Floristic Diversity, Community Structure and Species Richness of Malta (Citrus Sinensis) Based Traditional Homegardens of Tehri Garhwal, Uttarakhand, India

Suraj Goswami (goswami30suraj@gmail.com)
Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry
Arvind Bijalwan
Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry
Bhupendra Singh
Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry
Taufiq Ahmed
Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry
Sandeep Kumar
Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry

Research Article

Keywords: Agroforestry, Homegarden, Important Value Index, Multipurpose Tree Species

Posted Date: May 9th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1616775/v1

FLORISTIC DIVERSITY, COMMUNITY STRUCTURE AND SPECIES RICHNESS OF MALTA (*Citrus sinensis*) BASED TRADITIONAL HOMEGARDENS OF TEHRI GARHWAL, UTTARAKHAND, INDIA

Suraj Goswami*, Arvind Bijalwan, Bhupendra Singh, Taufiq Ahmed, Sandeep Kumar

College of Forestry, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri, Uttarakhand, India- 249199s

*Corresponding author's E-mail: goswami30suraj@gmail.com

Telephone number: 7252023623

Abstract

Traditional homegardens of Uttarkhand is a multipurpose and diverse farming system. It serves as a significant livelihood strategy for regulating household socioeconomic conditions. The present study aims to determine the floristic diversity, community structure, and species richness of Malta (*Citrus sinensis*) based traditional homegardens. The present study was conducted at two elevation ranges i.e. 1300-1500 masl and 1500-1700 masl in two blocks (Chamba and Jakhanidhar) of Tehri Garhwal district of Uttarakhand. Crop species inventory was prepared by homestead survey and random quadrat sampling method used for phytosociological and other parameters of trees. A total of 46 species were documented during the study, out of which 27 agriculture crops (58 %), 15 fruit crops (33%), and 3 multipurpose trees (6%).*Citrus sinensis* (density: 106-313 trees/ha; IVI: 128-216) was found to be the most dominating and important species of these homegardens in Garhwal Himalayas followed by *Grewia optiva*, *Citrus limon*, *Mangifera indica*, and *Psidium guajava*. The results of floristic diversity showed that the highest value of the Shannon and Weiner index (1.88), Simpson diversity index (0.76) and Margalef index (6.16) was recorded. The higher values of all diversity indexes (0.81, 0.47 and 2.24 respectively) were recorded in upper elevation. The value of Jaccard & Sorensen (Similarity) index among all study sites ranged from 23.07 to 27.77 and 33.33 to 42.47 respectively. Diversity and species richness of Malta-based traditional homegarden is high as compared to mono-cropping and provides food, fodder, fruits, and small timber to the farmers of the Tehri Garhwal region.

Keywords: Agroforestry, Homegarden, Important Value Index, Multipurpose Tree Species.

INTRODUCTION

Homegardens agroforestry system is one of the most predominant types of land utilizing system appropriate for high rainfall zones in tropical conditions. It represents an intimate, multistory mixture of different perennial and annual crops, sometimes it is associated with domestic animals, around the homestead which serves as a permanent or temporary source of income (Kumar, 2017; Kumar and Tripathi, 2017). The majority of the homegardens have a3-4 strata with ground layer, topmost tree layer, and middle layer (between the ground and top layer). The ground canopy layer is again divided into two classes, (a) layer having less than 1-meter strata dominated by different vegetables and arable plants and (b) layer having 1 to 3-meter strata (comprises of food plants like cassava, banana, papaya, yam, etc.). The topmost tree layer can be grouped into two classes, including, a predominant layer of trees of more than 25 meters in height, and a co-dominant layer of medium-sized trees of 10 to 20 meters possessing the following lower layer. The premature trees are the part of the middle layer and these trees may keep on becoming taller and eventually become a part of the upper tree layer. It demonstrates, that the structure is not at all static in nature and the substitution of species makes dynamicity in the structure of homegardens although the general structure and capacity of the framework are kept up (Nair, 1993; Kumar and Nair, 2004; Peyre, *et al.* 2006).

Citrus sinensis, commonly known as Sweet Orange or Malta is a significant individual from the family Rutaceae and is supposed to be originated in tropical and subtropical areas in South East Asia (particularly India, China, and the locales between these two nations). This fruit is considered as the best source of vitamin C, sugar, amino acids, and different supplements and is famous for its sweet taste, charming flavor, and reviving juice (Ghosh, 1990; Sharma *et al.,* 2012).*Citrus sinensis* is a medium-sized tree, mostly cultivated on family farms at heights ranging from 900 to 2200 m amsl that flower March to April and harvested in November to December. The crop is primarily sold as a substitute for Mousambi (*Citrus limetta*) and has yet to establish a distinct market character. Other Citrus fruits, such as those grown in Western India, compete fiercely with Malta oranges. Their sour flavor and thick skin make them less appealing to customers and limit their commercial potential as fresh fruit (Choudhary *et al.,* 2015).

Maharashtra, Andhra Pradesh, Punjab, Karnataka, Uttarakhand, Himanchal Pradesh and Bihar are prime cultivators of the Citrus fruit crops in India. In India, sweet oranges are grown on 185 thousand hectares (18.45 percent of total Citrus fruit area) and produce 3266 thousand MT (26.03 percent of total Citrus production). (NHB, 2017-2018). It is considered a significant money crop in the Western Himalayan locales including Uttarakhand (Pandey *et al.,* 2011). The state agriculture and watershed divisions presented and advanced sweet orange in slope areas under the program for horticulture development (Choudhary *et al.,* 2013).

In Uttarakhand, Citrus spp. occupied about 13.90 percent (27400 ha) of total fruit area in the year 2010-11. Garhwal locale is the significant Citrus growing area of Uttarakhand with 50.20 percent (13755 ha) of the total area of Citrus and which was around 51.1 percent (67729 t) of the total Citrus production in the state in the year 2010-11. Rudraprayag district marks itself particularly underway of Citrus species, with the production of 45.03 percent (30938 t) of the total area of the Citrus production which is higher than Garhwal division region [34.2 percent (4704 ha)] (Gunwant *et al.,* 2013). According to USDA, every 100 grams of Malta fruit has 47 calories, 0.94 g of protein, 0.12 g of fat, 2.4 g of soluble fiber, 53.2 mg of vitamin C, 0.1 mg iron, 14 mg phosphorus, 10-milligram magnesium, and 181 mg potassium (USDA nutrient database, 2014). Despite its high nutritional, pharmacological, and therapeutic potential, the Malta fruit has a lot of difficulties reaching the markets in Uttarakhand, due to the inadequate roads and transportation accessibility in rural places, selling fresh fruits to the market does not earn good prices. Another key cause for its poor image and marketing is the lack of properly managed and organized orchards. Malta trees are typically not managed properly for commercial production, which might result in a loss in productivity (Goswami *et al.* 2020).

Economic importance of *Citrus sinensis*: Malta (*C. sinensis*) being a wild variety has a high growth potential throughout the terrain of the upper and lower Himalayas. It has extensive coverage due to high seed growth about high plant numbers. It contains high nutritional values of potassium, calcium, and vitamin C content. *C. sinensis* has long been used to treat gastrointestinal issues (such as cramps, constipation, colic, and diarrhea), lung problems (such as cough, cold, bronchitis, and tuberculosis), obesity, menstrual issues, cardiac problems (such as chest pain, high blood pressure), anxiety, depression, and anxiety (Favela-Hernández *et al.* 2016).*Citrus sinensis* peels have the potential to produce bio-fuel that is affordable, ecologically

sound, and easily obtainable, as well as offering employment opportunities for local people out of waste (Ukaoma *et al.* 2021). The seed oil is also extracted from *C. sinensis*, which is mostly used for nutritional as well as industrial purposes.

Citrus sinensis is a key component fruit crop in Uttarkhand's traditional homegarden agroforestry systems, and also a source of revenue. The focus of this research was to evaluate the species composition and understand the diversity and species richness of Malta-based traditional home gardens and its emphasis toward the floral diversity.

Materials and Methods

Study area

The investigation was led in Jakhanidhar block (lower elevation 1300-1500 m) and Chamba block (upper elevation 1500-1700 m) of region Tehri Garhwal district, the western central part of Uttarakhand, India (presented in Table 1). Geographically, the district is located at 30.3` and 30.53` north latitude and 77.56`and 79.04` east longitude. The climate of the investigation region ranges from temperate to sub-tropical. Winters are bitterly cold and charming in summer. Rainfall is generally constant in the study area throughout the year, with an average annual precipitation of 1200-1500mm. The monsoon season, which lasts from July through September, has the highest rainfall. The hilly soil (brown to dark brown) is the dominant soil type of investigation area, which is settled from granite ferrous biotite, sctics granites, gnesiss, and phyllites. The total geographical area of the district is 3642 sq km out of which 56.68 % land comes under forest territory.

The majority of population of study area are engaged with agriculture thus varieties of traditional and modern agroforestry practices are adopted by farmers of Tehri Garhwal district (Bijalwan 2011, Vikrant *et al* 2021).

Table 1. Geographical informationof the study sites in Tehri Garhwal district of Uttarakhand.

Elevation	Village Name	The altitude range of study (masl)	Latitude(N)	Longitude (E)
Lower elevation	Jhelam	1300-1400	30°19’29.7”	78°32’59.8”

(1300-1500 m)	Navakot	1300-1400	30°19’59.8”	78°31’7.8”
	Sondhar	1400-1450	30°19’36.1”	78°33’46.5”
	Petab	1400-1450	30°20’35.6”	78°32’04.2”
Upper elevation (1500-1700 m)	Budogi	1500-1550	30°21’59.1”	78°26’35.2”
	Pipali	1500-1550	30°22’52.6”	78°26’46”
	Jagdhar	1600-1656	30°19’26”	78°23’57.9”
	Dargi	1637-1698	30°19’8.1”	78°24’33.7”

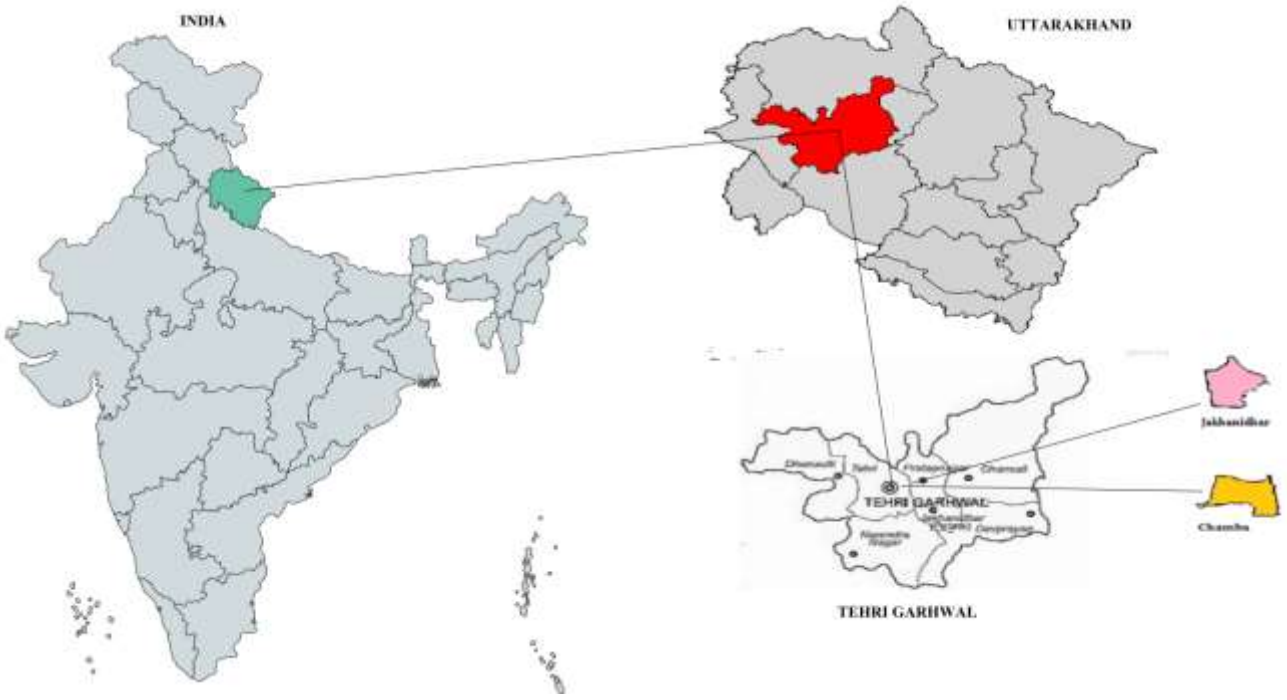


Figure 1: Location of the study site at Tehri District of Uttarakhand.

Sampling

The investigation was done in *Citrus sinensis* (L.) Osbeck based traditional homegarden system (Agri-Horticultural system). After the pilot survey study sites was selected based on availability and dominance of Malta homegardens. To conduct the household survey, a total of 15 households were randomly selected from each village, thus a total of 120 households were selected from 8 villages. Crop species inventory prepared by homestead survey (through informal discussion with household individuals) to collect data from the respondents and all the

recorded species were documented and analyzed for floristic diversity following Samant *et al.* (1998).

The random quadrat sampling method was adopted to study the phyto-sociology of tree species. Random 120 quadrats of 10 × 10 m (0.01 ha) size (15 quadrats from each village) were laid out in a *Citrus sinensis* based homegarden system for the collection of field data.

Methodology

For IVI (Important value index), the diameter at breast height (dbh, i.e., 1.37 m above ground level)) with help of the caliper of each tree in the sample plots were measured for calculation of basal area (MacDicken et al., 1991). The basal area was calculated using dbh as follows:

$$BA = \frac{\pi D^2}{4}$$

BA=basal area (m^2); =Pi is constant (3.143); and D=diameter at breast height (cm).

The Important Value Index (IVI) is used to determine the overall importance and dominance of *Citrus sinesnsis* and other tree species in the study area. In evaluating this list, the relative density, relative frequency, and relative dominance are added according to Curtis (1959) and Phillips (1959). The relative density, relative frequency, relative dominance are calculated using the following equations.

$$\text{Relative density} = \frac{Numberofindividualsofthespecies}{Numberofindividualsofallspecies} \times 100$$

$$\text{Relative frequency} = \frac{Numberofoccurrenceofthespecies}{Numberofoccurrenceofallthespecies} \times 100$$

$$\text{Relative dominance} = \frac{Totalbasalareaofthespecies}{Totalbasalareaofthespecies} \times 100$$

The importance value index (IVI) was determined as the sum of relative frequency, relative density, and relative dominance (Phillips, 1959).

$$\text{Importance value Index} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

Floristic Diversity

Species richness is the total species present in the area. Total species Richness (TSR) is assessed by a simple count of the number of species present in the investigation area. The Margalef index calculates species abundance and despite its attempts to compensate for investigating impacts, it

is quite sensitive to sample size. (Magurran, 2004) and calculated by using the formula given by Marglef (Marglef, 1968).

$$d = s - 1/lnN$$

Where s= total number of species N= basal cover of all species (m^2 ha^{-1})

Shannon Weiner index measures the species richness and abundance of community in an area - the higher value indicates the higher diversity according to Shannon and Weiner (1949)

$$H' = -Pilog\ 2Pi$$

Where Pi is the proportion of total stand basal area represented by the i^{th} species.

Simpson diversity is used to the assessment of the variety of organisms in a habitat is carried out by Simpson (1949).

$$Cd = (Ni/N)2$$

Ni and N were the same as explained above and it varies between 0-1.

Where, D = Simpson index of dominance

P_i=the proportion of importance value of the i^{th} species ($\boldsymbol{Pi = ni / N}$, n_i is the importance value index of all the species).

The similarity index represents the presence and absence of specific species in two samples or regions. The coefficient of Sorensen (K) and the coefficient of Jaccard (S) were used to measure species turnover among the sites (Legendre and Legendre, 1984) by the following formula:

$$S\ (\%) = \frac{(a \times 100)}{(a+b+c)}$$

$$K\ (\%) = \frac{(2a \times 100)}{(2a + b + c)}$$

Where 'a' =number of common species for both floristic site, 'b' = number of species present in the first floristic site, 'c' = number of species present in the second floristic site.

Different quantitative parameters and data analysis of *Citrus sinensis* based homegarden was done with the help of Microsoft Office Excel 2010.

Results

Floristic diversity

A detailed comprehensive list of all 47 plant species belonging to 23 families has been compiled from the 120 homegardens consisting of 20 (42.55 %) tree species and 27 agriculture crops (57.44%). The list of agriculture crops grown by farmers is presented in table 2 and tree species in table 3.

A homegarden comprises various layers like understory, middle and top story. In the understory, annual crops like vegetables, cereals, pulses, and oilseeds were recorded. The cropping pattern was worked around two seasons privately alluded to as Kharif and Rabi. The highest number of crops 21 (75%) were recorded during the Kharif season while the least 7 (25%) were recorded during the Rabi season. In the all-investigation area, 21 vegetable crops (77.77%), 2 cereal crops (7.4%), 3 pulse crops (11.11%), and 1 oilseed crop (3.7%) were recorded (Fig 2&3).

In the middle story mainly fruit trees were predominant. In the top story, multipurpose trees were viz. Bhimal (*Grewia optiva*), Toon (*Toona ciliata*), Dekan (*Melia azedarach*), and Walnut (*Juglans regia*) are grown by farmers. The concentrations of fruit trees were a distinct feature of the investigated homegardens and make a significant contribution to household nutrition. There were 15 tree species recorded at lower elevations (1300-1500m) belonging to 10 families and 10 tree species from upper elevations (1500-1700m) belonging to 6 families. A total of 5 multipurpose trees belonging to 4 families were documented from the different study sites. The Meliaceaefamily (2 species) rank top in the MPTs. The most common MPTs were *Grewia optiva* followed by *Juglans regia, Melia azadarach*, *Celtis australis*, and *Toona ciliate*. Tree species are cultivated for a variety of purposes, including food, fuel-wood, fodder, timber, and economics. Fruit trees not only offer sustenance throughout their lives, but the final harvest of timber also generates a profit. Many species in home gardens are utilized as fodder (for example *Grewia optiva, Melia azedarach,* and *Celtis australis*), and also help to relieve pressure on the nearby forests. Overall, the Solanaceae family was the most dominating family (5 species) followed by Rutaceaae, Brassicaceae, and Fabaceae. While among the fruit crops, Rutaceae was the most dominating family (4 species) followed by Rosaceae (3 species) (Fig 5).

In the present study, communities in the study locations were completely reliant on homegarden species for seven different purposes (Fig 2), including food (48.1%), fruit (34%), fodder (8.5%), spices (8.5%), revenue (8.5%), fuel-wood (4.25%), and building (4.25%) were recognized.

In recent years, residents noticed that the productivity of *Citrus sinensis* is lessened owing to 1) dieback mostly due to old trees and deficiency of nutrients, 2) fruit dropping (deficiency of

boron), 3) monkeys attack, destroying fruit and agriculture crops, as a result, rural people are less engaged in the cultivation of Malta fruit, agriculture, and migration is becoming a serious issue. Malta grower faces different institutional challenges from production to consumption; some of them are un-established market (associate with other crops), distorted market linkages, undefined government policies, and least seller proposition concerning price assurances. To do this, locals should come along with NGOs, Financial intermediaries, state and central governments worked together to accommodate these challenges.

Important value index

The Important Value Index of all investigation areas of both elevations is presented in table 4. In homegarden, at the both elevation range (lower & upper elevation*) C. sinensis* was the most abundant tree species, at lower elevation (1300-1500 m), the maximum average density (225 individuals/ha) and IVI (157.38) followed by *G. optiva* and *P. guajava,* while at upper elevation maximum average density and IVI is 165 individual per ha and 157.52 respectively, followed by *G. optiva* and *C. limon*.

Table 2: List of agricultural crops grown in homegarden

Sl.No.	Scientific Name	Common Name	English Name	Family
1	*Abelmoschus esculentus* L.	Bhindi	Ladyfinger / Okra	Malvaceae
2	*Amaranthus* spp.	Cholai	Amaranthus	Amaranthaceae
3	*Brassica juncea* L.	Rai	Mustard greens	Brassicaceae
4	*Brassica oleracea* var. capitataL.	Bandh gobhi	Cabbage	Brassicaceae
5	*Capsicum annum* L.	Mirch	Chili	Solanaceae
6	*Capsicum annuum* L. var. annum	Simala Mirch	Capsicum	Solanaceae
7	*Colocasia antiquorum* Schott	Arbi/Pindalu	Taro	Araceae
8	*Coriandrum sativum* L.	Dhaniya	Coriander	Apiaceae
9	*Cucurbirta maxima*	Kaddu	Pumpkin	Cucurbitaceae
10	*Lagenaria siceraria*	Lauki	Bottle Gourd	Cucurbitaceae
11	*Solanum lycopersicum*	Tamatar	Tomato	Solanaceae
12	*Momordica dioica*	Kankoda	Spine gourd	Cucurbitaceae

13	*Pisum sativum* L.	Mattar	Pea	Fabaceae
14	*Solanum melongena*	Began	Brinjal	Solanaceae
15	*Spinacia oleracea* L.	Palak	Spinach	Chenopodiaceae
16	*Zingiber officinale*	Adarak	Ginger	Zingiberaceae
17	*Zea Mays* L.	Makki	Maize	Poaceae
18	*Dolichos lablab* (L) sweet	Sem	Bean	Fabaceae
19	*Phaseolus vulagris* L.	Rajma/Chhemi	Kidney Bean	Fabaceae
20	*Brassica compestris*	Sarson	Mustard	Brassicaceae
21	*Raphanus sativus* L.	Muli	Radish	Brassicaceae
22	*Solanum tuberosum* L.	Aalu	Potato	Solanaceae
23	*Allium cepa* L.	Piaz	Onion	Amaryllidaceae
24	*Allium sativum* L.	Lahsun	Garlic	Amaryllidaceae
25	*Curcuma longa* L.	Haldi	Turmeric	Zingiberaceae
26	*Triticum aestivum*	Gehu	Wheat	Poaceae
27	*Lens culinaris*	Musoor	Lentil	Fabaceae

Fig 2: Major identified used categories of plant species in the study area.

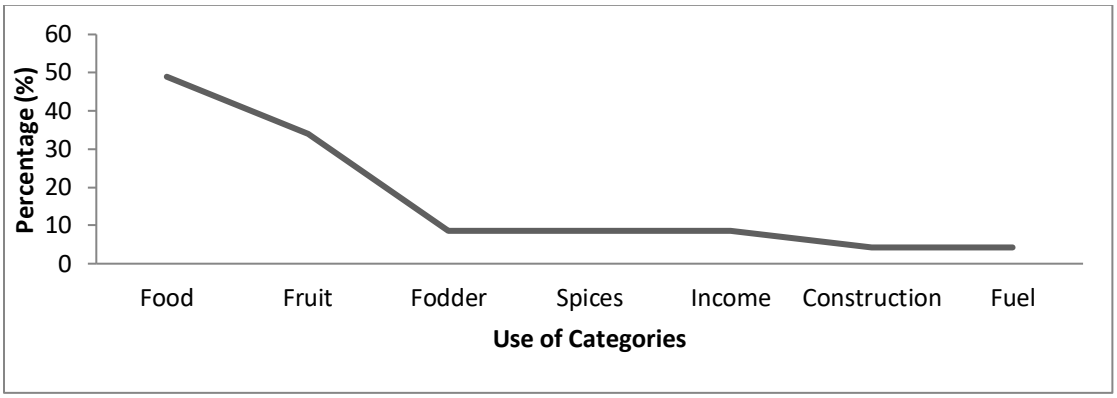
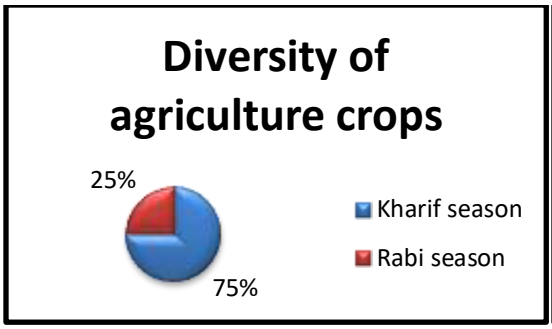


Fig 3 & 4: Diversity of agriculture crop and various kinds of food crops raised in homegardens during Kharif and Rabi seasons.



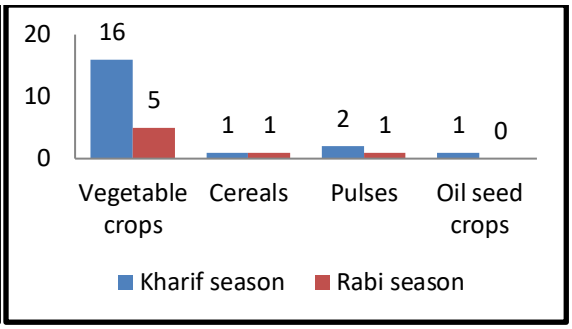


Table 3: List of tree species grown in Malta based traditional homegarden

a) Fruit crop species				
Sl. No.	Scientific Name	English Name	Common Name	Family
1	*Carica papaya* L.	Papaya	Papeeta	Caricaceae
2	*Citrus limon* (L.)Brum.f.	Lemon	Lemon	Rutaceae
3	*Citrus maxima*	Lemon	Chakotara	Rutaceae
4	*Citrus nobilis*	Orange	Narangi	Rutaceae
5	*Citrus reticulata*	Tangerine	Santara	Rutaceae
6	*Citrus sinensis* (L.) Osbeck	Sweet Orange	Malta	Rutaceae
7	*Juglans regia* L.	Walnut	Akharot	Juglandaceae
8	*Malus× domestica* Borth	Apple	Seb	Rosaceae
9	*Mangifera indica* L.	Mango	Aam	Anacardiaceae
10	*Musa paradisica* L.	Banana	Kela	Musaceae
11	*Phyllanthus emblica* L.	Indian gooseberry	Aonala	Phyllanthaceae
12	*Prunus armeniaca* L.	Apricot	Khumani	Rosaceae
13	*Prunus persica* (L.)Batsch	Peach	Aroo	Rosaceae
14	*Psidium guajava* L.	Guava	Amarood	Myrtaceae
15	*Punica grantum* L.	Pomegranate	Anar	Punicaceae

b) Multipurpose trees (MTs)				
16	*Celtis australis* L.	European nettle tree	Khadik	Cannabaceae
17	*Grewia optiva*	Grewia	Bhimal	Malvaceae
18	*Juglans regia* L.	Walnut	Akhrot	Juglandaceae
19	*Melia azedarach* L.	Persian lilac	Dekkain	Meliaceae
20	*Toona ciliata*	Red cedar	Toon	Meliaceae

Fig. 5: Distribution of fruit crops family-wise in the Malta-basedtraditional homegardens of the study area.

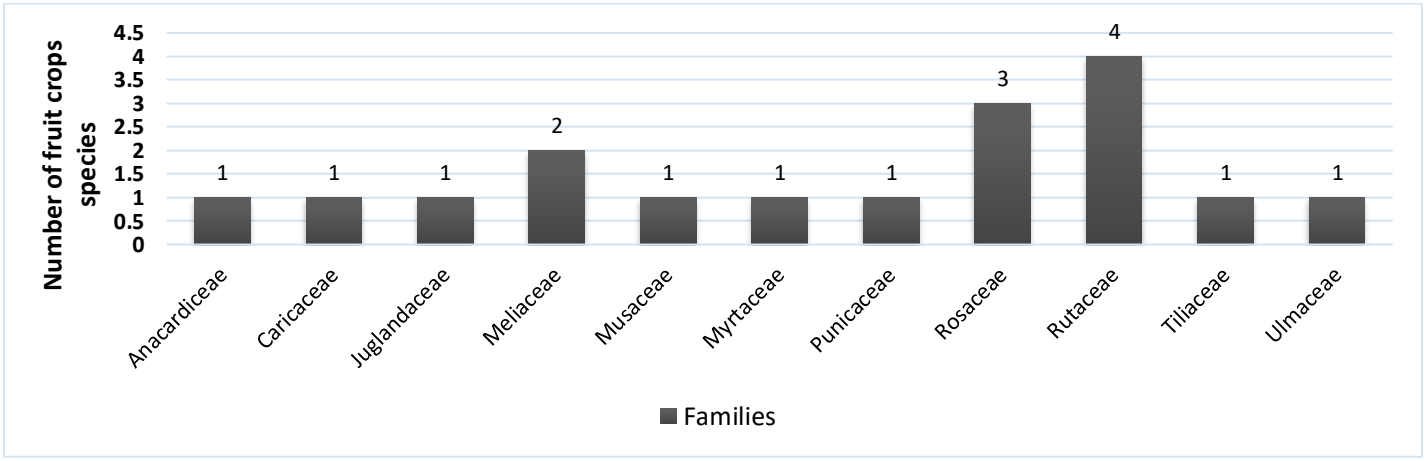


Table 4: Average importance value index (IVI) of trees in the different studied areas at two elevations in Tehri Garhwal district of Uttarakhand.

Trees	Lower Elevation (1300-1500 m)				Upper Elevation (1500-1700 m)			
	Sonadhar	Jhelam	Navakot	Petab	Jagdhar	Dargi	Budogi	Pipali
***Citrus sinensis* (L.) Osbeck**	171.46	153.7	175.56	128.81	139.73	216.01	142.19	132.15
Citrus limon	30.56	4.68	21.8	16.52	58.8	37.02	23.3	28.98
Grewia optiva	40.38	20.77	–	14.21	60.46	15.92	56.7	67.94
Citrus nobilis	6.12	14.05	–	17.78	–	21.79	24.09	18.74
Psidium guajava	24.26	–	12.38	28.79	–	–	24.6	24.2
Punica grantum	13.81	–	12.54	8.53	–	–	17.09	–
Malus domestica	6.06	5.25	8.61	4.39	–	–	–	28.3
Carica papaya	–	9.16	11.25	23.91	–	–	–	–
Juglans regia	–	15.73	3.36	14.72	–	–	–	–

Mangifera indica	–	26.65	14.44	27.31	–	–	–	–
Phyllanthus emblica	–	–	3.11	9.76	–	–	–	–
Prunus persica	–	–	13.69	5.39	–	–	–	–
Citrus maxima	7.31	–	–	–	–	–	–	–
Toona serrata	–	–	11.22	–	–	–	–	–
Melia azadarach	–	–	12.26	–	–	–	–	–
Phyllanthus emblica	–	–	–	–	–	–	12.14	–
Prunus persica	–	–	–	–	–	9.48	–	–
Celtis australis	–	–	–	–	41.33	–	–	–

Table 5: Total species richness and diversity parameters of tree species on all study sites along the altitudinal gradient.

Study sites	**TSR**	**MI**	**H'**	**D**
Lower elevation (1300-1500m)				
Sondhar	8	4.21	1.39	0.64
Jhelam	8	4.25	1.08	0.47
Petab	12	6.16	1.88	0.76
Navakot	12	4.67	1.58	0.67
Upper elevation (1500-1700m)				
Jagdhar	4	3.35	1.19	0.67
Dargi	5	2.44	0.81	0.41
Budogi	7	3.53	1.55	0.72
Pipali	6	2.95	1.45	0.71

TSR- Total Species Richness; MI- Margalef's index of species richness; H'- ShannonWeiner index; D- Simpson diversity index

Fig 6. Similarity index between homegarden of adjacent sites.

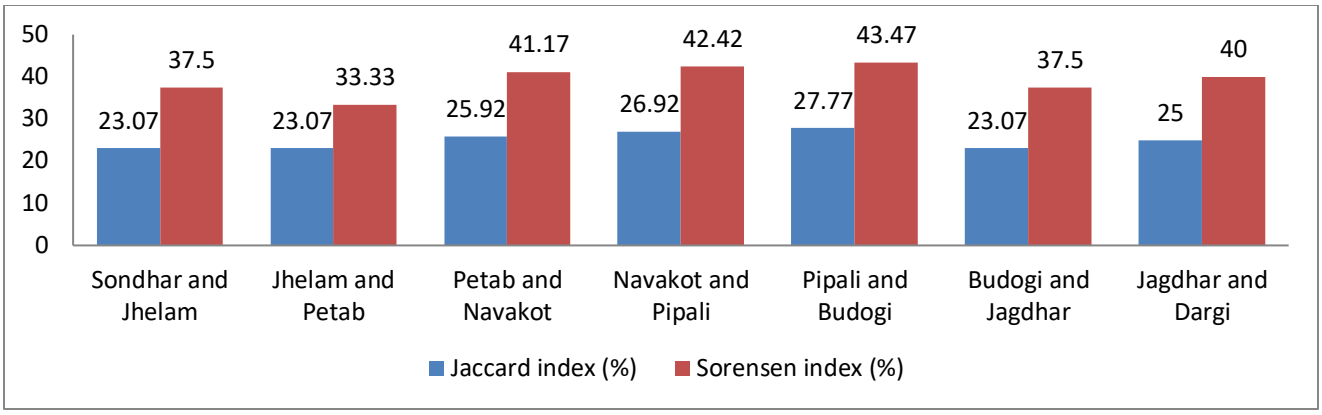


Table 6: Preference ranking for often used trees in Tehri Garhwal's Malta-based homdegarden.

Scientific Name	Lower Elevation Site (1300-1500m)				Upper Elevation Site (1500-1700m)				Total	Rank
	Sonadhar	Jhelam	Navakot	Petab	Jagdhar	Dargi	Budogi	Pipali		
Citrus sinensis	27	32	47	29	16	33	25	25	234	**1**
Citrus limon	5	1	9	3	7	-	5	5	35	**2**
Grewia optiva	5	3		2	5	1	7	8	31	**3**
Psidium guajava	4	-	4	6	-	5	4	4	27	4
Citrus nobilis	1	3		5		3	4	3	19	5
Mangifera indica	-	1	5	4	-	-	-	4	14	6
Punica grantum	2	-	4	2	-	-	3	-	11	7
Carica papaya	-	1	4	3	-	-	-	-	8	8
Prunus persica	-	-	5	1	-	1	-	-	7	9
Phyllanthus emblica	-	-	1	3	-	-	2	-	6	10
Malus× domestica Borth	1	-	4	1	-	-	-	-	6	10
Juglans regia	-	2	1	2	-	-	-	-	5	11
Melia azedarach	-	-	4	-	-	-	-	-	4	12
Celtis australis	-	-	-		3	-	-	-	3	13
Toona ciliata	-	-	3	-	-	-	-	-	3	13
Citrus maxima	1	-	-	-	-	-	-	-	1	14
Total	46	43	91	61	31	43	50	49	414	

Species richness

Total species richness and diversity parameters of each site at both elevations are presented in Table 5. The highest value of total species richness was recorded in Petab (12) and Navakot village (12), followed by Sondhar and Jhelam due to a higher number and variety of tree species in the agroforestry ecosystem compared to other study sites. The species richness and diversity were low in all studied land-use systems of both elevations because all land-use systems were dominated by *Citrus sinensis.*

Margalef's index of richness was highest (6.16) in lower elevation and lowest (2.44) in upper elevation. The Shannon Weiner index value was highest (1.88) in lower elevation and lowest (0.81) in upper elevation due to the higher number of species in lower elevation compared to upper elevation. The Shannon Weiner index varies from low to moderate, with a value of 0.81–1.88. As a result, the species chosen by the community are not extremely diverse, with just species that the community needs to be planted.

Simpson's Diversity Index is used to quantify the variety of organisms in a habitat. The range of Simpson's Diversity Index from 0 to 1 and the value which is close to 1 indicates the highest diversity. The Simpson index of diversity was found highest (0.76) in lower elevation and lowest (0.41) in upper elevation.

Jaccard and Sorensen similarity indices were studied between homegarden of adjacent villages with an altitudinal gradient (Fig 6). The highest similarity was found between Pipali-Budogi villages; the values of Jaccard and Sorensen indices were 27.77 and 43.47, respectively; followed by Navakot-Pipali villages (26.92 and 42.42, respectively).

The most dominant species of both elevations was *Citrus sinensis*. Based on the preference ranking of tree species presented in Table.6, the *Citrus sinensis* ranked first followed by *Citrus limon* (second position) and *Grewia optiva* (third position).

Traditional management techniques such as preserving unsold *Citrus sinensis* fruit in a soil pit and consuming it during the summer season. In areas where snowfall is a serious issue, fruits are removed before snowfall.

The Malta-based traditional homegarden agroforestry system has a wide assemble of potentialities in compassing social; economic; environmental prospects of Tehri Garhwal Himalayas. The present studies which were carried have profoundly dictated the same and need be to access the situation beholding the cynicism of the problems of farmers to benefits the

unexplored market for the effective measure of livelihood as the socio-economic growth of the region.

DISCUSSION

Floristic diversity and important value index

The diversity of the present study is much less than 182 species from 71 families documented by Vijayakumari *et al.* (2019) from a homegarden in Tamil Nadu (2019). Shaikia *et al*. (2012) recorded 294 plant species belonging to 92 families in upper Assam, while Tynsong *et al.* (2010) found 197 plant species in the War Khasi community of Meghalaya. It is conceivable that the higher number of species reported in the above-mentioned research is related to the larger sample size and geographical coverage of the sample (Sahoo *et al.* 2011) and shows that if the sample number is larger, the total number of species recorded in the present study may increase. All homegardens in the altitudinal zone would have a very similar species composition.

The composition of plant species and their characteristics varied dramatically from one investigation site to the next, depending on the local community's social and cultural needs. Maximum reported crops in all the investigation areas were viz. Okra, Chili, Capsicum, Tomato, Brinjal, Pea, Radish, Potato, Onion, Garlic, Turmeric, Mustard greens, Pumpkin and Bottle gourd. Amaranthus, Coriander, Lentil, and Kidney bean are grown uncommon in investigation areas. Similar findings were brought to light from the findings of Nautiyal *et al.* (1998).

The number of trees in the agroforestry system with a decrease in altitude was reported by Bijalwan *et al*. (2016), a similar pattern observed in this study. Malta (*Citrus sinensis*), Narangi (*Citrus nobilis*), Lemon (*Citrus limon*), Guava (*Psidium guajava*), and Apple (*Malus domestica*) are common in all the investigation areas. Mango (*Mangifera indica*), Papaya (*Carica papaya*), Peach (*Prunus persica*), and Amla (*Phyllanthus emblica*) are uncommon in the investigation area. Citrus fruits were utilized to treat stomach problems; and also used to prepare juice and pickles (Kala, 2010).

The most common MPTs were *Grewia optiva* followed by *Juglans regia* L.*, Melia azadarach* L., *Celtis australis* L., and *Toona serrata,* which is similar to the finding of Tiwari *et al.* (2016).

According to Caballero (1992), *Citrus sinensis, Psidium guajava,* and *Mangifera indica* were the dominant fruit tree species in this prevalent altitudinal variation for the homegarden species, similar to the present finding of the study, because it is consumed as an edible fruits (Kala,

2010). Citrus fruit were utilized to the stomach problem and also used to prepare juice, pickles, while fruits also used making different types of beverages (Chatraborty et al. 2011). Low soil fertility, lack of quality seeds, poor infrastructure, transportation facilities, non-availability of technology, inadequate pest, and disease management, and insufficient irrigation facilities in the area are among issues that home gardeners encounter. Farmers are facing high costs, low returns, and low income as a result of their small and fragmented land holdings and little purchasing power (Gariya *et al.* 2020).

Homegardens of both elevations were dominated by *Citrus sinensis. Citrus sinensis*, a subtropical fruit grown under the traditional Agri-Horticulture system in the Garhwal Himalayas, had a higher IVI value observed by Bijalwan *et al.* (2011), which is similar to the finding of the present study.

Choudhary *et al.* (2015) observed that Malta grower of Chamoli district of Uttarakhand earnings nearly tripled income after the institutional development in the form of farmer interest groups and the federation as training and the building of a common facility center. Thus, the government should promote a small skill training program focused on product value addition among Malta growers. Along with this program, the government should introduce a new variety of Malta such as BARI-1 Malta. BARI-1 Malta is a sweet orange variety developed by Bangladesh Agricultural Research Institute. It is a good source of vitamin C and minerals, and it is popular among consumers because of its sweet and sour taste and pleasant flavor. As a result, it is rising in popularity day by day. (Islam *et al.* 2017). *C. Sinensis* has multipurpose uses and every part of this tree is used for different uses and has the potential for preventing village migration by providing regular work.

Species richness

Kumar (2011) also reported Simpson's diversity value for woody strata ranges from 0.50-0.76, 0.32-0.55, and 0.38-0.55 for small, medium, and large homegarden respectively. This is almost similar to the present study. According to Colwell *et al.* (2012), the species richness within a particular environment is highly dependent on sample size. The sampling strategy and species richness or statistical model applied to analyze the information has been proposed that the estimation of species richness and diversity is influenced by the sampling strategy (Dorazio *et al.*, 2006).

*Citrus sinensis*is ranked first, followed by *Citrus limon* and *Grewia optiva*, based on the tree species preference rankings, similar findings were observed by Rana *et al.* (2016) and Gariyal *et al.* (2020).

Conclusion

Uttarakhand's mountainous region provides a wide arena of homestead farming where *Citrus sinensis* proved to be an important fruit crop in terms of richness, productivity, employability in contrast to the monocropping. The Tehri Garhwal's rural community benefit from a Malta-based homegarden that provides food, fodder, fruits, and small timber thus the home garden is an important source of food security and generates additional revenue. Villagers of the investigated site primarily cultivate agriculture and vegetable crops for their consumption. They also grow garlic, potato, and onion as cash crops. Floristic diversity, composition, and density of species present in homegarden are mainly depending on socio-economic factors in the investigation site. Several species were notably affected by altitudinal zones. Effectively conventionally maintaining a homegarden has a lot of promise for sustainable development and environmental protection. By working together, Malta growers can minimize transportation costs; value-adding their products, derive access to new varieties, and enhance market access.

Recommendation

Further studies need to be carried out to quantify the spectrum of benefits that the Malta-based traditional homegarden agroforestry system provides.

Author Contribution Conceptualization, S.G., A.B., B.S., T. A., and S.K; validation, formal analysis, investigation, data correction, S.G.; methodology, writing—review, editing, and supervision, S.G.; A.B., B.S., T.A., and S.K; All authors have read and agreed to the published version of the manuscript.

Code Availability Not applicable.

Declarations

Ethics Approval Not applicable.

Informed Consent Not applicable.

Confict of Interest The authors declare no competing interests.

Reference

Bijalwan A, (2011) Structure, Composition, and Diversity of Horticulture Trees and Agricultural Crops Productivity under Traditional Agri-Horticulture System in Mid Hill Situation of Garhwal Himalaya, India. American Journal of Plant Sciences 3: 480-488. https://www.scirp.org/pdf/AJPS20120400007_26802760.pdf

Bijalwan A. and Dobriyal, MJR (2016) Geometry, Distribution and Regeneration Pattern of Trees in Agroforestry Systems along with Altitude and Aspects in the Upper Yamuna Region of Uttarakhand Himalaya, India. Applied Ecology and Environmental Sciences4: 15-25. http://pubs.sciepub.com/aees/4/1/3/

Caballero J (1992) Maya homegardens: past, present and future Etnoecológica 1: 35-54. https://www.uv.mx/ethnobotany/caballero_files/caballero%201992%20ETNOECOLOGICA.pdf

Chakraborty, I., Chaurasiya, A.K., and Saha, J. (2011). Quality of diversified value addition from some minor fruits. *J. Food Sci Technol*, 48(6):750-754.https://link.springer.com/article/10.1007/s13197-010-0194-y

Choudhary D, Ghosh I, Chauhan S, Bhati S and Juyal M (2013). Case Studies on Value Chain Approach for Mountain Development in Uttarakhand, India. ICIMOD, Kathmandu, Nepal,1-44. https://lib.icimod.org/record/28849/files/WP2013-6.pdf?type=primary

Choudhary D, Kunwar MS and Rasul G (2015). From Farmer to Entrepreneurs – Strengthening Malta Orange Value Chains Through Institutional Development in Uttarakhand, India. Mountain Research and Development 35: 4–15. https://bioone.org/journalArticle/Download?urlId=10.1659%2FMRD-JOURNAL-D-14-00036.1

Curtis JT (1959). The vegetation of Wisconsin: An ordination of plant communities. Madison, WI: University of Wisconsin Press. https://uwpress.wisc.edu/books/0467.htm

Dorazio RM, Royle JA, Soderstrom, B., and Glimskar, A. (2006). Estimating species richness and accumulation by modeling species occurrence and detectability Ecology 87(4): 842-854. https://doi.org/10.1890/0012-9658(2006)87[842:ESRAAB]2.0.CO;2

Favela-Hernández, JMJ, González-Santiago O, Ramírez-Cabrera MA, Esquivel-Ferriño, PC, Camacho-Corona, MDR (2016). Chemistry and Pharmacology of *Citrus sinensis*. Molecules 21, 247. https://www.mdpi.com/1420-3049/21/2/247/pdf

Gariya K, Dwivedi GK, Kumar, V., and Tewari, SK (2020). Agrobiodiversity, Composition and Functional Characteristics of Homegardens in Bhimtal Block of Nainital District, Uttarakhand, India. International Journal of Agriculture, Environment and Biotechnology 13(2): 01-11. https://ndpublisher.in/admin/issues/IJAEBv13n2c.pdf

Goswami S, Bijalwan A and Kalpana. (2020). Malta (Citrus sinensis): An Important but Underrated Fruit of Uttarakhand, India. International Journal of Current Microbiology and Applied Sciences 9(8): 2852-2855. https://www.ijcmas.com/9-8-2020/Suraj%20Goswami,%20et%20al.pdf

Gunwant V, Raturi M, Hussain M and Rana D (2013) Marketing of sweet orange (Malta) in India. International Journal of Emerging Research in Management and Technology 3(2): 45-49. https://scholar.google.com/scholar?cluster=10063840399766537383&hl=en&oi=scholarr

Islam MR, Ona AF, Dhar M, and Amin, M (2017). Influence of organic manures with recommended inorganic fertilizers on yield of sweet orange (Bari malta 1). Journal of Bioscience and Agriculture Research 13: 1146-1150. https://www.journalbinet.com/uploads/2/1/0/0/21005390/140_jbar_influence_of_organic_manures_with_recommended_inorganic_fertilizers_on_yield_of_sweet_orange.pdf

Kala CP, (2010). Home Gardens and Management of Key Species in the Pachmarhi Biosphere Reserve of India. Journal of Biodiversity 1(2): 111-117.

http://www.krepublishers.com/02-Journals/JBD/JBD-01-0-000-10-Web/JBD-01-2-000-10-Abst-PDF/JBD-01-2-111-10-011-Kala-C/JBD-01-2-111-10-011-Kala-C-Tt.pdf

Kumar BM (2011). Species richness and aboveground carbon stocks in the homegardens of central Kerala, India. Agriculture, Ecosystems and Environment 140: 430–440. https://ur.booksc.eu/dl/13239132/0aad8d

Kumar V (2017). Importance of Homegardens Agroforestry System in Tropics Region. In: Prithwraj Jha (eds), Biodiversity, Conservation, and Sustainable Development. New Academic Publishers, New Delhi, 2. https://www.researchgate.net/publication/287996797_Importance_of_Homegardens_AgroforestySystem_in_Tropics_Region

Kumar V and Tripathi AM (2017).Vegetation composition and functional changes of tropical homegardens: Prospects and challenges. In: Gupta, S.K., Panwar, P. and Kaushal, R. (Eds). Agroforestry for increased production and livelihood security. New Delhi Publishing Agency, New Delhi, 475-505. https://www.researchgate.net/publication/301765561_Vegetation_composition_and_functional_changes_of_tropical_homegardens_Prospects_and_challenges#fullTextFileContent

Legendre L and Legendre P (1984). Écologie Numérique, Tome 1: Traitement Multiple des DonnéesÉcologiques, Masson, Paris, France.http://refhub.elsevier.com/B978-0-12-409548-9.10595-0/rf0275

Magurran AE (2004). Measuring Biological Diversity. Blackwell Publishing Company, London. https://www2.ib.unicamp.br/profs/thomas/NE002_2011/maio10/Magurran%202004%20c2-4.pdf

Margalef R (1968). Perspective in ecological theory. University of Chicago Press. Chicago, 78-87. https://aslopubs.onlinelibrary.wiley.com/doi/epdf/10.4319/lo.1969.14.2.0313

Nair PKR (1993). An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht, Dordrecht, The Netherlands, 499.

http://apps.worldagroforestry.org/Units/Library/Books/PDFs/32_An_introduction_to_agroforestry.pdf?n=161

Nair PKR (2008). Perspective agroecosystem management in the 21st century: It is time for a paradigm shift. Journal of Tropical Agriculture 46(1-2): 1-12. http://jtropag.kau.in/index.php/ojs2/article/download/181/181

National Horticulture Board Database, 2018. Ministry of Agriculture, Government of India.http://nhb.gov.in/statistics/Publication/Horticulture%20Statistics%20at%20a%20Glance-2018.pdf

Nautiyal S, Maikhuri RK, Semwal RL, Rao KS and Saxena KG (1998). Agroforestry system in the rural landscape – a case study in Garhwal Himalaya, India. Agroforestry system 41: 151-165. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1043.6341&rep=rep1&type=pdf

Pandey D, Kumar A and Singh R (2011). Marketing of sweet orange (Malta) in Kumaon region of Uttarakhand. Journal of Recent Advances in Applied Sciences 6–11. https://www.semanticscholar.org/paper/MARKETING-OF-SWEET-ORANGE (MALTA)-IN-KUMAON-REGION-Pandey Kumar/596d9cd501f2e64f4f1794c52c43b0ac27006663

Peyre, A., Guidal, A., Wiersum, K.F. and F. Bongers. 2006. Homegarden dynamics in Kerala, India. In: Kumar B.M. and Nair P.K.R. (eds), Tropical homegardens: A time-tested example of sustainable agroforestry. 87–103 https://www.researchgate.net/publication/350517060_Homegardens_as_sustainable_land_use_practice_Prospects_and_Challenges [accessed Feb 23 2022].

Phillips EA (1959). Methods of Vegetation Study. Henry Holt. & Company, New York. https://www.worldcat.org/title/methods-of-vegetation-study/oclc/834599852

Rana P, Tewari SK and Kumar V (2016). Floristic Structure, Composition and Functional Characteristics of Homegardens in Garhwal Region, Uttarakhand, India. International

Journal of Agriculture, Environment and Biotechnology 9(6): 1045-1059. http://ndpublisher.in/admin/issues/ijaebv9n6q.pdf

Sahoo UK, Rocky P, Vanlalhriatpuia K and Upadhyaya K (2011). Species composition, Production and Energetic Sustainability of Homegarden in the Highlands of Eastern Mizoram, India. Trees and Forestry Sciences and Biotechnology 6: 81–92. http://www.globalsciencebooks.info/Online/GSBOnline/images/2012/TFSB_6(SI1)/TFSB_6(SI1)81-92o.pdf

Samant SS, Dhar U and Palni LMS (1998). Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values. Nainital: Gyanodaya Prakashan. https://www.worldcat.org/title/medicinal-plants-of-indian-himalaya-diversity-distribution potential-values/oclc/40912888

Shaikia P, Choudhari B and Khan ML (2012). Floristic composition and plant utilization pattern in homegardens of Upper Assam, India. Tropical Ecology,53(1): 105-118. https://www.researchgate.net/publication/216381456_Floristic_composition_and_plant_utilization_pattern_in_homegardens_of_Upper_Assam_India#fullTextFileContent

Shannon CE and Weaver W (1963). The Mathematical Theory of Communication. University of Illinois Press, Urbana, U.S.A. https://pure.mpg.de/rest/items/item_2383164/component/file_2383163/content

Sharma T, Khan MK, Misra P and Shukla PK (2012). Micropropagation of Kinnow through nodal explants. The Bioscan 295-297. https://www.researchgate.net/publication/265532714_MICROPROPAGATION_OF_KINNOW_THROUGH_NODAL_EXPLANTS

Simpson EH (1949). Measurement of diversity. Nature 163:688. https://www.nature.com/articles/163688a0.pdf

Tiwari V, Rawat R, Negi KS and Chandra S (2016) Inventorying Plant Biodiversity in Home Gardens: A Case Study of Alaknanda and Mandakini Valleys, Garhwal Region of Uttarakhand, India. Asian Agri-History 275:290.

https://www.researchgate.net/publication/317015429_Inventorying_Plant_Biodiversity_in_Home_Gardens_A_Case_Study_of_Alaknanda_and_Mandakini_Valleys_Garhwal_Region_of_Uttarakhand_India

Tynsong H and Tiwari BK (2010). Plant Diversity in the homegardens and their Significance in the Livelihoods of War Khasi Community of Meghalaya, Northeast India. Journal of Biodiversity 1(1): 1-11. http://www.krepublishers.com/02-Journals/JBD/JBD-01-0-000-10-Web/JBD-01-1-000-10-Abst-PDF/JBD-01-1-001-10-006-Tynsong-H/JBD-01-1-001-10-006-Tynsong-H-Tt.pdf

Ukaoma AA, Duru MC, Iwu I, Nwachukwu N, Adamu I and Anyanwu C (2021). *Citrus sinensis* (L.) Peels; Potential for Biofuel Production. Internatinal Journal of Advanced Research 9(9): 2320-5407. https://www.journalijar.com/uploads/616805068077f_IJAR-37230.pdf

USDA Nutrient Database. (2014). United States Department of Agriculture, National Nutrient Database for Standard Reference Release 26, Fruits and Fruit Juices.https://www.ars.usda.gov/ARSUSERFILES/80400535/DATA/SR26/SR26_DOC.PDF

Vijayakumari J, Prabha VS, Jebarubi E, Raj TLS and Rayan S (2019). Floristic Diversity Assessment of Home Garden in Palayamkottai Region of Tirunelveli District, Tamil Nadu a Means of Sustainable Biodiversity Conservation. International Journal of Trend in Scientific Research and Development 3: 1484-1491. https://www.ijtsrd.com/papers/ijtsrd23390.pdf

Vikrant, K. K., Chauhan, D. S., & Rizvi, R. H. (2021). Assessment of Biomass and Carbon Stock along Altitudes in Traditional Agroforestry System in Tehri District of Uttarakhand, India. In G. Shukla, S. Chakravarty, P. Panwar, & J. A. Bhat (Eds.), Agroforestry - Small Landholder's Tool for Climate Change Resiliency and Mitigation. IntechOpen. https://doi.org/10.5772/intechopen.96072