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Structure Composition and Diversity at Mahatma Gandhi Botanical Garden Biodiversity Heritage Site of the University of Agricultural Sciences, Bangalore

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Abstract

Botanical gardens dedicate their resources to the research and preservation of plants as well as educating the public about the diversity of plant species found across the world. As a result, this study was conducted to determine the tree composition and diversity of the Mahatma Gandhi Botanical Garden, GKVK, Bengaluru. The garden was divided into ten parts with an area of 26 hectares. The trees with girth size of at least thirty centimetres were considered for enumeration, after enumeration it was observed that there were 2140 trees from 186 different species; twelve of these are naturalized forest tree species, while the remaining 174 are planted species. The tree diversity was found to be highest in block 1 and lowest in block 2, where the number of tree species was found to be 83 and 34, respectively in block 1 and 2. Importance Value Index (IVI) was found highest for *Millettia pinnata* (25.71), *Azadirachta indica* (25.17) and *Albizia lebbeck* (16.59), where these three tree species comprise around 27.73 per cent of the total tree population. The highest tree population was found in the girth class 30-60 cm, followed by 60-90 cm, where combinedly they account for sixty per cent of total tree population. The majority of the trees fall under height classes 6-9 m, 9-12 m and 12-15 m, where they account for 61.5 per cent of total tree population. It was found that trees in botanical gardens belong to 49 families, where the highest tree population was found in the Fabaceae family, which was followed by Meliaceae and Myrtaceae. The overall results revealed that the botanical garden is rich in tree species composition and diversity.

Keywords : Shannon-wiener diversity index, Simpson diversity index, Botanical garden and importance value index

Botanical gardens are vibrant living museums, showcasing the beauty and diversity of plant life from around the world. It is a place, where diversified collections of plants are maintained for educational, conservation, scientific or economic purposes (Hawksworth, 1995). It acts as a Centre for *ex-situ* conservation and serves as a living repository. The botanic garden acts as a place of aesthetic beauty and also offers ample opportunities to study various aspects of plant biology and also helps in generating public awareness, imparting environmental education and developing a global strategy for the conservation of plant species.

The big priority of the Botanical Garden (BG) is to keep living and dried specimens for better knowledge of plant species; to cultivate ecologically, economically, medicinally and horticulturally significant plant species and to act as a living repository for native, naturalized and alien plant species to collect, propagate, conduct research and to aid in *ex-situ* conservation; to act as a center for

rescue, recovery and rehabilitation of valuable plant species to generate public awareness, impart environmental education and finally to develop an effective strategy for conservation of plant species. With the significant increase in conservation efforts, BGs are increasingly active in the *in-situ* and *ex-situ* management and conservation of plant resources, sometimes in collaboration with other organizations (Hawksworth, 1995 and Heywood & Watson, 1995). The role of botanical gardens in the *ex-situ* conservation of plant species gained significant momentum after the 'Earth Summit' or Convention on Biological Diversity, shortly CBD' that was held in Rio de Janeiro, Brazil, South America from 3 to 14 June, 1992. Botaniac gardens linked with herbaria and gene banks generally maintain substantial data, the availability of such data is important in conserving plant genetic resources and instrumental in developing the Global Strategy for Plant Conservation (GSPC), which was adopted by the Convention on Biological Diversity (CBD). In this regard, the present study aimed 1) to assess the quantitative structure of tree species and 2) to quantify tree species diversity and composition at Mahatma Gandhi Botanical Garden, University of Agricultural Sciences, Bangalore.

Material and Methods

The study was conducted in the Mahatma Gandhi Botanical Garden located inside the University of Agricultural Sciences, Gandhi Krishi Vignana Kendra campus, Bengaluru, Karnataka. It is located at 13.04° North Latitude and 77.34° East Longitude at an elevation of 3,100 feet (930 m). The garden is spread over 65 acres (26 ha) of land and supports an array of plants (much emphasis on the Angiosperm group). The garden is divided into 10 blocks and species were planted block-wise systematically following Bentham and Hooker's System of Classification (1862 - 1883) and the layout of the Mahatma Gandhi Botanical Garden is depicted in Plate 1.

The climate is characterized by semi-arid with annual rainfall of about 915 mm. The rainfall received in two peaks during May (125 mm) and August - September (298 mm). In the domain area April, May and June are the hot months (31.7°C) while, November, December and January are the cold months (16.43°C). The reference evapotranspiration (ETo) is 4.5 mm/day with a peak in April month (7.6 mm/day). The soil in the area represents the typical lateritic area and belongs to the Vijayapura series, which is a dominant soil series of the Bengaluru plateau. These soils are

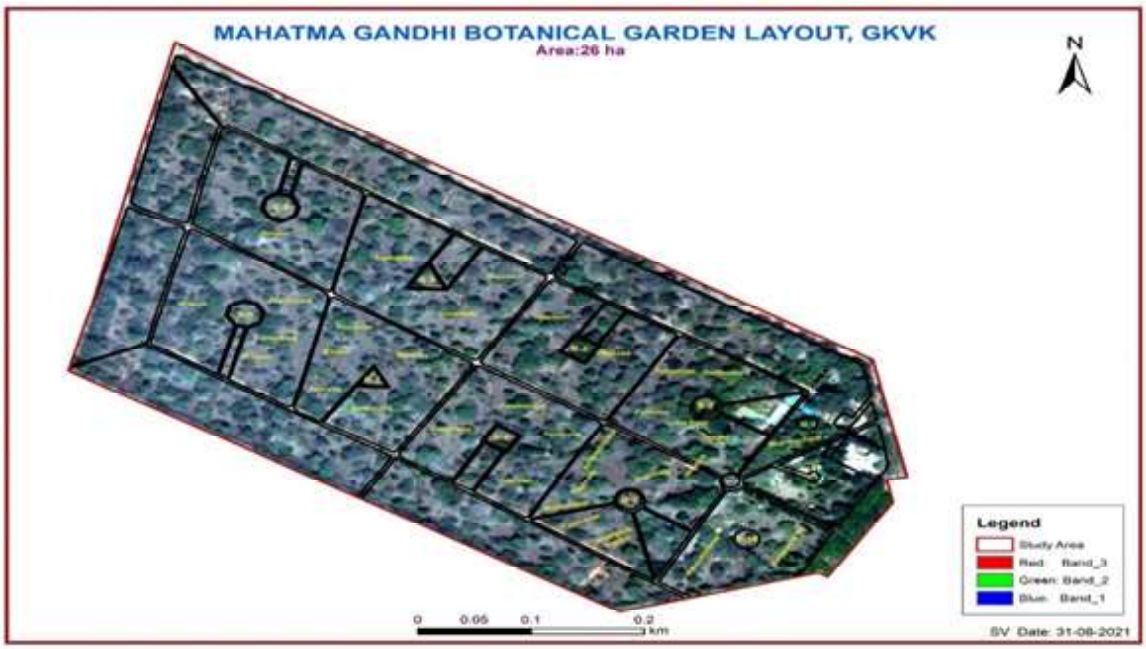

Plate 1 : Quick bird satellite image (50 cm) of Mahatma Gandhi Botanical Garden, GKVK, Bengaluru

classified as fine, kaolinitic, Isohyperthermic, Typic Kandiustalf, as per USDA classification.

The study followed the systematic assessment of tree species in the whole area. Plants having ≥ 30 cm Girth at Breast Height (GBH) were considered as trees. Hence, only trees having ≥ 30 cm GBH were considered for measurement. From each block, the number of each tree was counted and recorded in the field data sheet while the total height and GBH of the trees were measured using a clinometer and measuring tape, respectively. Tree species were identified directly in the field with the assistance of Curator and Botanist of the Botanical Garden.

The Data Generated was used to Compute The Structural and Diversity Parameters by using The Following Formulas

Shannon - Wiener index (H^l)

Species richness is the number of different species represented in an ecological community, landscape, or region. Species richness is simply a count of species and it does not take into account the abundances of the species or their relative abundance distributions. So, to estimate the species richness Shannon-wiener diversity index was determined, which is the measure of the average degree of uncertainty in predicting to what species individuals chosen at random from a collection of 'S' species and 'N' individuals will belong (Magurran, 2003). This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even. Thus, H^l=0 when all species are represented by the same number of individuals. It is estimated by using the formula :

$$H^1 = \sum_{i=1}^{s} [(^{ni}/_{N}) \text{ In } (ni/N)]$$

where n_i is a number of individuals belonging to the i^{th} species, N is the total number of individuals in the sample and S is the number of species.

Simpson's Diversity Index (1-D)

This Simpson index (Simpson, 1949) is popularly used to know the evenness in distribution or degree of concentration and is calculated by using the formula.

$$\lambda = \sum_{i=1}^{n} Pi^2$$

Where 'Pi' is the proportion of individuals of i^{th} species relative to the total number of species on the farm; 'n' is the total number of species.

Simpson's Diversity Index is a measure of diversity. It is often used to quantify the biodiversity of a habitat. It considers the number of species present, as well as the abundance of each species (Magurran, 2003). It can also be estimated through the following formula:

Simpson's index of diversity = 1- D (Simpson dominance index)

Importance Value Index (IVI)

Data collected was subjected to analysis by assessing relative frequency, relative density and relative dominance. Based on these parameters the importance value index (IVI) at the species level was calculated following the method of Curtis and Mointosh, (1950). The IVI is the sum of assessing relative frequency, relative density and relative dominance for each species. However, IVI also gives the importance of species in the community by assessing the rank of individual species, based on the pooled data of relative density and relative frequency of trees.

- Density = Number of individuals of the species 'A' per unit area
- Relative density % (RD) = (Number of individuals of species 'A' / Total number of individuals of all species) x 100
- Relative dominance % (Rd) = (Total basal area of species 'A' / Total basal area of all the species) x100
- Frequency (f) = (Number of times which species 'A' occurs / Total number of blocks) x 100
- Relative Frequency % (Rf) = (Frequency value of each species 'A' / Sum of Frequency value of all species) x 100

The IVI for each species is calculated by the formula:

IVI = Relative density % (RD) + Relative dominance % (Rd) + Relative Frequency % (Rf)

Results and Discussion

The complete enumeration of trees having girth size of more than 30 cm was carried out in the Mahatma Gandhi Botanical Garden, GKVK, Bengaluru in 2021 to find out the different tree composition and diversity. The results of the study are presented in tabular form and discussed simultaneously.

Tree Composition of Mahatma Gandhi Botanical Garden, GKVK, Bengaluru

Botanical Garden was established in the year 1971, before that the entire area was a natural forest, which was under the maintenance of the Karnataka Forest Department. However, a portion of the area was cleared for the construction of the building. Hence, at present botanical garden has both natural forest tree species and planted tree species. Mahatma Gandhi Botanical Garden is divided into 10 blocks, where each block was found to be 2.6 ha and species were planted block-wise systematically following Bentham and Hooker's System of Classification (1862 - 1883). The Garden contains around 700 species of plants, herbs, shrubs and trees (Nagaraja *et al*., 2020). After the field survey, a total of 186 tree species belonging to 49 families were found in the garden and the list

Table 1

Different tree composition in Mahatma Gandhi Botanical Garden

Sl. No.	Family and tree species	Tree population
1	**Fabaceae**	**873**
	Acacia auriculiformis	42
	Acacia ferruginea	2
	Acrocarpus fraxinifolius	3
	Albizia amara	35
	Albizia lebbeck	110
	Albizia odoratissima	35
	Bauhinia purpurea	5
	Butea monosperma	29
	Caesalpinia coriaria	8
	Caesalpinia platyloba	1
	Cassia fistula	81
	Cassia spectabilis	2
	Colvillea racemosa	5
	Dalbergia latifolia	2
	Delonix regia	58
	Enterolobium contortisiliquum	1
	Gliricidia sepium	14
	Hardwickia binata	54
	Kingiodendron pinnatum	3
	Leucaena leucocephala	46
	Millettia pinnata	249
	Peltphorum pterocarpum	1
	Pterocarpus dalbergioides	1
	Pterocarpus marsupium	2
	Pterocarpus santalinus	4
	Samanea saman	6
	Saraca asoca	2
	Schotia brachypetala	1
	Senna siamea	41
	Tamarindus indica	28
	Xylia xylocarpa	2
2	**Myrtaceae**	**199**
	Callistemon sp.	1
	Callistemon viminalis	3
	Eucalyptus citriodora	50
	Eucalyptus globulus	36
	Eucalyptus tereticornis	19
	Psidium guajava	1
	Syzygium cumini	4
	Syzygium operculatum	85
3	**Meliaceae**	**302**
	Amoora lawii	12
	Azadirachta indica	258
	Chukrasia tabularis	2

Continued....

Table 1 Continued....

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
	Khaya grandifoliola	3
	Khaya senegalensis	3
	Melia dubia	13
	Swietenia macrophylla	1
	Swietenia mahagoni	4
	Toona ciliata	6
	Proteaceae	**97**
	Grevillea robusta	97
	Simaroubaceae	**32**
	Ailanthus excelsa	11
	Ailanthus malabarica	1
	Simarouba glauca	20
	Anacardiaceae	**86**
	Anacardium occidentale	69
	Mangifera indica	9
	Semecarpus anacardium	2
	Spondias pinnata	6
	Ebenaceae	**22**
	Diospyros buxifolia	1
	Diospyros melanoxylon	15
	Diospyros montana	5
	Diospyros sylvatica	1
	Moraceae	**38**
	Antiaris toxicaria	1
	Artocarpus heterophyllus	4
	Artocarpus lacucha	3
	Broussonetia papyrifera	1
	Ficus amplissima	1
	Ficus benghalensis	3
	Ficus benjamina	1
	Ficus drupacea	2
	Ficus elastica	1
	Ficus hispida	1
	Ficus krishnae	1
	Ficus lyrata	1
	Ficus microcarpa	4
	Ficus neriifolia	1
	Ficus racemosa	1

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
	Ficus religiosa	3
	Ficus tsjahela	1
	Ficus virens	4
	Milicia excelsa	1
	Streblus asper	3
	Arecaceae	**50**
	Adonidia merrillii	1
10	**Malvaceae**	**25**
	Guazuma ulmifolia	1
	Hibiscus tiliaceus	2
	Pterospermum diversifolium	1
	Sterculia balanghas	11
	Sterculia foetida	3
	Sterculia urens	5
	Sterulia guttata	1
	Thespesia populnea	1
11	**Bignoniaceae**	**31**
	Crescentia cujete	2
	Dolichandrone atrovirens	3
	Jacaranda mimosifolia	1
	Millingtonia hortensis	2
	Oroxylum indicum	1
	Tabebuia aurea	1
	Tabebuia impetiginosa	2
	Tabebuia rosea	18
	Tecoma stans	1
12	**Sapindaceae**	**13**
	Dimocarpus longan	4
	Sapindus laurifolius	4
	Schleichera oleosa	5
13	**Casuarinaceae**	**9**
	Casuarina equisetifolia	9
14	**Lamiaceae**	**42**
	Gmelina arborea	1
	Gmelina asiatica	3
	Tectona grandis	37
	Vitex altissima	1

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
15	**Annonaceae**	**110**
	Polyalthia longifolia	110
16	**Sapotaceae**	**10**
	Chrysophyllum cainito	1
	Madhuca indica	4
	Madhuca longifolia	1
	Manilkara hexandra	3
	Mimusops elengi	1
17	**Araucariaceae**	**9**
	Agathis robusta	3
	Araucaria cookii	5
	Araucaria cunninghamii	1
	Anthocephalus cadamba	2
	Canthium parviflorum	8
	Gardenia latifolia	1
	Hamelia patens	2
	Ixora brachiata	10
	Mitragyna parvifolia	2
18	**Oleaceae**	**7**
	Ligustrum perrottettii	3
	Olea dioica	4
19	**Erythroxylaceae**	**23**
	Erythroxylum monogynum	23
20	**Santalaceae**	**19**
	Santalum album	19
21	**Combretaceae**	**16**
	Combretum erythrophyllum	1
	Terminalia arjuna	2
	Terminalia bellirica	1
	Terminalia catappa	5
	Terminalia mantaly	1
	Terminalia tomentosa	5
	Terminalia catappa	1
22	**Rutaceae**	**10**
	Aegle marmelos	4
	Clausena dentata	1
	Limonia acidissima	2

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
	Vepris bilocularis	2
	Zanthoxylum rhetsa	1
23	**Euphorbiaceae**	**13**
	Croton oblongifolius	1
	Mallotus philippensis	6
	Manihot glaziovii	1
	Reutealis trisperma	3
	Securinega leucopyrus	1
	Suregada angustifolia	1
24	**Rhamnaceae**	**7**
	Ziziphus xylopyrus	6
	Zizipus rugosa	1
25	**Cannabaceae**	**5**
	Celtis tetrandra	3
	Celtis wightii	2
26	**Apocyanaceae**	**4**
	Alstonia scholaris	1
	Wrightia tinctoria	2
	Wrightia tomentosa	1
27	**Lythraceae**	**5**
	Lagerstroemia lanceolata	3
	Lagerstroemia speciosa	2
28	**Rubiaceae**	**26**
	Adina cordifolia	1
	Plumeria alba	5
29	**Ulmaceae**	**1**
	Holoptelea integrifolia	1
30	**Phyllanthaceae**	**6**
	Bridelia retusa	6
31	**Pinaceae**	**10**
	Cedrus deodara	6
	Pinus roxburghii	4
32	**Lecythidaceae**	**5**
	Barringtonia acutangula	1
	Barringtonia asiatica	1
	Careya arborea	2

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
	Couroupita guianensis	1
33	**Podocarpaceae**	**4**
	Podocarpus chinensis	2
	Podocarpus macrophyllus	2
34	**Celastraceae**	**2**
	Cassine paniculata	2
35	**Cornaceae**	**1**
	Alangium lamarckii	1
36	**Calophyllaceae**	**2**
	Mesua ferrea	2
37	**Dipterocarpaceae**	**4**
	Hopea parviflora	4
38	**Apocynaceae**	**6**
	Alstonia scholaris	1
39	**Verbenaceae**	**1**
	Citharexylum quadrangulare	1
40	**Menispermaceae**	**1**
	Anamirta cocculus	1
41	**Sterculiaceae**	**1**
	Pterospermum rubiginosum	1
42	**Cupressaceae**	**3**
	Cupressus sempervirens	1
	Cupressus torulosa	1
	Thuja occidentalis	1
43	**Araliaceae**	**1**
	Schefflera actinophylla	1
44	**Moringaceae**	**3**
	Moringa oleifera	3
45	**Oxalidaceae**	**1**
	Averrhoa carambola	1
46	**Burseraceae**	**1**
	Commiphora wightii	1
47	**Lauraceae**	**2**
	Litsea coriacea	1
	Persea macrantha	1

Continued....

TABLE 1 Continued....

Sl. No.	Family and tree species	Tree population
48	**Clusiaceae**	**1**
	Clusia rosea	1
49	**Elaeocarpaceae** *Elaeocarpus tuberculatus*	**1** 1
	2140 trees from 49 families	

of tree species along with their families and tree population are mentioned in Table 1.

The highest tree population was observed (Table 1) in the family Fabaceae with a tree population of 873, followed by Meliaceae with a tree population of 302. The highest tree population of these two families was due to the high population of naturally grown species like *Millettia pinnata* (249) *Albizia lebbeck* (110) and *Azadirachta indica* (258). Trees belonging to the Fabaceae family form specific adaptations to environmental conditions and lineage-specific strategies to cope with environmental stresses with higher leaf thickness and higher wood density of geoxyles as responses to harsher open environments. Fabaceae in general and

TABLE 2

List of naturally grown tree species in Mahatma Gandhi Botanical Garden

Sl. No.	Tree species
1	*Acacia auriculiformis*
2	*Acacia ferruginea*
3	*Albizia amara*
4	*Albizia lebbeck*
5	*Albizia odoratissima*
6	*Erythroxylum monogynum*
7	*Eucalyptus citriodora*
8	*Eucalyptus globulus*
9	*Eucalyptus tereticornis*
10	*Hardwickia binata*
11	*Millettia pinnata*
12	*Syzygium cumini*

ectomycorrhizal species showed better nutrient status (Gomes *et al.,* 2021). Plant species belonging to Meliaceae family have higher regeneration capacity when compared to other species in a natural ecosystem (Rahman *et al*., 2011).

Out of 186 tree species present in Mahatma Gandhi Botanical Garden, 12 tree species were naturally grown (Table 2) in the area even well before the

TABLE 3

List of planted tree species in Mahatma Gandhi Botanical Garden

Sl. No.	Tree species
1	*Acrocarpus fraxinifolius*
2	*Adina cordifolia*
3	*Adonidia merrillii*
4	*Aegle marmelos*
5	*Agathis robusta*
6	*Ailanthus excelsa*
7	*Ailanthus malabarica*
8	*Alangium lamarckii*
9	*Alstonia scholaris*
10	*Amoora lawii*
11	*Anacardium occidentale*
12	*Anamirta cocculus*
13	*Anthocephalus cadamba*
14	*Antiaris toxicaria*
15	*Araucaria cookii*
16	*Araucaria cunninghamii*
17	*Artocarpus heterophyllus*
18	*Artocarpus lacucha*
19	*Averrhoa carambola*
20	*Azadirachta indica*
21	*Barringtonia acutangula*
22	*Barringtonia asiatica*
23	*Bauhinia purpurea*
24	*Bridelia retusa*
25	*Broussonetia papyrifera*
26	*Butea monosperma*
27	*Caesalpinia coriaria*
28	*Caesalpinia platyloba*
29	*Callistemon sp.*

Continued....

TABLE 3 Continued....

Sl. No.	Tree species
30	*Callistemon viminalis*
31	*Canthium parviflorum*
32	*Careya arborea*
33	*Cassia fistula*
34	*Cassia spectabilis*
35	*Cassine paniculata*
36	*Casuarina equisetifolia*
37	*Cedrus deodara*
38	*Celtis tetrandra*
39	*Celtis wightii*
40	*Chrysophyllum cainito*
41	*Chukrasia tabularis*
42	*Citharexylum quadrangulare*
43	*Clausena dentata*
44	*Clusia rosea*
45	*Cocos nucifera*
46	*Colvillea racemosa*
47	*Combretum erythrophyllum*
48	*Commiphora wightii*
49	*Couroupita guianensis*
50	*Crescentia cujete*
51	*Croton oblongifolius*
52	*Cupressus sempervirens*
53	*Cupressus torulosa*
54	*Dalbergia latifolia*
55	*Delonix regia*
56	*Dimocarpus longan*
57	*Cupressus sempervirens*
58	*Cupressus torulosa*
59	*Diospyros montana*
60	*Diospyros sylvatica*
61	*Dolichandrone atrovirens*
62	*Elaeis guineensis*
63	*Elaeocarpus tuberculatus*
64	*Enterolobium contortisiliquum*
65	*Ficus amplissima*
66	*Ficus benghalensis*
67	*Ficus benjamina*
68	*Ficus drupacea*
69	*Ficus elastica*
70	*Ficus hispida*

Continued....

TABLE 3 Continued....

Sl. No.	Tree species
71	*Ficus krishnae*
72	*Ficus lyrate*
73	*Ficus microcarpa*
74	*Ficus neriifolia*
75	*Ficus racemose*
76	*Ficus religiosa*
77	*Ficus tsjahela*
78	*Ficus virens*
79	*Gardenia latifolia*
80	*Gliricidia sepium*
81	*Gmelina arborea*
82	*Gmelina asiatica*
83	*Grevillea robusta*
84	*Guazuma ulmifolia*
85	*Hamelia patens*
86	*Hibiscus tiliaceus*
87	*Ficus virens*
88	*Gardenia latifolia*
89	*Gliricidia sepium*
90	*Gmelina arborea*
91	*Gmelina asiatica*
92	*Khaya senegalensis*
93	*Kingiodendron pinnatum*
94	*Lagerstroemia lanceolata*
95	*Lagerstroemia speciosa*
96	*Leucaena leucocephala*
97	*Ligustrum perrottettii*
98	*Limonia acidissima*
99	*Litsea coriacea*
100	*Madhuca indica*
101	*Madhuca longifolia*
102	*Mallotus philippensis*
103	*Mangifera indica*
104	*Manihot glaziovii*
105	*Manilkara hexandra*
106	*Melia dubia*
107	*Mesua ferrea*
108	*Milicia excelsa*
109	*Millingtonia hortensis*
110	*Mimusops elengi*
111	*Mitragyna parvifolia*

Continued....

TABLE 3 Continued....

Sl. No.	Tree species
112	*Moringa oleifera*
113	*Olea dioica*
114	*Oroxylum indicum*
115	*Peltphorum pterocarpum*
116	*Persea macrantha*
117	*Mesua ferrea*
118	*Milicia excelsa*
119	*Millettia pinnata*
120	*Millingtonia hortensis*
121	*Mimusops elengi*
122	*Mitragyna parviflora*
123	*Moringa oleifera*
124	*Olea dioica*
125	*Oroxylon indicum*
126	*Peltphorum pterocarpum*
127	*Persea macrantha*
128	*Phoenix dactylifera*
129	*Phoenix sylvestris*
129	*Phoenix sylvestris*
130	*Pinus roxburghii*
131	*Plumeria alba*
132	*Podocarpus chinensis*
133	*Podocarpus macrophyllus*
134	*Polyalthia longifolia*
135	*Psidium guajava*
136	*Pterocarpus dalbergioides*
137	*Pterocarpus marsupium*
138	*Pterocarpus santalinus*
139	*Pterospermum diversifolium*
140	*Pterospermum rubiginosum*
141	*Reutealis trisperma*
142	*Roystonea regia*
143	*Samanea saman*
144	*Santalum album*
145	*Sapindus laurifolius*
146	*Saraca asoca*
147	*Schefflera actinophylla*
148	*Schleichera oleosa*
149	*Schotia brachypetala*
150	*Securinega leucopyrus*
151	*Semecarpus anacardium*

Continued....

TABLE 3 Continued....

Sl. No.	Tree species
152	*Senna siamea*
153	*Simarouba glauca*
154	*Spondias pinnata*
155	*Sterculia balanghas*
156	*Sterculia foetida*
157	*Sterculia urens*
158	*Sterulia guttata*
159	*Streblus asper*
160	*Suregada angustifolia*
161	*Swietenia macrophylla*
162	*Swietenia mahagoni*
163	*Syzygium cumini*
164	*Syzygium operculatum*
165	*Tabebuia aurea*
166	*Tabebuia impetiginosa*
167	*Tabebuia rosea*
168	*Tamarindus indica*
169	*Tecoma stans*
170	*Tectona grandis*
171	*Terminalia arjuna*
172	*Terminalia bellirica*
173	*Terminalia catappa*
174	*Terminalia mantaly*
175	*Terminalia tomentosa*
176	*Thespesia populnea*
177	*Thuja occidentalis*
178	*Toona ciliate*
179	*Vepris bilocularis*
180	*Vitex altissima*
181	*Wrightia tinctoria*
182	*Wrightia tomentosa*
183	*Xylia xylocarpa*
184	*Zanthoxylum rhetsa*
185	*Ziziphus xylopyrus*
186	*Zizipus rugosa*

establishment of the Botanical Garden, and the remaining 174 tree species were periodically planted (Table 3).

The number of tree species (186) having girth at breast height of more than 30 cm found in Mahatma Gandhi Botanical Garden was less than the number of species reported by Fathima *et al*. (1974), where they recorded 530 plant species in the entire GKVK campus. This could be because the native woodland was cleared to build the Botanical Garden. Every year, a large number of young trees are planted in the Botanical Garden to preserve unique and endangered plant species.

The girth class distribution of trees in the Botanical Garden varies from 0.3 m to 3.6 m girth (Table 4). The girth class of 0.3-0.6 m has the highest number of individuals (732) and the girth class of 3.3-3.6 m has the least number of individuals (2). These results were similar to the findings of Reddy *et al*. (2008), where Mudumalai Wildlife Sanctuary was having 65.4 per cent of trees with girth size 0.3 m to 0.6 m.

TABLE 4

Girth class distribution of tree species in Mahatma Gandhi Botanical Garden

Girth class (m)	No. of trees	Percentage (%)
0.3 - 0.6	732	34.21
0.6 - 0.9	726	33.93
0.9 - 1.2	423	19.77
1.2 - 1.5	146	6.82
1.5 - 1.8	40	1.87
1.8 - 2.1	32	1.50
2.1 - 2.4	22	1.03
2.4 - 2.7	11	0.51
2.7 - 3.0	3	0.14
3-3 - 3.0	3	0.14
3.3 - 3.6	2	0.09
Total	2140	100.00

In the Botanical Garden, it was observed that trees having higher girth size were lesser in number, which gives an inverted 'J' shaped curve. Out of a total of 2140 trees, girth classes 0.3-0.6 m, 0.6-0.9 m, 0.9-1.2 m and 1.2-1.5 m comprise about 732, 726,

423 and 146 trees respectively, which aggregate to form about 94.73 per cent of the total tree population in the garden. But the remaining girth classes contribute only about 5.27 per cent. This indicates that more tree girth size class were lesser, which indicates that most of the trees in the Botanical Garden are younger with smaller to medium girth size. Similar results were found in the study at Hollongapar Gibbon Wildlife Sanctuary, where a reverse 'J' shaped curve was obtained. This might be due to the good regeneration capacity of trees and most of the trees are planted in the garden a few years back (Sarkar and Devi, 2014).

Another similar type of research conducted by Ndah *et al.* (2013) in the Takamanda Rainforest, Cameroon found that with increasing girth the number of trees decreased gradually and resulted in an inverted 'J' shaped curve.

The relative height ensemble in the forest was an important criterion for understanding the nature of the forest. The tree heights in the Botanical Garden ranged from 1 m to 27 m (Table 5). Most of the trees in the Botanical Garden fall under the height class 6-9 m, which comprises about 25.61 per cent of the total tree population and it was followed by the 9-12 m height class, which consists of about 22.48 per cent of the total tree population. From Table-5, it is clear that trees were more under medium range height class (6-15 m), where around 61.5 per cent (1316 trees out of 2140) of trees fall under this category. The height classes 1-3 m, 3-6 m, 12-15 m, 15-18 m, 18-21m, 21-24 m and 24-27 m contain 3.50, 6.68, 11.07, 12.71, 4.35 and 0.19 per cent of trees respectively, which aggregates about 38.5 per cent (824 individuals out of 2140 trees).

Trees having less height, tree population was also less and with increasing tree height, the tree population increased up to 9 m, later tree population followed the decreasing trend. A similar type of result was found, where tree population increases with increasing height in natural forests and most of them are categorized under the height class 10-20 m (Alamgir and Al-amin, 2005; Ni *et al*., 2014).

The Botanical Garden was spread over an area of 26 hectares and found 2140 trees distributed among 186 tree species (Table 1). *Azadirachta indica* and *Millettia pinnata* were more frequently found in almost all the blocks, these trees comprise 12.06 per cent (Table 6) and 11.64 per cent of total trees respectively. *Albizia lebbeck* and *Polyalthia longifolia* contribute about 110 trees each to the total number of trees in the garden,

TABLE 5

Height class distribution of trees in Mahatma Gandhi Botanical Garden

Height class (m)	No. of trees	Percentage (%)
1-3	75	3.50
3-6	143	6.68
6-9	548	25.61
9-12	481	22.48
12-15	287	13.41
15-18	237	11.07
18-21	272	12.71
21-24	93	4.35
24-27	4	0.19
Total	2140	100.00

TABLE 6

Based on tree population top ten dominant tree species of Mahatma Gandhi Botanical Garden

Tree species	No. of trees	(%) of total trees
Azadirachta indica	258	12.06
Millettia pinnata	249	11.64
Albizia lebbeck	110	5.14
Polyalthia longifolia	110	5.14
Grevillea robusta	97	4.53
Syzygium operculatum	85	3.97
Cassia fistula	81	3.79
Anacardium occidentale	69	3.22
Delonix regia	58	2.71
Hardwickia binata	54	2.52
Total	1171	54.72

which is about 10.28 per cent (Table 6) of the total tree population. *Grevillea robusta, Syzygium operculatum, Cassia fistula, Anacardium occidentale, Delonix regia and Hardwickia binata* comprise about 4.53, 3.97, 3.79, 3.22, 2.71 and 2.52 per cent (Table 6) of the total tree population in the garden. These major 10 tree species were found in large numbers in the garden, this might be because these trees are well adapted to the tropical environment and have good root and shoot growth due to a higher carbon assimilation rate to resist environmental stress conditions, hence showing higher survivability (Abhilash and Devakumar, 2023). Most of these trees belong to the Fabaceae family, which are well adapted to tropical conditions with more resistance to environmental stress conditions (Narain and Singh, 2013).

TABLE 7

Based on tree population dominant top three tree species in different blocks of Mahatma Gandhi Botanical Garden

Blocks	Tree species	No. of individuals	% of block tree population
Block-1	*Polyalthia longifolia*	83	28.14
	Grevillea robusta	27	9.15
	Roystonea regia	19	6.44
Block-2	*Syzygium operculatum*	47	25.00
	Polyalthia longifolia	27	14.36
	Millettia pinnata	24	12.77
Block-3	*Azadirachta indica*	50	22.52
	Syzygium operculatum	19	8.56
	Cassia fistula	18	8.11
Block-4	*Azadirachta indica*	30	17.54
	Anacardium occidentale	21	12.28
	Cassia fistula	18	10.53
Block-5	*Azadirachta indica*	26	13.54
	Millettia pinnata	26	13.54
	Grevillea robusta	23	11.98
Block-6	*Millettia pinnata*	64	19.69
	Grevillea robusta	32	9.85
	Azadirachta indica	27	8.31
Block-7	*Azadirachta indica*	55	26.44
	Millettia pinnata	31	14.90
	Albizia lebbeck	17	8.17
Block-8	*Azadirachta indica*	30	12.45
	Tectona grandis	28	11.62
	Hardwickia binata	22	9.13
Block-9	*Millettia pinnata*	28	14.36
	Azadirachta indica	27	13.85
	Albizia lebbeck	15	7.69
Block-10	*Roystonea regia*	23	22.33
	Millettia pinnata	15	14.56
	Albizia lebbeck	12	11.65

Block-1 was dominated by *Polyalthia longifolia, Grevillea robusta* and *Roystonea regia* (Table 7) where these three constitute about 43.73 per cent of the tree population in the block. Block-2 was dominated by *Syzygium operculatum* (25%) and block-3, block-4, block-5, block-7 and block-8 were dominated by *Azadirachta indica,* where it contributed about 22.52, 17.54, 13.54, 8.31 and 12.45 per cent to the tree population of each block respectively.

Shannon-Wiener index showed that the diversity of trees in Mahatma Gandhi Botanical Garden, GKVK exhibited a higher diversity value of 5.52 (Fig. 1). Shannon-Wiener index was highest for the block-1 (4.83), block-9 (4.75) and block-3 (4.44). This shows that these blocks contain a greater number of diversified tree species than other blocks. Block-2 (3.94) and block-7 (3.96) were found to have the least Shannon-Wiener index, which indicates that these blocks have very little tree diversity when compared to other blocks in the Botanical Garden. The shannon-wiener index of KNUST botanic garden in Kumasi, Ghana (Acheampong *et al*., 2021) was found to be 3.36, which is less than that of Botanical Garden, GKVK, Bengaluru. Kuningan Botanical Garden had a diversity index of 2.8, it was compared to Gunung Ciremai National Park, which has a diversity index of 4.9 (Nugraha, 2011). The diversity indices of Kuningan Botanical Garden and Gunung Ciremai National Park were still low, when compared to the Shannon diversity index of Mahatma Gandhi Botanical Garden (5.52). This is because Kuningan Botanical Garden and Gunung Ciremai National Park have only 27 tree species and 113 tree species respectively, whereas the botanical garden of the present study has 186 tree species.

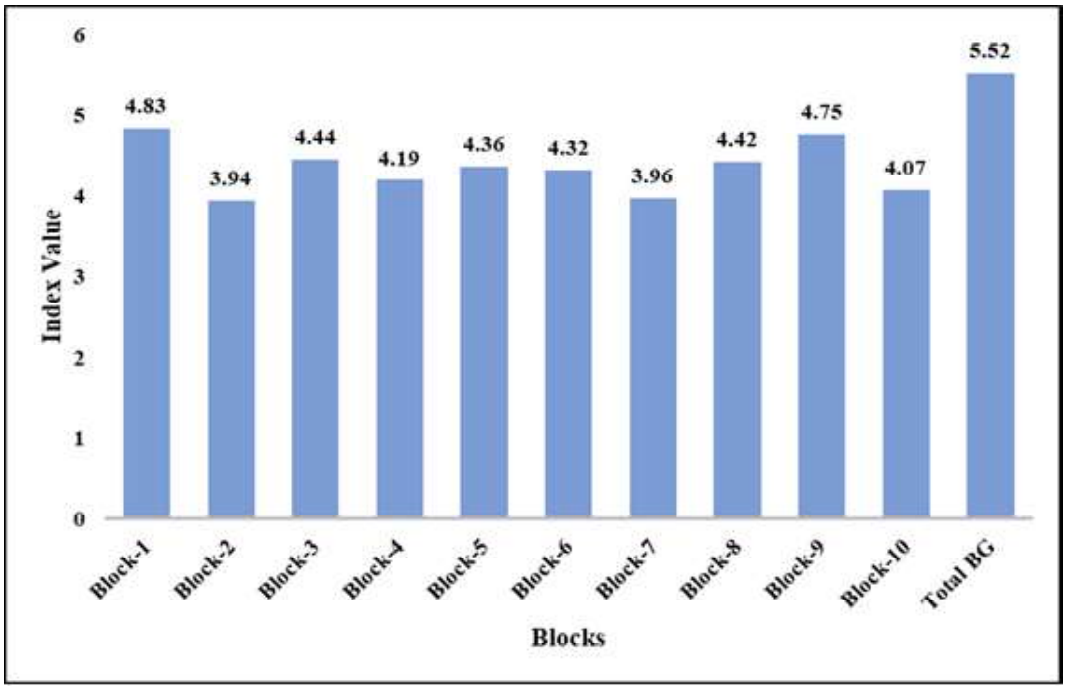

Fig. 1 : Shannon wiener diversity index of Mahatma Gandhi Botanical Garden

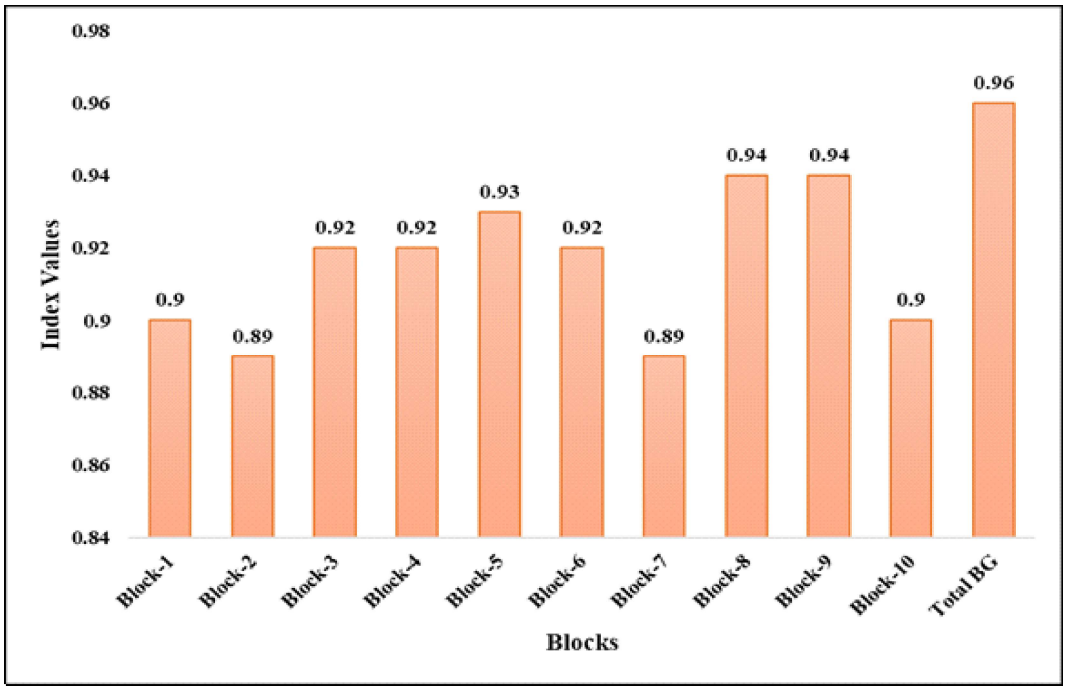

Fig. 2 : Simpson's diversity index of Mahatma Gandhi Botanical Garden

Simpson's Diversity Index shows that the diversity in Mahatma Gandhi Botanical Garden was very high (0.96). The Simpson's diversity index (Fig. 2) in the garden ranged from 0.89 to 0.96. It was found that block-1 had a comparatively moderate value of Simpson's index even though it had the highest Shannon-Wiener index (Fig. 1), this indicates that block-1 had a greater number of tree species but those

trees were not evenly distributed all over the block-1. It was observed that the diversity and distribution of tree species were highest in block-8 and block-9 and lowest in block-2 and block-7. Simpson's diversity index of trees in the Biodiversity Heritage site of GKVK was found to be 0.89 (Sumanth and Prasanna, 2022), which is the lowest when compared to the index of Mahatma Gandhi Botanical Garden (0.96).

Simpson's diversity index indicates the diversity and distribution of tree species all over the Botanical Garden. highest Simpson's index was observed in block-8 (0.94) and block-9 (0.94) when compared to all other blocks (Fig. 2). This indicates that those blocks contain high diversity and the tree species are well distributed all over the block. Comparatively lower Simpson's index was found in block-2 (0.89) and block-7 (0.89).

The Shannon-Wiener index and Simpson's Diversity Index in Mahatma Gandhi Botanical Garden were found to be greater when compared to the diversity of Hulikal Ghat natural forest reported by Vinayaka *et al*. (2016).

Millettia pinnata (IVI=25.71), *Azadirachta indica* (IVI=25.17) and *Albizia lebbeck* (IVI=16.59) are the three major tree species (Table 8), which were present in Mahatma Gandhi Botanical Garden, GKVK, Bengaluru. These three tree species comprise around 27.73 per cent of the total tree population in the Botanical Garden. These three species were left unfelled while converting the natural forest area into a Botanical Garden, this might be the reason for their dominance in the Garden. Even though the frequency of occurrence of *Albizia amara* is 1, its IVI (6.32)

TABLE 8

Importance value index (IVI) of dominant tree species of Mahatma Gandhi Botanical Garden

Tree species	Frequency of species	Relative density %	Relative dominance %	Relative frequency %	IVI
Millettia pinnata	1.0	11.64	11.71	2.37	25.71
Azadirachta indica	1.0	12.06	10.75	2.37	25.17
Albizia lebbeck	1.0	5.14	9.08	2.37	16.59
Anacardium occidentale	1.0	3.22	5.51	2.37	11.10
Syzygium operculatum	0.8	3.97	3.92	1.90	9.78
Grevillea robusta	0.5	4.53	2.72	1.18	8.44
Polyalthia longifolia	0.2	5.14	1.74	0.47	7.35
Cassia fistula	0.9	3.79	1.39	2.13	7.31
Hardwickia binata	0.8	2.52	2.55	1.90	6.97
Leucaena leucocephala	0.6	2.15	3.29	1.42	6.86
Delonix regia	0.6	2.71	2.38	1.42	6.52
Albizia amara	1.0	1.64	2.32	2.37	6.32
Eucalyptus citriodora	0.6	2.34	2.38	1.42	6.14
Acacia auriculiformis	0.7	1.96	2.44	1.66	6.06
Albizia odoratissima	0.8	1.64	1.93	1.90	5.46
Tamarindus indica	0.8	1.31	2.00	1.90	5.20
Ailanthus excelsa	0.7	0.51	2.62	1.66	4.80
Butea monosperma	0.9	1.36	1.23	2.13	4.72
Roystonea regia	0.2	1.96	2.21	0.47	4.65
Eucalyptus globulus	0.7	1.68	1.21	1.66	4.56

is lesser than *Millettia pinnata* (IVI=25.17), *Azadirachta indica* (IVI=25.17), *Albizia lebbeck* (IVI=16.59) and *Anacardium occidentale* (IVI=11.10), this is mainly because the relative dominance of these four species was much larger than that of *Albizia amara.* The tree species that have a frequency of 0.1 indicates that the particular tree species is present only in a particular block out of a total ten blocks. So, the distribution of those tree species was confined only to a single block but the tree species having higher IVI and frequency of occurrence was dominant and distributed all over the Botanical Garden.

The importance Value Index for *Millettia pinnata* was 6.08 in the Biodiversity heritage site of GKVK (Sumanth and Prasanna, 2022), which is much lower when compared to the current study, but IVI for *Acacia auriculiformis* at the heritage site was 38.64 which is higher than the IVI of the botanical garden (6.06). This type of result indicates that the IVI of a particular tree species varies with the place and plant population of the locality.

The study reveals that the Mahatma Gandhi Botanical Garden is rich in tree composition and diversity, which is conserving 186 tree species belonging to 49 families. Trees belonging to Fabaceae and Meliaceae families showed higher regenerative capacity and survivability in the garden, which ultimately resulted in dominance of *Azadirachta indica* and *Millettia pinnata* in all the blocks of the garden. Diversity indices showed that the highest diversity was observed in Block 1 and the lowest in Block 2. The highest IVI for *Millettia pinnata* indicates its higher relative density, relative dominance and relative frequency in the garden.

This study provides an overview of the importance of botanical gardens in *ex-situ* conservation of biodiversity by maintaining diversified tree composition. With increasing human activities, biodiversity conservation is a real challenge nowadays. So, the estimation of diversity at botanical gardens provides the biodiversity conservation potential of botanical gardens, which in turn helps to simultaneously conserve biodiversity. To conserve biodiversity, it is necessary to conserve botanical gardens, so this type of study at different botanical gardens provides an insight into the role of botanical gardens in conserving biodiversity, which ultimately leads to a comprehensive understanding of biodiversity conservation at botanical gardens.

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