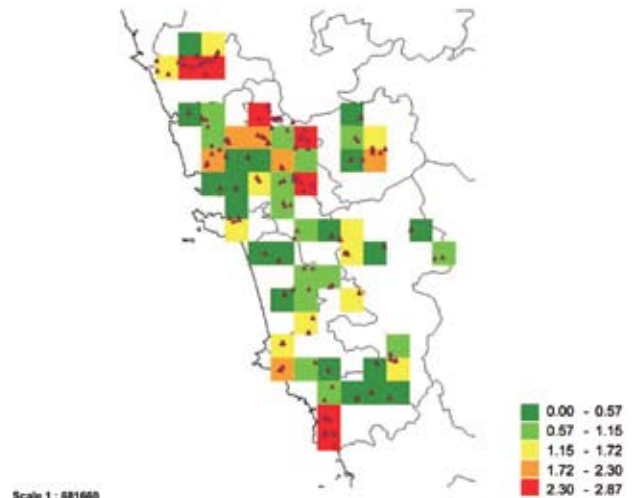


Fig. 4. Map of Goa showing diversity of kokum accessions for fruit diameter.

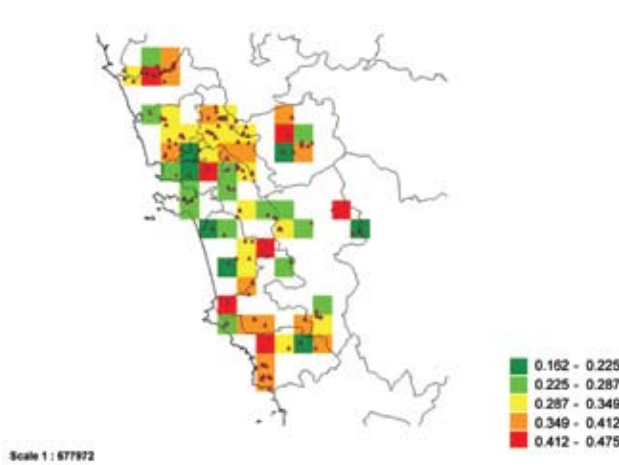


Fig. 5. Map of Goa showing distribution of *kokum* accessions for rind thickness.

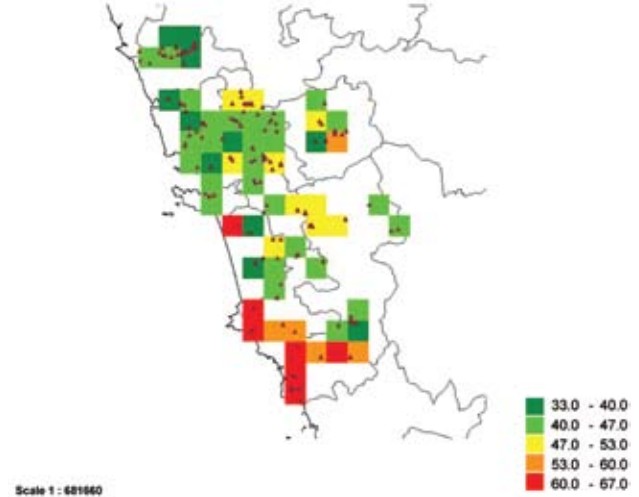


Fig. 6. Map of Goa showing richness of *kokum* accessions for rind thickness.

to 67.00 (represented by red grids) was found in southern taluks, viz., Quepem, Canacona and Salcete. The distribution of *Jatropha* in Andhra Pradesh was studied using DIVA-GIS by Sunil *et al.* (16), wherein it was reported that Medak, Nizamabad districts of Andhra Pradesh and Bastar and Dantewada districts of Chhattisgarh were found promising for diverse germplasm with respect to fruits per cluster. Gawankar *et al.* (5) found that rind thickness and rind percentage of six promising accessions of *kokum* varied from 0.30 to 0.48 cm and 34.08 to 79.13 percentage. In the present study, rind thickness ranged from 0.14 to 0.48 cm. Among all 268 accessions studied, Acc. No. 263 (Tambdi Suria-3) recorded the highest rind thickness of 0.475 cm.

Similarly in another evaluation of 108 genotypes of *kokum*, Kshirsagar *et al.* (9) reported that ten promising *kokum* accessions had rind percentage ranging from 38.53 to 72.73. Gawankar *et al.* (2) reported that high variability existed among the different *kokum* seedling types under study in respect of rind thickness and percentage. Konkan Amruta- a released variety was reported to have an average rind thickness of 0.45 cm and rind percentage of 50.94 (Patil *et al.*, 12). Similar variability in jackfruit accessions of Western Ghats region was reported using D² cluster analysis (Jagadeesh *et al.*, 7).

Besides this, the correlation studies (Table 2) showed that fruit diameter had a highly significant and positive correlation with fruit weight and rind thickness. Therefore, accessions promising for these important yield characters need to be selected from the trees already located. Further exploration is warranted in the regions of Bicholim, Pernem, Ponda and Canacona taluks which recorded the highest diversity index range for yield characters.

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Table 2. Correlation matrix for fruit characters.

Character	Fruit weight	Fruit diameter	Rind thickness
Fruit weight	1.000		
Fruit diameter	0.789**	1.000	
Rind thickness	0.228**	0.203**	1.000

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