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Review article

Genetic resource management of jackfruit (*Artocarpus heterophyllus* Lam.)

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ABSTRACT

Jackfruit (Artocarpus heterophyllus Lam.), a giant and unique tropical composite fruit, is widely distributed in equatorial countries. Jackfruit shows a significant range of genetic diversity, especially within South and South East Asia, which aids in the selection of superior desirable types.Genetic resource management includes exploration, collection, evolution, characterization, conservation and exchange.The importance of conservation of genetic resources is very much essential to avoid the genetic erosion. Jackfruit genotypes have been collected in tropics for conservation, study, and improvement, but limited collections exist in India, Indonesia, Thailand, Nepal, Malaysia, Philippines, Vietnam, Sri Lanka, and Bangladesh. Mitra and Maity were initiated in 1990 for the collection and evaluation of over 1460 jackfruit trees in West Bengal. In situ conservation is crucial for the effective management and maintenance of agroecosystems, as farmers with deep crop knowledge are likely to understand their type and variation. Jackfruit germplasm is mainly stored in field gene banks or orchards, despite potential threats like disease, insect infestation, and natural disasters.Identification of the diverse germplasm for higher yield to develop improved cultivars suited for changing climate can help achieve nutritional and food security demands of the increasing global population. The present paper elaborated the status of different Artocarpus species, genetic diversity and in situ and ex situ conservation of species and, varieties for utilizing the gene pool for crop improvement.

***Keywords*:** Genetic diversity, genetic resource, heterozygous jackfruit

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae and is a tetraploid with a somatic chromosome number of 56 (2n=4x=56). This family contains 55 genera and 900 to 1000 species along with fig, mulberry and hedge apple. Jackfruit is one of the most important fruits of this family. The genus *Artocarpus*, the third largest genus in the Moraceae family, includes about 50 species with milky latex of which 15 bear only edible fruit (Chandrashekar *et al*., 2018). Jackfruit is known as "Poor man's food" and it is the largest tree-borne fruit in the world (Choudhury *et al*., 2017). Immature jackfruits are commonly used in cooking, salads, and curries as a vegetable source. Ripe jackfruit can be consumed in different ways, including raw, cooked, jackfruit candy, and jackfruit leather. In India, jackfruit seeds are used to make a dessert by boiling them in sugar (Jagdale *et al*., 2021). Nowadays, jackfruit is also called as "Superfood" for its nutritional value and health benefits. The average nutritional composition of ripe jackfruit pulp (per 100 g) contains carbohydrate (16–25.4 g), protein (1.2–1.9 g), fat (0.1–0.4 g), energy (88–410 kJ), fibre (1.0–1.5 g), and water (72–94 g). The protein and carbohydrate content of different jackfruit seed species varies from 5.3 to 6.8% and 37.4 to 42.5 per cent, respectively (Jagdale *et al*., 2021).

Jackfruit is highly cross-pollinated and mostly propagated through seeds. As it is heterozygous in nature, exhibits high genetic diversity in a seedling population. Species diversity and genetic diversity within the species have been increased as a result of cross-pollination and predomination of seed propagation over a long period of time due to their influence on the evolutionary process of extinction, selection, gene drift, gene flow, and mutation

(Chandrasekhar *et al*., 2018). Gaining knowledge of individual variability and relatedness among individuals allows for the detection of duplicates and the selection of superior genotypes or genotype combinations to produce desired traits. Thus, selections made from naturally occurring open-pollinated seedlings by man have played the most significant role in the development of new jackfruit.

Over the past few decades, several jackfruit genotypes have been collected throughout the tropics for their conservation, study and improvement. In India, Indonesia, Nepal, Malaysia, Thailand, the Philippines, Sri Lanka, Vietnam, and Bangladesh, jackfruit collections for evaluation and selection are limited and therefore, the information available on the performance of the genotypes is also limited (IPGRI, 2000; Haq and Hughes, 2002). India and Bangladesh have reported a moderate level of jackfruit genetic diversity erosion (Dhakar *et al*., 2020). The most desirable varieties grown in India are low in productivity, storage, and processing quality. Despite being widely planted, jackfruit is rarely thought of as a commercial fruit crop (Bose and Mitra, 1990). This is because of a lack of improved varieties, a wide range of fruit quality, a long gestation period (8–10 years), and a high level of vulnerability to borer infestations. However, in recent years, jackfruit has gained commercial importance as a result of growing knowledge of its nutritional value in the human diet and its various uses. Here we provide a brief review on the genetic resources and management of jackfruit and its wild relatives in different jackfruit-growing areas of the world to identify the diverse germplasm for higher yield to develop cultivars suited for changing climate which can help to achieve food and nutritional security.

Origin and distribution

It originated in the evergreen rain forests of the Western Ghats of India (Haq, 2006). It is cultivated widely at low elevations throughout India, in many parts of Southeast Asia (Rahman *et al.,* 1999), in northern Australia as well (Azad *et al*., 2007), and in the evergreen forest zone of West Africa (Burkill, 1997). Major Jackfruit producers are India, Vietnam, Malaysia, Myanmar, Indonesia, Bangladesh, Sri Lanka, Brazil, West Indies, Pakistan and other tropical countries. India is the world's second-largest producer of jackfruit, just after Indonesia and India is known as the motherhood of the jackfruit **(**Sidhu**,** 2012). The area under jackfruit cultivation in India is 1.87 lakh hectares and the production is 17.39 lakh MT (NHB, 2019-20). Jackfruit is adapted to a wide range of habitats (Haq, 2006) and it can therefore help to mitigate the effects of environmental and climatic changes. Certainly, jackfruit's slow acceptance due to the large size fruit, weight more or less 30kg, strong aroma and unusual appearance.

The commercial cultivars of jackfruit are included in a single species *A. heterophyllus*. Moreover, *A. lakoocha* (Monkey jack), *A. altilis* or *A. communis* (Breadfruit), *A. hirsutus* (Wild jack), *A. camansi* (breadnut), *A. odoratissima* (marang) and *A. lingnanesis* (kwaimuk) are important species of the genus *Artocarpus* (Saxena *et al*., 2011).

Genetic diversity

Genetic diversity is the heritable materials that differ within a group of plants (Van Hintum, 1995). The genetic diversity of plant species is manipulated by plant breeding and made suitable for modern agricultural systems. In other words, it is the genetic stock for plant breeding. In recent years scientists have been studying the genetic diversity of different crop species for their efficient utilization and conservation.

Jackfruit exhibits a significant range of variation in its morpho-agronomic characteristics, which can be attributed to the fact that Jackfruit trees are primarily cross-pollinated and predominantly propagated through seeds. This variation encompasses traits such as tree growth habit (which can be open, spreading, low-spreading, or sparse upright), tree growth rate (ranging from fast to slow), canopy structure (often dense with a dome-shaped, slightly pyramidal, or flat top, ranging from 3.5 to 6.7 meters in height), leaf characteristics like shape (obovate, oblong, lanceolate, elliptic, elliptic-obovate, oval), leaf size (ranging from 4 to 25 cm in length and 2 to 12 cm in width), and fruit attributes such as shape (ellipsoid, oblong, spheroid, claviform, round), size, colour, fruit-bearing age, seasonality, and fruit maturity. Moreover, there are notable variations in the flesh types, sweetness, flavour, and taste, as well as in the density, size, and form of the spines on the rind, bearing, and sensory quality, as documented by Azad (2000).

Table 1: Diversity of important *Artocarpus* species.

***Artocarpus* sp.**	**Special Characteristics**	**Origin and distribution**	**Source**
A. altilis or A.communis (Breadfruit)	Evergreen in tropics and deciduous in monsoon countries. Principally important as carbohydrate food source and used more as a vegetable than as a fruit.	Native of Polynesia and important staple food in Polynesia.	Ragone (2018).
A. lakoocha (Monkey jack)	Deciduous tree, round or irregular small fruits, dull yellow colour with pink tinge. Fruits are sour and used as chutney or pickle	Native of sub-Himalayan region of India and grows up to an altitude of 1200 above MSL.	Bishnoi *et al*. (2017).
A. hirsutus (Wild jack)	It is commonly known as Wild jack, valued for its timber, smaller size of spherical fruits.	It is only endemic species of south western Ghats of peninsular India.	Solanki *et al.* (2020) and Gangaprasad *et al.* (2019).
A. integer or A. champedan (Champedak)	It is a monoecious, branched, evergreen, medium-sized, mid-canopy tree. The fruits are of smaller size and exhibit a waistline, a slight narrowing around the middle, resulting in a cylindrical shape. Taste is similar to jackfruit with a hint of durian.	Native to India, but cultivated in Malaysia, Indonesia, Thailand and Philippines.	De Almeida Lopes *et al.* (2018).
A. camansi (Breadnut)	It is very spiny fruits with numerous large, light brown seeds and little pulp.	Native to Indonesia, New Guinea and Philippines.	Ragone (2006).
A. odoratissimus (Marang)	It known as tarap or marang, tree cannot tolerate low temperatures (below 7^0C). It thrives within the latitude range of 15 degrees north to 15 degrees south.	Its primary found on the island of Borneo, specifically in regions including Brunei, Kalimantan (Indonesia), Sabah, and Sarawak (Malaysia).	Bakar and Bakar (2018).
A. annulatus	It is the nearest identified wild relative of two important but underutilized fruit tree species: jackfruit (*A. heterophyllus*) and cempedak (*A. integer*).	This is distributed on to the Padawan Limestone Area in Sarawak, Malaysia, where an endemic species is found.	Dickinson *et al*. (2020).
A.mariannensis	Diploid species, bears smaller fruit containing both seeds and starchy pulp.	Native to islands of western Micronesia	Ragone (2018).

Fig. 1 : *A. lakoocha*

Fig. 2 : *A. altilis*

Fig. 3 : *A. hirsutus*

Fig. 4 : *A. integer*

Table 2: Variationin plant morphologicalcharacters

Characteristics	Range
Tree growth rate	Fast, moderate, slow
Tree habit	Sparse upright, spreading, low spreading and open
Tree crown shape	Pyramidal, broadly pyramidal, spherical, elliptical and irregular
Canopy	Mostly dome-shaped, slightly pyramidal or flat toped. Canopy diameter ranges from 3.5m to 6.7 m
Leaf size	Leaf length 4 to 25 cm; leaf width2 to 12 cm
Leaf shape	Elliptical, broadly elliptic, narrowly elliptic, obovate and oblong
Leaf petiole	Petiole length: 1.2 to 4.0 cm
Fruit maturity	Variable
Fruit shape	Obloid, spheroid, ellipsoid, clavate, oblong and irregular
Fruit seasons	Variable
Number of fruits per plants	15 to 1450
Fruit thickness	Thin, thick and medium
Fruit weight (kg)	1.2 to 22.0
Fruit texture	Firm, fibrous, melting, course and crisp
Seed shape	Oblong,ellipsoid, irregular,spheroid,reniform, elongated
Seed weight (g)	250 to 1230

Source: Azad (2000); Mitra and Maity (2002)

Table 3: Variationinfruitcharacteristics

Characteristics	Range
Fruit weight (kg)	1.2 to 22.0
Fruit length (cm)	20.5 to 60
Fruit diameter (cm)	16.4 to 29.5
Fruit girth (cm)	50.5 to 95.8
No.of bulbs/fruit	24.2 to 580.2
Pulp (%)	18.3 to 60.9
Seed (%)	2.6 to 23.1
Rachis (%)	1.5 to 21.4
Rind (%)	20.6 to 72.0
Brix (°)	13.8 to 25.3

Source: Haq (2006)

Germplasm Resources

Cultivars

There aren't many trustworthy records on the actual jackfruit varieties that have been produced as a result of breeding initiatives throughout different nations. It appears that cultivars are generically categorised according to a few fruit-related traits. The categories were based on the aroma of the pulp, the tree productivity, and the seasonality of the fruit availability. As there are numerous other local names for jackfruit cultivars, some characteristics were left out of this classification (Azad, 2000; Haq, 2006).

At the University of Agricultural Sciences in Dharwad, India, a crop improvement initiative was launched (Jagadish *et al*., 2007). Thirty varieties from the coastal region and sixty types from the hilly region were evaluated and selected for the programme. With these chosen materials, additional breeding work is currently being done. In the Philippines, a variety, "EVIARC Sweet" was identified through selection and the variety has already been released

Table 4 : Selected Cultivars in different countries

Country	Cultivars
India	Champa, Gulabi, Hazari, Varika, Rudrakshi, Gulabi, Safeda, Khaja, Bhusila, T-Nagar jak, Bhadaiyan, Handia, Velipala, Kooli, Gerissal, Barica, Ghila, and Karcha
Bangladesh	Topa, Hazari, Chala, Goal, Koa, Khaja
Australia	Black gold, Honey gold, Lemon gold, Golden nugget, Cheena, Chompa Gob Coching, Galaxy, Fitzroy, Nahen, Kapa, Mutton and Varikkha
Mayanmar	Kala, Talaing
Malaysia	J-30, J-31, NS-1, Na 2, Na 29, Na 31
Indonesia	Mini, Kandel, Tabouey
Philippines	TVC, J-01, J-02, Torres, EVIARC Sweet
Srilanka	Varaka, Vela, Peniwaraka, Singapore Jak/Ceylon jak, Kuruwaraka
USA	NS-1, J-30, J-31, Black gold, Galaxy, Cheena, Golden Nugget, Lemon Gold, Honey Gold, Delightful, Tabouey
Thailand	Kun Wi Chan, Dang rasimi, Kha-numlamoud, Kha-numnang

Souce: Valavi *et al.*, 2011

Table 5: Characterization, evaluation and selection of promising lines of jackfruit

Country	Characterization, Evaluation	Selection
India	281	54
Sri Lanka	77	3
Pakistan	10	5
Nepal	350	47
Vietnam	202	8
Philippines	148	2
Bangladesh	70	10
Thailand	81	2
Indonesia	28	4

Source: Haq (2006)

Table 6: Jackfruit collection in different countries.

Country	No. of Accession
India	947
Bangladesh	130
Pakistan	10
Nepal	350
Indonesia	155
Philippines	178
Thailand	87
Sri Lanka	77
Vietnam	202
Brazil	45
Australia	14
China	76
Costa Rica	15
Malaysia	155
New Guinea	10
USA Florida & Hawaii	19
Other Pacific Islands	30

Source: Haq (2006)

Fig. 5 : Variation in tree crown shape

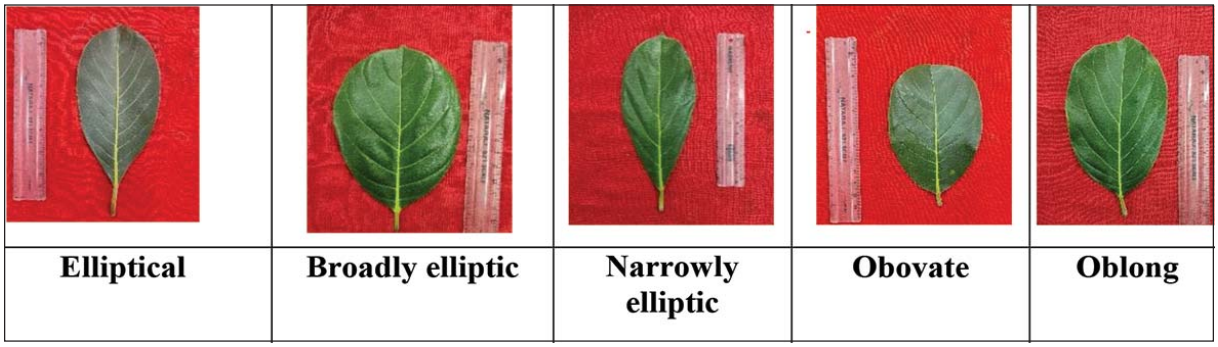


Fig. 6 : Variation in leaf shape

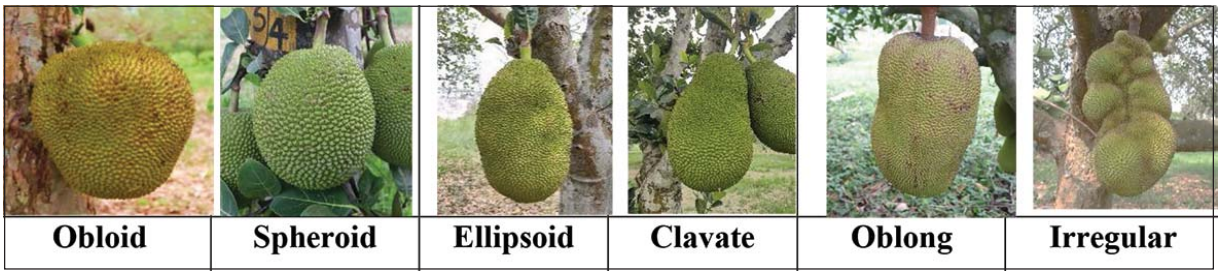


Fig. 7 : Variation in fruit shape

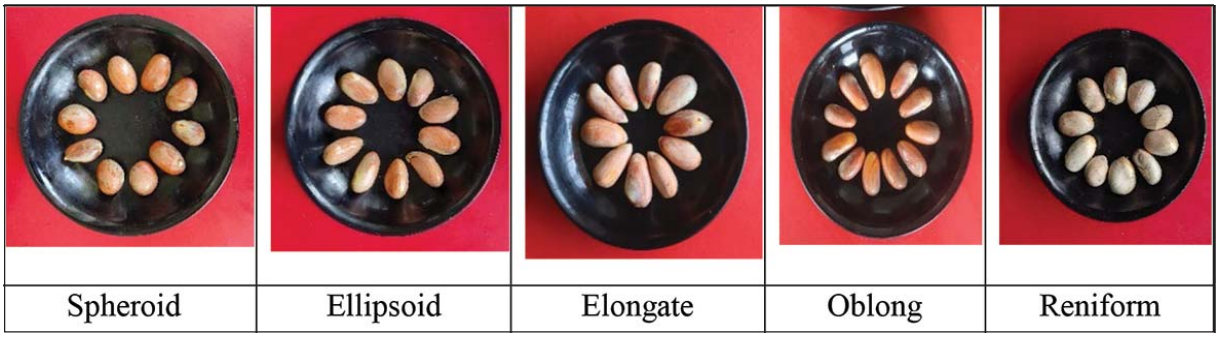


Fig. 8 : Variation in seed shape

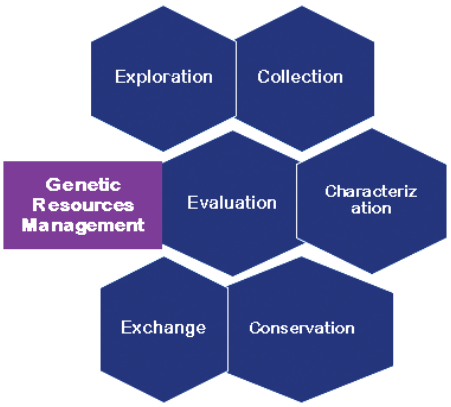
(<www.agribusinessweek.com/new-jackfruit-variety-food products-developed> accessed on 13.3.2009).

A modest breeding programme has also been initiated recently in South Florida (Cambell *et al*., 2004). According to superior qualities of precocity and yield as well as fruit quality traits of scent, edible percentage, flesh hardness, colour and flavour, eleven cultivars have so far been chosen for inclusion in its jackfruit development project. This evaluation was carried out over two years in a research field station and 3 progenies were selected which could hold promise as dwarf varieties. Because farmers are in the best position to understand consumer preferences, they can choose the best crop varieties using farmer-participatory techniques. The farmers are significant retailers at the neighbourhood market. As a result, because farmers are involved in the jackfruit industry as producers, consumers and merchants, it has become more acceptable for the selection process to take into account their tastes. Farmers, however, propagate trees using seeds from the mother trees, which do not remain true to type. As a result, there was little evidence that this selection had an impact on cultivar development. Only asexual ways of propagation from better mother trees will allow for selection to be successful. High plant output, a longer fruiting season, acceptable flesh colour and texture and fruit sweetness are what farmers seek.

Gunasena *et al*. (1996) stated that superior jackfruit mother trees (or plus trees as he called them) can be used for the improvement of the species as the population of the field is composed of variable genotypes. Furthermore, the breeding method using the hybridization of perennial trees is cumbersome, time-consuming and sometimes impossible. Therefore, the selection of superior mother trees is more convenient than other breeding methods. The jackfruit has a lengthy juvenile phase before it begins to develop fruit and may live for over a century. Therefore, the improvement of trees by hybridization is not suitable for jackfruit. Saving time, money, and effort is achieved by the process of choosing better mother trees from the current population. Superior fruiting cultivars with acceptable timber properties will need to be given more focus, especially for household gardens. Since good timber varieties are not always also prolific in fruit production, the use specifications can frequently be in conflict.

Genetic resources management

Plant genetic diversity that has direct or indirect significance to humans can be found both between and within plant species. It consists of weedy races, possible domesticates, other wild species, farmers' variations, outdated cultivars, current cultivars, breeding lines and genetic stocks. Plant Genetic Resource (PGR) diversity decreased as a result of the introduction of enhanced variety/hybrid monocultures (limited genetic base), changes to agroecosystems, industrialization and other developmental processes (extinction, genetic erosion). PGR make up a national heritage that requires effective management and preservation for future generations. When it comes to crop improvement, food security, and nutrition, it is the most essential raw ingredient. Genetic resource management includes exploration, collection, evolution, characterization, conservation and exchange.



Exploration, collection and characterization

Mitra and Maity were initiated in 1990 the collection and evaluation of more than 1460 jackfruit plants in West Bengal. The Faculty of Horticulture Research Station, Bidhan Chandra Krishi Viswa Vidyalaya, is preserving 35 varieties, out of more than 1460 jackfruit plants studied by Mitra and Maity (2002), that have been identified as excellent clones. Twenty-three superior genotypes were chosen by Akter and Rahman (2017) based on cultural and environmental adaption. Regarding fruit attributes such as fruit size, sweetness, bulb colour, hardness of bulb, total soluble solids, percentage of edible portion as well as yield, the germplasm AHJ-02, AHJ-03, AHJ-04, AHJ-05, AHJ-06, AHJ-07, AHJ-09, AHJ-11, AHJ-14, AHJ-16, AHJ-18, AHJ-19, AHJ-21 and AHJ-23 were discovered to be suited for jackfruit growing in Bangladesh's Jamalpur region**.**

Kavya and Shyamalamma (2019) characterized twenty jackfruit accessions with two distinct fruit shapes, *viz*. obolid and ellipsoid were collected from different jackfruit growing districts in Karnataka. They found that most of the trees were erect type, with medium to low branching density and the branching pattern was irregular. It was found that 50-60% accessions with obolid fruit, then ellipsoid fruits. Kumaraswamy, Allilugatta 5, Manipur Parmesh and Swarna accessions were obolid fruits and Ashoka Yellow, Byrachandra, Ashoka Red, Janagere and NSP were ellipsoid fruits have been identified for commercial purposes. Simon *et al*. (2007) used RAPD markers to estimate the genetic diversity of twelve high-yielding jackfruit. The genetic dissimilarity matrix was computed using Squared Euclidian Distances, revealing a minimum genetic distance of 5% between the genotypes ('M0') and 'Kerala', indicating their similar geographical origin, and a maximum genetic distance of 7.9% between a clone of 'Mottavarica' ('M0') and 'Chandrahalasu' from distant locations.

Collection, characterization, conservation, evaluation and utilization of jackfruit germplasm at different All India Centres Research Project

- **Mohanpur (West Bengal):**Out of the 58 genotypes that were maintained, evaluations and characterizations of 41 genotypes have been documented.
- **Jorhat (Assam):** In-situ characterization and evaluation were conducted on 18 local genotypes from three agro-climatic zones in four districts of Assam: Morigaon, Kamrup, Barpeta, and Darang.
- **Kannara (Kerala)**: In the field gene bank, 10 accessions were conserved, 16 genotypes were evaluated, 11 were collected, and 3 genotypes were characterized.
- **Kovvur (Andhra Pradesh):** In the reporting period, a newly discovered genotype with small, round fruits was obtained from Devarapalli village in the West Godavari District of Andhra Pradesh. Currently, there are 31 genotypes under conservation in the field gene bank, with 26 of them in the bearing stage and 5 in the pre-bearing stage.
- **Periyakulam (Tamil Nadu)**:Explorations were conducted in Kulasekarem, Thiruvaadanai, Sethaiyathoppu, Keeranur, Kudimiyanmalai, and Pudhukottai district. A total of 23 accessions were conserved, with 14 of them currently in the bearing stage and 9 genotypes in the pre-bearing stage.
- **Lembucherra (Tripura)**:In the reporting period, 20 local jackfruit accessions were identified and their physico-chemical characteristics were assessed.(Source: http://krishi.icar.gov.in/jspui/handle/123456789/75189)

Germplasm collection and conservation

The collection, characterization, and evaluation of jackfruit germplasm have only sometimes been tried by a few programmes at the national level throughout Asia. With the exception of two regional initiatives, neither regional nor international organisations, have made a systematic effort to gather and assess germplasm: Conservation and Use of Native Tropical Fruit species Biodiversity in Asia (Mal *et al*., 2001) and Underutilized Tropical Fruits in Asia Network (UTFANET) (Haq, 2003). It is necessary to gather germplasm from selected regions of the Indian subcontinent and Southeast Asia, specifically from the place of origin as well as centre of diversity. Haq (2006) mentioned that the Andaman Islands and the Western Ghat, which may contain wild jackfruit germplasm, need

to have their genetic material systematically collected.

Conservation of genetic diversity

There are some worries about the decline of genetic variety even while jackfruit germplasm resources are not in danger (Haq, 2002). Since the diversity of the jackfruit gene pool has not been extensively assessed, it is believed that attention must be paid to conserving its diversity. Many desirable traits may be lost if the key desired characteristics are not preserved. The conservation process may follow the methods below:

***1. In situ* conservation**

For the agro-ecosystems to be managed and maintained effectively, *in situ* conservation is crucial. Because they have a deep understanding of their trees, farmers are likely to be familiar with the type and degree of variation.

In situ conservation is an option but is hardly used because jackfruit is typically grown in backyard gardens. Because of their potential as wood, some farmers in Bangladesh favour and preserve "straight stem" varieties. For "on-farm" conservation to be successful, farmers must be persuaded of the importance of diversity and its utility to them. Whenever they're convinced, it will be possible to persuade them to keep growing trees in conventional agro-ecologies.

Based on the available information, the diversity of wild populations of *A. heterophyllus* in forest settings, including the Andaman Islands, the Western Ghats of India, and the South-Eastern region of India, does not provide enough data to identify specific areas of diversity. Once this information is accessible, such wild populations can be designated as biosphere reserves and included in the major natural ecosystem areas.

***2. Ex situ* conservation**

Jackfruit seeds are challenging to preserve because they quickly lose viability **(**Gawankar *et al*., 2020**).** At lower or ambient temperatures, it is impossible to dry and store the seeds for more than around 5 weeks (Sonwalker, 1951).

Cryogenic preservation of embryos of jackfruit was described by Haq (2006). Seeds must have a little moisture content (16–26%) to be stored cryogenically. Fu and Xia (1993) and Chandel *et al*. (1995) demonstrated that as seed maturity increased, embryonic axis' physiological features, susceptibility to desiccation and freezing thresholds changed. The jackfruit embryo size is not identical, which presented issues for these authors. The greatest embryos for survival and repeated regeneration are those that measure 4-5 mm and come from mature, ripened fruits. Before being treated with a mixture of dimethyl sulphoxide (DMSO) and 0.5% proline, the chosen fresh embryos must be slightly dehydrated (to 60% moisture content). It is necessary to freeze things gradually, thus they must first be pre-frozen at 1°C every minute until they reach -40°C before being immediately submerged in liquid nitrogen at -196°C.

Theoretically, seeds kept in cryogenic conditions are in a condition of suspended existence and ought to last forever. But further research is required to understand how performance would change over time after storage. Axes taken from jackfruit seeds that had been cryopreserved had a 50% survival rate, according to Thamsiri (1999).

Slow-growth strategies can be used to store vegetatively grown clonal material *in vitro* for medium-term preservation. Pathogens are also removed from samples using in vitro techniques, preserving healthy samples. To standardize procedures for jackfruit in vitro storage, Mandal (1997) proposed that a thorough examination is required.

3. Field gene banks

The majority of jackfruit germplasm is maintained within field gene banks or orchards, often referred to as repositories or collections of living plants. Disease, insect infestation and natural disaster concerns exist for them. Because evaluation may be done on the developing plants, field orchards have the benefit of having readily available germplasm. The expensive establishment and upkeep costs as well as the threats to sustainable existence are drawbacks. In Haq's (2006) article, several field gene banks that had been created at Horticultural research centres and Universities around Asia were mentioned. A sizable collection kept in the field of Florida's Fairchild Tropical Garden was described by Cambell *et al*. (2004).

Numerous other nations, including as Australia, Fiji and Hawaii preserve small collections in their fields. For the purposes of starting improvement projects or on-farm testing, these collections serve as the origin of genetic material.

Farmer participatory conservation

PlavuJayan, 54-year-old farmer from Kerala known as Jackfruit Man who has planted over 20,000 seedlings from over 23 native varieties of this tropical fruit tree. The remarkable thing is not just the number of trees, but the up to 23 native varieties of 'Plavu' he has planted and possibly helped revive. These include 'Thamara Chakka', 'Rudrakshi', 'Football Varikka', 'BaloonVarikka', 'Kashumanga Chakka', 'Then Varikka', 'MadalillaChakka', 'PadavalamVarikka', 'ThengaChakka' 'AthimadhuramKoozha' and 'VakathanamVarikk a'< https://indianexpress.com/article/india/genome-conservation-the-jackfruit-man-6106829/>.

Conclusion and future scope

Genetic resources are of fundamental importance in crop variety improvement programmes. This is required for developing improved crop cultivars, which could contribute to national development by acquiring productive as well as qualitative attributes. Therefore, the available germplasm of jackfruit must be protected. Ultimately, horticulturists and plant breeders can select germplasm following their requirements. These jackfruit germplasms may be used in the programme to generate new varieties in the future. On-site selection and evaluation directly done by breeders in the farms of jackfruit farmers and growers is the main approach in this collaborative breeding work.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Review article

Production and marketing of medicinal and aromatic plants : prospects and constraints-A review

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ABSTRACT

The purpose of this paper is to review the prospects and constraints of production and marketing of medicinal and aromatic plants. Relevant and scholarly articles of various researchers were reviewed for the period of 2000 to 2023. Medicinal and aromatic plants provide a higher return compared to traditional crops. However, marketing is an important constraint in cultivation. The seed, bark, roots, flowers, leaves, and stem used as raw materials for the herbal, pharmaceutical and cosmetic industries. Medicinal and aromatic plants use to make different value-added herbal products, so farmers can cultivate on a large scale and get a remunerative return, while consumers may receive the health benefits of herbal products. This paper tries to fill the gap and contributes literature on production, marketing and constraints in cultivation of medicinal and aromatic plants, which may be helpful in improving the supply chain of medicinal and aromatic plants.

***Keywords*:** Constraints,cultivation, marketing channel, medicinal and aromatic plants

INTRODUCTION

Medicinal and aromatic plants can grow successfully in rain-fed and dry land conditions (Hanumanthappa *et al.*, 2018). Many medicinal and aromatic plants are cultivated in India.There is a huge gap in the supply and demand of medicinal plants to manufacture Ayurvedic medicines in the country (Anonymous, 2020). There is a growing demand at the global level for high-quality, certified organic herbal products, and this gap can only be minimized by the commercial production of medicinal plants at a large scale (Sanwal *et al*., 2017; Gaurav *et al*., 2018). The export of medicinal plants and their derivatives was 1920.41 metric tons in the year 2017-18 and it is gradually increasing over years (Anonymous, 2019). Some of the most demanded medicinal plants are Isabgol, Ashwagandha, Amla, Aloe vera, etc. Medicinal plants are a good source of income for farmers, as there use in traditional and alternative healthcare systems (Anonymous, 2016; Chhabra, 2018). There is a huge gap between demand and supply for medicinal plants for the manufacturing of Ayurvedic medicines in the country (Anonymous, 2017). Mentha species has valuable anticancer bioactive compounds (Esmaeili *et al.*, 2023). An important medicinal plant Senna has high demand in the international market (Kumar *et al*., 2022). Pharmaceutical properties are based on the presence and abundance of secondary metabolites, such alkaloids, and flavonoid etc. (Thokchom *et al*., 2023) However, out of total medicinal plants, only 15 per cent are cultivated, while the remaining 85 per cent are collected from forest ecosystems and other natural habitats (Economic Times, 2022).

Medicinal and aromatic plants are important source of foreign exchange earnings for developing countries (Rao *et al*., 2022). Siwach *et al.* (2013) concluded that various *ex-situ* and *in-situ* conservation practices need to be increased to battle the existing challenges. In India, many of medicinal plants are under threat because of excessive and unsustainable collection, utilization, over exploitation, or unskilled harvesting practices (Kumari *et al*., 2011) Many of the medicinal plants are profusely indigenous to developing countries (Bukar *et al*., 2016).

The Central Institute of Medicinal and Aromatic Plants launched 'Sustainable Aroma Cluster' in the Bhagauli village of Barabanki district in Uttar

Pradesh, State in India. The cluster shows the use of innovative farming technologies to maintain constant economic output levels while also protecting soil health and biodiversity (Hindustan Times, 2023). Push and pull factor are the main drivers of medicinal and aromatic plants cultivation (Mohapatra *et al.*, 2018).

Sustainable collection can be achieved through two important elements: an adequate legal framework for forest land and training and skill development of farmers. Because of its climate and natural environmental diversity, hand-picked selection or cultivation method followed for growing many medicinal and aromatic plants (Zrira, 2013). Gularia and Gupta (2020) recommended the formation of cooperatives for farmers engaged in growing of medicinal and aromatic plants so that farmers they are aware of market trends and conditions. The wholesalers augment value by drying, processing, and bulk packaging of medicinal plants. Processor mix different medicinal plants to create ready to eat products to treat diseases (Mpelangwa *et al*., 2022).

The cost of cultivation per acre of Isabgol and Patchouli in Maharashtra was calculated ₹ 3,994.46 and ₹ 32,707.17, and the return was ₹ 5,172 and ₹ 1,01211, respectively. The returns from Patchouli were higher than Isabgol (Jadhav *et al*., 2001). The cost of cultivation of henna in the Pali district of Rajasthan especially skilled labour is required for its transplanting, and 55 per cent of labour costs alone account for the total establishment cost. The overall cost incurred was ₹ 8,464 per hectare, with labour accounting for 94 per cent (Chand *et al*., 2002). The production cost was ₹ 12.76 per kg of the sweet flag leaves, which gives ₹ 8.09 profits to the farmer (Deshpandey *et al*., 2008). In Palmarosa, production costs are higher, and net returns are also higher due to good demand in the market. The farmer gets a net profit of ₹ 24117 per acre in the first year, ₹ 43676 in the second year, ₹ 45631 in the third year, and ₹ 39422.24 in the fourth year (Mounika, 2015). The cost of cultivation is ₹ 15000 per hectare, and the net profit is ₹ 20000 per hectare. The yield of the raw straw of the Isabgol may be about 1000-1600 kg per hectare (Jat *et al*., 2015).

The cultivation of rosemary can produce good-quality essential oil in the subtropical province of northern India (Verma *et al*., 2020). High-quality seed production and export are the best choices (Padma, 2019). Plants part such as leaves and flowers are the main source of phytochemicals, whereas fruits, seeds, leaves (Srinivasan *et al*., 2022) stems, roots, and rhizomes, are ancillary sources (Prasathkumar, 2021). The antimicrobial compounds present in medicinal plants used in essential oils, folk medicine or isolated compounds such as flavonoids, alkaloids, and antioxidant agents (Rios and Recio, 2005; Ortega Ramirez *et al*., 2014). Medicinal plants are useful in safe antiviral materials (Vimalanathan *et al*., 2009). Indigenous people and local communities used herbs to treat malaria, collected from the nearby forest area (Kumar *et al*., 2020). There are needs of chain of actors at the local and regional level, national and international levels (Padulosi *et al*., 2008).

Medicinal and aromatic plants will continue to be potential sources of active, useful chemicals compounds that are used in the cure of various ailments. The cultivation of medicinal and aromatic plants provides a livelihood for the people. The role of government is pivotal in the overall cultivation, conservation, marketing, and sustainability of the sector.

Medicinal and aromatic plants are good source of income to farmers and it's demanded by many industries for various herbal products. However marketing of medicinal and aromatic plants is important constraint for farmers. This paper contributes literature on production, marketing and constraints in cultivation of medicinal and aromatic plants, which may be helpful in improving the supply chain of medicinal and aromatic plants.

METHODOLOGY

The present study followed a literature review methodology to collect the data and information. The data were collected using the keywords "medicinal plants" along with marketing, cultivation, good agricultural practices, marketing channel, constraints in production, and marketing. Scientific platforms such as Google Scholar, Scopus, and the National Medicinal Plant Board website were explored, along with websites, annual reports, magazines, newspapers, etc. The collected information presented in the paper. This paper highlights the production prospects and marketing

of medicinal and aromatic plants, prevalent marketing channels, and constraints in production and marketing of medicinal and aromatic plants.

DISCUSSION

1.1 Status of medicinal and aromatic plants

The fluctuation in the area and production of medicinal and aromatic plants was observed during 2005-06 to 2015-16 in India. The coefficient of variation was found to be 47.87 per cent (Chowti *et al*., 2018). Production of mentha subsequently increased over the years (Singh, 2013). Rajasthan shares 90 per cent of the total production of henna in the country (Chand *et al.*, 2002). Major part of the henna production exported to Europe, African countries, the Middle East, and the USA (Gaur *et al*., 2017). India is a traditional exporter of essential oils like sandalwood, lemongrass, palmarosa, spices, etc. (Kumar and Jnanesha, 2017). India is the second-largest exporter of medicinal and aromatic plant-based commodities after China (Tripathi *et al*., 2017).

1.2 Prospects of medicinal and aromatic plants cultivation

- Cultivation of *Aloe vera* plant is economically attractive (Bali *et al.,* 2015).
- Diverse flora can use in local medicinal plants as medicine or as an additional income source for local livelihoods (Yadav *et al*., 2018; Gupta *et al*., 2022; Handa, 2022)
- Collection, primary processing and selling of medicinal plants contribute to the cash income of the poor men and women people (Gaurav *et al*., 2018).
- Good agricultural practices (GAP) for medicinal plants are important to regulate the quality and production of the plants and many countries are implementing it (Singh *et al*., 2021; Bisht*et al.*, 2022).
- Medicinal plant enterprises are employment-generating, profitable, and income-generating sources with foreign exchange earnings (Palash *et al*., 2021).

1.3 Production of medicinal and aromatic Plants

Vanilla production in India showed significant growth in the area, production, and productivity of the crop. Among the major producers of vanilla, Indonesia ranks first, Madagascar ranks second, China ranks third, and India ranks fourth. In India, Karnataka is the major producer of vanilla, followed by Kerala and Tamil Nadu (Balamurugan, 2009).

Before enter into commercial cultivation of medicinal plants, an understanding of agro-ecological zone, good agricultural practises, quality targets, and agro-economics is required (Singh *et al*., 2022). Singapore, Japan, Germany, Malaysia, and United States have the highest importing advantages. The global market for medicinal and aromatic plants is mostly competitive (Roosta *et al*., 2017). A good fraction of India's population depends on medicinal plants for their health care requirements (Jeelani *et al*., 2018). Leaf sap sucking insects and pests, leaf diseases, and insects attacking on flowers are important insect pests (Ghakur, 2018). A diversified cropping system with basil, peas, and menthol mint is suitable and sustains higher yields and returns to farmers (Khan and Verma, 2018). The newly developed variety of menthol mint "CIM-Kranti" is cold and frost tolerant and it has potential to produce 10 to 15 per cent more oil up to 145 to 160 kg per hectare in the summer as compared to other popular commercial grown variety of menthol mint (Sharma *et al*., 2019). Traditional methods of conservation of medicinal plants have made an immense contribution (Msuya and Kideghesho, 2009).

Medicinal plants grown in the Himachal Pradesh region are of enormous use in the herbal as well as in pharmaceutical industries (Samant *et al.,* 2007). Based on favourable climatic conditions and high market demands, Rosemary ranked first in the Himalayan region of Uttarakhand State in India. Agroforestry helps in cultivation as well as the conservation of many medicinal plants (Rao *et al*., 2004). The research on medicinal plants with respect to climate change is very erratic and insignificant compared to commercial crops (Das *et al*., 2016)

1.4 Marketing of medicinal and aromatic Plants

Value-chain embodies an important change in development and the relationships among producers, processors, traders, and consumers (Devaux *et al*, 2018). The growers sell their entire produce in its raw form to the different processing

industries rather than processing it (Malik, 2007). There are two key marketing channels involved in the marketing of this crop. Channel I was producer to a local trader to industry, and channel II was producer to processor to industry. Most of the aromatic plants are marketed through the channel I, and only one-fourth of the produce is marketed through channel II (Suresh *et al*., 2012).

Madhavji (2009) reported three important marketing channels for Coleus medicinal plant marketing in Gujarat: Channel I, Producer—wholesaler—retailer—consumer in regulated market. Channel II Producer—wholesaler—consumer in cities and Channel III Producer—consumer. Most of Coleus (85 per cent) is marketed by the channel Producer to Wholesaler in regulated markets and Retailer to Consumer. Producers received a higher share of consumers' rupees in channel III, which was producer-to-consumer.

1.5 Price, cost and margin

Gondalia and Patel (2007) reported that producers' net share in the consumer rupee and marketing efficiency was found to be 58.26 per cent and 1.40 respectively. The share of value addition and primary processors of the fruit is very small, and the alternative models of production and processing should improve to better realize the ecological and economic benefits of underutilized fruit species (Daniel, 2009). Contractual as well as non-contractual systems, their nature, and performance were examined in the study for policy concerns and the net earnings benefit of the small farmers' producer (Singh, 2009).Training should also be providing to all the intermediaries involved in the marketing of medicinal plants (Gondalia and Patel, 2007).

Guleria *et al*. (2014) identified channels involved in marketing of medicinal plants in the Mid Hills of Himachal Pradesh and found most of *Ghritkumari* was marketed (43.60 per cent) through the channel → Producers → Cooperative Societies → Local processor, and 24.75 per cent of aloe vera was marketed through the channel → Producer → Local Traders → Processing units outside the state. Choudhry *et al*. (2017) identified marketing channel of mentha channel I Producer, Processor, Industry (company) and channel II Producer, Local Trader, Industry (company). The cost incurred by the producer in marketing Mentha was found to be 162 per kg in channel II and 156 per kg in channel I. The overall gross price received by the farmers was highest in Channel I and lowest in Channel II. The cost incurred by farmers was higher in Channel II. Major marketing channel of medicinal and aromatic plants are Collector/ growers to local traders to commission agent to wholesaler to Industry/Company and to Consumer (Chaubey, 2011).

1.6 Constraints in production and marketing of medicinal plants

Lack of technical knowledge and awareness for increasing oil recovery from the crop, low price (Anonymous, 2020) in the market, and lack of storage and market facilities near the production area of the crop are important constraints. The mint crop is highly sensitive to lower and higher temperature. Lack of processing and value-added facilities was major constraints reported by 80 per cent of the mint growers (Pawar and Hange, 2008). Lack of information, high cost of input, lack of supply of electricity, and a regulated market were the major problems faced by farmers (Kumar and Venkatesan, 2011).

Lack of proper marketing information, pest and disease problems, higher cost of cultivation, and fluctuation in market price, low price which are major challenges faced by producers during the crop production and marketing phase, lack of a minimum support price, lack of a regulated and organized market (Ajjan *et al*., 2008; Bhattacharya *et al*., 2008; Ahmed and Sharma, 2012; Ram *et al*., 2012; Pangriya, 2015; Balaji *et al*., 2016; Mohapatra *et al*., 2018). To understand the farming system and the success of the value chain of the plants, a thorough financial feasibility and technical study are required (Alam and Belt, 2009). The widespread price difference was found to be the most important marketing problem in vanilla production (Balamurugan, 2009).

Most of the farmers felt that the lack of a minimum support price, the lack of subsidies, the lack of good credit facilities (Luan, 2020) and shortage of human labour during peak season observed major challenges faced by them (Guleria *et al*., 2014;). Supply chain management, consultancy, processing, and trading are the major

areas for entrepreneurship in the medicinal and aromatic plant sector (Rathore and Mathur, 2018). Local collectors have well-known, steady supply relationships with processors.Sustainability is another challenge for medicinal and aromatic plants (Chandra, 2020) due to over-exploitation (Vidhyarthi *et al.*, 2013). Poor knowledge of the package of practice, and inadequate domestication are important constraints of the sector (Nwafor *et al.*, 2021). Marketing is a major issue for medicinal and aromatic plant cultivators.

CONCLUSION

Lack of improved production technology and an unregulated market are major constraints in the sector. Understanding the production and marketing of medicinal and aromatic plants is an important step in designing future policies to deal with to overcome the challenges and formulate a suitable and sustainable strategy for the sector. There is a need for an organised supply chain for medicinal and aromatic plants. In addition, the results of the present study are significant for policymakers and industrial personnel engaged in the entrepreneurship and business of medicinal and aromatic plant-based resources. Overcoming the identified challenges would benefit both primary producers and actors involved in the medicinal and aromatic plants supply chain.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Review article

A review on essential oil extraction from ornamental crops : method & prospects

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ABSTRACT

Essential oils are secondary metabolites composed of terpene derivatives an accumulated in trichomes (outgrowth from the epidermis of plant). According to the industry sources more than 3,000 essential oils are known, out of which 300 use for commercial purposes. Essential oil is known to occur in leaves of some plants like marigold and lavender and in flowers of rose, jasmine, champaka and tuberose. Essential oil contains on an average 100 chemical components, some are antibacterial, antiseptic, antidepressant. Oil is used in aromatherapy, perfumery, pharmaceuticals and carminative. Major constituents in rose are 1-Citronellol, Nerol, Geraniol, Linalool and Eugenol used in moisturizer, perfume whereas in jasmine are Benzyl ethanoate, Salicylic acid methyl ester, Methyl 2-aminobenzoate, Benzoic acid benzyl ester used in antiaging creams. In tuberose Eugenol, Benzyl Alcohol, Farnesol and Methyl benzoate are the major constituents used in aphrodisiac.Essential oil is extracted through various methods including distillation (Rose, Jasmine, Chrysanthemum), solvent extraction (Rose), soxhlet extraction (Chrysanthemum), Maceration (Jasmine), Enfleurage (Tuberose), CO_2 extraction (Jasmine, Marigold). A lot of exogeneous (light, temperature, seasonal variation and soil), endogenous factor (part of plant, age of plant) effect the quality of essential oil. Estimated world production of essential oil is 2,50,000 tones, global export of essential oil increased about US$ 8254. In this review paper we have discussed the importance of essential oils of common flowering plants, their extraction methods, marketing and prospects.

***Keywords*:** Antiseptic,aromatherapy,distillation, essential oil, perfumery, solvent extraction

INTRODUCTION

Floral essential oils are essentially derived from the flowering parts of plants, capturing the naturally sweet and floral scents found in flowers. These oils, renowned for their aromatic qualities, are commonly utilized in perfumes and other fragrances, and are readily available for both fragrant and medicinal purposes. The growing global interest in natural and nature-based products has propelled a green movement, contributing to the expanding applications, ensuring a promising future for the essential oil and aroma industry.

There are total of 3,000 known varieties, find applications in diverse fields due to their complex compositions, containing various chemical components with different functions(Sankarikutty *et al.,* 2003). These are secondary metabolites, vast mixtures of organic substances primarily composed of terpene derivatives and phenyl propanoids, and are accumulated in specialized structures like glandular cells and glandular trichomes. Regardless of the source, essential oils have intricate compositions, including alcohol, alkanals, acetone, hydroxybenzene, organic esters, alkoxy compound, terpenoids, *etc*. Commercially extracted oils commonly come from flowers like jasmine, rose, tuberose, marigold, plumeria, champak, magnolia, millingtonia, and ylang-ylang.

Essential oils and their uses

Chemically, essential oils are volatile compounds with varying therapeutic effects, influenced by factors like extraction methods and plant growth conditions. Physically, environmental factors such as altitude, geographical location, and harvesting methods can alter the chemical components. Aromatically, true essential oils have

subtle, plant-like scents, while spiritually; each plant is believed to have a healing element, historically used for protective purposes (Halder *et al*., 2018).Essential oils find diverse applications, such as in aromatherapy, skincare products, massage, relaxation, and household cleaning. Aromatherapy utilizes essential oils to promote relaxation and well-being, with specific oils believed to have therapeutic properties. Essential oils with beneficial skin properties are commonly incorporated into skincare products, while their use in massage oils helps relieve muscle tension and induce relaxation. Additionally, some essential oils with natural antimicrobial properties serve as alternatives in household cleaning products Chouhan *et al.,* 2017). For example, tea tree oils are commonly used for their disinfectant properties in homemade cleaning solutions(Carson *et al.*, 2006).Certain essential oils, such as citronella, lemongrass, and eucalyptus, are known for their insect-repellent properties. They can be used as a natural alternative to chemical-based insect repellents (Trongtokit *et al.,* 2005).

Characteristics of essential oil

Essential oils are highly concentrated. These are liquid at room temperature due to presence of oleates which is unsaturated fatty acid. They have characteristics aroma. Essential oil does not rancid due to presence of high vitamin E. Essential oil volatilize without undergoing decomposition. They do not leave greasy stain on paper due to high vapor pressure. These oils are generally insoluble in water due to hydrophobic nature. These are generally soluble in organic solvents, fatty acid, mineral oils. These have high boiling point. Most of the essential oils have a high refractive index which means degree of thickness. (Duarte *et al.,* 2017).

Different methods of oil extraction are:

1. Distillation: a. Water distillation; b. Steam distillation; c. Steam and water distillation

2. Solvent extraction;

3. Expression;

4. Maceration;

5. Soxhlet extraction;

6. Enfleurage;

7. Supercritical fluid extraction

Sindhu and Saha (2010) suggested different oil extraction methods for floriculture as:

Rose- Steam distillation; **Jasmine -** Solvent extraction; **Tuberose-** Solvent extraction; **Marigold -** Solvent extraction; **Geranium -** Steam distillation; **Lavender** - Stem distillation;***Viola odorata-*** Solvent extraction

1. a) Water Distillation: Silva *et al*. (2005) described following steps are used in water distillation.Round bottom flask containing plant material into it and water is added into it just to cover the plant material which 10 % more than material. Connect the condenser one side to the material containing flask and other side of condenser to another empty flask which receive the oil.**Advantages:**It is easy to constructandit is suitable for field operation (Mohammad Azmin *et al.*,2016).**Disadvantages:**Extraction process is slower. Development of objectionable odour due to charring of plant material at bottom of still.Producing pollutant in the processing area**.**It is expensive method(Mohammad Azmin *et al.*,2016)

Example: Extraction of Jasmine essential oil. In astudy, Dinh Phuc *et al*. (2019) foundthat the optimal distillation temperature was120 ^{0}C in 6 hours, the water-material ratio of 2:1.The laboratory-scale yield was determined to be 0.092%. The analysis of compound content in the jasmine essential oil should be conducted using GC-MS.

1. b) Steam distillation: The plant material is heated at not >100ºC.Steam boiler is used to generate steam which id passed through distillation tank.Over perforated grid plant material is tightly packed (Kanat *et al.,* 2020).

Advantages of steam distillation: Amount of steam can be readily controlled. Process is ideal for heat sensitive essential oils.No thermal decomposition in oil constituents.Oil is superior in quality (Shankraswamy, 2020).

Disadvantages: Capital expenditure is high (Shankraswamy,2020).

Methods for essential oil extraction from roseand marigold: Verma *et al*.(2001) noted thatmean oil was highest in hydrodistillation method which was 0.37% and highest pH, ester value, carbonyl value were recorded in steam-distillation method.

Table 1: List of major flower crops for essential oil and their chemical constituents

Crop	Scientific name /species	Family	Major constituents	Reference
Rose	*Rosa damascena, Rosa bourboniana Rosaalba, Rosagallica, R. centifolia, R. rugosa*	Rosaceae	1-citronellol (40-65%), Nerol, Geraniol, linalool, eugenol (*variety*: Noorjahan, Rose Sherbet, Jwala , Himroz, Arka Sukanya, Arka savi, Madhosh	(Harrie *et al.*, 2003)
Jasmine	*Jasminumauriculatum*	Oleaceae	Benzyl acetate, Methyl salicylate, Methyl anthranilate, Benzyl benzoate (*variety*: CO-1 Mullai , CO-2 Mullai, Parimullai)	
Jasmine	*J.grandiflorum*	Oleaceae	(Variety) CO-1 Pitchi, CO-2 Pitchi	
Jasmine	*J.sambac*	Oleaceae	(*variety*: Single Mogra,Double Mogra, Gundu Malli, Iruvatchi, Madenban, Ramabanam)	(Temraz *et al.*, 2009)
Marigold	*Tagetes erecta* (African marigold) *T.minuta,T.lucida T.patula,T.tenuifolia*	Asteraceae	Piperitone,D-limonene Estrugol Tagetone	(Krishan *et al.*, 2004; Verma *et al.*, 1999;Ogunwande& Olawore, 20006)
Tuberose	*Polianthes tuberosa*	Agavaceae	4- Allyl-2-methoxyphenol, Phenylmethanol, trans-farnesol, n-butanoic acid, Benzoic acid methyl ester, cis-3,7-Dimethyl-2,6-octadien-1-ol, Methyl 2-aminobenzoate (variety:Calcutta Single, Pune Single, Mexican Single, Hyderabad Single, Coimbatore Single, Bangalore Single, Shringar, Prajwal, Rajat Rekha, Arka Nirantara).	(Rakthworm *et al.*, 2009)
Raat ki rani	*Cestrum nocturnum*	Solanaceae	The major constituents were β-phellandrene (12.1%), linalool (11.3%), α-phellandrene (9.2%), (E)-β-ocimene (9.1%).	(Reza *et al.*, 2013)
Carnation	*Dianthus caryophyllus*	Caryophyllaceae	Linalool (34.65%); Farnesene (10.24); α-Terpineol (6.27%); Geraniol (5.79%);Cembrene A (5.77); cis-3-hexenyl tiglate (3.13 %);Tau-Cadinol (1.77%)	(Kirillov *et al.*, 2017)
Magnolia	*Magnolia grandiflora*	Magnoliaceae	Extraction of fresh flowers through petroleum ether yields 1.2 to 1.6 % flower concrete. 0.1 to 0.15 % volatile oil obtained from leaves. The leaf oil contains Phenols, Carbonyl compounds and Sesquiterpenes.	(Yahaya*et al.*, 2022)

Crop	Scientific name /species	Family	Major constituents	Reference
Michelia	*Michelia champaca*	Magnoliaceae	The constituents of flower concrete are Phenylethyl alcohol, Ionones, Dihydroionones, Dihydro-β-ionol, Indole and Methyl anthranilate. The constituents of absolute are Phenyl ethyl acetate, β-ionone, Methyl anthranilate, Methyl palmitate, Methyl linoleate.	(Kai Cheng*et al.*, 2020)
Gardenia	*Gardenia jasminoides*	Rubiaceae	Linalool (34.65 %), Farnesene (10.24 %), α-Terpineol (6.27 %),Geraniol (5.79 %), Cembrene	(Zhang *et al.*, 2020)
			A (5.77 %), cis-3-hexenyl tiglate (3.13 %), Tau-Cadinol (1.77 %)	
Geranium	*Pelargonium X hortorum*	Geraniaceae	Citronellol (37.5); Geraniol (6%); Caryophyllene oxide (3.7%);Menthone (3.1%);Linalool (3.0%); β-bourbonene (2.7%); Iso-menthone (2.1%); Geranyl Formate (2.0%)	(Lis-Balchin 2004)
Calendula	*Calendula officinalis*	Asteraceae	Thirty compounds were found in common in both essential oils, with the sesquiterpene alcohol, α-cadinol as the most abundant compound (leaf: 32.3% and flower: 31.3%, respectively).	Gunes *et al.*, 2021
Chrysanthemum	*Chrysanthemum indicum,*	Asteraceae	Camphor, Isoborneol, α-Terpinene, Caryophyllene oxide	(Fadia*et al.*, 2020)
	Chrysanthemummorifolium		Camphor, Curcumene, τ-Eudesmol, Pentacosane, Borneol	(Fadia*et al.*, 2020)
Lotus	*Nelumbo nucifera*	Nymphaeceae	Palmitic acid methyl ester (22.6%);Linoleic acid methyl ester (11.16 %);Palmitoleic acid methyl ester (7.55 %);Linolenic acid methyl ester (5.16%)	(Songhee Jeon,2009)
Daffodil	*Narcissuspoeticus*, *N. tazetta*	Amaryllidaceae	The flower contains 0.20 to 0.26 % concrete. The concrete contains 2.2 to 3.5 % volatile oil.The principal constituents are Eugenol, Benzyl alcohol, Cinnamyl alcohol, Benzaldehyde and Benzoic acid.	(Zarifikhosroshahi *et al.*, 2021)

Table 2: Effects of different storage temperatures and durations on essential oil content of *R. damascena* Mill (*source:*** Kazaz *et al.,* 2009)**

Time of storage (Days)	0^0C	Oil Content %3^0C	Mean
0	0.043	0.043	0.043
7	0.040	0.037	0.039
14	0.030	0.029	0.030
21	0.021	0.024	0.023
28	0.021	0.022	0.022
Mean	**0.031**	**0.031**	

1. c) Steam and water distillation: Over grid plant material is kept and water if filled beneath.Condensate oil separated in oil separator due to their differences in specific gravity.Total time for distillation is 6-8 hours (Shankaraswamy, 2020)

Advantages: Obtain maximum oil; Component of the volatile oil are less susceptible to hydrolysis and polymerization; Oil quality is superior (Shankaraswamy, 2020).

Disadvantages: Oils of high boiling range require a greater quantity of steam for vaporization; Plant material become wet which slow down distillation(Shankaraswamy, 2020).

2. Solvent extraction: Should have low boiling point: Should be chemically inert(Souyi, 2023).

The following solvents are used: Petroleum ether; N-Hexane; Benzene

To extract oil from concrete, generally ethyl alcohol is used. The alcohol is removed by evaporation.Solvent extraction resulted in the production of 39 g of concrete oil from *Rosa damascena*, accounting for 0.19% based on petal weight, as reported by Younis *et al*. (2008). Additionally, *Rosa centifolia* yielded 30 g (0.15%) of concrete oil, while *Rosa bourboniana* and Rosa 'Gruss en Teplitz' produced 19 g (0.09%) and 12 g (0.06%) of concrete oil, respectively.

3. Expression (Cold fat extraction): Essential oil is obtained by using high mechanical pressure to squeeze the oil from plant material.Cold press machine has one inlet from where material was feed andtwo exits that obtained oil and non-oiled cake was exit (Souyi, 2023).

Advantage: Simple to use, short duration process, low cost, use small quantity of raw material, by product in the form of presscake is also obtained (Souyi, 2023).

Disadvantage: More than7% of oil remains in seed. (Souyi, 2023).

4. Maceration: Coarsely powdered material placed in a stoppered container with solvent allowsstanding at room temperature for 3 days.When material is completely dissolved the mixture is strained out and pressed (Verma, 2012).

5. Soxhlet Extraction: Dried sample was placed in thimble which is attached to Soxhlet extractor. In a round bottom flask petroleum ether is filled.Then place it over heating mantle for boiling.Collect the pure oil after distillation (Zygler *et al.,* 2012).

6. Enfleurage: It requires fixed oil such as lard or fat.In this process, a thin film of fat is spread on the both side of glass plate mounted one above other to form air tight compartment within wooden frame called "Chassis".Freshly harvested flower is scattered on the top of fat layer, left for 24 hours.After removing withered blossom replace by fresh one and procedure being repeated for 30 or 40 times. Fat becomes saturated with fragrance of flower, final productcalled "Pomade"(Souyi, 2023, Shanakaraswamy,2020).

Extraction Methods for tuberose oil and their chemical components: The objectives of the project were to compare essential oil extraction methods from the double flower variety of tuberose (*Polianthes tuberosa* L.). The chemical composition of absolute was analyzed by gas chromatography-mass spectrometry (Rakthaworn *et al.,* 2009)**.**

Cold enfleurage:Palm wax was heated to 80^0C for 2h and poured into rectangular glass trays. Following the cooling process, allow the wax to return to room temperature. Subsequently, place tuberose flowers on the wax within each tray and cover them with another waxed tray. Fresh flowers were swapped every 24 hours. The extraction of

floral scents from the wax was achieved using ethanol, with the subsequent evaporation of ethanol leaving behind the absolute de enfleurage (Rakthaworn *et al.,* 2009).

Hot enfleurage; Palm oil heated at 60^0C, flower are warmed at 30 min, cooled down at room temperature. At 8-10^0C overnight palm oil is again heated at 60^0C. It is then filtered and substituted along fresh blossom (Rakthaworn *et al.,*2009)..

7. Supercritical Fluid Extraction: Supercritical $CO_2$is an excellent organic solvent to extract essential oil. When extraction is complete the pressure is reduced to ambient and Carbon dioxide reverts to a gas leaving no residue (Inzendy *et al*., 1998).

Example: Supercritical CO2 extraction of *Narcissus poeticus* L.flowers for the isolation of volatile fragrances compounds. Baranauskiene *et al*. (2022) developed a method with the primary objective was to assess the impact of pressure and the inclusion of a co-solvent in the supercritical CO_2 extraction (SFE-CO_2) process applied to freeze-dried *N. poeticus* flowers. Increasing the pressure from 36 to 48 MPa and incorporating 5% co-solvent ethanol into the CO_2 flow significantly boosted the yield of the lipophilic fraction in the extraction of freeze-dried *N. poeticus* flowers. A total of 116 volatile compounds were identified in the extracts through GC-TOF/MS analysis. Key constituents contributing to the fragrance of *N. poeticus* included benzyl benzoate (9.44–10.22%), benzyl linoleate (1.72–2.17%), and benzyl alcohol (0.18–1.00%). The addition of ethanol as a co-solvent facilitated a decrease in the proportion of higher alkanes, accompanied by an increase in the concentration of recovered benzyl aromatics.

Deg and Bhapka Method: It is a kind of a hydrodistillation method. The distillation apparatus is divided into three main parts i.e. Deg (Still), Bhapka (Receiver), and Chonga (Condenser cum Connecting Pipe) (Shukla *et al*., 2023).

Phase-wise manufacturing procedure (*Source:* https://www.dcmsme.gov.in/tcsp/Program%20 Overview/Kannauj_V1.pdf

Phase 1: Preparation of equipment andraw materialin **deg**.

Rose petals are plucked in early morning and submerged with the requisite amount of water. The lid is then sealed with an amalgamation of cotton and clay.The Bhapka is filled with a base oil or carrier oil such as sandalwood oil, then sealed using cotton cloth strips and earthen clay. Subsequently, this Bhapka is immersed into a compact tank constructed from bricks and concrete. The Deg and Bhapka are interconnected through a Chonga and tightly sealed using cloth and earthen clay.

Phase 2:Heating and condensation process; The Deg is heated using both wood and cow dung cakes. The inclusion of cow dung cakes is essential for regulating and monitoring the temperature during the heating process.There is a need to increase the pressure inside the Deg considerably. Further pressure is used to seal the deg. The major tool as condenser is chonga.

Phase 3:Cooling phase: In this phase, the Bhapka demonstrates a holding capacity exceeding 5-10 kg of the base material. The Bhapka's temperature is gradually lowered within a water tank to facilitate the extraction of Attar**.** After 4-5 hours when the required quantity of vapor arecondensed, then a wet cloth is rubbed all over the Bhapka to stall the distillation process and is replaced by another Bhapka. The Bhapka is then allowed to cool.

Phase 4:Separation process: Once the temperature of the mixtures have lowered, this mixture of water and oil is segregated by two possible methods: i.)Via a perforation at the base, directly from the Bhapka and ii.) By pouring the mixture in an open trough.

Phase 5: Purification of essential oil: Insoluble material can be removed by filtration. Anhydrous sodium sulphate is added to oil to remove the water. After 5hrs, the oil is filtered.

Phase 6: Storage of essential oil: Essential oil can be stored in small amber glass bottles, large stainless steel or aluminum containers**.** To prevent darkening, essential oil should be stored in cool area away from light and heat.

The effects of storage temperature and duration on essential oil content and composition oil rose (*Rosa damascena* Mill.).

Stein (1990) observed the impact of varying storage temperatures (0°C and 3°C) and durations (7, 14, 21, and 28 days) on the oil yield and essential oil components of *Rosa damascena* Mill. Rose oils were extracted through hydrodistillation using a Clevenger-type apparatus, and the components

within the rose oil were subsequently analyzed using Gas Chromatography-Mass Spectrometry (GCMS).

The highest oil content values were obtained from the rose petals distille dimme diately after the harvest (0.043%) ~and oilcontentsofthe petalsstored for 7 days (0.039%) at both storage temperatures **(**Kazaz *et al.*, 2009). Analysis revealed a rise in the citronellol content in oils derived from immediately distilled petals during storage, accompanied by a decrease in the rates of geraniol and nerol (Kazaz *et al*., 2009). Optimal results in both rose oil content and quality were observed in oils obtained from promptly distilled petals. This study suggests that the adverse changes mentioned can be mitigated by storing petals at 0°C for up to 7 days.

According to Mirzaei *et al*.(2015) damask rose (*Rosa damascena* Mill.) essential oil is affected by short and long-term handling. Given the perishable nature of the flowers, effective post-harvest handling is crucial in the context of rose essential oil production. To assess the impact of various storage conditions on damask rose essential oil (EO) yield and quality, petals were subjected to three storage conditions: packaging in LDPE and poly-film PET/EVOH/LDPE bags, and immersion in water containers at room temperature (RT) or in a refrigerator (4°C) for 1–3 days (short-term storage). Over an extended handling period (7, 14, and 21 days), the assessment focused on petals packed in PET/EVOH/LDPE bags, examining frozen, active, and passive Modified Atmosphere Packaging (MAP), as well as RT conditions. It is found out thatapplying PET poly-film bags used in the short-term handling of petals at RT for1 day, with an appropriate concentration of geraniol and citronellol in the EO, would be suggested as an effective method.

Effect of carnation essential oil: Study has been conducted about effect of carnation essential oil extracted from carnation calli on extending shelf life of yoghurt. Yoghurt is the coagulated milk product obtained by lactic acid fermentation through the action of *Lactobacillus delbreukii* sub sp. *bulgaricus* and *Streptococcus thermophilus*. Fragrance is predominantly due to eugenol, β-caryophyllene and benzoic acid derivatives. The cultivar 'Ellat', indicated that levels of these compounds rise during flower development (Zuker *et al*.,2002). Screening of essential oils for antibacterial activity was done by disc diffusion method (Prabuseenivasan *et al.,* 2006) using pathogenic strains incubated at 37 ºc for 24 hrs. Eugenol in carnation essential oil was added to milk, at the percentages of (0.2, 0.4, 0.6, and 0.8 µl/ml milk, respectively before using the milk in the yoghurt manufacture. Assem *et al*. (2019) showed that *S. aureus* was found to be highly sensitive to the eugenol in carnation essential oil action with different concentration which the diameter of inhibition zone ranged between 7.00 and 12.00 mm, followed by E. coli, *L. monocytogenes* and *S. typhamurium*.

Prospects in essential oil

Top companies in essential oil market (*Source:*https://www.pharmaadda.in/top-essential oil-manufacturers-in-india.

1.Young Living: Young Living is a popular essential oil company known for its wide range of high-quality essential oils. They have a strong commitment to purity and sustainability in their sourcing and production processes.

2. doTERRA: doTERRA is another prominent essential oil company that emphasizes rigorous testing and quality control. They source their oils from around the world and promote sustainable practices.

3. Plant Therapy: Plant Therapy is a family-owned essential oil company that focuses on providing affordable, high-quality oils. They have a transparent approach to their sourcing, testing, and manufacturing processes.

4. Mountain Rose Herbs: Mountain Rose Herbs is a well-respected company that offers a diverse selection of organic essential oils. They prioritize sustainable and ethical practices in their sourcing and packaging.

5. Aura Cacia: Aura Cacia is known for its extensive range of essential oils, including both single oils and blends. They offer oils that are sourced sustainably and provide detailed information about their quality testing.

6. Rocky Mountain Oils: Rocky Mountain Oils is a reputable company that provides high-quality essential oils sourced from around the world. They prioritize purity, quality, and customer satisfaction.

7. Edens Garden: Edens Garden is a popular essential oil company that offers a wide variety of oils, including organic options. They focus on transparent sourcing and quality assurance, along with affordable pricing.

8. Plant Guru: Plant Guru is known for its affordable essential oils without compromising on quality. They offer a range of oils sourced from various regions and promote sustainable practices.

9. NOW Foods: NOW Foods is a well-established company that provides a broad selection of essential oils. They emphasize quality and purity, and their oils undergo extensive testing.

10. Florihana: Florihana is a French company that specializes in organic essential oils. They are known for their commitment to sustainable agriculture, eco-friendly packaging, and rigorous quality control.

Top essential oil manufacturers in India (*Source :* https://www.pharmaadda.in/top-essential-oil-manufacturers-in-india)

1. Essential Oil Association of India, Shakarpur Delhi
2. Kshrey Essential oils and Ayurveda, Gurugram, Haryana
3. Moksha Life style Products, Karnal Road Delhi
4. BMV Fragrances Private Limited, Greater Noida UP
5. Shiva Exports India, Kannauj UP
6. Fragrance Palace, Janpat New Delhi
7. Indian Aroma Exports, UP
8. Natures Natural India, Delhi
9. Vinayak Ingredients (India) Pvt. Ltd., Mumbai
10. India Essential Oils, Delhi

Scenario of essential oil :

Global scenario : Essential Oil Industry business in global is estimated to about US$14 billion. While, India's share is just about 10% though potential is much more (Singh, 2014).In 2022, the market size of essential oils worldwide reached USD 21.79 billion, with an expected CAGR of 7.9%.from 2023 to 2030.This is attributable to the increasing demand from major end-use industries such as food & beverage, personal care & cosmetics, and aromatherapy. Encompass intricate and volatile chemical compounds renowned for their antifungal, antibacterial, anti-inflammatory, and antiviral attributes.(*Source:*Anonymous, 2022).

Sales channel insights : Other sales channel dominated with the highest revenue share of 63.4% in 2022. Its high share is attributable to the increasing awareness of essential oil among people has given rise to more retail sales especially through convenience stores.

However, key players have adopted multi-level marketing strategies to expand their business and improve their sales (*Source :* https://www. skyquestt. com/report/essential-oils-market) For instance, doTerra has managed to achieve 5 million global customers of which 70% are wholesale customers.

Application insights : The global market was predominantly led by the Spa & Relaxation sector, capturing the highest revenue share at 40.17% in 2022 *(source :* https://www.skyquestt.com/report/essential-oils-market). This dominance is a result of the evolving lifestyles of consumers worldwide. In the realm of perfume applications, essential oils are classified as base notes, middle notes, and top notes based on their volatility.

Regional Insights: The European region asserted its dominance in the global market, securing the highest revenue share at 43.3% in 2022. The presence of influential entities like the European Federation of Essential Oils (EFEO) has played a pivotal role in fostering industry growth within Europe*(Source:* Anonymous, 2022).

Nations in the Asia Pacific region, including India, China, and Indonesia, stand as industry trailblazers and have established themselves as primary exporters of some of the most valuable oils and extractsin the world such as champaca extract, jasmine extract, davana oil, frankincense oil, sandalwood oil, spice oils, etc. (*Source:* https:// www. transparen cymarket research.com/essential-oil-market.html)

Indian scenario : The collective share of flavors in the food, dental, and pharmaceutical sectors amounts to approximately 22,000 MT, while the remaining portion is dedicated to perfumery. The estimated annual production of perfumery raw materials stands at around 57,252 million tons, valued at Rs. 175 billion US$. Noteworthy among the essential oils currently produced in India are

citronella, lemongrass, basil, mint, sandalwood, palmarosa, eucalyptus, cedarwood, vetiver, geranium, rose oil, lavender, davana oil, and khus oil. The export of essential oils reached 170 US $ in the year 2010-2011, compared to 150 US $ in the previous fiscal year 2009-2010. The production of certain oils like mint, aromatic grass, linalool, geranium, lavender, and rose oil during 2010-2011 contributed to an annual saving of Rs. 601 crores in foreign exchange (*Source:* https:// www.kenresearch.com/industry reports/india-flavor-fragrance-industry).

Future Prospects : Indigenous production fulfills around 90% of the current essential oil demand in the country, with the remaining 10% sourced through imports. This growth has been characterized by both vertical and horizontal expansions in essential oil production. (Pujari *et al*., 2020). Antibiotic multi-resistance has become a global emergency in recent decades.The broad-spectrum antimicrobial activity manifested by EOs, in a similar context, must be noticed. Microbial growth related to food industry and cultural related artwork which can be controlled by use of essential oil. Their nature as a complex chemical mixture, which varies in terms of the quantity of their individual bioactive components, makes them resistant to any mechanism of microbial resistance. The use of these natural compounds for inhalation and their interactions with the central nervous system are still topics of fascination that, however, require more robust scientific confirmation, which we expect in the near future. (Napoli *et al.*, 2021).

CONCLUSION

With the fast-changing scenario in floriculture trade, availability of different climatic zones, knowledge of different method of extraction, cheap Labour and skilled manpower, our growers can do extremely well in the competitive landscape, strategically entering the essential oil extraction sector as a business is imperative to navigate the rapidly evolving industry dynamics.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Performance of turmeric genotypes for growth, yield and foliar disease incidence under Terai region of West Bengal

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ABSTRACT

A field experiment was undertaken at ICAR-AICRP on Spices, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal for four consecutive years i.e., from 2016-17 to 2019-20 to study the performance of twelve turmeric genotypes namely LTS01, LTS02, RH80, RH9/90, IT10, IT23, IT36, NDH11, NDH128, TCP191, TCP2 (Local check) and Prathiba (National Check) for growth, yield, dry recovery and foliar disease incidence. The experiment was laid out in randomized block design with three replications. The pooled data of the experiment revealed that the highest yield (38.73 t/ha) was recorded by TCP191 followed by IT10 (24.65 t/ha) and the lowest yield was recorded by IT23 (16.96 t/ha). Among the different evaluated genotypes, the highest dry recovery (22.63%) was recorded in TCP191 followed by TCP2 (22.00%) and the lowest was recorded in RH 9/90 (20.23%). With respect to leaf spot and leaf blotch, the lowest disease incidence was recorded by TCP191 (3.15 PDI & 2.61 PDI, respectively) followed by LTS1 (8.36 PDI, & 9.46 PDI, respectively). Thus, considering the yield and reaction to disease incidence of turmeric genotypes, TCP191 may be recommended for cultivation in the Terai zone of West Bengal, India.

***Keywords*:** Dry recovery, leaf blotch, leaf spot, turmeric, yield

INTRODUCTION

Turmeric (*Curcuma longa*) is considered as one of the most useful and sacred medicinal spice crops of India since time immemorial. It holds a significant part in the history of India and its people and is relegated as "Indian saffron" (Pickersgill, 2005) considering its orange yellow colour dried rhizomes. It possesses several medicinal and antioxidant properties beneficial for humankind and holds a great importance in various religious and cultural ceremonies of the nation. India is the largest producer and exporter of turmeric which is contributing about 80% of total production and 45% of export (Nybe *et al.,* 2007). In India, it is mainly grown in Andhra Pradesh, Odisha, Tamil Nadu, Kerala and West Bengal. In pharmaceutical industries, it is valued for the anti-cancerous, anti-inflamatory and antiseptic properties for producing mono-terpenes and sesquiterpenes in dry and fresh rhizomes (Priyanka *et al.,* 2015). The production of turmeric is influenced by various diseases like soft rot, leaf blotch and leaf spot etc. Among the serious problems, leaf blotch is caused by *Taphrinamaculans* (Sharma *et al.,* 1994) and leaf spot is caused by *Colletotrichum capsici* are very common in turmeric growing belts. Due to its social and economic importance the crop is always on a great demand throughout the year. A lots of trial on fertilizer, spacing, date of planting, size of planting material, mulching material and irrigation schedule etc. have been conducted to standardize suitable package of practices and to fulfill the demand but very little work has so far been undertaken to identify the promising genotypes along with low incidence of foliar diseases for *Terai* region of West Bengal. Keeping this in view, an experiment was undertaken at ICAR-AICRP on Spices, Uttar Banga KrishiViswavidyalaya, Pundibari, Cooch Behar, West Bengalfor four consecutive years *i.e.*, from 2016-17 to 2019-20 to study the performance of twelve turmeric genotypes for selection of suitable turmeric genotype with respect to growth, yield and

disease resistance to leaf blotch and leaf spot incidence for *Terai* zone of West Bengal.

MATERIALS AND METHODS

The field experiment was carried out at AICRP on Spices, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India (26º 40′ N and 89º 38′E and 43 meter above the MSL) for four consecutive year from 2016-17 to 2019-20 to study the performance of twelve turmeric genotypes. The soil of the experimental plots was medium to upland, coarse, sandy loam, medium in water holding capacity with low p^H and good organic matter content. Twelve turmeric genotypes were taken as treatments. Twelve turmeric genotypes namely LTS 01, LTS 02, RH 80, RH 9/90, IT 10, IT 23, IT 36, NDH 11, NDH 128, TCP 191, TCP 2 (Local check) and Prathibha (National check), were evaluated in each year. Source of the genotypes studied in the experiment has been given in the following Table:

Source of the genotypes studied in the Experiment

Sl. No.	Genotypes	Place of origin	State
1.	IT 10	Raigarh	Chhattisgarh
2.	IT 23	Raigarh	Chhattisgarh
3.	IT 36	Raigarh	Chhattisgarh
4.	RH 9/90	Dholi	Bihar
5.	RH 80	Dholi	Bihar
6.	TCP 191	Pundibari	West Bengal
7.	NDH 11	Kumarganj	Uttar Pradesh
8.	NDH 128	Kumarganj	Uttar Pradesh
9.	LTS 1	Guntur	Andhra Pradesh
10.	LTS 2	Guntur	Andhra Pradesh
11.	TCP-2 (LC)	Pundibari	West Bengal
12.	Prathiba (NC)	ICAR-IISR	Kerala

Every year, planting was done in the last week of April and harvested in the first week of the February. The experiment was laid out in Randomised Block Design with 3 replications. Planting was done in raised beds of 3 m × 1 m plot size with a spacing of 30 cm row to row and 20 cm plant to plant. Recommended package of practices was followed to raise a healthy crop. Data were collected from five randomly selected plants from each replication. The observations on plant height (cm), number of tillers per plant, number of leaves per plant, pseudo-stem girth (cm), leaf length (cm), leaf breadth (cm), fresh rhizomes yield per plot (kg), fresh rhizome yield per hectare (t/ha) and dry recovery (%), leaf blotch incidence (PDI) and leaf spot incidence (PDI) were recorded. The mean values of the data were subjected to statistical analysis as per the method suggested by Gomez and Gomez (1984). For calculation of PDI the following scales were adopted for disease severity.

Severity scale for calculating Per cent Disease Index PDI:

0 : No disease on leaf
1 : Spot covering <1% leaf area
3 : Spots 1-10% leaf area
5 : Spots 11-25% leaf area
7 : Spots 26-50% leaf area
9 : Spots >51% leaf area

$$\text{Disease severity or Infection index} = \frac{\text{Sum of all disease rating}}{\text{Total number of rating} \times \text{maximum disease grade}} \times 100$$

Note:

Scale for disease severity : 0 to 9 scale

If there are 5 samples : Rating of 5 samples are 5, 1, 0, 0 and 1 scale, respectively.

$$\text{Then, PDI} = \frac{(5 + 1 + 0 + 0 + 1)}{5 \times 9} \times 100$$

PDI = 15.56

Disease Scale :

0% PDI (No reaction) -Total Resistant to the disease

1-10% PDI- Highly resistant or tolerant to the disease

11-20% PDI - Moderately resistant or tolerant to the disease

21-30% PDI- Highly susceptible to the disease

31% PDI>- Extremely susceptible to the disease

RESULTS AND DISCUSSION

The analysis of variance showed significant variations among the genotypes for all growth (Table 1), yield (Table 2) as well as disease incidence (Table 3). The plant height ranged from 114.73 to 144.66 cm. Among the turmeric genotypes, TCP 191 recorded the highest plant height (144.66 cm) followed IT 10 (139.30cm) and Pratibha (129.46 cm), whereas IT 23 recorded the lowest plant height (114.73 cm). The variation in plant height is probably due to genetic variation among the genotypes. The highest number of tillers per clump was produced by RH 9/90 (3.08) which was statistically *at par* with RH 80 (2.97), NDH 128 (2.94), LTS 1 (2.79), TCP 191 (2.79) and IT 36 (2.77), while the lowest tillers per plant produced by IT 23 (2.45) and LTS 2 (2.45). A range of 0-7 number of tillers was reported by Vinodhini *et al*. (2019) which was in accordance with the present findings.

The number of leaves among the turmeric genotypes ranged from 7.58 to 8.42 (Table 1). The maximum number of leaves per clump (8.42) was registered in the genotype TCP 191 which was *at par* with RH 9/90 (8.33) and RH 80 (8.17). The pseudo-stem girth ranged between 6.55 cm to 7.56 cm among the genotypes (Table 1). On the pooled results, the highest pseudo-stem girth was valued in the genotype RH 9/90 (7.56 cm) which was statistically *at par* with RH 80 (7.48 cm), LTS 2 (7.45 cm), NDH 11 (7.49 cm), IT 10 (7.35 cm), LTS 1 (7.29 cm and TCP 2 (7.22 cm). It is clear from the results that pseudo-stem girth varied significantly among the genotypes and positively associated with the rhizome yield per plant. Mamatha (2016) also reported that pseudo-stem girth has high direct effect on rhizome yield which was in accordance with the present findings. Hence, greater pseudo-stem girth supports better source sink relationships which ultimately increases the yield.

Leaf length and leaf width displayed significant variation among the 12 turmeric genotypes evaluated. According to the pooled results, leaf length ranged from 49.46 cm to 62.51 cm while, leaf breadth ranged from 13.00 cm to 15.89 cm (Table 1). Maximum length of leaf (62.51 cm) was recorded in Prathiba and it was statistically *at par* with IT 10 (62.28 cm). The minimum leaf length was recorded in IT 23 (49.46 cm). The broadest leaf (15.89 cm) was observed in NDH 11 and it was statistically *at par* with Prathiba (15.67 cm) followed by IT 10 (14.89 cm), LTS 1 (14.73 cm) and TCP 191 (14.04 cm). The genotype RH 80 recorded narrowest (13.00 cm) leaves, while the genotypes Prathiba, NDH 11, IT 10, LTS 1 RS 1 and TCP 191 have bigger leaves, as compared to other genotypes.

There was a significant difference among 12 turmeric genotypes with respect to fresh rhizome yield for both plot and hectare yield (Table 2). The maximum fresh rhizome yield per plot was recorded in genotype TCP 191 (18.90 kg/3 m^2) followed by IT 10 (12.33 kg/3 m^2), TCP 2 (11.62 kg/3 m^2) and Pratibha (11.52 kg/3 m^2). Based on pooled result, it was evident that the highest yield per hectare was

also recorded by TCP191 (38.73 t/ha) followed by IT10 (24.65 t/ha) and the lowest yield was recorded by IT23 (16.96 t/ha) followed by NDH128 (17.82 t/ha) and RH-80 (17.88 t/ha). Singh *et al.* (2003) reported wide variability for rhizome yield while studying variability among 65 exotic and indigenous genotypes of turmeric. The genotype TCP 191 recorded about 62.39% and 66.72% higher fresh rhizome yield over TCP 2 (local check) and Prathiba (National check), respectively. Among the different turmeric genotypes, the dry recovery percentage ranged between 20.23 to 22.63% (Table 3). The highest dry recovery was recorded in TCP-191 (22.63%) and it was lowest in RH 9/90 (20.23%).

Based on the pooled results on per cent disease incidence (PDI) (Table 3), among the turmeric genotypes, TCP 191 (3.15 PDI), LTS 1 (8.36 PDI) and RH 80 (9.92 PDI) were highly resistant to leaf blotch. The performance of LTS 2 (10.41 PDI), NDH 128 (12.85 PDI), NDH 11 (14.24 PDI) and Prathiba (18.52 PDI) were moderately tolerant against leaf blotch. The results on per cent disease incidence (PDI) of genotypes IT 23 (35.06 PDI), IT 36 (35.44 PDI) and RH 9/90 (32.21 PDI) indicated that these genotypes were extremely susceptible to leaf blotch disease as compared to other genotypes. Sharma and Krishnamurthy (1962) screened 4 short duration genotypes and 7 long duration genotypes of *Curcuma longa* for varietal resistance of turmeric crop against leaf spot and leaf blotch diseases and found there was considerable variability in the genotypes in the degree of tolerance to both the leaf diseases. Generally, the long duration types of *Curcuma longa* were susceptible to leaf spot while Kesari types of *Curcuma longa* are resistance to leaf blotch. The evaluation of 19 different varieties of turmeric against shoot borer, leaf spot and leaf blotch infestation by Joseph and Nair (1981) confirmed that the varieties exhibited significant variability in their reaction to the pest and diseases. The varietal resistance of *Curcuma longa* to leaf spot was reported by many workers (Anonymous, 1986).

Table 1: Growth parameters of turmeric genotypes (Pooled data of 4 years)

Genotypes	Plant height (cm)	Number of tillers per plant	Number of leaves per plant	Pseudo-stem girth (cm)	Leaf length (cm)	Leaf breadth (cm)
IT 10	139.30	2.66	7.70	7.35	62.28	14.89
IT 23	114.73	2.45	7.97	7.21	49.46	13.54
IT 36	124.79	2.77	7.98	6.69	52.00	13.46
RH 9/90	121.37	3.08	8.33	7.56	50.08	13.59
RH 80	124.32	2.97	8.17	7.48	50.80	13.00
TCP 191	144.66	2.79	8.42	6.77	58.24	14.04
NDH 11	123.90	2.52	7.96	7.49	56.11	15.89
NDH 128	115.71	2.94	7.84	7.11	50.28	13.35
LTS 1	124.83	2.79	7.58	7.29	53.01	14.73
LTS 2	124.18	2.45	7.80	7.45	53.30	13.93
TCP-2 (LC)	125.27	2.51	7.84	7.22	51.28	13.88
Prathiba (NC)	129.46	2.53	7.97	6.55	62.51	15.67
S.Em (±)	**1.62**	**0.12**	**0.14**	**0.12**	**0.94**	**0.23**
CD at 5%	**4.54**	**0.36**	**0.39**	**0.34**	**2.65**	**0.63**

LC - Local Check, NC - National Check and NS – Non-significant

Table 2: Fresh rhizome yield per plot and hectare of turmeric genotypes

Genotypes	Yield per plot (kg/3 m^2)					Projected yield (t/ha)				
	2016-17	2017-18	2018-19	2019-20	Pooled	2016-17	2017-18	2018-19	2019-20	Pooled
IT 10	11.57	14.55	12.43	10.77	12.33	23.31	28.52	25.07	21.71	24.65
IT 23	9.93	5.78	8.58	8.83	8.28	20.02	12.72	17.31	17.80	16.96
IT 36	12.47	5.90	7.71	9.05	8.78	25.13	12.60	15.55	18.25	17.89
RH 9/90	11.47	7.07	7.54	10.35	9.11	23.11	15.26	15.20	20.86	18.61
RH 80	11.43	6.76	8.20	9.23	8.91	23.05	13.35	16.52	18.61	17.88
TCP 191	15.67	21.13	19.73	19.07	18.90	31.58	45.14	39.78	38.44	38.73
NDH 11	10.90	10.45	10.78	11.15	10.82	21.97	21.15	21.73	22.49	21.84
NDH 128	10.30	6.15	9.15	8.85	8.61	20.76	14.21	18.45	17.84	17.82
LTS 1	9.63	7.97	8.64	10.29	9.13	19.42	16.31	17.42	20.75	18.47
LTS 2	12.53	7.80	8.51	8.78	9.41	25.26	16.87	17.16	17.71	19.25
TCP 2 (LC)	9.37	11.88	12.01	13.24	11.62	18.88	25.64	24.21	26.69	23.85
Prathiba (NC)	11.00	11.50	12.46	11.13	11.52	22.18	23.18	25.12	22.43	23.23
S.Em (±)	0.69	1.11	0.52	0.46	0.39	1.33	1.70	1.04	0.93	0.65
CD at 5%	2.05	3.28	1.52	1.35	1.10	3.93	5.02	3.07	2.73	1.83

LC - Local Check, NC - National Check and NS – Non-significant

Table 3: Dry recovery, leaf blotch and leaf spot diseases of turmeric genotypes

Genotypes	Dry recovery (%)					Leaf blotch incidence (PDI)	Leaf spot incidence (PDI)
	2016-17	2017-18	2018-19	2019-20	Pooled	Pooled	Pooled
IT 10	21.33	21.00	20.50	20.32	20.79	25.76	12.25
IT 23	21.00	22.00	21.53	20.97	21.37	35.06	14.41
IT 36	21.67	21.33	20.92	21.14	21.26	35.44	17.29
RH 9/90	22.00	19.00	19.74	20.19	20.23	32.21	19.19
RH 80	21.33	21.00	20.85	20.97	21.04	9.92	13.59
TCP 191	22.00	23.33	22.69	22.50	22.63	3.15	2.61
NDH 11	22.33	21.00	21.57	21.24	21.54	14.24	12.79
NDH 128	19.67	21.67	21.29	20.96	20.90	12.85	10.07
LTS 1	22.00	21.33	20.94	21.12	21.35	8.36	9.46
LTS 2	20.33	22.00	22.25	21.80	21.60	10.41	15.18
TCP-2 (LC)	22.00	22.67	21.86	21.47	22.00	23.32	14.83
Prathiba (NC)	20.67	21.00	21.17	21.35	21.05	18.52	13.57
S.Em (±)	**0.95**	**0.66**	**0.31**	**0.17**	**0.33**	**1.48**	**0.89**
CD at 5%	**N.S.**	**1.96**	**0.90**	**0.49**	**0.86**	**4.16**	**2.49**

LC - Local Check, NC - National Check, PDI – Percent Disease Index

Table 4: Correlation coefficient analysis on growth, yield and disease incidence of turmeric genotypes

	PH	NTPP	NLPP	PSG	LL	LB	DR	LBI	LSI	YPP
PH	1.000	-0.026	0.218	-0.319	0.766**	0.341	0.423	-0.342	-0.560	0.875**
NTPP		1.000	0.420	0.135	-0.310	-0.480	-0.450	-0.082	-0.041	-0.085
NLPP			1.000	-0.139	-0.086	-0.302	0.114	0.002	-0.082	0.414
PSG				1.000	-0.394	-0.126	-0.317	-0.041	0.296	0.382
LL					1.000	0.752**	0.125	-0.224	-0.366	0.601*
LB						1.000	0.078	-0.185	-0.175	0.277
DR							1.000	-0.464	-0.616*	0.658*
LBI								1.000	0.727**	-0.420
LSI									1.000	-0.716**
YPP										1.000

*Significant at 5% probability level, **Significant at 1% probability level. PH - Plant height (cm), NTPP - Number of tillers per plant, NLPP - Number of leaves per plant, PSG - Pseudo-stem girth (cm), LL - Leaf length (cm), LB - Leaf breadth (cm), DR - Dry recovery (%), LDI - Leaf blotch incidence (PDI), LSI - Leaf spot incidence (PDI), YPP - Yield per plot (kg/3m^2)

The pooled data of leaf spot in Table 3 revealed that TCP 191 (2.61 PDI) and LTS 1 (9.46 PDI) showed highly resistant reaction against leaf spot disease. While other genotypes NDH 128 (10.07 PDI), IT 10 (12.25 PDI), NDH 11 (12.79 PDI), Prathiba (13.57 PDI), RH 80 (13.59 PDI), IT 23 (14.41 PDI), TCP 2 (14.83 PDI), LTS 2 (15.18 PDI), IT 36 (17.29 PDI) and RH 9/90 (19.19 PDI) showed moderate resistance to leaf spot disease. Kar and Mahapatra (1981) reported the occurrence of different species of *Colletotrichum* on the leaves of various host plants including turmeric plant in West Bengal. Palarpawar and Ghurde (1997) reported heavy losses in the yield of turmeric rhizome due to leaf spot disease incited by *C. capsici* and *C. curcumae* in Maharashtra state.

Result of the correlation coefficient analysis (Table 4) revealed that the rhizome yield per plot showed positive and significant correlation with plant height (0.875**) followed by dry recovery percentage (0.658*) and leaf length (0.601*). As the findings are in desirable direction and indicated certain inherent relationship between plant height, leaf length, dry recovery percentage and rhizome yield these traits may be further studied or utilized in future turmeric crop improvement program. Similar findings were also reported by Luiram *et al.* (2019), Dhanalakshmi *et al.* (2021) and Poonam *et al.* (2022) in turmeric. On the other hand, both leaf blotch incidence (PDI) (-0.420) and leaf spot incidence (PDI) (-0.716**) showed negative correlation with the rhizome yield per plot. However, the significant negative correlation was observed between leaf spot incidence (PDI) (-0.716**) and rhizome yield per plot. This finding is in agreement with Santosh and Simon (2020) and Kumar *et al.* (2020) in turmeric.

CONCLUSION

From the above findings of the field experiment, it may be concluded that the turmeric genotype TCP-191 performed best amongst all the genotypes as well as over both the check varieties during the four consecutive years of the study with respect to fresh rhizome yield, dry recovery and tolerance to foliar diseases viz. leaf blotch and leaf spot in Terai agro-climatic conditions of West Bengal.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Fig trees (*Ficus* spp.) : Species diversity, medicinal usage and conservation at the Bangladesh Agricultural University Campus

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ABSTRACT

Ficus L. (Moraceae), commonly known as fig, is distributed in diverse ecosystems, especially in tropical and temperate regions. This study was carried out on twenty-four species of Ficus L. based on the morphological observations of taxonomically significant characteristics. Among 24-species, it was found that eighteen species were trees, four were shrubs and two were climbers. F. auriculata had the largest leaves, measuring (24-41×22-35.5cm), followed by F. lyrata(18-45×15-30cm) and F. bengalensis(18-20×8-15cm). In contrast, Ficus retusa had the smallest leaves, with dimensions ranging from 3-7×1-2 cm. The majority of species exhibit both medicinal and commercial applications. Additionally, certain plants are cultivated for ornamental purposes. A total of thirteen species have been classified as "least concerned" while eleven species have not yet been evaluated for their conservation status according to the criteria of IUCN. The present study, which investigates the species diversity within the genus Ficus, offers a valuable foundation for forthcoming endeavors in conservation and management, while also establishing a fundamental reference for subsequent research endeavors.

***Keywords*:** Ficus spp**.** diversity, medicinal uses, conservation status, BAUBG

INTRODUCTION

Ficus L., considered a keystone species in tropical rain forests, plays a very fundamental role in different ecosystems, due to its fruits which are consumed by insects, birds and animals throughout the year (Chaudhary *et al*., 2012). *Ficus* is one of the largest genera in the angiosperms with 884 species, distributed throughout the world primarily in subtropical and tropical regions (https:// powo.science.kew.org/ taxon/urn:lsid: ipni.org: names: 327905-2). *Ficus* is also considered one of the most diversified genera concerning its habits (deciduous and evergreen trees, shrubs, herbs, climbers and creepers) and life forms (free-standing trees, epiphytes, semi-epiphytes in the crevices, rheophytes and lithophytes) (Chaudhary *et al*., 2012); it grows everywhere in Bangladesh and some of them produce edible fruits (Khatun *et al.*, 2016). *Ficus* species are used for medicinal properties in Ayurvedic, modern medicine and pharmaceutical applications (Adebayo *et al*., 2009; Abdulla *et al*., 2010, Sharma *et al.*, 2016). For example, *F. racemosa* has been found to possess potential benefits in the treatment of skin cancer and wound healing (Lalla, 2005, Singh *et al*.,2019). The fruit extracts of *F. religiosa, F. benjamina* and *F. benghalensis* have been found to have noteworthy antimicrobial and antibacterial properties as reported by Mousa *et al*. (1994), Sharma *et al*. (2016) and Singh *et al*. (2020a, b). Several species of *Ficus* are also employed in the treatment of cholera, diarrhoea, dysentery, mumps, vomiting and other related ailments.

Ficus is the most conspicuous and problematic genus because its microscopic flowers are located inside the closed fleshy receptacle (*i.e*., Syconium) (Sharma *et al.*, 2016). Therefore, vegetative morphology plays an important role in the identification of different species (Corner, 1965). Leaf and fruit (Syconium) morphology vary significantly among the *Ficus* species and act as important characteristics for identification (Nair *et al*., 2021). Leaf size can also provide clues about

the species' habitat, growth conditions and evolutionary adaptations. Some species may have large, broad leaves adapted for capturing more sunlight in dense forests, while others may have smaller leaves suitable for arid or open environments. The fig, a unique fruit type of the genus *Ficus*, morphology varies in different aspects like shapes, sizes, colors and textures; its' structure, including the presence or absence of specific features like ostioles (tiny openings through which wasps enter to pollinate the fig) can also aid in species differentiation (Nair *et al*., 2021). Hence, the present study was conducted to assess the species diversity of the genus *Ficus* based on observations of taxonomically significant morphological traits including leaf size, shape and fig size in the Bangladesh Agricultural University Campus and their uses have been reviewed.

MATERIALS AND METHODS

Field surveys were conducted to identify and document different *Ficus* species within the Bangladesh Agricultural University Campus. The locations, habits and characteristics of each species were recorded. The collected specimens underwent a comprehensive morphological examination followed by taxonomic identifications through comparative analysis using available keys. Measurements were conducted using a measuring scale to determine the dimensions of leaf size (in cm), leaf shape and fig size (in cm).

RESULTS AND DISCUSSIONS

A total of 24 *Ficus* species were identified from the Bangladesh Agricultural University(BAU) campus, mostly trees. Some are shrubs and a few climbers. Leaf area varied widely among different *Ficus* species (Figure 1). *Ficus auriculata* has the highest average leaf area whose value is 934.05 cm^2 followed by *F. lyrata* whose value is 708.75 cm^2. On the other hand, *F. retusa* has the lowest average leaf area whose value is 7.5 cm^2 followed by *F. natalensis* (14.63 cm^2). Fig size of different *Ficus* species has been shown in Figure 2. The fig size of *F. simplicissima, F. carica* and *F. lyrata* were the largest (4.0 cm) followed by *F. pumila* (3.67 cm). *F. microcarpa nitida* produced the lowest average fig size whose value is 0.75 cm. *Ficus elastica, F. heterophylla, F. maclelendii, F. religiosa* and *F. semicordata* are the second last and their value is 1.0 cm.

A short description of each of *Ficus* species present at the BAU Campus with their uses has been presented below:

1. *Ficus altissima* Blume

Common Name : Kathal Bot (Bangla), Council Tree (English)

A big tree having a large crown; Leaf entire, oblong, variegated, quite thick, green-white, 10-15 cm × 6-9 cm. Figs are deep orange and 1.5 cm in size (Plate A-1).

Use : Leaves and bark are used in skin diseases. Methylated flavonoids were found only in *Ficus altissima*, indicating that flavonoids could play an important role in the systematics of the genus (Sharaf *et al*., 2000). Stem and bark produce white latex which is used to make rubber. The foliage can be used in various flowering arrangements. Figs are used as food for animals, especially for birds and bats (tropical.theferns.info).

Conservation Status : Least concern (Lc)

2. *Ficus auriculata* Lour.

Common Name : Borodumur (Bangla), Australian Fig, Eve's Apron (English)

Ficus auriculata Lour is a perennial evergreen shrub or small tree, grown in tropical regions. Leaves are very large having rough surfaces on both sides and are green in color. The figs are also very big, about 3.5 cm in size having a light green color on the outside and pink color on the inside (Plate A-2).

Use: Used in the treatment of diarrhoea, dysentery, cuts, wounds, mumps, cholera, jaundice, etc.(Gairola and Biswas, 008). Young branches and leaves are used for food for elephants and camels. Figs are edible.

Conservation Status: Least Concern (Lc)

3. *Ficus benghalensis* L.

Common Name : Bot (Bangla), Banyan Tree (English)

Ficus benghalensis L. is a big tree having a large canopy. It also acts as a hemi-epiphyte. It is widely grown in tropical regions. Leaves are medium in size, thick and deep green. It produces small-sized fruits, about 1.65 cm in size which are very attractive to birds as they are deep orange (Plate A-3).

Use : Widely used in traditional medicine.The bark is useful for burning sensations, hemorrhages, diarrhea, dysentery, diabetes, ulcer and skin diseases. The leaves are good for ulcers, leprosy, skin allergies etc. The buds are used in diarrhea and dysentery. Latex is useful in rheumatism, hemorrhoids, inflammation and skin diseases (Rakesh *et al.,*2022). Figs are eaten by birds and mainly spread by them.

Conservation Status: Not Evaluated (NE)

4. *Ficus benjamina* L.,

Common Name : Pakur (Bangla),Yellow Fig, Java Fig (English)

This species is widely grown in tropical and subtropical regions. It is a big, evergreen tree having a large canopy with many branches. Leaves are medium in size and dark green in color. Figs are small, about 1.05 cm in size and orange in color (Plate A-4).

Use: *Ficus benjamina* possesses significant medicinal value, as it is employed in the treatment of several ailments such as malaria, influenza, dysentery, bronchitis, acute enteritis, pertussis and febrile seizures in pediatric patients (Hasti *et al*., 2014). Plant extracts can enhance the antioxidant defense system in humans, making them a preferred choice due to their ability to reduce side effects and toxicity compared to synthetic alternatives.

Conservation Status: Least Concern (Lc)

5. *Ficus benjamina curly*

Common Name : Weeping Fig (English)

Description: This species is also known as weeping fig, grown in sub-tropical regions. It is a small tree or large shrub. Leaves are small in size light green in color and curled at the apex.

Use: It contains various antioxidants. It is grown in households, parks and yards as ornament plants. Leaves can be used as cut flowers in different flowering arrangements. Figs are about 3 cm in size (Plate A-5).

Conservation Status : Not Evaluated (NE)

6. *Ficus carica* L.,

Common Name: Angir-dumur (Bangla), Common Fig, European Fig (English)

The species is indigenous to an area extending from Asiatic Turkey to northern India. It is a big evergreen tree. Leaves are large and green in color. Leaves have very rough surfaces. Figs are about 4 cm in size and reddish (Plate A-6).

Use: The species has some medicinal value. Figs can supply a lot of vitamins and minerals and can combat the hidden hunger caused by the micro-nutrient deficiency (Ashrafuzzaman *et al*., 2021). Leaves, fruits and roots of the plant are used in native medicinal system for different disorders such as gastrointestinal (colic, indigestion, loss of appetite and diarrhea), respiratory (sore throats, cough and bronchial problems), inflammatory and cardiovascular disorders etc. (Penelope *et al.*, 1997). Additionally, fruits are edible and consumed as well as dried form by human.

Conservation Status: Least concern (Lc)

7. *Ficus elastica* Roxb. ex Hornem

Common Name: Rubber Gachh, Attah Bar (Bangla), Indian Rubber Tree (English)

Ficus elastica Roxb. ex Hornem.is a large perennial tree grown in tropical regions. Leaves are thick and glossy and deep green. Figs are small in size, about 1 cm and yellowish-orange in color(Plate A-7).

Use : It produces latex which is used to make rubber. This rubber is very good in quality and used in day-to-day life activities. It is used in traditional medicine for various health problems, including pain, rheumatism, diarrhea, hypertension, infection, skin allergies, anemia, wounds, hernia and hemorrhoids(Arsyad *et al.*, 2023). Figs are eaten by birds, squirrels and other animals.

Conservation Status: Least Concern (Lc)

8. *Ficus fistulosa* Reinw. Ex Blume

Common Name: Yellow Stem Fig (English)

Ficus fistulosa is an evergreen tree grown in tropical and sub-tropical regions. Leaves are large and thin and light green to green in color. Figs are about 2.5 cm in size and light green (Plate A-8).

Use : *Ficus fistulosa* is a traditional medicine used in the remedies of diarrhoea, diabetics and malaria (Sharma *et al.*, 2016). Sometimes they are also cultivated as ornamental plants.

Conservation Status: Least concern (Lc)

9. *Ficus geniculata* Kurz.

Common Name: Dotted Fig (English)

It is a large tree. The plant of this species is widely available in subtropical regions. Leaves are

medium to large. Figs are green at an early stage and yellow when mature, size is 2 cm (Plate A-9).

Uses: It has both nutritional and ethano-medicinal values. Tribal people use young leaves and buds for cooking purposes. Besides, it contains phenols (Abdulla *et al.*,2010) and some anti-oxidants which are used for the treatment of leucorrhoea and degenerative diseases.

Conservation Status: Not evaluated (NE)

10. *Ficus assamica* Miq

Common Name: Bhui-dumur, Bala-lata, Ballam Dumur (Bangla)

This species is widely found in the Indian subcontinent. It is a shrub. Leaves are small to medium in size. Figs are quite small, 1 cm in size and green in color in the early stage and yellowish-orange in color in the mature stage (Plate A-10).

Use: The plant has several uses in the medicine branch. Leaf pastes are used in skin diseases like rheumatism, ear infections etc. (Abdulla *et al.*, 2010). Figs are edible.

Conservation Status: Least Concern (Lc)

11. *Ficus simplicissima* Lour.

Common Name: Dangra, Khandadumur, Khuskadumur (Bangla)

This species is grown in tropical regions. It is a small tree or shrub in nature. Leaves are large and membranous. Figs are 4 cm in size and red when ripe (Plate A-11).

Use : *F. simplicissima* is used to treat pneumonia, vitiligo, diarrhea, tonsillitis, cough, and rheumatic pain and promote lactation (Au *et al.*, 2009). Leaves are used as fodder. Figs are used as food for birds, squirrels, and other animals.

Conservation Status: Not evaluated (NE)

12. *Ficus hispida* Blanco

Common Name: Kakdumur (Bangla), Opposite-leaved Fig, Rough-leaved Stem Fig (English)

Ficus hispida Blanco is grown in tropical and subtropical regions. It is a large shrub or small tree by nature. Leaves are quite medium to large in size and green in color. Leaves have very rough, surface hairy. Figs are 2.5 cm in size (Plate A-12).

Use : Figs are widely consumed as food in several West Asian countries. Traditionally, different parts of the plant have been used in the treatment of ulcers, psoriasis, anemia, jaundice, vitiligo, hemorrhage, diabetes, convulsion, hepatitis, dysentery, piles, biliousness and purgative etc. (Abdulla *et al.*,2010).

Conservation Status: Not evaluated (NE)

13. *Ficus krishnae* C.DC.

Common Name: Krishna Bot (Bangla), Krishna's Fig, Krishna's Butter Cup, Sacred Fig Tree (English)

This species is native to the Indian sub-continent. It is an evergreen tree having many branches. Leaves are medium in size dark green in color on the upper side and light green on the lower side. Leaves are pocket-shaped at the lower end. Figs are 2 cm in size and orange in color when they are ripe (Plate B-13).

Use : It has been used extensively by ayurvedic practitioner in India to treat various ailments such as ulcers, vomiting, fever, inflammations, leprosy, syphilis, biliousness, dysentery and inflammation of liver (Au *et al.*, 2009).

Conservation Status: Least Concern (Lc)

14. *Ficus lyrata* Warb.

Common Name: Fiddle Fig Tree, Banjo Fig (English)

The species is grown in tropical rainforest. It is a large big, evergreen tree having a large canopy. Leaves are very big in size and lyre in shape. Leaf surface is smooth on the upper side and rough on the lower side and the veins are very clear to see. Figs are large, 4 cm in size and green in color and yellowish at a mature stage (Plate B-14).

Use : The plants may be used as indoor plants. The broad leaves of this *Ficus* houseplant remove chemicals like formaldehyde, ammonia and benzene from the air more efficiently than most medicinal air purifiers. Fiddle leaf fig is a rich source of antioxidants like flavonoids and phenols. These antioxidants treat liver fibrosis (accumulation of cells and collagen in the liver) and lower cholesterol levels. (Abdel-Hameed, 2009).

Conservation Status : Not evaluated (NE)

15. *Ficus maclellandii* King

Common Name : Narrow Leaf Fig, Long Leaf Fig (English)

This plant is native to India, Southeast Asia, and China. It is an evergreen tree. It is also called banana leaf fig or alii fig commonly. Leaves are long and

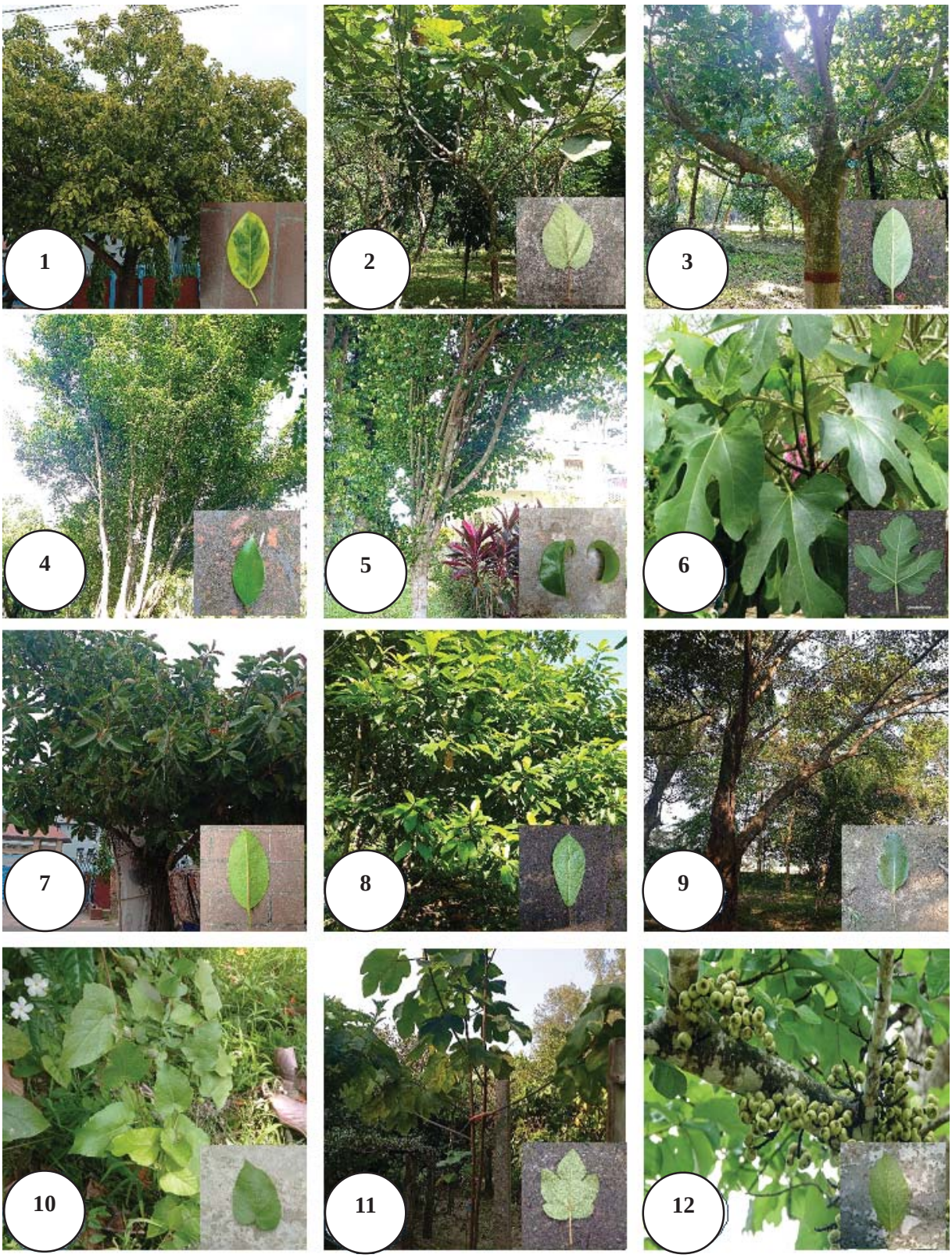

Plate A : Photographs of different Ficus species:(1) ***Ficus altisssima,*** **(2)*Ficus auriculata,*** **(3)** ***Ficus benghalensis,*** **(4)** ***Ficus benjamina,*** **(5)** ***Ficus benjamina curly,*** **(6)*Ficus carica,*** **(7)*Ficus elastica,*** **(8)*Ficus fistulosa,*** **(9)** ***Ficus geniculata,*** **(10)** ***Ficus assamica*** **(11)** ***Ficus simplicissima,*** **(12)** ***Ficus hispida***

Plate B: (13) *Ficus krishnae*, (14) *Ficus lyrata*, (15) *Ficus maclellandii King*, (16) *Ficus microcarpa*, (17) *Ficus retusa*, (18)*Ficus microcarpanitida* (king) F.C.Ho, (19) *Ficus natalensislepriurii*, (20) *Ficus pumila*, (21) *Ficus racemosa*, (22) *Ficus religiosa*, (23) *Ficus rumphii*, (24) *Ficus semicordata*

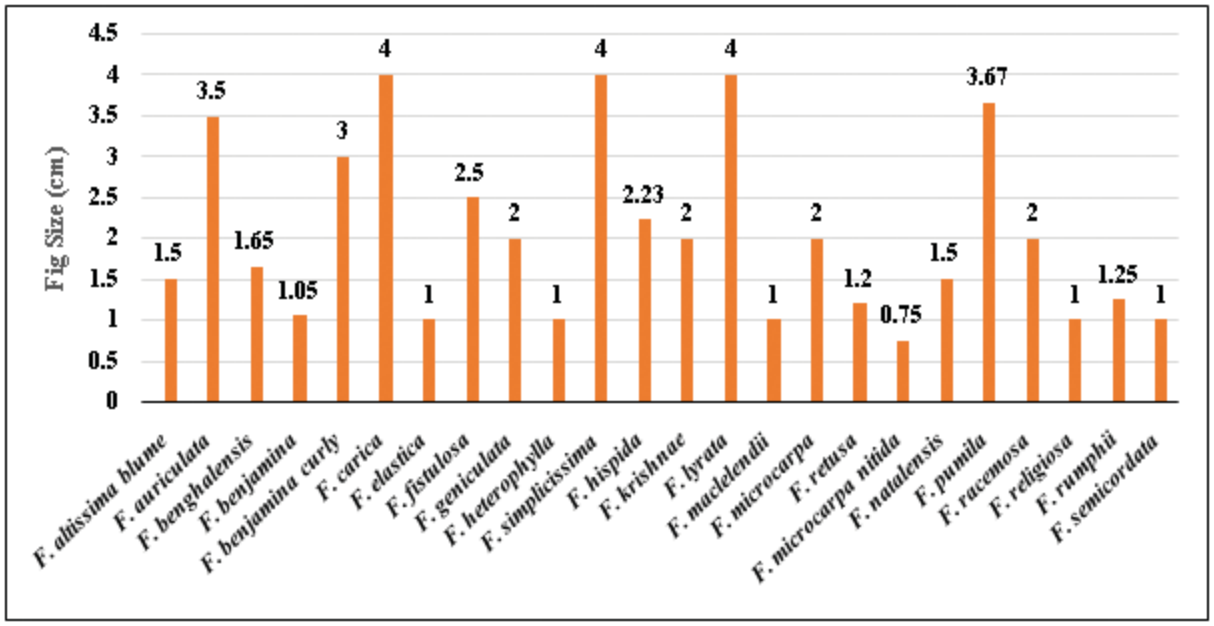

Fig. 1: Fig size (cm) of different *Ficus* species of the study area

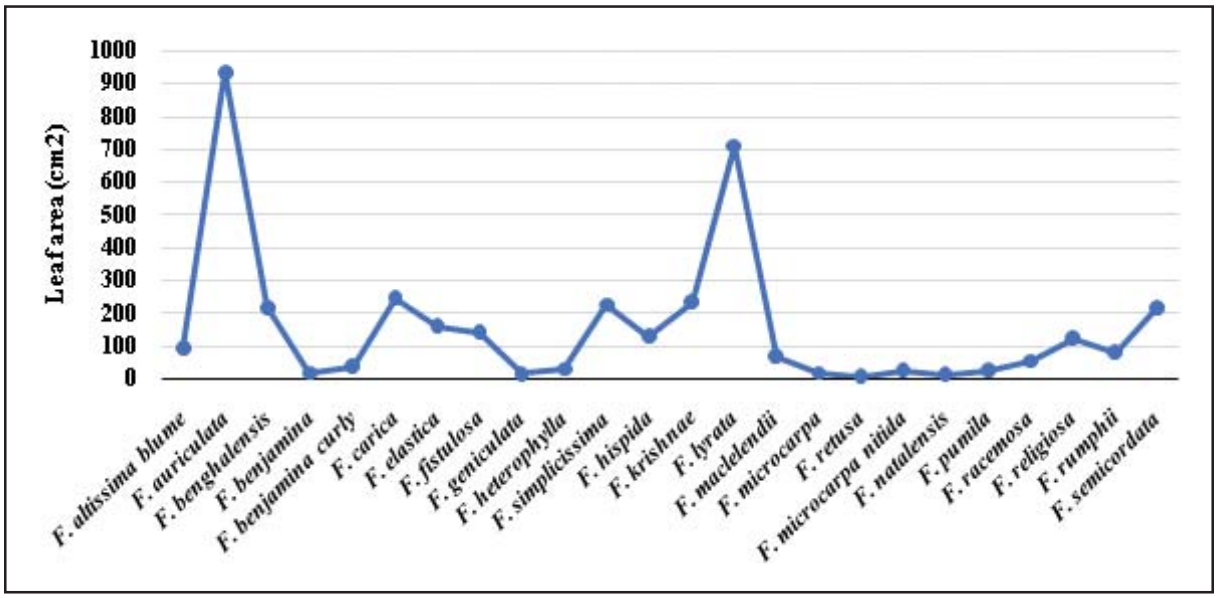

Fig. 2 : Leaf area (cm^2) of different Ficus species of the study area

narrow in shape and light green to green in color. Figs are 1 cm in size and orange in color (Plate B-15).

Use : Figs are eaten by birds and other animals. Woods can be used as firewood. The bark *isused for treating wounds, diabetes, hemorrhoids, and diarrhea.*

Conservation Status : Not evaluated (NE)

16. *Ficus microcarpa* Blume L. f.,

Common Name : Green Island Ficus (English)

This species is native to tropical and subtropical areas. It is an evergreen, perennial tree. Leaves are small in size dark green in color and rounded at the apex. Figs are 2 cm in size and green-yellowish in color (Plate B-16).

Use : *Ficus microcarpa* is cooling, astringent, and anti-bilious. It is found to have good healing

property, and is used in the preparation of oils, and ointments for external application in the treatment of ulcers. (Kumar *et al,* 2012).The plant is widely used as an indoor plant for beautification. Figs are eaten by birds.

Conservation Status: Not evaluated (NE)

17. *Ficus retusa* L.

Common Name : Chinese Banyan, Pot Belly Fig, Indian Laurel, Curtain Fig (English)

The species is widely grown in tropical areas. It is an evergreen-perennial tree. Leaves are small in size and green to dark green. Figs are 1.2 cm in size (Plate B-17).

Use : The root, bark, and leaf latex are used to treat wounds, headaches, liver diseases, toothache and ulcers. Aerial roots are useful in treating skin diseases (Abdel-Hameed, 2009).This species is used for ornamental purposes indoors as bonsai.

Conservation Status: Not evaluated (NE)

18. *Ficus microcarpanitida* (king) F.C.Ho

Common Name: Jir, Kamrup (Bangla), Chinese Banyan, Malyan Banyan (English)

This species is native to China through tropical Asia and the Caroline Islands to Australia. It is an evergreen perennial tree. It is a large tree having a large canopy but it is often kept small for beautification. Leaves are small to medium in size and dark green in color and pointed towards the end. Figs are 0.75 cm in size and green in color (Plate B-18).

Use : Figs are eaten by birds. The plants are sometimes used for medicinal purposes and are mostly used as indoor plants for beautification.

Conservation Status : Not evaluated (NE)

19. *Ficus natalensislepriurii* (Miq.)

Common Name: Barkcloth Fig, Natal Fig, Mistletoe Fig, Triangle Fig, Sweetheart Tree (English)

This is a tropical and sub-tropical species. It is a shrub. Leaves are medium to large in size and dark green in color. Figs are 1.5 cm in size and green when unripe and pinkish when mature (Plate B-19).

Use : It is mostly grown as a bonsai plant for ornamental purposes. Besides, different plant parts are used in traditional medicine. The root has analgesic properties and is used for the treatment of headaches, arthritis etc. (Kumar *et al.,* 2012).

Conservation Status: Least Concern (Lc)

20. *Ficus pumila* L.

Common Name : Lata Dumur, Dewal Dumur (Bangla), Fig Ivy, Creeping Fig, Climbing Fig (English)

It is a climbing perennial. A native of China and Japan also found in South East Asia. Leaves are small in size greenish in color. Figs are 3.75 cm in size and purple-black in color (Plate B-20).

Use : They are widely used to soften the look of concrete garden walls. They can also used as a groundcover. Figs are edible. The plants are used for local medicinal use.

Conservation Status : Least Concern (Lc)

21. *Ficus racemosa* Willd.

Common Name : Jogyadumur (Bangla), Cluster Fig, Indian Fig, Redwood Fig (English)

The species is widely grown in the Indian subcontinent. It is a big, evergreen tree. Leaves are medium in size and dark green in color. Figs are 2 cm in size and green in color at an immature stage and deep orange at a mature stage (Plate B-21).

Use: Different parts of the plant have been used for traditional medicines. They are used for the treatment of diabetes, diarrhea, liver disorders, respiratory and urinary diseases, etc.(Abdel-Hameed*,* 2009).

Conservation Status: Least Concern (Lc)

22. *Ficus religiosa* Forssk.

Common Name: Ashwatha, Ashwath, Panbot (Bangla), The Pipal, Bo-tree (English)

This plant is native to tropical and subtropical regions. It is a big evergreen tree having a large canopy. Leaves are medium to large have a pointed tail towards the end and are green in color. Figs are 1 cm in size and green at the immature stage and orange to reddish at the mature stage (Plate B-22).

Use: This species has been widely used in traditional medicine for many years. Different plant parts are used for about fifty types of disorders such as diabetes, diarrhea, asthma inflammatory disorders and sexual disorders, gastric problems etc. (Kumar *et al*, 2012).

Conservation Status : Least Concern (Lc)

23. *Ficus rumphii* Blume

Common Name: GaiAswatha, Sunmjor (Santal) (Bangla), Golden Rumph's Fig, Golden Mock Bodhi Tree (English)

This species is widely grown in the Indian subcontinent. It is a big tree having a large canopy and vigorously grown branches. Leaves are very similar to *Ficus religiosa* but do not have a tail at the end of the leaves. Leaves are green. Figs are 1.25 cm in size and green in color (Plate B-23).

Use: The plant is widely used in traditional medicines. The bark is used for snake-biteand the juice extracted from the plant is also taken internally with turmeric, pepper etc. to treat asthma. (Kumar *et al.,* 2012).

Conservation Status: Least Concern (Lc)

24. *Ficus semicordata* Miq.

Common Name : Sadimadi-dumur (Bangla)

The species is grown in tropical areas. It is a big tree. Leaves are medium in size and green to dark green but they are not equal on both sides. Leaves are cordate shaped that's why they are called semi-cordata. Figs are 1 cm in size and reddish when ripe (Plate B-24).

Use : The plant has medicinal value. They have some antioxidant activity, antidiabetic potential etc. (Sharma *et al.,* 2016). Figs are eaten by birds for food.

Conservation Status : Not evaluated (NE)

CONCLUSION

A total of 24 species (out of 884) are found in BAU campus. Most of them are trees, some are shrubs and climbers. It is also found that fruits are used as food for birds, insects, animals even humans. They are very healthy and nutritious and energetic. They contain different types of chemicals and minerals like protein, fat, starch, vit-C, beta-carotene etc. They can serve widely in the pharmaceutical industry and clinical uses. Many important drugs can be invented by using them. People can get benefitted from this. More further studies should be done to explore the potentiality of these plants.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Effect on vegetative growth and yield attributes of strawberry *Fragaria* × *ananassa*) cv. Winter Dawn in grown in nutrient film technique under shade net conditions

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ABSTRACT

With the view to assess the growth, production and quality of strawberry cv. Winter Dawn grown in hydroponic system under shed net condition, an experiment was conducted at the Department of Horticulture, Naini Agricultural Institute, SHUATS, Prayagraj during the years 2021-2022 and 2022-2023. The experiment was laid in the Complete Randomized Block Design (CRBD) with three replications and nine treatments. Based on the outcomes of the experiment, the overall best results for vegetative growth and fruiting attributes are shown under the nutrient treatment of Grow at 96 ml + Micro at 104 ml and Bloom at 102 ml feed for 12 hours i.e. at the period of 6 hrs morning and 6 hrs evening of running water. The solution of Grow, Micro and Bloom at a certain concentration and time showed significant increased in vegetative growth like plant height, number of leaves, plant spread, root length as well as fruiting attributes like number of flowers, number. of fruits and average fruit weight of strawberry plant.

***Keywords*:** Bloom, Grow,Hydroponics, Micro, NFT system, urban farming

INTRODUCTION

Strawberry (*Fragariax ananassa*) is a member of the Rosaceae family and Fragaria genus. Essentially, it is a little perennial herbaceous plant. In the last two decades, strawberry production and area have increased exponentially due to the fact that the majority of the crop is now grown in greenhouses (Thakur and Shylla, 2018). In India, it is cultivated on 3000 hectares with an annual output of 14,000 MT (NHB 2021), with Haryana being the largest producer (1,650 MT), followed by Mizoram (1,080 MT), Meghalaya, Maharashtra, and Himachal Pradesh (Anonymous, 2019b).The agro- climatic conditions in Uttar Pradesh are favourable for strawberry production, which has the potential to be a lucrative crop. The strawberry plants are strongly affected by the environmental parameters like temperature, photoperiod and light intensity. It requires optimum day temperature of 16ºC to 27ºC and night temperature 7ºC to 13ºC.

It is concerned that certain regions have a dearth of cultivable arable lands due to adverse topographical or geographical characteristics, and that in urban areas, soil and other rooting mix ingredients are just unavailable for crop production. The difficulty of finding suitable labour is a major issue for both traditional open-field agriculture and the pot cultivation technologies. This is an ideal environment for the introduction of soil-less culture or hydroponics. To compensate for the shortage of arable land brought on by a growing population, hydroponics provides an alternate means of cultivating food crops. Hydroponic agriculture is advantageous because it results in tidier plants, more effective use of nutrients since they are tailored to individual plants' requirements, plants that are free of weeds and pests, a greater yield per unit of land, and a higher price per unit of harvest (Puspitahat *et al.*, 2022). The Nutrient Film Technique is a popular hydroponic method for growing food crops (NFT). A thin nutritional layer

is provided at the system's base, where plant roots may take up optimal conditions. Plant nutrients are continually cycled through the system for the specified number of hours. A plant's roots can develop in the nutritional solution. Application of this method must account for the potential of surplus water, which will decrease oxygen levels. Because of this, the NFT system's nutrient layer is strategically laid out, with a maximum solution height of 3 mm, to supply the necessary amounts of nutritional water and oxygen (Purbajanti*et al.*, 2017).

Several variables, including water quality, nutrient solution, EC value, nutrient solution pH, water flow rate, gutter slope, medium, and others, must be taken into account for successful hydroponic farming. Most importantly, in hydroponic technology, EC and pH value control of fertilizer solutions are essential (Binaraesa, 2017). To a large extent, the pace at which nutrients are absorbed by the roots in NFT hydroponics is determined by the gutter's slope, as this determines the velocity with which nutrient solution is distributed (Asmana *et al.*, 2017).

Production of strawberry in hydroponic culture eliminates soil borne diseases, pests, and nematodes leading to better vegetative growth parameters, number of fruits, and yield of good quality strawberry fruits. The research work on effect of different growing systems on growth, production and quality attributes of strawberry *(Fragaria x ananassa)* under shade net conditions in India is very limited. Besides, no report is available regarding growing of strawberry in hydroponic system under Prayagraj condition of Uttar Pradesh. Considering advantages of hydroponic system, an investigation was undertaken with the aim to assess the effect on growth, yield and quality analysis of strawberry (*Fragaria x ananassa*) cv. Winter Dawn in NFT (Nutrient Film Technique) system in shade net conditions.

MATERIAL AND METHODS

The experiment was conducted at the experimental farm Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences(SHUATS), Prayagraj during the years 2021-2022 and 2022-2023 under shade net condition. Prayagraj is located in a climatic zone which experiences hot summer and fairly cold winter. During the investigation in winter months, especially December and January the temperature falls as low as 2°C- 5°C or even low whereas there may be an occasional spell of frost during the winters. However, occasional showers are uncommon during winter months. This investigation was conducted at the experimental farm of SHUATS Research Farm. 350 plants of strawberry cv. Winter Dawn were selectively brought from National Bureau of Plant Genetic Resources (ICAR) Regional Station, Bhovali, Nainital, Uttarakhand, India and planted in hydrophonic system on 14th November 2021. The plants were planted in a small plastic basket inside the high-quality PVC pipe as shown in Fig.1. In one configuration, four 4-foot-long PVC pipes were arranged in two tiers using iron angles, and net pot holes (20) measuring 4 inches in size were cut into the pipes. Spacing of plant to plant 12 cm. and row to row 30.48 cm the perforations were then used to accommodate the hydroponic net pots. A circulatory pump located in the nutrient reservoir tank was responsible for recalculating the nutrient solution throughout the hydroponic unit (Fig. 2 and 3).

The plants were fed with nutrient film method (NFT) as per treatments (Fig.4). The NFT (Nutrient Feeding Technique) is a constant supply of nutrients to the plant roots. Timer is not used rather a submersible water pump is used to pump the nutrient solution into the plant growing tray, the solution flows horizontally encountering the plant roots. The water is then drained out back to the water reservoir through the drain tube. An air pump is used to supply air to the air stone which supplies oxygen to the water-nutrient solution. The plants are grown in a plastic container that has holes at the bottom so that the roots can dangle into the constantly flowing water supply. 3-nutrients set were feed in the experiment. The nutrient sets were procured from Ponic Greens Agro Pvt Ltd., Plot No 511, Golf Course Road, sector 43, Gurugram 122002, India. The nutrient sets (liquid form) are Nute Grow, Nute Micro &Nute Bloom. The nutrients composition of the sets are described in the table.

Nute Grow (G) : NPK: 1-0-4	**Nute Micro (M): NPK: 2-0-0**	**Nute Bloom (B)**: **NPK: 1-3-4**
Total Nitrogen (N) 1% ((NH4) 1%). Water-soluble Potassium-Oxide (K2O) 4%. Derived from: magnesium nitrate, potassium nitrate.	Total Nitrogen (N) 2% ((NH4) 2%). Water-soluble Calcium (Ca) 2.4%. Water-soluble Magnesium (Mg) 0.1%.	Total Nitrogen (N) 1% ((NH4) 0.05%, (NO3) 0.4% & (NO2) 0.55%) Available Phosphate (P2O5) 3%
	Boron (B) 0.02%.	Water-soluble Potassium-Oxide (K2O) 4%
	Iron (Fe) 0.05% (chelated Iron (Fe) 0.05%). Manganese (Mn) 0.02% (chelated Manganese (Mn) 0.02%). Derived from: calcium nitrate, magnesium nitrate, iron EDTA, iron DTPA, EDDHA iron, manganese EDTA, and boric acid.	Sulfur (S) 0.2%. Derived from: mono calcium phosphate, monoammonium phosphate, potassium nitrate, potassium sulfate, and urea

Treatment Details

Factor 1 : Water flow schedule

[Morning (M) +Evening (E)]

I. Total 4 hrs. of water flow i.e. 2 hrs. of morning and 2 hrs. of evening
II. Total 6 hrs. of water flow i.e. 3 hrs. of morning and 3 hrs. of evening
III. Total 12 hrs. of water flow i.e. 6 hrs. of morning and 6 hrs. of evening

Factor 2 : Plant growth stages

(different stages of plant have been counted from the date of planting (14th November) in the system

I. S_1 : Seedling stage (1-6 weeks)
II. S_2 : Vegetative growth stage (6-10 weeks)
III. S_3 : Transition stage (10-12 weeks)
IV. S_4 : Bloom and ripening stage (12-16 weeks)

The experiment was laid in the Complete Randomized Block Design (CRBD) with nine treatments and three replications in each treatment. Number of plants taken in each replication were nine. So, total number of plants in the experiment was (9x3x9)=plants are 243. The treatment combination has been presented in Table 1.

Application of nutrients to the strawberry plants

For preparing the nutrient solution initially two nutrient stock solutions A and B of capacity 100 liters were prepared and then diluted to 200 litres capacity tank which were connected to the drip line. The concentration (ppm) of nutrients in solution supplied through drip line as per treatments at different stages of Plant growth. In each replicated treatment a 15-litre capacity water can was used (Fig.3) and 15 litre water is fed to the plants daily in recycling system (Fig 3). The water is changed from the hydroponic system every 15-days interval. Under no circumstances should plants be allowed to suffer from water stress. Once in a week, plain water was applied to flush out the excess salts which remained in the root zone to prevent the increase in electrical conductivity (EC) in the root zone**.**

Observation taken

Plant height, plant spread and root length were taken 120 days after planting from each plant. Using a measuring scale, average height of each plant was measured from the crown to the tips of the leaves (cm). The plant spread (cm) was determined by using a measuring scale to observe the canopy of the plant in both the East-West and North-South directions. The average root length (cm) in centimetres was calculated from the root lengths of 10 randomly chosen plantlets grown in each replication. The number of flowers was calculated from each representative plant at monthly intervals after first flowering till end of the season and their average was taken. The weight of fruit was recorded with the help of weighing balance and fruit weight calculated and expressed in grams (g) as per the

Table 1: Treatment combination applied instrawberry cv. Winter Dawn

Treatments	Nutrient doses ml/15Liters of water											
	4 hours- M (2) +E (2)				6 hours- M (3) +E (3)				12 hours-M (6) +E (6)			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
	G M B	G M B	G M B	G M B	G M B	G M B	G M B	G M B	G M B	G M B	G M B	G M B
T_1	6,6,6	09,09,06	06,11,11	06,13,13	7,7,7	09,09,07	07,11,11	07,13,13	8,8,8	10,10,08	08,12,12	08,14,14
T_2	9,9,9	11,11,09	06,13,13	09,15,15	10,10,10	12,12,10	10,14,14	10,16,16	11,11,11	13,13,11	11,15,15	11,17,17
T_3	12,12,12	14,14,11	12,16,16	12,18,18	13,13,13	15,15,13	13,17,17	15,19,19	14,14,14	16,16,14	14,18,18	14,20,20
T_4	15,15,15	17,17,15	15,19,19	15,21,21	16,16,16	18,18,16	18,22,22	16,24,24	17,17,17	19,19,17	17,21,21,	17,23,23
T_5	18,18,18	20,20,18	18,22,22	18,24,24	19,19,19	21,21,18	21,25,25	19,27,27	20,20,20	22,22,20	22,24,24	20,26,26
T_6	21,21,21	23,23,21	21,25,25	21,27,27	22,22,22	24,24,22	24,26,26	22,28,28	23,23,23	25,25,23	25,27,27	23,29,29
T_7	24,24,24	26,26,24	24,28,28	24,30,30	25,25,25	27,27,25	27,29,29	25,31,31	26,26,26	28,28,26	28,30,30	26,32,32
T_8	27,27,27	29,29,27	27,31,31	27,33,33	28,28,28	30,30,28	30,32,32	28,34,34	29,29,29	31,31,29	31,33,33	29,35,35
T_9	30,30,30	32,32,30	30,34,34	30,36,36	31,31,31	33,33,31	33,35,35	31,37,37	32,32,32	34,34,35	34,34,32	32,36,36

Total nutrient solution applied from 1st day of feeding to last day of feeding i.e., Date of planting (14th November) to date of final harvest (25th February)

T_1 – 91 (ml) Nute grow, 123 (ml) Nute micro, 117 (ml) Nute bloom

T_2 – 123(ml) Nute grow, 156(ml) Nute micro, 150(ml) Nute bloom

T_3 – 164(ml) Nute grow, 192(ml) Nute micro, 185(ml) Nute bloom

T_4 – 200(ml) Nute grow, 194(ml) Nute micro, 191(ml) Nute bloom

T_5 – 238(ml) Nute grow, 268(ml) Nute micro, 261(ml) Nute bloom

T_6 – 274(ml) Nute grow, 300(ml) Nute micro, 294(ml) Nute bloom

T_7 – 310(ml) Nute grow, 336(ml) Nute micro, 330(ml) Nute bloom

T_8 – 346(ml) Nute grow, 372(ml) Nute micro, 366(ml) Nute bloom

T_9 – 382(ml) Nute grow, 404(ml) Nute micro, 399(ml) Nute bloom

Table 2:Plant growth of strawberry cv. Winter Dawn, as affected by Nutrient Film Technique (NFT) in shade net conditions during 2021 and 2022

	Plant height (cm) at 120 days after planting in NFT System									Plant Spread (cm) at 120 days after planting in NFT System								
	2021			2022			Pooled			2021			2022			Pooled		
	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs
T_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T_1	12.02	14.9	15.57	12.92	15.8	16.47	12.47	15.35	16.02	23.92	21.33	23.68	25.56	20.97	24.64	24.74	21.15	24.16
T_2	12.59	15.26	15.93	13.72	16.39	17.06	13.16	15.83	16.5	21.29	22.09	22.74	22.46	23.26	23.93	21.88	22.68	23.34
T_3	12.82	15.44	16.11	13.98	16.6	17.27	13.29	15.93	16.6	21.25	22.82	23.49	22.47	24.04	24.71	21.86	23.43	24.10
T_4	12.95	15.59	16.26	14.15	16.79	17.46	13.49	16.12	16.79	21.42	21.93	22.6	22.68	23.19	23.86	22.05	22.56	23.23
T_5	14.09	16.89	17.56	14.45	17.25	17.92	13.7	16.42	17.09	22.72	23.21	23.88	23.14	23.63	24.3	22.93	23.42	24.09
T_6	15.72	18.55	19.22	17.32	20.15	20.82	16.22	19.02	19.69	24.59	24.96	25.63	26.01	26.38	27.05	25.3	25.67	26.34
T_7	15.12	17.88	18.55	16.48	19.24	19.91	15.29	18.07	18.74	22.86	23.01	23.68	24.52	24.67	25.34	23.69	23.84	24.51
T_8	15.22	17.99	18.66	16.68	19.45	20.12	16.2	19	19.67	22.79	22.68	23.35	24.31	24.2	24.87	23.55	23.44	24.11
T_9	15.09	17.84	18.51	16.89	19.24	19.51	16.06	18.62	19.09	21.75	22.93	25.6	24.21	24.39	26.06	22.98	23.66	25.83
	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test
Pot Media	**0.315**	**0.651**	*	**0.313**	**0.645**	*	**0.236**	**0.488**	*	**0.288**	**0.595**	*	**0.235**	**0.485**	*	**0.229**	**0.472**	*
Treat-ments	**0.63**	**1.301**	*	**0.625**	**1.29**	*	**0.473**	**0.976**	*	**0.577**	**1.191**	*	**0.47**	**0.97**	*	**0.457**	**0.944**	*

Table 3:Root length and flower production in strawberry cv. Winter Dawn, as affected byNutrient Film Technique (NFT)in shade net conditions during 2021 and 2022

	Root Length (cm) at 120 days after planting in NFT System									Number of flowers per plant in NFT System								
	2021			2022			Pooled			2021			2022			Pooled		
	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs
T_0	0	0	0	1.02	1.02	1.02	0.51	0.51	13	0	0	0	0	0	0	0	0	0
T_1	23.77	24.57	25.24	24.98	25.78	26.45	24.38	25.18	17.52	31.79	38.04	38.71	32.69	38.94	39.61	32.24	38.49	39.16
T_2	23.75	25.32	25.99	24.99	26.56	27.23	24.37	25.94	16.7	27.22	31.91	32.58	28.15	33.04	33.71	27.69	32.48	33.15
T_3	23.92	24.43	25.1	25.2	25.71	26.38	24.48	25.52	17.09	28.45	33.26	33.93	29.61	34.42	35.09	28.42	33.17	33.84
T_4	25.22	25.71	26.38	25.66	26.15	26.82	24.79	25.29	17.04	30.45	35.54	36.21	31.65	36.74	37.41	30.05	35	35.67
T_5	25.36	25.51	26.18	27.04	27.19	27.86	26.13	26.45	16.81	36.45	42.37	43.04	36.81	42.73	43.4	33.63	39.14	39.81
T_6	27.09	27.46	28.13	28.53	28.9	29.57	26.91	27.04	17.97	39.12	44.93	45.6	40.48	46.29	46.96	38.94	44.64	45.31
T_7	25.29	25.18	25.85	26.83	26.72	27.39	26.1	26.12	18.73	37.39	42.98	43.65	38.99	44.58	45.25	36.56	41.94	42.61
T_8	24.25	25.43	28.1	26.73	26.91	28.58	26.91	27.19	18.61	34.12	39.3	39.97	35.58	40.76	41.43	36.02	41.57	42.24
T_9	24.66	25.82	26.49	25.77	26.93	27.6	25.01	26.18	18.07	31.79	36.67	37.34	33.19	38.07	38.74	36.16	41.5	42.17
	SE (m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test
Pot Media	**0.309**	**0.638**	*	**0.154**	**0.319**	*	**0.203**	**0.418**	*	**0.402**	**0.831**	*	**0.403**	**0.831**	*	**0.398**	**0.821**	*
Treat-ments	**0.618**	**1.276**	*	**0.309**	**0.638**	*	**0.405**	**0.837**	*	**0.805**	**1.661**	*	**0.805**	**1.662**	*	**0.796**	**1.642**	*

Table 4:Fruit production and fruit weight (g) in strawberry cv. Winter Dawn, as affected byNutrient Film Technique (NFT)in shade net conditions during 2021 and 2022

	Number of fruits per plant in NFT system									Average fruit weight (g) in NFT system								
	2021			2022			Pooled			2021			2022			Pooled		
	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs	4hrs	6hrs	12hrs
T_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T_1	10.95	11.1	11.87	11.35	11.3	11.97	11.15	11.2	11.92	39.92	42.1	42.77	40.82	43	43.67	40.37	42.55	43.22
T_2	14.95	15.5	16.17	15.05	17.1	17.77	15	16.3	16.97	41.92	44.2	44.87	43.35	45.33	46	42.64	44.77	45.44
T_3	15.28	16.1	16.77	14.98	17.3	17.97	14.97	16.4	17.07	42.49	44.78	45.45	43.65	45.94	46.61	42.79	45.07	45.74
T_4	15.28	16.1	16.77	14.14	16.46	17.13	14.71	16.28	16.95	44.91	47.55	48.22	46.11	48.75	49.42	44.3	46.77	47.44
T_5	14.62	15.13	15.8	14.58	16.59	17.26	14.93	16.35	17.02	45.86	48.63	49.3	46.22	48.99	49.66	45.57	48.27	48.94
T_6	16.62	17.74	18.41	16.45	18.87	19.54	16.04	17.68	18.35	47.22	49.99	50.66	48.58	50.55	51.32	46.75	48.97	49.69
T_7	15.62	16.48	17.15	15.28	17.64	18.31	14.95	16.39	17.06	44.91	47.39	48.06	46.37	48.85	49.52	46.12	48.74	49.41
T_8	14.95	15.5	16.17	14.81	16.86	17.53	15.72	17.3	17.97	46.7	49.4	50.07	48.3	50.2	50.67	47.76	50.1	50.67
T_9	14.28	14.75	15.42	14.18	16.15	16.82	14.57	15.83	16.5	44.79	47.25	47.92	46.19	48.65	49.32	46.45	49.03	49.7
	SE (m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test	SE(m)	C.D. at 5%	F-test
Pot Media	0.335	0.691	*	0.434	0.896	*	0.235	0.485	*	0.306	0.631	*	0.31	0.64	*	0.305	0.63	*
Treat-ments	0.669	1.382	*	0.868	1.793	*	0.47	0.971	*	0.612	1.262	*	0.621	1.281	*	0.61	1.259	*

formula given below- Average fruit weight = Total weight of Fruits (g) / Numbers of Fruits.

The data were analysed by a statistical method known as the Complete Randomized Block Design (CRBD) "analysis of variance method" to look into the connections between the variables (Panse and Sukhatme, 1985). Each component of the combined s2 and dn1 variances may be traced back to a unique cause. F values were calculated by comparing the variance of the replication and treatment effects with the variance of the error, and P values of 0.05 were used to evaluate statistical significance. A key difference was established for mean comparisons across treatments at the 5% level of significance.

RESULTS AND DISCUSSION

Plant height (cm)

The data regarding the plant height (cm) of strawberry cv. Winter Dawn was found significantly affected by different treatments and timing of running water in hours as indicated by Table 2. It was found that Treatment T_6 (96,104,102 ml of G, M, B respectively) when applied with 12 hours of running water, it recorded the maximum plant height [19.22 (2021-22), 20.82 (2022-23) and 19.69 (Pooled)] cm over all other treatments during both the years of study as well as pooled analysis. It was followed by Treatment T_8 (120,128,126) with 12 hours of running water which recorded the 2nd best plant height [18.66 (2021-22), 20.12 (2022-23) and 19.67 (Pooled)] cm. The minimum height of plant [12.02 (2021-22), 12.92 (2022-23) and 12.47 (Pooled)] cm was recorded in treatment T_1 (27, 39, 36 ml of G, M, B respectively) with 4 hours of running water during both the years of study as well as pooled analysis. Higher plant height under T_6 and T_8 may be attributed to optimum availability of macronutrients and micronutrients for better plant growth. These elements affect the meristematic growth of plant and the CO_2 fixation is enhanced which, leads to enhanced photosynthesis(Abdullah *et al*., 2021). The macronutrient Nitrogen, especially, when applied at optimum level has a growth promoting effect by affecting the production of cytokinin, which in turn affects the elasticity of cell wall and increases the meristematic cells (Bloom *et al*., 2006).Similar findings have been reported by Abdullah *et al*. (2021) and Hindersah *et al*. (2021) while working

Figure - 1

Figure - 2

Figure - 3

Figure - 4

on strawberry. However, hydroponically grown plants had more height than the pot culture grown plants. This may be due to continued supply of nutrients to the roots than in the pot culture media. It was also observed by Kulkarni *et al*. (2017) that plants grown in hydroponically settings (Spinach-28.33cm and Coriander-47.21cm) had somewhat better height when compared to soil grown plants.

Plant spread (cm)

The data regarding the plant spread (cm) of strawberry cv. Winter Dawn was found significantly affected by different treatments and timing of running water in hours as indicated by Table 2. It was found that Treatment T_6 (96,104,102 ml of G, M, B respectively) when applied with 12 hours of running water, it recorded the maximum plant spread [25.63 (2021-22), 27.05 (2022-23) and 26.34 (Pooled)] cm over all other treatments during both the years of study as well as pooled analysis. It was followed by Treatment T_9 (132,136,135 ml of G, M, B respectively) with 12 hours of running water, which recorded the 2nd best plant spread [25.6 (2021-22), 26.06 (2022-23) and 25.83 (Pooled)] cm. It was also observed that treatment T_9 (132,136,135 ml) was found at par with treatment T_6 (96,104,102 ml) when applied with 12 hours of running water. The minimum spread of plant during 2021-22 i.e., 21.25 cm was recorded in treatment T_3 (50,60,57 ml) with 4 hours of running water where-as during 2022-23 the minimum spread of 22.46 cm was found under treatment T_2 (35,48,46 ml) with 4 hours of running water. According to pooled analysed data the minimum spread of the plant 21.86 cm was found under treatment T_3 (50,60,57 ml) with 4 hours of running water. The plant spread was higher because in hydroponic system, all the nutrients were sufficiently available for plants due to the controlled pH condition in the hydroponic system (Sharma *et al*., 2018). The optimum availability of both macronutrients and micronutrients through Nute grow, Nute Micro and Nute bloom led to the vigorous increase in plant spread. Another reason may be that there is very less mechanical hindrance than any other mediums of growth in hydroponics; as a result, plant grows vigorously. Similar results were reported by Chow *et al*. (2002) while working on strawberry hydroponic system.

Root Length (cm)

120 days after planting, the root length (cm) of strawberry cv. Winter Dawn was found significantly affected by different treatments and timing of running water in hours as indicated by Table 3. It was found that Treatment T6 (96,104,102 ml of G, M, B respectively) with 12 hours of running water recorded the maximum root length [28.13 (2021-22), & 29.57 (2022-23)] cm over all other treatments during both the years of study but pooled analysis data showed T8 (120,128,126 ml of G, M, B respectively) with 12 hours of running water was found the best with 28.36 cm root length. The minimum root length (cm) i.e., 23.75 cm was found under treatment T_2 (35,48,46) with 4 hours of running water during 2021-22 where-as during 2022-23, 24.98 cm of root length was found minimum under treatment T_1 (27,39,36) with 4 hours of running water. However, according to pooled data, 24.37 cm root length was found minimum under treatment T_2 (35, 48, 46) with 4 hours of running water. The highest root length may be due to optimum availability of phosphorous which help in root growth and development. Due to its limited mobility, fixation by the soil, and low diffusion coefficient, phosphorus is commonly used as a fertilizer. Similar results were also reported by Noh *et al*. (2017) and Tohidloo *et al*. (2018). It was also found that hydroponically grown plants had more root length than the pot culture grown plants. This may be because of optimum nutrient availability in hydroponics due running water containing nutrients while in pot culture media in which the nutrients were lost due to fixation. Similar results were observed by Girdthai *et al*. (2010) while working on peanut and Horibe (2017) while working on edible opuntia.

Number of flowers per plant

It was observed that Number of flowers per plant increased throughout the period of observation till the harvest stage during both the years (2021-22 and 2022-23) of study. The data regarding It was observed that the Number of flowers per plant of strawberry cv. Winter Dawn were significantly influenced by different treatments and timing of running water in hours as indicated by Table 3. It was found that Treatment T_6 (96,104,102 ml of G, M, B respectively) with

12 hours of running water recorded the maximum number of flowers per plant[45.6 (2021-22),46.96 (2022-23)& 45.31 (Pooled)] over all other treatments during both the years of study as well as pooled data. It was followed by Treatment T_7 (108,116,114 ml of G, M, B respectively) with 12 hours of running water which recorded the 2nd best treatment with [43.65 (2021-22), 45.25 (2022-23 ml)& 42.61 (Pooled)]number of flowers per plant during both the years of study and pooled data. The minimum Number of flowers per plant [27.22 (2021-22), 28.15(2022-23) & 27.69 (Pooled)] was recorded in treatment T_2 (35, 48, 46 ml) with 4 hours of running water during both the years of study and pooled analysis data. The number of flowers increased due to availability of optimum plant nutrients through the hydroponic system. The availability of all the nutrients led to biosynthesis of growth regulators like Auxin and cytokinin (Halbert-Howard *et al*., 2021). Auxin might have been involved in the floral bud initiation of plants, while cytokinin may have been involved in nutrient mobilization to the reproductive structures (Renau-Morata *et al*., 2021). Similar reports were reported by Caruso *et al*. (2011) and Rana and Prasad (2022).The hydroponically grown strawberry had a greater number of flowers per plant than the plants grown by pot culture. This may be due to optimum nutrient availability in hydroponics where running water containing nutrients while in pot culture media in which the nutrients were lost due to volatilization by the action of microbes. Similar results were observed by Rana and Prasad (2022) while working on strawberry.

Number of fruits per plant

The data regarding the number of fruits per plant of strawberry cv. Winter Dawn were significantly influenced by different treatments and timing of running water in hours as indicated by Table 4. It was found that Treatment T_6 (96,104,102 ml of G, M, B respectively) & T_2 (46, 56, 54 ml of G, M, B respectively) with 12 hours of running water recorded the maximum number of fruits per plant [18.41 (2021-22), 19.54 (2022-23) & 18.35 (Pooled)] over all other treatments during both the years of study as well as pooled data. It was followed by Treatment T_7 (108,116,114 ml) with 12 hours of running water which recorded the 2nd best treatment with [17.15 (2021-22) &18.31 (2022-23)] number of fruits per plant during both the years of study whereas according to pooled data, treatment T_8 (120,128,126 ml) with 12 hours of running water was found 2nd best with 17.97number of fruits per plant. The minimum number of fruits per plant [10.95 (2021-22) & 11.35 (2022-23)] was recorded in treatment T_1 (27, 39, 36 ml) with 4 hours of running water during both the years of study as well as pooled analysis data.

The Treatment T_6 containing Nutegrow, Nute Micro and Nute bloom @ 96ml, 104ml and 102 ml respectively in 15l of water with 12 hours of running water recorded maximum number of fruits per plant. This is because nutrients are continuously available with the ideal pH, more starch, carbohydrates, and photosynthesis accumulates, leading to more blooms per plant and a greater rate of fruit set, which results in more fruits per plant. Similar results were reported by Shawer (2014) while working on cucumber and Halbert-Howard *et al*. (2021) while working on tomato. The number of fruits per plant was higher in hydroponically grown plants due to the fact that in hydroponics culture the plant roots were provided with nutrients directly which lead to profuse growth of above ground plant parts. The higher vegetative growth led to higher photosynthesis in plants leading to availability of nutrients to the reproductive sinks leading to increase in number of fruits per plant. Similar reports were also observed by Chow *et al*. (2002) and Rana and Prasad (2022).

Average fruit weight (g)

It was observed that the average fruit weight (g) of strawberry cv. Winter Dawn were significantly influenced by different treatments and timing of running water in hours as indicated by Table 4. It was found that Treatment T_6 (96,104,102 ml of G, M, B respectively) with 12 hours of running water recorded the maximum average fruit weight (g) [50.66 (2021-22) & 51.32 (2022-23)] g over all other treatments during both the years of study whereas according to pooled data, treatment T_8 (120,128,126 ml of G, M, B respectively) with 12 hours of running water recorded significantly best treatment with 50.67 g average fruit weight. It was also found that treatment T_8 (120,128,126 ml) was found at par with T_6 (96,104,102 ml) with 12 hours

of running water during both the years of study whereas according to pooled data, T_6 (96,104,102), T_7 (108,116,114 ml) & T_9 (132,136,135 ml) were found at par with T_8 (120,128,126 ml) with 12 hours of running water. The minimum average fruit weight [39.92 (2021-22), 40.82 (2022-23) & 40.37 (Pooled)] was recorded in treatment T_1 (27, 39, 36 ml) with 4 hours of running water during both the years of study as well as pooled analysis data.The Treatment T_6 containing Nute grow, Nute Micro and Nute bloom @ 96ml, 104ml and 102 ml respectively in 15l ml of water with 12 hours of running water recorded maximum average fruit weight. With the optimal availability of nutrients to the plant's roots and the perfect pH, more starch, carbohydrates, and photosynthesis accumulate, resulting in higher fruit weight. The optimal availability of K in plants causes an increase in carbon content, which in turn influences dry matter and fruit yield (Lim *et al.*, 2015).

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Evaluation of lisianthus (*Eustoma grandiflorum*) cultivars for growth and floral attributes under High Altitude and Tribal zone of Andhra Pradesh

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ABSTRACT

A field experiment was conducted to study the evaluation of Lisianthus cultivars under polyhouse conditions for different growth and floral attributes in the high altitude and tribal zone of Andhra Pradesh at Horticultural Research Station, Dr YSR Horticultural University, Chintapalli, Alluri Seetharamaraju District, Andhra Pradesh during early summer of 2023. Six lisianthus cultivars Viz., Rosita 3 Blue Picotee Ver-2, Rosita 4 Pure White, Excalibur 3 Blue Picotee, Rosita 3 Pink Picotee, Rosita 4 Green and Rosita 3 Blue were utilized in the experiment. Among the cultivars, plant height (104.30cm), number of leaves (55.40), number of shoots per plant (5.0) was the highest in Rosita 4 Pure White and internodal length (9.80 cm) was highest in Rosita 3 Blue PicoteeVer- 2, whereas days taken to flower bud initiation (51.80) was the lowest in Rosita 3 Blue and days taken to flower bud initiation to flower opening (13.40) was lowest in Rosita 4 Pure White. Number of flowers per plant (16.80) and number of petals per flower (18.00) were highest in Rosita 4 Pure White. Bud diameter (5.88 cm) and flower diameter (21.20) were highest in Rosita 4 Green, whereas bud length (4.42 cm) and flower length (4.72 cm) were highest in Rosita 3 Blue PicoteeVer- 2.

***Keywords*:** Eastern ghats, high altitude, lisianthus, performance, tribal zone

INTRODUCTION

Lisianthus (*Eustoma grandiflorum*), commonly called prairie gentian is a member of the family Gentianaceae and is a high-end ornamental cut flower native to warm regions of Northern-South America, Southern-United States, Mexico and the Caribbean islands. Lisianthus is a herbaceous annual growing to 15 to 60 cm tall, with bluish-green, slightly succulent leaves. They possess large funnel-shaped flowers that grows on long straight stems, or branching stems that can growup to eighteen feet tall. Flowers can grow up to two inches and which are found in a varied colour. Lisianthus are long-stemmed flowers in cymes, with often only a few openings at a time. Sepals on lisianthus are only fused close to the base and are much smaller than petals (Namratha *et al.,* 2021).

Lisianthus crop requires a moderate climate and is cultivated at an altitude range of 1,000-1,800 m above MSL and optimum day night temperatures between 20-24°C and 16-18°C respectively. The optimal light levels for lisianthus flowers are 4,000 to 6,000 ft candles. Plants show rosetting if the temperatures are high during seedling up to 3 pairs of leaves (Harbaugh *et al.,* 2000, Ahmad *et al.,* 2017). It is a moderately cold-tolerant annual or biennial plant. Conventionally, it is propagated vegetatively by cuttings and sexually by seeds (Mousavi *et al*., 2012a; Rezaee *et al*., 2012; Uddin *et al*, 2017). Lisianthus is generally a slow growing plant, requiring 5 to 6 months from sowing to flowering (Uddin *et al*., 2013). Reeta *et al*. (2020) suggested that pinching and one to two layers of support netting are required for production of quality flowers in lisianthus.

Lisianthus crop is gaining immense popularity in the floriculture sector worldwide for its thornless rose like appearance and good post-harvest life. These flowers are excellent cut flowers and available in a large range of colours like white, blue, purple, pink and bicolour. Production of lisianthus cut flower industry has risen tremendously in recent years. Spain, Holland, Italy, France and Portugal are the main lisianthus producing countries

(Namesny, 2005 ;Anitha *et al.,* 2019). It is one of the new flower species that is brought to the world market and more recently introduced to the Indian market (Reeta *et al.,* 2020). In European and Asian markets it is already listed among the top selling cut flowers.

The performance of cultivars modifies with the region, season and cultivars, hence it is necessary to evaluate cultivars for their suitability and adaptability regarding growth and floral parameters. There is enormous potential for the production of new flower crops in the High Altitude and Tribal (HAT) zone that comes under the Eastern Ghats region of Andhra Pradesh due to its distinct climatic range which is adequate to grow lisianthus crop. Identification, introduction and evaluation of vital cut flower like lisianthusis required to improve the trade and livelihood of the tribal communities of this region. Up to now, no attempt was made on the evaluation of lisianthus genotypes under the Eastern Ghats region conditions of Andhra Pradesh. By observing these conditions, a field experiment was initiated to select suitable lisianthus cultivars for the HAT zone of Andhra Pradesh.

MATERIALS AND METHODS

A field experiment was conducted at Horticultural Research Station, Dr YSR Horticultural University, Chintapalli, Andhra Pradesh during the period from March 2023 to June 2023 under polyhouse conditions to evaluate different cultivars of lisianthus. The location falls under the Agro-climatic zone of High Altitude and Tribal Zone with an average annual rainfall from South-West monsoon of more than 1300 mm, a maximum temperature range of 17 to 35 ºC, a minimum temperature range from 5 ºC to 24ºC and is located at an altitude of 933 m MSL. The geographical situation is 170.13' N latitude and 840.33' E longitude (Sivakumar *et al.,* 2020). The experiment was laid out in Randomised Block Design with 6 cultivars and 4 replications. Six cultivars of lisianthus seedlings were planted in the main field under a naturally ventilated polyhouse and irrigated at regular intervals. Plant protection measures were taken on a need basis to maintain healthy crop. The experimental field was brought to fine tilth and made into raised beds of 1m width and 4.5 m length to raise each cultivar. Well decomposed farm yard manure was mixed with soil before planting. Six cultivars of lisianthus namely Rosita 3 Blue Picotee Ver-2, Rosita 4 Pure White, Excalibur 3 Blue Picottee, Rosita 3 Pink Picottee, Rosita 4 Green and Rosita 3 Blue were planted at a spacing of 15 cm between rows and 10 cm between plants.

Data on growth parameters *viz*., plant height (cm), number of leaves per plant, number of shoots per plant, internodal length (cm) and floral parameters *viz*., days taken to flower bud initiation, days taken to flower bud initiation to flower opening, flower bud diameter (cm). flower bud length (cm), number of flowers per plant, number of petals per flower, flower head diameter (cm), flower length (cm) and vase life (days) were collected to compare the performance of the cultivars.

RESULTS AND DISCUSSION

Growth parameters: The mean performance for growth parameters showed variation among the cultivars and is given in Table I. The lisianthus cultivars showed significant difference with respect to all growth parameters except the days taken from flower bud initiation to flower opening.

Plant height (cm) : The maximum plant height was observed in Rosita 4 Pure white (104.30cm), followed by Rosita 3 Blue PicoteeVer- 2 (96.20 cm) and the minimum plant height was observed in Rosita 4 Green (78.1 cm). Genotype and environmental factors plays an important role to regulate plant height along with it's overall performance. Uddin *et al.* (2013) stated that plant height of lisianthus is genetically controlled. Similar findings were reported in Bhargav *et al.* (2020) and Ahmad *et al.* (2017); Anitha *et al.* (2019) and Namratha *et al.* (2021).

Number of leaves per plant: The maximum number of leaves was observed in Rosita 4 Pure white (55.40 cm), followed by Rosita 3 Pink Picotee (45.40cm). Namratha *et al.* (2021) stated that the leaves are the functional unit of photosynthesis, which greatly influenced the growth and flower yield of the crop. Lisianthus shows variations in number of leaves among cultivars which is also observed by Ahmad *et al.* (2017); Anitha *et al.* (2019); Bhargav *et al.* (2020) and Namratha *et al.,* (2021).

Table 1: Performance of lisianthus cultivars for growth attributes under high altitude zone Andhra Pradesh

Cultivar	Plant height (cm)	No of leaves per plant	Number of shoots per stem	Internodal length (cm)	Days taken to flower bud initiation	Days taken to flower bud initiation to flower opening
Rosita 3 Blue PicoteeVer- 2	96.20	32.40	4.20	9.80	56.20	13.80
Excalibur 3 Blue Picottee	80.60	32.40	3.20	9.60	56.00	14.60
Rosita 4 Pure White	104.30	55.40	5.00	8.40	61.20	13.40
Rosita 3 Pink Picotee	95.70	45.40	4.00	7.80	55.20	13.60
Rosita 4 Green	78.10	25.80	1.60	8.80	54.40	14.20
Rosita 3 Blue	86.00	35.20	3.00	9.64	51.80	14.40
C.D.	8.84	9.16	2.01	1.24	2.11	NS
SE(m)	**2.98**	**3.09**	**0.68**	**0.42**	**0.71**	**0.41**
C.V.	**7.38**	**18.26**	**43.24**	**10.33**	**2.85**	**6.47**

Table 2: Performance of lisianthus cultivars for floral attributes under high altitude zone of Andhra Pradesh

Cultivar	Number of flowers per stem	No of petals / flower	Bud diameter (cm)	Bud Length (cm)	Flower length (cm)	Flower diameter (cm)	Vase life of flowers (days)
Rosita 3 Blue PicoteeVer- 2	6.00	16.40	5.64	4.42	4.72	18.90	13.80
Excalibur 3 Blue Picottee	5.40	15.20	4.64	3.80	4.24	17.50	10.00
Rosita 4 Pure White	16.80	18.00	5.48	3.50	4.06	19.80	14.60
Rosita 3 Pink Picotee	8.60	12.00	4.64	3.70	4.26	17.60	11.20
Rosita 4 Green	2.80	15.60	5.88	3.58	4.12	21.20	12.80
Rosita 3 Blue	5.60	15.80	5.60	3.60	4.12	19.00	11.60
C.D.	**4.80**	**1.53**	**0.56**	**0.37**	**NS**	**1.32**	**1.51**
SE(m)	**1.62**	**0.51**	**0.19**	**0.13**	**0.18**	**0.44**	**0.50**
C.V.	**47.96**	**7.42**	**7.92**	**7.47**	**9.25**	**5.21**	**9.21**

No of shoots per stem : The highest number of shoots was observed in Rosita 4 Pure white (5.00), followed by Rosita 3 Blue PicoteeVer- 2 (4.20). Namratha *et al.*(2021) stated that variation for number of shoots per stem may be due to genetic behaviour of the cultivar and increased number of branches leads to production of more number of leaves in turn it will enhance the yield of flowers. The results are in line of confirmation with Uddin *et al.* (2015) ; Ahmad *et al*. (2017) and Namratha *et al.* (2021).

Internodal length (cm) : Longest Internodal length was observed in Rosita 3 Blue PicoteeVer-2 (9.80 cm) followed by Rosita 3 Blue (9.64 cm).Namratha *et al.* (2021) stated that the variation in internodal length among the cultivars may be under genetic control and added that higher the internodal length more will be the plant height. Anitha *et al.* (2019) and Namratha *et al.* (2021) also reported similar results.

Days taken to Flower bud initiation: Significant variation was observed in case of days required for flower bud initiation among different lisianthus cultivars. Minimum number of days taken to flower bud initiation was noticed in Rosita 3 Blue (51.80) followed by Rosita 4 Green (54.40). Wazir (2014) observed similar variation in days to visible flower bud and stated that these variations were primarily controlled by genotype which is also supported by Uddin *et al.* (2015) and Ahmad *et al.* (2017). Lines that produce early flowering bud can be sorted as early lines and the others as late (Ahmad *et al*., 2017).

Days taken to Flower bud initiation to flower opening: Variation was observed for days taken to flower bud initiation to flower opening among

different cultivars.The minimum number of days taken to flower bud initiation to flower opening was noticed in Rosita 4 Pure white (13.40) followed by Rosita 3 Pink Picotee (13.60) and maximum was observed in Excalibur 3 Blue picottee (14.6). Similar findings was also observed by Wazir (2014) and Ahmad *et al*. (2017).

Floral parameters: The performance for floral parameters showed variation within the cultivars and are shown in Table 2. Significant difference was observed in all floral parameters excluding flower length among the lisianthus cultivars studied.

Number of flowers per stem : Lisianthus exhibited significant variartion in case of number of flowers per stem. Highest number of flowers per plant was observed in Rosita 4 Pure white (16.80) followed by Rosita 3 Blue PicoteeVer- 2 (6.00) whereas lowest was observed in Rosita 4 Green (2.80). Ahmad *et al*. (2017) stated that variation in flower number is controlled by genotype. Similar variation in number of flowers per stem was observed by Uddin *et al.* (2015) ; Ahmad *et al*. (2017); Namratha *et al.* (2021) and Anitha *et al.* (2019).

No of petals per flower : Variation regarding number of petals per flower was observed among different cultivars of Lisianthus. Number of petals per flower was highest in Rosita 3 Blue PicoteeVer-2 (16.4) and lowest was recorded in Rosita 3 Pink picotee (12.00). Ahmad *et al*. (2017) also observed similar variation and stated that Lisianthus lines are classified in to single and double according to the number of petals in flower. Uddin *et al.* (2015) stated that petal number varied significantly among lisianthus lines.

Bud diameter (cm): Significantvariation in case of bud diameter was recorded in lisianthus. Flower bud diameter was observed highest value in Rosita 4 Green (5.88 cm) and lowest value in Rosita 3 Pink picotee and Excalibur 3 Blue picottee (4.64 cm). Similar variation was observed by Namratha*et al.,* (2021).

Flower head diameter (cm): Lisianthus cultivars expressed significant variation in case of flower head diameter among different cultivars of Lisianthus. The maximum flower head diameter was observed in Rosita 4 Green (21.20 cm) and the minimum was observed in Excalibur 3 Blue picottee(17.5 cm). Similar variation in flower head diameter was also observed by Harbaugh *et al.* (2000), Wazir (2014) and Uddin *et al*. (2015) ; Ahmad *et al*. (2017); Namratha *et al*. (2021) andAnitha *et al.* (2019).

Bud Length (cm): Variation was observed in case of flower bud length in lisianthus cultivars. Flower bud length was observed highest in Rosita 3 Blue PicoteeVer- 2. (4.42 cm) and and lowest was observed in Rosita 4 Pure white (3.5 cm). Similar findings was observed in lisianthus conducted by Anitha *et al.* (2019).

Flower length (cm): Variation was observed in case of flower length in lisianthus cultivars. Flower length was observed highest in Rosita 3 Blue PicoteeVer- 2 (4.72 cm) and lowest was observed in Rosita 4 Pure white (4.06 cm). Similar variation was observed in lisianthus by Anitha *et al.* (2019).

Vase life of flowers (days): The postharvest life of *Eustoma grandiflorum* cut flower is limited by poor bud opening and bent neck in open flowers (Farnaz *et al*., 2014). The vase life of the inflorescence was considered terminated when 50% of the open florets had wilted (Cho *et al*., 2001). Lisianthus showed significant variation in vase life among the cultivars under study. Maximum vase life was recorded by Rosita 4 Pure white (14.60 days) and minimum was recorded by Excalibur 3 Blue Picottee (10.00 days). Similar variation in vase life among different lisianthus cultivars was also reported by Uddin *et al.* (2013); Ahmad *et al.* (2017); Anitha *et al.* (2019) and Bhargav *et al.* (2020).

From the present study, it can be assumed that among the cultivars, Rosita 4 Pure White followed by Rosita 3 Blue PicoteeVer- 2 have performed well under polyhouse conditions of High Altitude and Tribal zone of Andhra Pradesh in view of cut flower attributes like plant height, number of shoots per plant, simultaneous flowering and good vase life. Therefore, it can be popularised for cut flower production under protected conditions in this region. However, further authentication regarding various aspects like yield parameters and standardization of cultural practices in this region may be required for confirmation.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Studies on status, potentiality and distribution of medicinal plants in Karandeniya DS division, Sri Lanka through field and GPS coordinates App. Study

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ABSTRACT

Medicinal plants have been heavily used in traditional medicine. However, most farmers are reluctant to grow medicinal plants due to various reasons. This case study was aimed to analyse the present status, potential, and distribution of forty two medicinal plants in the Karandeniya DS division in Galle district and make suggestions to promote medicinal plant cultivation. In this study, medicinal plants were selected based on priority to conserve (threaten MP, endangered, rare, cultivated species) and economic importance (value added MP). The snowball sampling technique was used to select the samples of 50 households from five GN divisions. Primary data were collected through a field survey using a pre-tested structured questionnaire, and GPS data was collected through GPS coordinates App. Descriptive statistical methods and the Wilcoxon signed rank test were employed to analyze the primary data and GPS data was analyzed by Arc GIS software. The results revealed that the majority of respondents (64%) cultivate medicinal plants at a small-scale level for domestic usage. Some respondents (12%) cultivate medicinal plants for the preparation of value-added products and generate income by selling them. Among them, 64% of respondents are producing turmeric powder, 10 % are producing ginger powder, and8% produce medicinal oil as value-added products at household level. Further, it was revealed that 74% of respondents are willing to produce value-added products, and 90% are willing to expand their medicinal plant cultivation. Overall satisfaction level on medicinal plant cultivation is high where the mean value is 3.76 (1=very low and 5= very high). Results of the Wilcoxon sign rank test showed that respondent's attitudes on medicinal plant cultivation were significant ($p<0.05$).

***Keywords*:** *Karandeniya* DS division, medicinal plants, plant distribution, potential of cultivation, value-added products.

INTRODUCTION

Medicinal plants are defined as having active ingredients used in herbalism or used in drug development and synthesis. In the general traditional system of medicine available in Sri Lanka is four types, namely *ayurveda*, *Siddha*, *Unani*, and *Deshiya Chikitsa* (Jayalath *et al*., 2004). At present, Sri Lanka has 29.7% forest cover and it is known as the most biologically diverse country in Asia (UNFCC, 2017).There are 3771 flowering plant species, out of which about 927 (24%) are endemic to the country (Gunatilleke *et al*., 2008). Cultivation and sustainable harvesting of medicinal plants with scientific knowledge and a proper marketing system might be a great source of additional income for the improvement of the livelihood of rural people (Joshi *et al*., 2014, Zhang, 2018). Medicinal plants offer alternative remedies with tremendous opportunities to generate, income, employment, and foreign exchange for developing countries (Rajeev and Rajamanoharan, 2020). Traditionally the rural poor especially women collected and dried medicinal plants and transported these raw materials to market (Joshi *et al*., 2014).

Medicinal plants are mainly used for traditional medicine, but farmers are reluctant to grow medicinal plants since most young generations are not interested in traditional medical practice because it is less profitable compared to growing

cash crops for many reasons (Rajeev *et al*., 2020). The lack of quality planting materials, unavailability of sufficient land for cultivation and unavailability of raw materials as well as lack of marketing opportunities were identified as major constraints for the development of the medicinal plants industry in Sri Lanka (Dharmadasa *et al.*, 2016). Therefore, the objectives of this study were to examine the present situation of medicinal plant cultivation, to analyze the potential of medicinal plant cultivation, and find the distribution of medicinal plants to conserve valuable plants and enhance the rural livelihood of farmers by value addition. Besides, a request was received from former officer in Charge, (Dr. C. S. Hettiarachchi) Government Medicinal plant garden and research center, Pinnaduwa, Galle, Sri Lanka. They wanted to assess present status, potential, and distribution of medicinal plants in Karandeniya DS division since they have done a lot of trainings, knowledge dissemination and planting material distribution programmes, incentives for cultivation mainly focusing Karandeniya DS division.

METHODOLOGY

This study was carried out in the *Karandeniya* divisional secretary‘s division which is situated in the Galle district. This area is relatively abundant of endangered, threaten and economically important medicinal and aromatic plants in Sri Lanka based on initial field survey, pre tested questionnaire and secondary information.

The study was carried out representing five Grama Niladari (GN) divisions in the *Karandeniya* DS division (Divisional Secretary‘s Division) where mostly the medicinal plants distribution and awareness programs have been conducted. They are namely 93C *Aganaketiya*, 93A *Pahala Kiripedda*, *Borakanda*, 91 *Karandeniya north* and 92F *Mahaedanda*. The households of the *Karandeniya* DS division in the Galle district were selected as the target group.

The sample was selected representing five GN divisions in *Karandeniya* DS division and fifty households were selected by using snowball sampling technique. Accordingly, 10 households were selected from each GN division. The details of villagers were collected from the Karandeniya Attorney General‘s office.

Primary data were collected through a field survey using a pre-tested structured questionnaire and each objective was tested by the questions based on variables extracted from literature. Key medicinal plant species used in this study were Aloe vera (*Aloe barbadensis*), Ginger (*Zingiber officinale*), Turmeric (*Curcuma longa*), Kowakka (*Coccinia grandis)*, Kuppameniya (*Acalypha indica*), Polpala (*Aerva lanata*), Akkapana (*Kalanchoelaciniata*),Heenbovitiya (*Osbeckia octandra*), Hathawariya (*Asparagus falcatus*), Pethithora (*Cassia borneensis*), Thippili (*Piper longum*), Gotukola (*Centella asiatica*), Welpenela (*Cardiospermum halicacabum*), Iramusu (*Hemidesmusindicus*), Neem (*Azadirachta indica*), Endaru (*Ricinus communis*), Heen Nidikumba (*Biophytum reinwardtii*), Heen Maduruthala (*Ocimum tenuiflorum*), Adathoda (*Adelodaserrata*), Heen Udupiyaliya (*Desmodium triflorum*), Neeramulliya (*Astera canthaauriculata*), Babila (*Sidaalnifolia*), Nika (*Vitexnegundo*), Pitawakka (*Phyllanthus niruri*), Tholabo (*Crinum asiaticum*), Beli (*Aeglemarmelos*), Gonika (*Hoya ovalifolia*), Ranawara (*Senna auriculata*), Nil katarodu (*Clitoria ternatea*), Yakinaran (*Atalantia ceylanica*), Ekaweriya (*Rauvolfia serpentina*), Sassada (*Aristolochia indica*),Wathabanga (*Ceodes grandis*), Rasakinda (*Tinospora cordifolia*), Ankenda (*Euodia lunuakenda*), Araththa (*Alpinia calcarata*), Nilawariya (*Indigofera tinctoria*), Weniwel (*Coscinium fenestratum*), Devadara (*Cedrus deodara*), Navahandi (*Rhipsalis baccifera*), Iriweriya (*Plectranthus zatarhendi*), Madan (*Syzygiyum cumini*), Athdemata (*Gmelina arborea*).

To create a map for the distribution of medicinal plants, global positioning system coordinates were taken by the GPS (Global Positioning Systems) Receiver App. Secondary data were collected from research articles, books, journals, and other appropriate sources.The collected data were tabulated and analyzed descriptively. The Wilcoxon signed ranked testwas used to analyze the respondent’s perception towards medicinal plant cultivation with SPSS software. A medicinal plant distribution map was created using GPS coordinates

through Arc-GIS (Geographic Information Systems) Software.

RESULTS AND DISCUSSION

As speculated, the results of this study (Table 1) revealed that the majority of inhabitants who participated in this study cultivated medicinal plants on a small scale in their home gardens. The study revealed that the majority 69% of respondents were above 45 years of age and 50% of respondents belonged to monthly Rs.10, 000 – Rs.25, 000 income levels. Among the respondents 86% were female and the rest were male respondents. However, 44% of respondents had an education level less than the ordinary level.

Present status of medicinal plant cultivation

In the studied sample majority of respondents (96%) have cultivated vegetables, flowers, fruit crops, and medicinal plants while 4% of respondents only cultivated medicinal plants. It implies the majority of respondents tend to cultivate medicinal plants with other crops. Source of the medicinal plants revealed that 90% of plants were cultivated by respondents and 10% of medicinal plants were naturally grown in their home gardens

Table 1: Demographic information of respondents

Variable	Categories	Percentages
Gender	Male	14%
	Female	86%
Age	26-35	14%
	36-45	22%
	46-55	55%
	56 Above	14%
Education level	University	6%
	Advanced level (A/L)	24%
	Ordinary Level (O/L)	26%
	6-9 Grades	36%
	1-5 Grades	6%
	No Schooling	2%
Income distribution(Rs.)	<10,000	4%
	10,000-25,000	50%
	25,000-50,000	34%
	50,000-75,000	10%
	>75,000	2%

Source: Survey data

(Fig. 1).The results revealed that the majority of respondents (56%) used leaves, while 23% used bark, stem, rhizome, bulb, and 14% used whole plants for different purposes such as preparing herbal drinks and cure for burns. Only a few of them used fruits and seeds.

The most dominant 32% type of medicinal plant was herbs (Fig. 2). Results revealed that 64% of cultivated medicinal plants are used only for domestic purposes such as the preparation of herbal drinks, as a spice; cure for burns, and as fruits or leafy vegetables. However, 2% of inhabitants had cultivated medicinal plants only for commercial purposes and 22% of inhabitants had nurtured themfor both domestic and commercial purposes (Fig. 3).

*Aloe barbadensis*was the most abundant species in the *Karandeniya* DS division followed by *Curcuma longa*, *Murraya koenigii*, *Zingiber officinale*, *Azadirachta indica*, *Coccinia grandis*, *Costuss peciosus* and *Centella asiatica* were prominent in that area. The majority of respondents allocate small-scale land areas for medicinal plant cultivation. In terms of land ownership, all of the

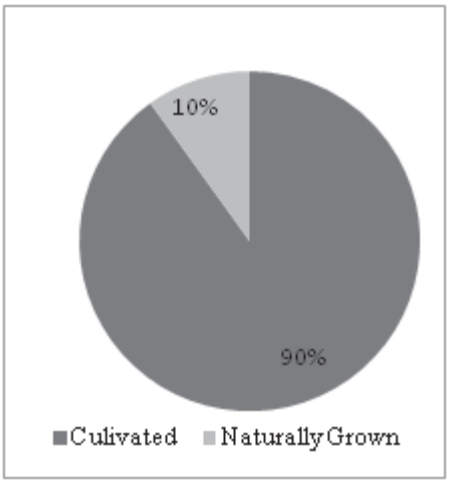

Fig.1 : Origin of medicinal plants

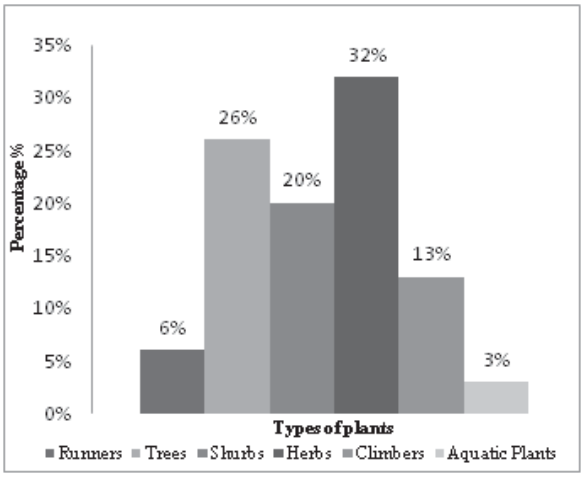

Fig. 2 : Types of plants

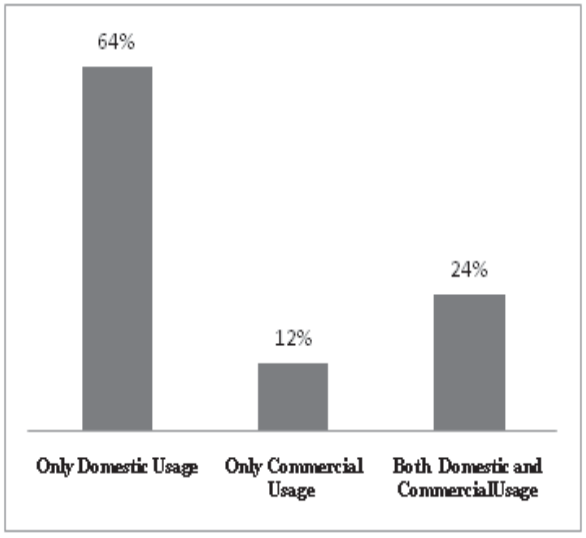

Fig. 3: Different purposes of medicinal plant cultivation

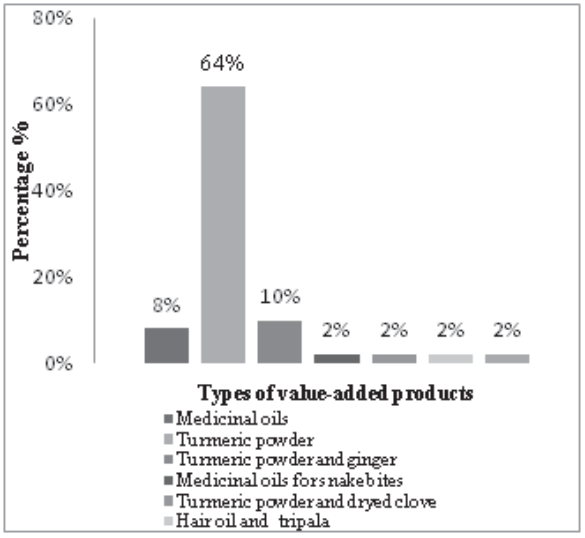

Fig. 4: Different value- added products generated from medicinal plants

respondents had their own lands. As far as cultural practices are concerned, 90% applied organic fertilizer to medicinal plants and practiced manual weeding.

Among respondents, the majority are producing value-added products such as turmeric powder, hair oils, and herbal oils (Fig. 4). Also, some plants, including *Centella asiatica*, *Cardiospermum halicacarbum*, *Casia occidentalis*, *Cassia tora*, *Aerva lanta*, *Alternanthera sessilis*, *Amaranthus viridis*, *Asteracantha longifolia*, *Leucas zeylanica*, *Oxalis corniculata*, are also utilized as veggies that are used to make herbal chymes as well as herbal teas (Ediriweera, 2007). Among all respondents, only 32% marketed their products, and neighbors acted as their primary customers.

Potentials of medicinal plant cultivation

The results revealed that 90% of the respondents are willing to expand medicinal plant cultivation since they have enough land areas compared to urban areas. Further, 74% of respondents were willing to produce value-added products. However, 26%were not willing to produce value-added products. Accordingly, they are willing to produce

value-added products such as ginger powder, turmeric powder, and organically grown *Aloe vera*. Low levels of value addition can be accomplished at the rural level by unskilled rural people. Developed nations also continue to gather high-value goods like mushrooms and medicinal plants for cultural and economic reasons (Schippmann *et al*.,2002). Particularly in India, medicinal plants are considered as industrial crops because its steadily increasing demand as value-added products (Rao *et al.*, 2009).

Perception of medicinal plant cultivation

Respondents' perception level of medicinal plant cultivation was measured by using 5 point Likertscale where 1= strongly disagree and 5= strongly agree considering the statements mentioned in Table 2.

Table 2 : Perception of respondents on medicinal plant cultivation

Criteria	Mean Value	Calculated Z value *	*p*-value**
Medicinal plants are easy to cultivate	4.64	6.40	0.000**
Well aware-of management practices	3.12	5.31	0.000**
Having enough knowledge about medicinal plants	3.06	4.38	0.000**
Aware of value addition	2.66	0.53	0.592
Aware of market opportunities	2.44	-1.41	0.159

Scale 1= strongly disagree and 5=strongly agree.
**Significant at $p<0.05$ level

Table3: Problems faced by respondents

Problems	Mean value	Calculated Z value*	*p*-value **
Lack of marketing opportunities	4.44	6.36	0.000**
Lack of credit facility	4.00	6.15	0.000**
Lack of raw materials	4.34	6.41	0.000**
Low-quality raw materials	4.28	6.47	0.000**
Lack of family support	3.26	4.10	0.000**
Pests and disease problems	2.58	0.18	0.861
Lack of subsidies	4.12	6.38	0.000**
Inability to meet export demand	4.30	6.45	0.000**
Lack of education and training programs	4.32	6.43	0.000**

Scale 1=strongly disagree and 5=strongly agree.
**Significant at $p<0.05$ level

Table4: Suggestions of respondents to improve the medicinal plant cultivation

Statement	Mean value	Calculated Z value*	*p* value**
Conduct awareness programs based on medicinal plant cultivation	4.66	6.41	0.000**
Implementation of proper marketing channel	4.70	6.45	0.000**
Government intervention in medicinal plant cultivation	4.50	6.33	0.000**
Increase the extension services	4.58	6.37	0.000**
Awareness of value additional opportunities	3.70	6.41	0.000**
Provide better planting materials	4.64	6.43	0.000**

Scale: 1= strongly disagree and 5= strongly agree.
**Significant at $p<0.05$ level

Wilcoxon sign ranked test was applied to analyze the data and results revealed that easiness of cultivation, awareness of management practices, and knowledge about medicinal plants were significantly affected by respondent's perception level of medicinal plant cultivation where *p* values of those factors were less than 0.05.

When considering the mean value analysis ofrespondent's perception of medicinal plant cultivation, it was revealed that "easiness of medicinal plant cultivation" has the highest contributionwhere the mean value is 4.64.In contrast, "knowledge of medicinal plant cultivation" has the lowest contribution to the farmers' perception of medicinal plantcultivation where the mean value is 3.06. Perspectives on awareness about value addition and market opportunities need to be enhanced among respondents.

Problems faced by respondents in medicinal plant cultivation

Problems associated with medicinal plant cultivation were measured by using 5 point likert scale where 1=strongly disagree and 5=strongly agree by considering the problems mentioned in Table 3.

Wilcoxon sign ranked test was applied to analyze the data and test results revealed that *p* values of all problems were less than 0.05, except the pests and disease problems. Accordingly, H_0 was rejected for all problems except pests and disease problems. That implies a lack of marketing opportunities; lack of credit facilities, lack of raw materials, low quality raw materials, lack of family support, lack of subsidies, inability to meet export demand, and lack of training programs were significantly affected to medicinal plant cultivation.

Further, mean value analysis revealed that problems such as lack of marketing opportunities, lack of credit facilities, lack of raw materials,low-quality raw materials, lack of subsidies, inability to meet export demand, and lack of training programs were high where mean value was 4. However, the problem related to lack of family support was normal level where the mean value is 3.

Literature reveals in Sri Lanka, it is difficult to find a properly fostered diffusion of knowledge on herbal medicinal systems and their applications to heal ailments. This is due to a lack of financing as well as various issues and limits. If there is a way to address these issues, the Sri Lankan medicinal plant industry could acquire a huge competition in the international market (Perera, 2020).

Suggestions of respondents

Respondent suggestions to enhance medicinal plant cultivation were measured by using 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree by considering the following suggestions as shown in Table 4.

Results of the Wilcoxon sign ranked teat revealed that the *p* values of all suggestions were less than 0.05. Accordingly, H_0 was rejected for all suggestions. That implied conducting awareness programs based on medicinal plant cultivation, implementation of proper marketing channels, government intervention in medicinal plant cultivation, increasing the extension services, awareness on value addition opportunities, and providing better planting materials, can recommended to enhance the medicinal plant cultivation in *Karandeniya* DS division. Further according to the mean values respondents strongly agreed (mean value = 5) on suggestions such as conducting more awareness programs based on medicinal plant cultivation, implementing of proper marketing channels, providing better planting materials, and increasing extension services. Also, they agreed (mean value = 4) on the following suggestions; government involvement in medicinal plant cultivation and awareness of value addition opportunities are important. That implies implementing proper marketing channels has the highest contribution to improving medicinal plant cultivation, while awareness programs on value addition have the lowest contribution to improving medicinal plant cultivation.

Distribution of medicinal plants cultivation

Turmeric (*Curcuma longa*) was the highly available species in 93C Aganaketiya, 93A Pahala Kiripedda, and Borakanda GN divisions, In addition, Aloe vera (*Aloe barbadensis*) was the highly available species in 92F Mahaedanda GN division, Ginger (*Zingiber officinale*) was the highly available species in Karandeniya North GN division.Identified the habitat of valuable, endangered medicinal plant species in selected study and they wereYakinaran (*Atalantiaceylanica*), Ekaweriya (*Rauwolfia serpentina*), Sassada (*Aristolochial indica*), Suriya (*Thespesia populnea*), Wathabanga (*Pisonia grandis*),

Rasakinda (*Tinospora cordifolia*), Ankenda (*Euodialunua-kenda*), Athdemata (*Gmelina arborea*), Araththa (*Alpinia calcarata*), Nilawariya (*Indigoferatimc-toria*), Edaru (*Ricinus communis*), Weniwel (*Coscinium fenestratum*), Devadara (*Cedrusdeo-dara*), Suduhadun (*Santalum albuml*), Navahandi (*Rhipsalis baccifera*).

Uses of medicinal plants by the people of study area

When considering the different uses of medicinal plants, it revealed that respondents were using medicinal plants for preparation of home remedies, for domestic usage, and preparation of some value-added products. Results showed that medicinal plants are mainly use for domestic purposes. Accordingly, most respondents (21%) used medicinal plants as a spice, while 17% of respondents used them as herbal porridgeand 13% of respondent had used as home remedies such as herbal drinks

Mostly people cultivate the medicinal plants for domestic usage, but some cultivate to make value added products and generate some income.Majority of produce is turmeric powder in home level use; some people produce herbal hair oils, medicinal oils for snake bites, kalka, dried cloves as value added products.

CONCLUSIONS

This study concludes that the people willing to use value addition, willing to expand the medicinal plant cultivation and overall satisfaction level about the medicinal plant cultivation is high among people, have positive attitude on easiness of medicinal plant cultivation, awareness on management practices and having knowledge on medicinal plants. Most importantly, there is a good tendency to attract farmers in the *Karandeniya* DS division to cultivate medicinal plants, practice value-addition, and identify the habitat of valuable medicinal plant species.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Effect of biofertilizers and humic acid on vegetative growth parameters in Sat Kara *(Citrus macroptera)* under soil media conditions

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ABSTRACT

An investigation on effect of biofertilizers and humic acid on vegetative growth parameters in Citrus macroptera seedlings under soil media conditions was studied during the period 2022–2023. Result after 2 months of transplanting of seedlings in the soil media, it was revealed that application of Humic acid (T_8) gave maximum plant height (11.63 cm); number of leaves/plant (7.33); leaf area/plant (5.63 cm^2); root length (14.37 cm); number of fibrous root (20); root diameter (1.65 mm); shoot: root ratio (3.98); fresh weight of shoot & root (0.89 g & 0.20 g); dry weight of shoot& root (0.234 g & 0.059 g); vigour index-1 & 2 (1123.33, 22.76); survival % in soil media (96.29%); chlorophyll-a, b & total chlorophyll (1.36 mg/g, 0.69 mg/g, 2.05 mg/g).Thus, the experiment concluded that the treatment T_8- Humic acid, which produced the most favourable results among all treatments, is most promising with results to meet the objectives of the experiment.

***Keywords*:** Biofertilizers, *Citrus macroptera*, humic acid, hydroponics**,** vigour index

INTRODUCTION

Citrus macroptera, also known as Satkara or Hatkora, is a fruit tree in the Rutaceae family. It is a semi-wild species of citrus that is native to Malaysia and is very widespread in India, especially in North East India, particularly in Mizoram and Manipur, where it is most frequently used as a flavouring and aromatic agent. The tree, which has thorns and may grow to a height of 5 m, is known locally as Heiribob. The rind is peeled and added fresh or dried for later use by the people of Manipur (Meitei *et al*., 2012). This tree has many long spines covering its stem, branches, and twigs. Satkara/ Hatkora are mostly used to treat infants' abdomen aches, hypertension, illness, fever, and diarrhoea (Grover *et al*., 2002). According to Rana and Blazquez (2012), the primary chemicals found in the essential oils extracted using hydro distillation from fresh *Citrus macroptera* peels include limonene, beta-caryophyllene, and geranial.Sat Kara is a medicinal plant with a wide range of pharmacological properties. Numerous parts of this plant, particularly the fruit, have a vast array of traditional medicinal uses for treating various illnesses. Many of the plant's active phytochemical components, including limonene, beta-caryophyllene, beta-pinene, geranial edulinine, ribalinine, isoplatydesmine, and others, have been identified thus far. Numerous investigations have shown the pharmacological potential of *C. macroptera's* fruits, leaves, and stems as hepatoprotective, hypoglycemic, thrombolytic, antioxidant, cytotoxic, antibacterial, and anxiolytic agents (Aktar and Foyzun, 2017).

Canellas and Olivares (2014) showed that humic acid consistently exhibits positive impacts on plant biomass and is widely acknowledged as a plant growth promoter, especially by changes in root architecture and growth dynamics, resulting in increased root size, branching, and a higher density of root hair with a larger surface area. In general, humic acid stimulation of root growth is more noticeable than stimulation of shoot growth. Devi *et al*. (2022) reported that among the different biofertilizer treatments application of *Azotobacter+ Trichoderma viride* recorded the maximum plant

height, leaf area/plant, seedling vigour index-I, seedling vigour index-II, fresh weight of shoot & root, and dry weight of shoot & root in Kachai Lemon (*Citrus jambhiri* Lush.). In Manipur, it is cultivated for its fruit peel as spice and its fruit price range from Rs.20-50/piece.

Citrus macroptera is generally propagated by seed since due to lacking of vegetative propagation of this important citrus species. There is no report regarding beneficial effect of biofertilizers and plant growth stimulators on vegetative growth parameters in *Citrus macroptera* grown under soil media conditions. To find out the suitable bio-fertilizer and to know the effect of growth stimulant like humicacid an experiment was therefore taken up.

MATERIALS AND METHODS

The experiment was conducted in the year 2022–2023 at the Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal, Manipur. The matured *Satkara* fruits (*Citrus macroptera)* were collected from Machi village in Tengnoupal district of Manipur. *Satkara* fruits were collected on 21st March, 2022 and seeds were extracted on the same date. After extraction, seeds were dried in laboratory or shade condition for 2 days. The seeds were treated with different treatment combination on 24th March, 2022. 10 seeds for each replication was taken and 30 seeds were treated under each treatment. The biofertilizers was purchased online from a bio-tech company. The biofertilizers were powder form of *Pseudomonas fluorescens (gm/kg of seed), liquid form of Azotobacter,* VAM, *Trichoderma viride* and Humic acid (ml/kg of seed). The seeds were sown in hydroponics on 24th March, 2022. Seedlings were raised in hydroponic condition for early germination and it was done by putting the seeds in the plastic tray and blotting paper are kept in between the thin bamboo stick. There were9 treatments: T_1- *Pseudomonas fluorescens* (5g/kg), T_2- *Azotobacter* (5ml/kg), T_3- VAM(5ml/kg), T_4- *Trichoderma viride* (5ml/kg), T_5- *Pseudomonas fluorescens* (2.5g/kg) + *Trichoderma viride* (2.5ml/kg), T_6- *Azotobacter* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg), T_7- VAM (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg), T_8- Humic acid (Plant growth stimulator) 5ml/kg and T_9- water soaking for about 12 hours (control). Seeds were treated with different biofertilizers for about two minutes. A total of 30 seeds were utilised for each treatment. The experiment was set up using a Completely Randomised Design (CRD), with nine (9) treatments replicated three times.

All of the experimental seeds were routinely maintained and given the right amount of water (proper filling water in hydroponics condition so that water are in contact with blotting paper) during the period of the research. The sprouted seedlings were transplanted from hydroponics condition to soil condition (poly bags) about three months from date of sowing.

The vegetative growth parameters, *viz.*,plant height (cm), number of leaves/plant, leaf area/plant (cm^2), root length (cm), root diameter (mm), number of fibrous root/plant, shoot: root ratio, fresh weight of shoot and root (g), dry weight of shoot and root (g), vigour index 1, vigour index 2, survival % under soil media, volume of the root (cm^3) and chlorophyll content (mg/g) were recorded 2 months after transplanting of seedlings in soil media (poly bags).

Plant height and root length were measured by using measuring scale**.** Leaf area was calculated by using leaf area meter after 2 months of transplanting to the polybags of soil media and it was expressed in square centimetre (cm^2).It is measured with the help of digital vernier calliper. Number of fibrous root was recorded by counting number of fibrous root/plant.

Shoot: root ratio : It is recorded by using the following formulae

$$\text{Shoot root ratio} = \frac{\text{Dry weight of shoot}}{\text{Dry weight of root}}$$

Survival % under soil : It is recorded by using the following formulae

$$\text{Survival \%} = \frac{\text{No.of seedlings survived}}{\text{Total no.of seedlings planted}} \times 100$$

Volume of the root: It was measuredafter 2 months of transplanting in to soil media the saplings were uprooted with care and the volume of the roots were determined by the water displacement method. The uprooted roots after washing were dipped in a measuring cylinder containing water and the readings were recorded before and after the placement of roots. The slight increase in water level was noted as root volume for the specific treatment and expressed in cubic centimetre (cm^3).

Measurement of Chlorophyll a and b: It is recorded by using the following formulae

$$\text{Chlorophyll a} = \frac{[12.7(A663) - 2.69(A645)] \times V}{1000 \times W}$$

$$\text{Chlorophyll b} = \frac{[22.9(A645) - 4.68(A663)] \times V}{1000 \times W}$$

$$\text{Total Chlorophyll content (mg/g)} = \frac{[20.2(A645) + 8.02(A663)] \times V}{1000 \times W}$$

Where ; V = final volume of chlorophyll extract in 80% acetone

W = fresh weight of tissue extracted

Vigour index: 1 (VI-1) was calculated using the following formula given by Abdul Baki and Anderson (1973).

VI-1 = Seedling length x Germination percentage

Vigour index: 2 (VI-2) was calculated as per the formula given by Bewley and Black (1982).

VI-2 = Seedling dry weight x Germination percentage

RESULTS AND DISCUSSIONS

Germination percentage

Germination percentage 2 months after sowing indicated that (Table 1) the treatment T_8-Humic acid having performed significantly more effectively than all the other treatments, produced the greatest seed germination percentage (96.67%). T_1- *Pseudomonas fluorescens* and T_3- VAM followed, with a mean of 76.67%, in that order. T_4- *Trichoderma viride*, T_5- *Pseudomonas fluorescens*+ *Trichoderma viride* and T_7- VAM + *Trichoderma viride* all showed similar mean values of 56.67%. Besides, T_9- Water soaking (control) had the lowest seed germination rate (50%), which was extremely lower than the results from the other treatments. The results of humic acid treated *Citrus macroptera* seeds improved vegetative growth might be due to it provides the plant with basic organic nutrients and major and minor mineral elements in addition to its high ability to retain water and high oxygen content, which aids in seed germination through its role as a catalyst, allows the seed to absorb nutrients. Further, it might be due to the respiration of seed tissue cells helps the embryo quickly transition from the non-self-feeding stage to the self-feeding stage within the seed. Besides, it promotes plant growth by boosting hormones like auxin and cytokinin that help with photosynthesis, stress resistance, and absorption of nutrients. Similar finding is also reported by Hussein *et al.* (2020) and Ampong *et al.* (2022).

Plant height (cm)

The information on the impact of biofertilizers and plant growth stimulator on seedling height of *Citrus macroptera* were significantly varied between the treatments (Table 1). The treatment T_8- Humic acid (11.63 cm) have highest maximum plant height, then T_5- *Pseudomonas fluorescens*+ *Trichoderma viride* (8.57 cm). Whereas, the lowest plant height (6.0 cm) was present in T_9- water soaking (control).The results from this study indicated that foliar application of humic acid considerably affected plant height, with the maximum value for this parameter obtained under 2% humic acid foliar spray and the lowest value for this parameter recorded under control conditions (Sani, 2014).

Number of leaves/plant

In Table 1, the statistical information obtained from the current study about the number of leaves/ plant (under soil condition) is presented. The treatment T_8- Humic acid (7.33) resulted in maximum number of leaves/plant. Whereas, the lowest no. of leaves/plant was recorded in T_7- VAM + *Trichoderma viride* (3.67) as compared to the

Table 1: Effect of Biofertilizers and humic acid on vegetative growth parameters of *Citrus macroptera* seedlings

Treatment	Details	Plant height (cm)	Number of leaves/ plant	Leaf area/ plant (cm^2)	Root length (cm)	Root diameter (mm)	Number of fibrous root	Shoot: root ratio	Seed germination (%)
T_1	*Pseudomonas fluorescens* (5g/kg)	7.40	4.33	3.53	11.00	1.14	8.67 (0.93)	3.12	76.67 (61.22)
T_2	*Azotobacter*(5ml/kg)	7.13	5.00	2.87	12.03	1.18	15.00 (1.18)	2.45	60.00 (51.15)
T_3	*VAM* (5ml/kg)	8.03	5.67	3.40	12.00	1.26	12.67 (1.04)	2.85	76.67 (61.22)
T_4	*Trichoderma viride* (5ml/kg)	6.90	5.33	2.70	10.57	1.21	15.00 (1.17)	1.78	56.67 (48.93)
T_5	*Pseudomonas fluorescens* (2.5g/kg) + *Trichoderma viride* (2.5ml/kg)	8.57	5.33	3.97	13.83	1.25	19.00 (1.28)	2.27	56.67 (48.93)
T_6	*Azotobacter* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	7.67	5.00	3.93	12.70	1.22	10.67 (0.96)	2.40	60.00 (50.85)
T_7	*VAM* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	6.47	3.67	3.23	10.27	1.19	12.00 (1.06)	2.21	56.67 (48.85)
T_8	Humic acid (Plant growth stimulator) 5ml/kg	11.63	7.33	5.63	14.37	1.65	20.00 (1.30)	3.98	96.67 (83.86)
T_9	Water soaking (control)	6.00	4.00	2.67	9.40	1.08	6.00 (0.74)	2.14	50.00 (45.00)
	S.Em±	**0.63**	**0.51**	**0.45**	**1.01**	**0.09**	**0.10**	**0.36**	**4.28**
	CD @ 5%	**1.87**	**1.51**	**1.34**	**3.01**	**0.28**	**0.31**	**1.08**	**12.71**

*Fig in the parenthesis are square root transformed values

Tables 2: Effect of Biofertilizers and humic acid on fresh weight of shoot &root, dry weight of shoot&root, VI-1, VI-2 and survival %of *Citrus macroptera* seedlings under soil media condition

Treatment	Details	Fresh shoot weight (g)	Fresh Root weight (g)	Dry shoot weight (g)	Dry root weight (g)	Vigour index-1	Vigour index-2	Survival % under soil
T_1	*Pseudomonas fluorescens* (5g/kg)	0.25	0.08	0.061	0.023	566.00	4.70	93.33 (9.69)
T_2	*Azotobacter* (5ml/kg)	0.26	0.13	0.066	0.028	422.67	4.23	91.67 (9.60)
T_3	*VAM* (5ml/kg)	0.29	0.14	0.078	0.033	610.00	5.86	81.11 (9.02)
T_4	*Trichoderma viride* (5ml/kg)	0.25	0.17	0.067	0.038	391.00	3.82	95.24 (9.78)
T_5	*Pseudomonas fluorescens*(2.5g/kg) + *Trichoderma viride* (2.5ml/kg)	0.37	0.18	0.096	0.042	502.67	5.48	86.67 (9.34)
T_6	*Azotobacter* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	0.28	0.11	0.070	0.029	465.33	4.23	82.14 (9.09)
T_7	*VAM* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	0.22	0.10	0.054	0.028	339.00	2.66	93.33 (9.69)
T_8	Humic acid (Plant growth stimulator) 5ml/kg	0.89	0.20	0.234	0.059	1123.33	22.76	96.29 (9.84)
T_9	water soaking (control)	0.20	0.09	0.048	0.022	325.00	2.68	80.55 (8.99)
	S.Em±	**0.04**	**0.02**	**0.012**	**0.004**	**64.71**	**1.19**	**0.20**
	CD @ 5%	**0.13**	**0.07**	**0.034**	**0.013**	**192.26**	**3.54**	**0.60**

*Fig in the parenthesis are square root transformed values

Tables 3: Effect of Biofertilizers and humic acid on volume of the root, chlorophyll-a, b, total chlorophyll of *Citrus macroptera* seedlings

Treatment	Details	Volume of the root (cm^3)	Chlorophyll-a (mg/g)	Chlorophyll-b (mg/g)	Total Chlorophyll (mg/g)
T_1	*Pseudomonas fluorescens* (5g/kg)	0.20	0.89	0.25	1.13
T_2	*Azotobacter* (5ml/kg)	0.20	0.88	0.25	1.13
T_3	*VAM* (5ml/kg)	0.33	1.16	0.52	1.69
T_4	*Trichoderma viride* (5ml/kg)	0.22	0.99	0.32	1.31
T_5	*Pseudomonas fluorescens* (2.5g/kg) + *Trichoderma viride* (2.5ml/kg)	0.23	1.06	0.23	1.29
T_6	*Azotobacter* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	0.13	1.08	0.45	1.52
T_7	*VAM* (2.5ml/kg) + *Trichoderma viride* (2.5ml/kg)	0.17	0.93	0.29	1.22
T_8	Humic acid (Plant growth stimulator) 5ml/kg	0.30	1.36	0.69	2.05
T_8	Water soaking (control)	0.10	0.84	0.20	1.04
	S.Em±	**0.006**	**0.061**	**0.027**	**0.012**
	CD @ 5%	**0.017**	**0.182**	**0.081**	**0.036**

water soaking (control). According to Mohammadipour *et al.* (2012), the best treatment for humic acid at 2000 mgL^{-1}, which resulted in 46.02 leaves per plant, whereas the least successful treatment was the control, which resulted in 30.67 leaves per plant in marigold. Further, Türkmen *et al*. (2004) reported that plant number of leaves was greatly impacted by humicacid treatments and tomato seedlings had the more leaves when HA_3 was applied.

Leaf area/plant (cm^2)

In the Table 1 clearly shows that the treatment T_8- Humic acid produced the largest leaf area per plant (5.63 cm^2), followed by T_5- *Pseudomonas fluorescens*+ *Trichoderma viride* (3.97 cm^2). In contrast, T_9- water soaking (control) produced the lowest leaf area per plant (2.67 cm^2). Motaghi and Nejad (2014) showed that application of 100 ppm humic acid during the vegetative growth stage resulted in the highest leaf area index compared to other treatments, whereas the control treatment had the lowest leaf area index.

Root length (cm)

In the Table 1, the maximum root length was obtained by Treatment T_8- Humic acid (14.37 cm), while the lowest root length (9.40 cm) across all the treatments was recorded by treatment T_9, water soaking (control). There was report about role of Humic acid in promoting seedlings' root growth in maize (*Zea mays*) (Canellas *et al*., 2002).

Root diameter (mm)

The data presented in Table 1 clearly show that the root diameter reacts significantly to the various treatments. The maximum root diameter (mm) was recorded in T_8- Humic acid (1.65 mm), followed by T_3- VAM (1.26 mm) and T_5- *Pseudomonas fluorescens*+ *Trichoderma viride* (1.25 mm). However, the treatment T_9- water soaking (control) was recoded lowest values (1.08 mm). Humic acid-Nitrogen treatment significantly increased root diameter and root surface area of sweet potato (Chen *et al.,* 2017).

Number of fibrous root/plant

The statistical analysis of Table 1, indicated that the various biofertilizers and their combinations had a significant impact on the number of fibrous roots that were observed under soil media condition. The maximum number of fibrous root (20) was obtained in T_8- Humic acid, followed by T_5- *Pseudomonas fluorescens*+ *Trichoderma viride* (19). The minimum number of fibrous root (6) was recorded in T_9 -water soaking (control).The effect of Humic acid treatment markedly increased the number of fibrous roots in tomato plants as compared to control (Sun *et al*., 2022).

Shoot: root ratio

Among the different treatment, T_8- Humic acid have the maximum shoot: root ratio (3.98), followed by T_1- *Pseudomonas fluorescens* (3.12) and T_3- VAM (2.85), whereas the T_4- *Trichoderma viride* gave the lowest shoot: root ratio (1.78). Meganid *et al.* (2015) reported that the shoot/root ratio increased with the addition of humic acid at 30 DAP in common bean plant.

Fresh weight of shoot and root (g)

The maximum fresh weight of shoot (0.89 g) and fresh root weight (0.2 g) was observed under soil in treatment T_8- Humic acid. However, the lowest fresh weight of shoot and root was recorded in T_9- water soaking (control) has mean values (0.20 g) and T_1- *Pseudomonas fluorescens* (0.08 g), respectively. The application of HA_2 led to the highest shoot and root fresh weights in tomato seedlings was observed by Türkmen*et al*. (2004). According to Meganid *et al.* (2015) results showed that at 15, 30, and 45 days after planting, humic acid application greatly raised the fresh and dry weights of the shoots and roots of common bean plant as compare to the control.

Dry weight of shoot and root (g)

The T_8- Humic acid had the maximum dry weight of shoot (0.234 g) and dry root weight (0.059 g), while the lowest dry weight of the shoot and root (0.048 g) & (0.022 g) was observed in T_9- water soaking (control). Türkmen *et al*. (2004) also reported that tomato (*Lycopersicon esculentum* L.) seedlings under saline soil conditions shoot and root dry weights were higher at HA_2 application than at other levels.

Vigour index-1 (VI-1) and Vigour index-2 (VI- 2)

The various treatments have a significant influence on the VI-1 and VI-2. Among the different treatment, the highest VI-1 (1123.33) and VI-2 (22.76) was observed under the T_8- Humic acid, while lowest mean VI-1 and VI-2 was found under the T_9- control (water soaking) and T_7- VAM + *Trichoderma viride*, (325) & (2.66), respectively. Ali *et al*. (2020) reported that Humic acid exhibited most impacts on the seedling vigour index in sorghum plant. According to Weerasekara *et al.* (2021) priming soybean seeds treated with humic acid for 3,5 and 7 hours which enhances the germination with the increase of time and increases the seedling vigour index as compared to control.

Seedlings survival (%)

The maximum survival % under soil condition (96.29 %) was observed in the treatment T_8- Humic acid followed by T_4- *Trichoderma viride* (95.24). The treatment T_9- water soaking (control) obtained the lowest mean values (80.55 %). According to Justi *et al.* (2019), plants treated with humic acid may have a higher chance of surviving of coffee seedlings in the field. Nasratullah (2020) observed that the application of humic had the largest number of survival seedlings (98.67%) of Rangpur Lime as compared to the control.

Volume of the root (cm^3)

The maximum root volume among the various treatments was reported in T_3- VAM (0.33 cm^3), which was noticeably greater compared to all other treatments. T_8- Humic acid came second, with a root volume of (0.30 cm^3) and it was statistically at par with T_3. In T_9- water soaking (control), the lowest root volume (0.10 cm^3) was recorded. The growth of a prolific root system during treatment may be the cause of the larger root volume. VAM expand their hyphae into the host root system and assist in the expansion of the plant's root system, which improves the plant's ability to absorb nutrients & water, and also helps in root growth and stimulates the growth of the whole plant. Maximum root volume (10.34 cm^3) under the treatment of *Azospirillum*, PSB, *Pseudomonas fluorescens*, and VAM was recorded by Fayaz *et al.* (2020) at 120 days in pummelo seedlings.

Chlorophyll content (mg/g)

It is clearly shown, that the treatment T_8- Humic acid had the highest mean value of the treatments, producing the highest amount of chlorophyll-a (1.36 mg/g), chlorophyll-b (0.69 mg/g), and total chlorophyll (2.05 mg/g), followed by T_3- VAM, which recorded chlorophyll-a (1.16 mg/g), chlorophyll-b (0.52 mg/g) and total chlorophyll (1.69 mg/g). while, treatment T_9- water soaking (control) had the lowest mean values for chlorophyll-a (0.84 mg/g), chlorophyll-b (0.20 mg/g), and total chlorophyll (1.04 mg/g) in comparison to other treatments. Meganid *et al.* (2015) showed that application of humic acid at 15, 30, and 45

DAP respectively in common bean plants had considerably higher chlorophyll levels than control plants. According Karakurt *et al*. (2009) application of humic acid had a significant impact on the total chlorophyll concentration, with chlorophyll b having the most significant impact in pepper plant. Further, Ali *et al.* (2020) also revealed that seeds treated with 6 g of humic acid per kg^{-1} of soil resulted in maximum chlorophyll-b and total chlorophyll in sorghum seedlings at a salinity level of 200 mM NaCl.

CONCLUSION

From the present investigation, it was found that the different biofertilizers singly and their combination and humic acid have positive effects on growth parameters of *Citrus macroptera* seedlings. Among the various treatments, it was observed that humic acid @ 5 ml/kg executed the best result with respect to plant height, number of leaves/plant, leaf area/plant, root length, number of fibrous root, root diameters, shoot: root ratio, fresh weight of shoot & root, dry weight of shoot & root, vigour index-1 & 2, survival % under soil condition, chlorophyll-a, b & total chlorophyll, so that it can be used for obtaining a higher number of seedlings of *Citrus macroptera.*

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Response of boron and zinc on growth, yield and quality of papaya cv. Red Lady

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ABSTRACT

The current study was carried out in Uttar Banga Krishi Viswavidyalaya Pundibari, West Bengal, in 2021–2022 to evaluate the response of micronutrients on papaya performance. The treatments were different concentrations of zinc and boron (T_1- distilled water sprayed; T_2- Borax 0.25%; T_3- Borax 0.5%; T_4- Zinc sulphate 0.25%; T_5- Zinc sulphate 0.5%; T_6-Borax 0.25% + Zinc sulphate 0.25%; T_7- Borax 0.25% + Zinc sulphate 0.5% ; T_8- Borax 0.5% + Zinc sulphate 0.25% and T_9 Borax 0.5% + Zinc 0.5%) with three replications. The findings showed that Borax 0.5% + Zinc sulphate 0.25% had the highest plant height at first flowering (93.17 cm) and at first harvesting (184.08 cm); plant girth at first flowering (18.58 cm) and at first harvesting (37.75 cm); plant spread E-W and N-S spread at first flowering (105.00 and 107.50 cm) and at first harvesting (199.92 cm and 202.75 cm) with maximum fruit yield of 25.47 kg. The treatment Borax 0.5% + Zinc sulphate 0.5% resulted inhighest total leaf count per plant at first flowering (32.50) and total soluble solids (12.83 ^oB) with lowest acidity (0.140%).

***Keywords*:** Fruit yield, growth, micronutrients, papaya, total soluble solids

INTRODUCTION

Papaya (*Carica papaya* L.) is a rapidly growing, short-lived perennial plant in the family Caricaceae (Siriwardana *et al.,* 2019). It is one of the major fruit crops grown in tropical and subtropical areas of the world (Eda, 2023). It is planted largely for its mouthwatering fruits, which are savoured both fresh and in different processed forms. Along with mangoes and pineapples, papaya is one of the most frequently produced fruits in the world. Its popularity is due to its adaptation to tropical temperatures, which accounts for around 15.36% of the world's total production of tropical fruits (Godi *et al.,* 2020). Papaya, the "common man's fruit," is a powerhouse of essential vitamins, fiber, and minerals. Its low fat and protein content make it a low-calorie fruit. The fruit's pharmaceutical properties have led to its use in traditional medicine for treating various disorders. The latex of unripe papaya contains chymopapain and lycopene, used for treating herniated lower lumbar vertebrae and preventing various types of cancer, respectively. Papaya juice helps alleviate colon infections, and the presence of vitamins A and C aids in improving eyesight and strengthening the immune system. Fresh green papaya leaves can be used as antiseptics, whereas brown leaves are a great tonic for blood-purifying activity (Koul *et al.,* 2022).

Lack of micronutrients create major issue that hampers soil and plant vigour all around the world and it reduces production (Imtiaz *et al.,* 2010). Micronutrients are required for betterplant development, blooming, improved fruit set, increased quality of higher fruit production and

longer shelf life of horticulture commodities (Raja, 2009; Shekhar *et al.,* 2010).

Indian soils have mild zinc and boron deficiencies and availability in the range of 40-55 percent and 25-30 percent, respectively. Micronutrient deficiencies have significant negative impact on crop improvement and sustainable viability of crops across different regions of India (Kumar *et al.,* 2011). Various biological activities, including photosynthesis, the synthesis of nucleic acids, proteins, and carbohydrates as well as the ability to resist biotic and abiotic challenges are all affected by Zn (Cakmak, 2008).

One of these study gaps relates to the efficient utilisation of micronutrients in papaya, such as zinc and boron. Fruit growers are quite concerned about the papaya micronutrient deficit issue. An efficient technique to complete and improve plant nutrition is foliar spray. Foliar spray can fill up nutrient deficiencies caused by stressed plants or poor soil conditions that prevent plants from absorbing nutrients from the soil. Micronutrient foliar sprays are efficient and have a rapid effect on plants. Requirement of micronutrients and their dose vary from crop to crop even variety to variety within the same crop. Besides, agro-climatic factor is another key point that interact with the crop, to be grown in a particular locality. There are little report on effect of zinc and boron on Red Lady variety of Papaya grown in Sub-Himalayan Terai area. With this view, an experiment was conducted to know the effect of boron and zinc and their combination on plant growth, fruit yield and quality.

MATERIALS AND METHODS

The field trial took place between 2021-2022 at the Instructional Farm, Department of Pomology and Postharvest Technology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. The location is 82 metres above mean sea level, longitude 89° 23′ 5″ E and latitude 26° 19′ 86″ N, within West Bengal's Sub-Himalayan Terai area. The experimental field was sandy loam in texture, acidic in nature with a soil pH of 5.52. Physico-chemical properties of soil were as follows – sand (62.31%), silt (20.55 %), clay (11.2 %) Organic carbon (0.75%), available nitrogen (216.5 Kg/ha), available phosphorous (18.24 kg/ha) and available potassium (112.63 kg/ha), available boron in soil (0.68 kg/ha) and DTPA Zinc (0.73 kg/ha).

Healthy papaya cv. Red Lady seeds were dipped in gibberellic acids (200 ppm) for 12 hours and then seeds were sown on polybags containing the rooting media (soil, cocopeat and sand in a ratio of 1:1:1) at the greenhouse which is located at Instructional Farm, Uttar Banga Krishi Vishwavidyalaya, Coochbehar, West Bengal. Papaya saplings were transplanted into the main field at row to row and plant to plant distance of 2 x 2 m. When plants were reached 8 leaves stage, the experiment was started with 9-treatments and each treatment was replicated three times, taking four plants in each replication, using a randomised block design (RBD). In each treatment of each replication, four plants were chosen. Nine different treatment combinations were used, including T_1- distilled water sprayed, T_2- Borax 0.25%, T_3- Borax 0.5%, T_4- Zinc sulphate 0.25%, T_5- Zinc sulphate 0.5%, T_6- Borax 0.25% + Zinc sulphate 0.25%, T_7- Borax 0.25% + Zinc sulphate 0.5%, T_8- Borax 0.5% + Zinc sulphate 0.25%, T_9 Borax 0.5% + Zinc 0.5%.

Before planting in each plot, the required dose of FYM @ 20 tonnes/ha was applied. Starting with the transplanting of seedlings, the recommended dosage of fertilisers (200g N, 200g P, and 250g K/ plant) was applied in four equal splits at two-month intervals in the form of urea, single super phosphate, and muriate of potash. After transplanting in the main field, the micronutrients were treated twice as foliar applications at 60 and 120 days.

The observations were made on different characters, viz., plant height and stem girth at first flowering and first harvesting, plant spread east-west and north-south at first flowering and first harvesting, total leaf count at first flowering, fruit firmness, total soluble solids, titrable acidity and yield per plant was recorded. The parameters were analysed using the statistical application OPSTAT.

RESULTS AND DISCUSSION

Growth attributes

The spraying of micronutrients significantly improved all papaya growth parameters (Tables 1 and 2). T_1 recorded considerably lower plant height (74.58 cm and 155.17 cm, respectively) than T_8, which had significantly higher plant height at first flowering (93.17 cm) and first harvesting (184.08 cm). The highest plant girth of the plant was

Table 1: Effect of micronutrient on plant height and plant girth of papaya *cv.* Red Lady

Treatment	Plant height at first flowering (cm)	Plant height at first harvesting (cm)	Plant girth at first flowering (cm)	Plant girth at first harvesting (cm)
T_1 - Control (distilled water sprayed)	74.58	155.17	12.33	28.92
T_2 - Borax @ 0.25%	79.17	161.58	13.42	30.25
T_3 - Borax @ 0.5%	85.83	167.33	14.25	31.50
T_4 - Zinc sulphate @ 0.25%	90.33	179.92	13.83	31.58
T_5 - Zinc sulphate @ 0.5%	92.25	175.08	15.67	33.42
T_6 - Borax @ 0.25% + Zinc sulphate @ 0.25%	81.33	172.83	15.00	34.17
T_7 - Borax @ 0.25% + Zinc sulphate @ 0.5%	87.25	178.00	15.92	35.83
T_8 – Borax @ 0.5% + Zinc sulphate @ 0.25%	93.17	184.08	18.58	37.75
T_9 - Borax @ 0.5% + Zinc sulphate @ 0.5%	90.50	180.75	17.08	36.17
SEm (±)	**0.70**	**4.01**	**0.50**	**0.42**
LSD (0.05)	**2.12**	**12.12**	**1.53**	**1.28**

Table 2: Effect of micronutrient on total leaf count and plant spread of papaya *cv.* Red Lady

Treatment	No. of leaves at first flowering	Plant spread E-W(cm) at first flowering	Plant spread E-W (cm) at first harvesting	Plant spread N-S (cm) at first flowering	Plant spread N-S (cm) at first harvesting	Yield per Plant (Kg/Plant)
T_1 - Control (distilled water sprayed)	19.92	91.58	180.25	93.33	183.17	12.23
T_2 - Borax @ 0.25%	24.08	95.83	187.92	97.17	190.75	15.08
T_3 - Borax @ 0.5%	26.75	98.42	190.33	100.33	192.67	17.19
T_4 - Zinc sulphate @ 0.25%	28.17	97.33	187.58	100.08	191.33	17.90
T_5 - Zinc sulphate @ 0.5%	30.58	96.92	195.42	101.58	197.25	19.98
T_6 - Borax @ 0.25% + Zinc sulphate @ 0.25%	25.25	99.75	192.67	101.08	192.08	18.72
T_7 - Borax @ 0.25% + Zinc sulphate @ 0.5%	26.00	101.75	194.08	103.17	195.50	22.88
T_8 – Borax @ 0.5% + Zinc sulphate @ 0.25%	29.17	105.00	199.92	107.50	202.75	25.47
T_9 - Borax @ 0.5% + Zinc sulphate @ 0.5%	32.50	102.17	195.83	104.67	198.92	22.41
SEm (±)	**0.38**	**1.24**	**1.44**	**0.83**	**1.26**	**0.63**
LSD (0.05)	**1.15**	**3.73**	**4.36**	**2.52**	**3.81**	**1.91**

recorded in T_8 at first flowering (18.58 cm) and at first harvesting (37.75 cm) and lowest at T_1 (12.33 cm and 28.92 cm) respectively. The total leaf count per plant at first flowering was highest in T_9 (32.50) and lowest in T_1 (19.92 cm). The maximum plant spread at first flowering in both directions (east-west, north-south) was recorded in T_8(105.00 and 107.50 cm) similarly highest plant spread at first harvesting in both directions (east-west, north-south) was also recorded in T_8 (199.92 cm and 202.75 cm respectively).

It was noted that zinc and boron singly and in combination increased plant height and plant spread

Table 3: Effect of micronutrient on fruit firmness, TSS,titrable acidity of ripe papaya*cv.* Red Lady

Treatment	Fruit firmness (Kg/cm^2)	TSS (^oB)	Titrable acidity (%)
T_1 - Control (distilled water sprayed)	5.75	9.36	0.158
T_2 - Borax @ 0.25%	6.04	9.92	0.154
T_3 - Borax @ 0.5%	6.29	10.77	0.152
T_4 - Zinc sulphate @ 0.25%	6.47	10.90	0.151
T_5 - Zinc sulphate @ 0.5%	6.84	11.58	0.148
T_6 - Borax @ 0.25% + Zinc sulphate @ 0.25%	6.66	11.35	0.151
T_7 - Borax @ 0.25% + Zinc sulphate @ 0.5%	6.75	11.48	0.146
T_8 – Borax @ 0.5% + Zinc sulphate @ 0.25%	6.98	12.34	0.144
T_9 - Borax @ 0.5% + Zinc sulphate @ 0.5%	7.12	12.83	0.140
SEm (±)	**0.10**	**0.32**	**0.002**
LSD (0.05)	**0.30**	**0.96**	**0.006**

(east-west and north-south) may be due to enhancing respiration and photosynthesis. Zinc is essential for nitrogen metabolism, auxin synthesis, cell division, and enlargement, promoting overall plant growth. Boron promotes the development of cell walls, maintains the structural integrity of cell membranesand aids in the movement of sugars and energy into the active areas of plants. Singh *et al.* (2010) and Jeyakumar *et al.* (2001) found increased plant height with boron and zinc sprays in papaya. Zinc and boron also contribute to increased plant girth by boosting metabolic activities, leading to cell division and elongation. When zinc and boron were applied as a foliar spray to papaya plants, Singh *et al.* (2010) and Jeyakumar *et al.* (2001) noted similar impacts on plant girth. Furthermore, the application of zinc and boron increases the total leaf count per plant due to enhanced photosynthetic substances and chlorophyll, which in turn encourages the development of leaf buds, cell division and expansion, delays the senescence of leavesand improves leaf persistence (Sajid *et al.*, 2010).

Fruit yield

Reviewing the data in Table 2 showed that foliar sprays of both micronutrients had significant impacts on papaya production per plant under various treatments. T_8 (Borax @ 0.5% + Zinc sulphate @ 0.25%) produced a much higher fruit production (25.47 kg), whereas control plants produced the lowest fruits fruit production (12.23 kg).This results confirmed the beneficial effect of micro-nutrients on papaya yield and the results was supported with the findings of Singh *et al.* (2010), and Modi *et al.* (2012).

The application of zinc and boron enhanced the output per plant, which can be attributed to more fruits. Boron application may have a positive effect on carbohydrate and RNA metabolism, leading to a significant increase in yield. Treatment with zinc increases both the rate of photosynthesis and the carbonic anhydrase activity in leaves.

Fruit quality attributes

When applied as a foliar spray, both the micronutrients had significant effects on papaya's fruit quality attributes (Table 3). Treatment with Borax @ 0.5% + Zinc sulphate @ 0.5% (T_9) recorded the highest fruit firmness (7.12 Kg/cm^2) and TSS (12.83 ^oB). While, the minimum value of fruit firmness, total soluble solid were recorded in treatment T_1 (control). At T_9 (Borax @ 0.5% + Zinc sulphate @ 0.5%), titrable acidity percent was considerably lowest among the treatments (0.140%) and highest under control (0.158%).

When applied as a foliar spray, both the micronutrients had significant effects on papaya's fruit quality traits, which might be due to the catalytic activity of both the micronutrients, as well as their synergistic impact, particularly at higher concentrations, may be responsible for the increased accumulation of TSS in fruits. According to theory, boron speeds up the transfer of sugars from leaves to developing fruits which hep to increase in TSS. Singh *et al.* (2010) and Rawat *et*

al. (2010) also observed beneficial effects of both the micronutrient on TSS concentration in papaya and guava, respectively. Additionally, the decrease in titrable acidity of papaya fruits with the application of both micronutrient and their combinations may be due to these micronutrients' beneficial effects on the speedy conversion of acids into sugars and their derivatives, possibly through the reversal of the glycolic pathway or their use as substrates in respiration. These results support the papaya research conducted by Singh *et al.* (2010).

CONCLUSION

According to the findings of the current experiment, T_8 (Borax @ 0.5% + Zinc sulphate @ 0.25%) had maximum positive impact on plant growth and higher production of quality papaya over control (with no micro-nutrient). Whereas, T_9 (Borax @ 0.5% + Zinc sulphate @ 0.5%) had maximum positive impact over control when it comes to production of papaya cv. Red Lady grown in Terai region of West Bengal.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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In vitro propagation of *Zamoculcas zamipholia* LODD., through indirect regeneration

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ABSTRACT

The Zamoculcas zamifolia LODD., commonly known as ZZ Plant, is considered as an ornamental foliage plant that its growing is recently getting into consideration in Iran. This plant is a virtuous choice for indoor use, due to its wonderful performance even without taking special care. The plant is naturally slow grown species and its propagation through conventional methods is also sluggish. So, due to these reasons, ZZ plant has got an expensive price in the market. Application of modern techniques such as micropropagation may provide its mass multiplication in shorter period as compared to conventional methods. In the present research work, the feasibility of in vitro propagation of this plant was evaluated. This experiment was undertaken as completely randomized design. The leaf segments procured from a healthy mother plant were surface sterilized with Colorax (Sodium Hypochlorite) and $HgCl_2$ and inoculated under in vitro conditions. The results showed that leaf explants of Zamoculcas may be efficiently established on MS medium comprising BA (2.0 mg/l) and NAA (0.2 mg/l) and produce callus tissues. The calli mass may produce maximum number of shoots (average 4 per each vessel) whenever sub-cultured on MS medium supplemented with BA (2 mg/l). The number of shoots was decreased if the IBA concentration was beyond 2 mg/l. Application of TDZ to regeneration medium had less number of microshoots as compared to BA treatment, but there was no significant statistical difference between these two treatments (P=0.05). Furthermore, the quality of plantlets induced by TDZ was higher than other treatments. The half strength MS medium supplemented with IBA (2 mg/l) and NAA (mg/l) is suggested for in vitro rooting of Zamoculcas microshoots. Application of NAA is also induced rooting, but the effectiveness was less than IBA.

***Keywords*:** Callus, differentiation**,** proliferation, propagation, ZZ plant

INTRODUCTION

Zamioculcas zamiifolia (Lodd.), also known as ZZ plant, is a monocot, tropical ornamental plant belongs to Araceae and native to Eastern Africa. The *Z. zamiifolia* is frequently used medicinally in the African countries. The juice from the leaves is used medicinally to treat earache and inflammatory conditions. Roots are used as a local application to treat ulceration by the Sukuma people in northwestern Tanzania (Moullec *et al*., 2015). The ZZ plant is enjoyed for its unique appearance, its ability to grow under low light conditions, and its tolerance to drought. The ZZ's naturally glossy leaves are so shiny that the plant appears to have been polished (Alizadeh *et al*., 2019). It produces succulent rhizomes at the base of its attractive dark green and glossy foliage (Lopez *et al*., 2009). It has recently gained commercial ornamental importance (Seneviratne *et al*., 2020) and the plants with green, dark purple and variegated green colors are presently available (Mayers, 2024). The dark purple is known as Black Zamiifolia, has more fan in Iran. Furthermore, plants with dwarf feature were recently produced through mutation induced by colchicine (Seneviratne *et al.,* 2020).

Zamiifolia, is a popular and low-maintenance houseplant. It can tolerate low light conditions, but prefers bright, indirect light. Direct sunlight should be avoided as it can scorch the leaves. The plant also grows well under fluorescent lighting and that's why it has gained popularity as a recent addition to pot plants especially in Iranian apartments and official areas. Overwatering can lead to root rot. a

well-draining potting soil should be used and a mix of regular potting soil with some perlite or sand works well. They can tolerate dry air and prefer average to warm temperatures and normal indoor humidity levels (Bown, 2000; Henny and Chen, 2013).

Propagation of Zamiifolia can be readily undertaken through division or leaf cuttings (Lopez *et al*., 2009; Malla *et al*., 2023). When re-potting a mature ZZ plant, developed rhizomes (underground stems) are carefully removed and gently separated the rhizomes into sections, ensuring that each section has both roots and stems. Each divided section is planted in its own pot with well-draining soil. The pots are placed in a warm, bright location but indirect sunlight. New growth would emerge from the divided sections within a few weeks.

The method of propagation through leaf cutting is more common especially for commercial mass multiplication and also when there are restrictions in terms of plant materials (Badizadegan *et al*., 2023). The mature leaves are grown individually or in groups in pots with a light substrate (Chen and Stump, 2006). The substrate should be moistened and the pots should be placed in a shady place (light intensity of 1000 to 1500 foot candles is enough). The rooting substrate can be a mixture of 60% peat and 40% perlite. This substrate should have favourable physical properties and its pH should be between 6 and 7 and the electrical conductivity of its saturated extract should be less than 2 ds/m (Chen *et al.*, 2004). Review of the literature with respect to the type of Zamophilia leaf cutting (Blanchard and Lopez, 2007), revealed that the leaf can be cut in different ways (Fig.1). The whole intact leaflet may be planted (a), or each leaflet may be cut from the middle part and each piece is inserted as an individual cutting. The b and c represent the upper and lower part of the leaflet, respectively). The study noted that both the upper and lower parts of the leaflet were capable of rooting successfully. However, the researchers observed a unique phenomenon when the end piece of the leaf was planted (Fig. 1b). This method resulted in the induction of more rhizomes, leading to the formation of additional stems. Consequently, this particular cutting technique was found to be more effective in stimulating rhizome growth and ultimately producing more stems.

Both stem division and leaf cutting techniques are extensively common in greenhouses and nurseries (Badizadegan *et al.*, 2023). However, the slow growth habit of ZZ plant (Henny and Chen, 2013) is a drawback for its mass propagation. Tissue culture techniques provide an opportunity for the large-scale production of an elite material and plants of commercial interest (Alizadeh *et al*., 2023).The micropropagation protocols for some Araceae genera such as *Alocasia*, *Anthurium*, *Aglaonema*, *Dieffenbachia*, *Philodendron*, *Spathiphyllum* and *Syngonium* has been already reported (Chen *et al*., 2006; Stanly *et al*., 2012; Chen *et al.*, 2018; Chen *et al*., 2012). Also, there are some contributions for *in vitro* propagation of green leaved Zamiifolia. The researchers studied the role of basal medium, plant growth regulators and also types of explants. Heping and Peng (2003) developed plantlets from leaf explants. Papafotiou and Martini (2009) demonstrated the effect of the inoculation position of leaf explants concerning growth regulators during the micropropagation of ZZ plant. A complete micropropagation protocol for Black-Leaved *Zamioculcas zamiifolia* was recently published by Pourhassan *et al*. (2023). In the present research work, in a series of experiments the feasibility of *in vitro* propagation of *Z. zamifolia* was evaluated.

MATERIALS AND METHODS

The present research was carried out in the Plant Tissue Culture Laboratory, located in the Department of Horticultural Sciences, Faculty of Plant Production, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. The greenhouse grown, mother and healthy plant of Zamifolia (*Z. zamifolia* LODD.) was obtained from Hirkan Plant Tissue Culture Company, Gorgan. The young leaves of the shoot tip and the base of the branch were removed, and the leaves in the middle part of the stem were used to prepare the explants.

Plant growth regulators benzyladenine BA, naphthalene-acetic acid NAA and thidiazuron TDZ were used. The stock solution of these substances was prepared with a concentration of 1 mg/ml (Alizadeh *et al*., 2019) and the required amount was added to the desired medium during the preparation of the culture medium. The types and concentrations of growth regulators for different stages of micropropagation are shown in Table 1.

A previous tissue culture study (Anonymous, 2014) had already documented a report on Zamophilia plant. Therefore, the MS medium supplemented with BA (2 mg/l) and NAA (0.2 mg/l) was chosen for callus induction, as it was recommended in the aforementioned report. The leaf explants were then inoculated on this medium using two surface sterilization methods.The leaf samples were firstly pre-treated with fungicide (Carbendazim 2 g/l for 3 hours). Then, these were transferred to a Laminar Air Flow hood where, sterilization procedures were followed. Alcohol, Colorax and mercury chloride were used for surface sterilization. Sterilization was done by two methods, which are briefly called "Colorax method" and "Mercuric method". The details of surface sterilization methods were as following:

Colorax method : 70% alcohol for 30 seconds, several rinses with sterile water, Colorax 15% for 20 minutes, several rinses with sterile water, Colorax 10% for 10 minutes, several rinses with sterile water, and then inoculation were done individually in each container.

Mercuric method : 70% alcohol for 30 seconds, several times of rinsing with sterile water, 0.1% mercury chloride for 5 minutes, several times of rinsing with sterile water and then inoculation were done individually in each container.

The degree of contamination, the percentage of establishment and the degree of browning or burning of the samples after the inoculation of leaf pieces were evaluated to determine the effectiveness of the disinfection method.

Following the callus induction in the leaf explants, the callus pieces were sub-cultured several times on the same culture medium or on the hormone-free medium. Therefore, several growing cultures containing healthy and actively growing callus were produced. The callus mass was then sub-cultured on different regeneration medium (Table 1). As much as possible, it was tried that the size of all callus pieces were the same and at least "pea size" when sub-cultured. After 6 weeks, data were taken from the regenerated samples and their average was used for statistical analysis.

The regenerated shoots in the previous section were inoculated in $^{1}/_{2}$ MS medium to induce rooting. Here, the entire mass of callus and its regenerated branches were removed from the culture at once. The branches were cut from the junction with the callus with a scalpel and inoculated individually on the rooting medium.

In the stages of regeneration and rooting, the number of produced branches was recorded and their length was measured. The callus volume along with the branches and the number of leaves were recorded. Callus growth rate was determined by observation and scoring as (0) no growth; (1) 30-50% volume increase in the callus; (2) 50-100% and (3)100% or more increase in callus volume.

The data collected from this experiment was analyzed using a completely randomized design with four replications. Mean data comparison was conducted using the LSD test at a 5% probability level with the assistance of SAS statistical software.

RESULTS AND DISCUSSION

In the present study, the possibility of regenerating whole Zamophilia plants from leaf explants was evaluated. Leaf pieces were cultured on commercial MS culture medium. After callus production, the callus pieces were sub-cultured on regeneration culture medium. The regenerated branches were then transferred to the rooting medium. The results of each of these steps are reported hereafter.

Culture establishment

In both methods of sterilization, some samples were successfully sterilized and established on the culture medium, but in general, Mercuric method was more effective. The degree of browning or tissue burning was almost the same in both methods. In both methods, a number of Zamophilia leaf pieces were successfully established in the jam bottles and callus formation was observed about 4 to 5 weeks after inoculation. The amount of culture establishment in these two methods has a significant difference ($P = 0.05$) and shows the better efficiency of mercury chloride (Fig. 2). What is certain is that mercuric chloride is dangerous for the environment as well as plant tissue culture user (Alizadeh, 2010). Therefore, the observations showed that using Colorax can also successfully establish enough *in vitro* samples in this plant (Fig. 2).

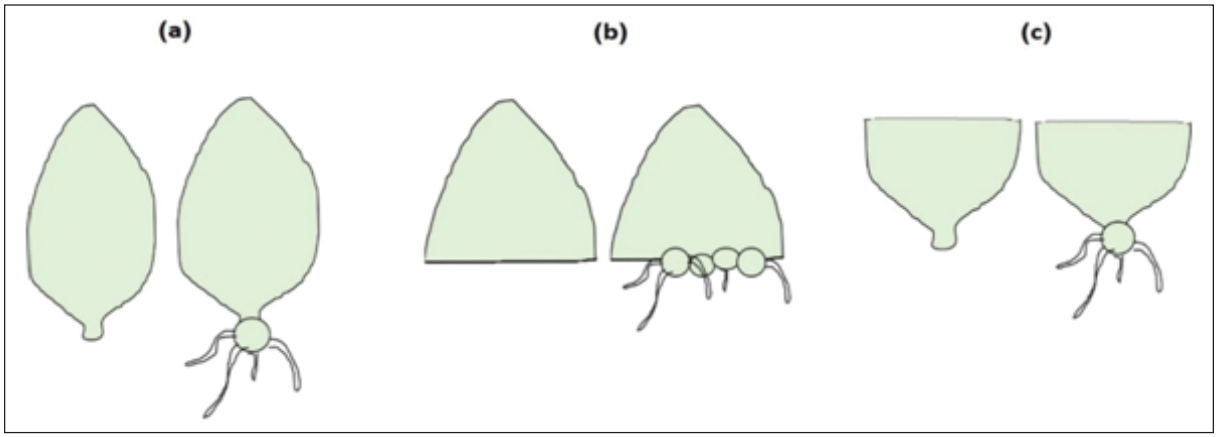

Fig. 1. Types of leaf cuttings in *Zamoculcaszamipholia*. Complete intact leaf (a), upper part of the leaf (b), lower part of the leaf (c). When the leaf iss cut and its upper part is planted, the number of induced rhizomes will be more (Drawing by author- M. Alizadeh).

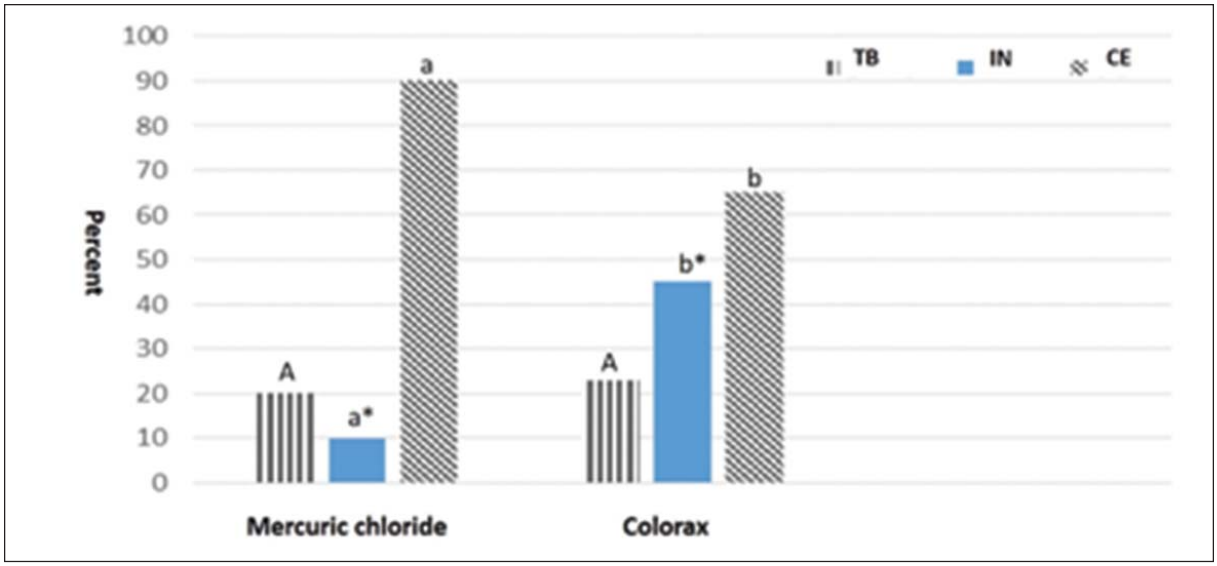

Fig. 2. The efficacy of two sterilization methods for *in vitro* culture establishment of ZZ plant. TB, IN and CE represent tissue browning, infection and culture establishment, respectively.

Shoot regeneration and proliferation

According to the recorded data, the leaf explants of ZZ plant were usually induced to produce callus tissue 4 to 5 weeks after inoculation. In the third week, the leaf parts were swollen and some samples were bent up from the middle due to the enlargement and were separated from the culture medium. From the third week onwards, callus formation appearedas tiny, snow-like particles on the cut edges of the explant tissue. It should be noted that, unlike its leaves, which are very shiny and green, the callus of ZZ plant is absolutely dark brown to black in color (Fig. 3). Regeneration from callus tissue is difficult in some plants (George, 1993), but according to the results of the present study, in the ZZ plant, just BA supplementation to the culture medium is sufficient to encourage the callus tissue and differentiation into shoot bud. A fascinating observation made in this section is the spontaneous branching of callus in certain culture containers when left unattended or uncultured for a period. As the water content decreases in the environment, the callus unexpectedly initiates branching. This phenomenon suggests that stress on callus tissue cells plays a crucial role, prompting plant cells to regenerate in order to ensure their survival (Alizadeh *et al.*, 2019).

Fig. 3. Different stages of *in vitro* propagation of ZZ plant. Inoculation of leaf explant (Up, left); shoot regeneration from callus tissue (Up, right); The influence of BA on shoot regeneration (Bottom, left); a whole rooted *Zamoculcas* plantlet (Bottom, right).

The number of regenerated branches and their length in different culture media was statistically different among treatments (Table 2). The difference in shoot regeneration from callus samples in response to different growth regulators was shown in Table 3. The highest number of shoots was observed in medium supplemented with BA (2.0 mg/l). It seems that increasing the concentration of cytokinin or adding NAA can lead to a decrease in the number of shoots. The TDZ also induced shoot proliferation, but its efficiency is not as high as BA. Based on the enquiry, it was found that the cost of TDZ is significantly greater than that of BA. As a result, when considering the commercial propagation of Zamophilia, it can be stated that the same concentration of BA at 2 mg/l is an effective and superior treatment option.

In other plants of Araceae family, such as *Anthurium* and *Pothos*, treatment with BA or another type of cytokinin such as kinetin has led to regeneration, which is consistent with the results of this research (Hamidah *et al.*, 1997; Zhang *et al*., 2005). The regenerated shoots in different culture media were not the same in terms of size (Table 2). Increasing the concentration of BA in the shoot proliferation medium causes the shoots to become shorter. Considering that this negative effect was also observed in the number of regenerated shoots, it is recommended not to use more than 2 mg/l BA in this plant. Also, the possibility of vitrification, which is an undesirable phenomenon, also exists in high concentrations of cytokinin (Alizadeh, 2010). Inclusion of NAA to the shoot proliferation medium caused the formation of a large volume of callus at the base of the shoots and the regenerated shoots were also less. In general, application of 2 mg/l BA for branching

Table 1: Culture medium and growth regulators treatments for *in vitro* propagation of ZZ plant

Plant growth regulator (mg/l)	Basal medium	Growth stage
Callus induction	MS	● BA (2.0) + NAA (0.1)
Shoot proliferation	MS	● BA (2.0)
		● BA (4.0)
		● BA (2.0) + NAA (0.2)
		● BA (4.0) +NAA (0.2)
		● TDZ (1.5)
Root induction	MS	● IBA (2.0)
		● IBA (2.0) + NAA (0.5)
		● NAA (0.5)

BA: Benzyl adenine; NAA: Naphtalene acetic acid; TDZ: Thidiazuron

Table 2: Variance analysis and mean data for *in vitro* traits of ZZ shoot proliferation stage

Sources of Variations	df	No. of Shoots	Shoot length	Callus volume	visual quality
Treatment	4	3.43*	1.11*	1.4 ns	0.56 ns
Error	10	1.4	1.15	1.6	1.66
* and ns, are significant at 5% level and no significant difference, respectively.					
		Mean comparison data			
BA (2.0)		3.67 a	50.3 a	1.1 a	1.6 a
BA (4.0)		1.43 b	34.6 ab	1.4 a	1.9 a
BA (2.0) + NAA (0.2)		2.59 ab	49.9 a	1.1 a	1.6 a
BA (4.0) +NAA (0.2)		1.10 b	18.2 b	1.6 a	1.3 a
TDZ (1.5)		2.10 ab	50.1 a	1.6 a	2.2 a

• The data followed by the same letter in each column do not have statistically difference.

Table 3: Variance analysis and mean data for *in vitro* traits of ZZ plant at rooting stage

Sources of Variations	df	No. of roots	Shoot length (mm)	No of leaves
Treatment	**3**	**26.98***	**0.93 ns**	**1.8 ns**
Error	**16**	**1.4**	**1.15**	**1.6**
* and ns, are significant at 5% level and no significant difference, respectively.				
		Mean comparison data		
$^1/_2$ MS free hormone (Control)		2.33 b	44.56 ns	2.34 ns
$^1/_2$ MS+ IBA (2.0)		2.99 a	43.65 ns	2.76 ns
$^1/_2$ MS + IBA (2.0) + NAA (0.5)		7.21 b	44.32 ns	2.41 ns
$^1/_2$ MS+ NAA (0.5)		2.45 b	44.28 ns	2.65 ns

* and ns are respectively significant at 5% level and no significant difference.

seems to be a reasonable combination. Application of TDZ (1.5 mg/l) in the proliferation medium produced fewer shoots than BA, but they were not statistically different from each other (Table 2).

Rooting

In this experiment IBA and NAA and their combined treatment was tested for rooting and the results obtained were as follows. Since the ZZ plant is a rhizomatous plant, no special problem was observed in its *in vitro* rooting. Therefore, even the shoots inoculated in $^{1}/_{2}$ MS medium without growth regulator also produced roots. Adding auxin significantly (Table 3) increased the number of roots, but the best result was obtained in the combination treatment of auxin. The number of roots produced in the treatment of IBA and NAA when they were used alone was not significantly different from the control, but while their combined application, more roots were observed (Table 3).

CONCLUSION

Based on the findings, it is recommended to use a MS medium comprising BA (2.0 mg/l) + NAA (0.2 mg/l) for efficient culture establishment of leaflet segments of ZZ plant and subsequent callus tissue production. Sub-culturing the calli mass on MS medium with BA (2 mg/l) is advised for maximizing the number of shoots. Further research could explore the potential for optimizing the use of TDZ to achieve a balance between microshoot production and plantlet quality, and investigate alternative methods for *in vitro* rooting that may enhance overall efficiency and yield.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Effect of organic and inorganic nutrients on growth, yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. NA-7 in the red and laterite zones of West Bengal

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ABSTRACT

An investigation was carried out at Bidhan Chandra Krishi Viswavidyalaya's Regional Research Sub-Station, Sekhampur, West Bengal, India during 2019-2020 and 2020-2021 to investigate the impacts of inorganic and organic nutrient management for plant growth, yield of aonla in Red and Lateritic Region of West Bengal. This investigation was arranged by utilizing Randomised Block Design, replicated thrice along with eight treatments (T1- Control (RDF: 600-300-600g NPK/ plant); T2 - 400-200-500g NPK +20 kg FYM/ plant; T3 - 400-150-450g NPK + 10 kg Vermicompost/plant; T4 - 550-300-600g NPK + 40g Azotobacter /plant; T5 - 600-250-600g NPK + 50g PSB/plant; T6 - 550-250-600g NPK + 40g Azotobacter + 50g PSB/plant; T7 - 350-150-500g NPK + 10 kg FYM + 40g Azotobacter + 50g PSB/ plant; T8 - 350-100-450g NPK + 10kg Vermicompost + 40g Azotobacter + 50g PSB/ plant). The findings depicted that the highest percentage increase in plant height (25.61%), canopy spread in North-South (13.61%), as well as East-West (14.50%) direction, maximum volume of fruit (29.28 ml), fruit length (3.64 cm), diameter (3.68 cm), fruit weight (30.20 g), flesh thickness (1.64 cm), TSS (10.81ÚBrix), ascorbic acid (526.36 mg/100 g of flesh pulp), juice content (49.33%), number of fruits/tree (1065.00) as well as maximum yield/tree (32.29 kg), were observed with the implementation of 550:250:600g NPK + 40g Azotobacter + 50g PSB /plant.

***Keywords*:** *Anola, FYM, biofertilizer, growth, yield, quality*

INTRODUCTION

Aonla (*Emblica officinalis* Gaertn.), commonly referred to as Indian gooseberry, holds significant nutritional value, ranking closely with Barbados cherry in terms of its impressive vitamin C content, ranging from 500-625mg/100g of fruit pulp (Singh *et al*., 2018). Aonla, with its immense potential to contribute economically to India, requires the promotion of cultivars with desirable horticultural traits and the expansion of cultivation areas across diverse ecosystems (Singh *et al*., 2019). In the Western region of West Bengal, aonla cultivation flourishes in varied ecological niches, including barren lands, and wastelands, and the suitability of these regions for aonla cultivation is attributed to the prevalence of lateritic soils (Ghosh *et al*., 2009). Soil fertility, type, and nutrient management significantly influence aonla growth and yield. The challenges posed by lateritic soils, such as hardening during dry seasons and deficiencies in major plant nutrients, necessitate effective nutrient management strategies. The escalating costs and adverse environmental impacts associated with continuous and excessive use of chemical fertilizers emphasize the importance of transition towards organic nutrient sources for enhanced production. Against this background, this study explores the synergistic effects of organic and inorganic nutrient management on sustainable aonla production in poor soil conditions.

Integrated Nutrient Management (INM) emerges as a dynamic approach to optimize crop yields while preserving the physical, chemical, and

microbiological integrity of the soil. INM involves a balanced combination of organic manure, chemical fertilizer, and biofertilizers tailored to specific land use systems, aimed at enhancing organic matter content and soil quality parameters. Since little information is available regarding the integrated nutrient management of aonla, particularly in red and lateritic tracts of West Bengal, this current experiment was conducted to develop organic and inorganic nutrient management schedule for feasible production of aonla in Red and Lateritic region of West Bengal.

MATERIALS AND METHODS

The current investigation was conducted at the Regional Research Sub-Station, Sekhampur of Bidhan Chandra KrishiViswavidyalaya, West Bengal during the period from 2019 to 2021. The experimental site is located at an altitude of 30m above MSL, at latitude $23^0$68'N and longitude $87^0$69'E. The experimental site has red and lateritic soil with low water holding capacity, pH 5.63, 0.17% organic carbon content, available nitrogen 160.16 Kg/ha, available phosphorus 19.04 Kg/ha, and available potassium 138.28 Kg/ha.The trees were uniform in height and 12 years old. A Randomised Block Design (RBD) was used to set up the experiment and it was replicated thrice with eight treatments, with each replication containing one plant (T_1 - Control (RDF: 600-300-600g NPK per plant); T_2 - 400-200-500g NPK +20 kg FYM per plant; T_3 - 400-150-450g NPK + 10 kg Vermicompost per plant; T_4 - 550-300-600g NPK + 40g *Azotobacter* per plant; T_5 - 600-250-600g NPK + 50g PSB per plant; T_6 - 550-250-600g NPK + 40g *Azotobacter*+ 50g PSB per plant; T_7 - 350-150-500g NPK + 10 kg FYM + 40g *Azotobacter* + 50g PSB per plant; T_8 - 350-100-450g NPK + 10kg Vermicompost + 40g *Azotobacter* + 50g PSB per plant). Fertilizers were applied in two equal splits, during January-February and September-October. Biofertilizers were applied to the rhizosphere soil, and mixed with organic manures (FYM/ Vermicompost), two weeks after the application of inorganic fertilizers in each split. The growth, yield and physico-chemical composition of fruits were observed two years consecutively and average was presented in the paper. The A.O.A.C. (1980) recommended methods were followed for the estimation of the acidity, total sugar, and ascorbic acid content. The pooled mean data analysis in this study followed the statistical method described by *Panse and Sukhatme* (1985).

RESULTS AND DISCUSSION

Growth parameters

The analysis of data from Table 1 revealed significant variations in the percentage increase of both plant height and canopy spread in the N-S and E-W directions due to different nutrient treatments. In the aggregated analysis, treatment T_6 (550:250:600g NPK + 40g Azotobacter + 50g PSB per plant) showed the highest enhancement in plant height (25.61%), while the control (RDF: 600:300:600g NPK) exhibited the minimum increase (20.85%). Similarly, the maximum percentage increase in canopy spread in both the East-West (14.50%) and North-South (13.61%) directions was observed in treatment T_6, whereas the minimum increase was noted in the control group for both directions (East-West: 11.93%, North-South: 10.77%).

This considerable growth improvement can be attributed to the synergistic effects of the nutrient components present in T_6. The balanced supply of essential nutrients, complemented by the synergistic effects of Azotobacter and PSB, likely promoted lateral growth and canopy expansion in both directions. This relationship likely contributed to enhanced root development, improved nutrient transportation, and increased growth parameters. Conversely, in the control treatment, nutrient deficiencies hampered optimal vegetative growth characteristics. Identical findings have been reported in aonla by researchers (Kour *et al.* 2019, Mandal *et al.*, 2013, Mustafa *et al*., 2013 and Yadav *et al.*, 2007).

Physical parameters of fruits

The application of various nutrient combinations significantly impacted the physical characteristics of aonla fruits as presented in Table 2. Treatment T_6 exhibited the maximum fruit volume (29.28 ml) and average fruit weight (30.20 g), statistically comparable to T_4 (550:300:600g NPK + 40g Azotobacter per plant), while the control treatment (RDF: 600:300:600g NPK) displayed the minimum fruit volume (24.89 ml) and weight (26.31 g).

Table 1: Effect of inorganic and organic nutrients composition on per cent increase in plant height and canopy spread of aonla cv. NA-7 (Pooled mean data from two years)

Treatment	% increase in plant height	% increase in Canopy spread	
		East- West	North- South
T_1	20.85 (27.16)	11.93 (20.20)	10.77 (19.15)
T_2	21.25 (27.44)	12.22 (20.46)	11.24 (19.58)
T_3	22.07 (28.01)	13.58 (21.61)	12.37 (20.58)
T_4	23.79 (29.18)	14.03 (21.99)	13.13 (21.23)
T_5	23.50 (28.99)	13.05 (21.17)	12.01 (20.27)
T_6	25.61 (30.39)	14.50 (22.37)	13.61 (21.64)
T_7	22.77 (28.49)	12.81 (20.97)	11.66 (19.96)
T_8	22.97 (28.62)	13.81 (21.81)	12.78 (20.94)
S.E.m(±)	**0.038**	**0.036**	**0.032**
C.D. at 5%	**0.116**	**0.111**	**0.099**

Data in the parenthesis are angular transformed value

T_1 - Control (RDF: 600-300-600g NPK per plant); T_2 - 400-200-500g NPK +20 kg FYM per plant; T_3 - 400-150-450g NPK + 10 kg Vermicompost per plant; T_4 - 550-300-600g NPK + 40g *Azotobacter* per plant; T_5 - 600-250-600g NPK + 50g PSB per plant; T_6 - 550-250-600g NPK + 40g *Azotobacter*+ 50g PSB per plant; T_7 - 350-150-500g NPK + 10 kg FYM + 40g *Azotobacter* + 50g PSB per plant; T_8 - 350-100-450g NPK + 10kg Vermicompost + 40g *Azotobacter* + 50g PSB per plant

Table 2: Effect of inorganic and organic nutrients composition on fruit physical characteristics and yield of aonla cv. Na-7 (Pooled mean data from two years)

Treatment	Fruit volume (ml)	Fruit length (cm)	Fruit diameter (cm)	Flesh thickness (cm)	Stone weight (g)	Fruit weight (g)	Yield (kg/tree)
T_1	24.89	2.70	2.96	1.19	1.79	26.31	22.70
T_2	26.44	2.79	3.02	1.29	1.86	26.73	23.59
T_3	27.93	2.94	3.27	1.36	1.91	27.61	25.20
T_4	28.52	3.46	3.55	1.58	1.76	29.61	30.14
T_5	28.00	3.37	3.44	1.53	1.66	28.82	27.60
T_6	29.28	3.64	3.68	1.64	1.62	30.20	32.29
T_7	25.85	3.10	3.19	1.43	1.90	27.33	25.51
T_8	27.39	3.24	3.38	1.47	1.96	28.43	27.94
S.E.m(±)	**0.381**	**0.044**	**0.042**	**0.022**	**0.032**	**0.362**	**0.479**
C.D. at 5%	**1.166**	**0.135**	**0.128**	**0.069**	**0.098**	**1.108**	**1.465**

T_1 - Control (RDF: 600-300-600g NPK per plant); T_2 - 400-200-500g NPK +20 kg FYM per plant; T_3 - 400-150-450g NPK + 10 kg Vermicompost per plant; T_4 - 550-300-600g NPK + 40g *Azotobacter* per plant; T_5 - 600-250-600g NPK + 50g PSB per plant; T_6 - 550-250-600g NPK + 40g *Azotobacter*+ 50g PSB per plant; T_7 - 350-150-500g NPK + 10 kg FYM + 40g *Azotobacter* + 50g PSB per plant; T_8 - 350-100-450g NPK + 10kg Vermicompost + 40g *Azotobacter* + 50g PSB per plant

Table 3: Effect of inorganic and organic nutrients composition on fruit chemical characters of aonla cv. Na-7 (Pooled mean data from two years)

Treatment	TSS (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg/100 g flesh pulp)	Total sugar (%)	Juice (%)
T_1	9.27	2.05	487.14	5.44	44.96
T_2	9.43	1.95	493.78	5.52	45.46
T_3	9.66	1.89	500.47	5.61	46.43
T_4	10.63	1.63	522.20	6.20	48.38
T_5	10.12	1.75	513.63	5.83	46.55
T_6	10.81	1.51	526.36	6.26	49.33
T_7	9.92	1.83	511.26	5.91	47.72
T_8	10.36	1.67	517.71	5.97	47.09
S.E.m(±)	**0.080**	**0.037**	**1.396**	**0.037**	**0.132**
C.D. at 5%	**0.244**	**0.113**	**4.274**	**0.113**	**0.405**

T_1 - Control (RDF: 600-300-600g NPK per plant); T_2 - 400-200-500g NPK +20 kg FYM per plant; T_3 - 400-150-450g NPK + 10 kg Vermicompost per plant; T_4 - 550-300-600g NPK + 40g *Azotobacter* per plant; T_5 - 600-250-600g NPK + 50g PSB per plant; T_6 - 550-250-600g NPK + 40g *Azotobacter*+ 50g PSB per plant; T_7 - 350-150-500g NPK + 10 kg FYM + 40g *Azotobacter* + 50g PSB per plant; T_8 - 350-100-450g NPK + 10kg Vermicompost + 40g *Azotobacter* + 50g PSB per plant

Moreover, plants treated with T_6 yielded the longest fruit length (3.64 cm) and widest diameter (3.68 cm), contrasting with the control treatment. Treatment T_6, comprising 550:250:600g NPK fertilizer, 40g Azotobacter, and 50g PSB, demonstrated the highest fruit yield per tree (32.29 kg), in contrast to the control (22.70 kg). The incorporation of Azotobacter and PSB likely played a pivotal role in augmenting the yield, as supported by the findings of Mandal *et al*. (2013) and Mustafa *et al*. (2013).

Quality parameters of fruit

A perusal of the data represented in Table 3 clearly showed significant variation in TSS, titratable acidity, ascorbic acid, total sugar and juice content of the pulp due to the application of different nutrient combinations. The maximum TSS content (10.8^0 Brix), ascorbic acid (526.36 mg/100g of pulp) and total sugar (6.26%) content were observed in the treatment T_6 (550:250:600g NPK + 40g *Azotobacter* + 50g PSB) which was statistically at par with treatment T_4 (550:300:600g NPK + 40g *Azotobacter* per plant) compared with minimum TSS content of 9.27^0 Brix and ascorbic acid content of 487.14 mg/100 g of pulp in plants under control (RDF: 600:300:600g NPK). Plants treated with T_6 showed a notable decrease in acidity content, recording 1.51%, whereas T_1 exhibited the highest acidity at 2.05%. The highest juice percentage (49.33%) was recorded from fruits of those plants received 550:250:600g NPK + 40g *Azotobacter* + 50g PSB compared with 44.96% in control. The application of Azotobacter and PSB enhanced fruit quality by supplying essential nutrients to the soil and promoting nutrient transformation. Similar outcomes have been also observed by Kour *et al*. (2019).

CONCLUSION

In the present investigation, various nutrient sources including 600:300:600g NPK (100% recommended dose of NPK), Vermicompost, Farm Yard Manure (FYM), and inoculations of Azotobacter and PSB (40g and 50g each) were administered to plants.From the results of two years investigation, it was observed that the application of both inorganic and organic nutrient treatments significantly impacted plant growth parameters, physico-chemical characteristics of fruits and yield parameters. Ultimately, it was concluded that the application of NPK at a ratio of 550:250:600g along

with 40g of Azotobacter and 50g of PSB per plant proved beneficial for enhancing yield and improving fruit quality in aonla (cv. NA-7) under the agro-climatic conditions of Sekhampur, Birbhum, West Bengal, India.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Panicle diversity of some mango varieties under semi-arid lateritic belt of Eastern India

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ABSTRACT

The present experiment was conducted during February to April in the year 2022 and 2023 selecting fifteen mango varieties from Institute of Agriculture,Visva-Bharati, Sriniketan, West Bengal as well as farmers homestead garden to study their morphological characters of panicles and distribution of types of flowers under semi-arid lateritic belt of Eastern India. In the present experiment the flowering of fifteen mango varieties viz., Bangalora, Banganpalli, Alphanso, Ratna, Sindu, Bombay Green, Vastara, Dasheri, Amrapali, Mallika, Swarnarekha, Meghlanthan, SafdarPasand, Himsagar, and Langra have been studied by selecting ten panicles from each plant in both the years with respect to different morphological parameters of panicle and flower distribution. The maximum length of panicle was noted in mango variety Ratna (43.1 cm) and it has also exhibited maximum numbers of rachis (65.6). Highest flowering duration has been observed under SafdarPasand (19.9 days) and lowest in Bangalora (10.1 days). Mainly the main stem and the branches or rachis are pigmented in mango panicles as pink, light pink, pinkish green, greening pink, green etc. Maximum male flowers per pinnacle (2056.2) have been noted in the mango Ratna and minimum in SafdarPasand (104.0). Number of hermaphrodite flowers per pinnacle of fifteen different mango varieties has been ranged from 19.0 (in Langra) to 314.2 (in SafdarPasand). Mango variety Langra has produced maximum hermaphrodite flowers (58.9 %) while lowest production of perfect flower was noted in Ratna (1.7%).

Keywords **:** Flower distribution, mango varieties, panicle morphology.

INTRODUCTION

Mango (*Mangifera indica* L.) holds cultural, economic, and agricultural significance in India. It symbolizes abundance, fertility, and sweetness in Indian culture. As a major export and integral part of Indian cuisine, it reflects the nation's rich biodiversity and cultural heritage, making it a fitting choice as the national fruit.India's mango biodiversity is impressive, with more than a thousand varieties cultivated nationwide (Singh *et al*., 2015). Mango is abundant source of vitamins A, C, and E, crucial antioxidants that enhance immunity and nourish skin. It also offers considerable amount of folate, potassium and fiber, promoting cardiovascular health and aiding digestion (Lebaka *et al*., 2021). Additionally, mango leaves are believed to possess medicinal benefits, particularly in traditional medicine for conditions like diabetes and hypertension (Kumar *et al*., 2021).

In India, mango trees usually bloom from late winter to early spring, varying based on the area and weather conditions. This flowering phase typically occurs between December and February, marking the beginning of the fruit-bearing process (Jameel *et al*., 2018). At this time, the trees adorn themselves with clusters of tiny, sweet-smelling flowers, adding splashes of white and pink to the scenery. These blooms play a crucial role in pollination, setting the stage for the growth of mango fruits in the subsequent months.The panicle of a mango tree refers to the flower cluster where individual flowers bloom. Each panicle consists of numerous small, fragrant flowers tightly packed

together (Geetha *et al*., 2016). These panicles emerge from the tree's branches during the flowering season, typically in late winter to early spring (Naidu *et al*., 2018; Sinha *et al*., 2020) and may be late or early due to environmental fluctuation (Chaurasia *et al*., 2023). The panicles vary in size and density, with some trees producing larger and more prolific clusters than others. Although some nutritional impact on flowering of mango and growth promotion has been reported by some workers (Deb and Reza, 2023; Deb and Reza, 2024; Choudhury and Ghosh, 2021), there is no such published reports regarding the panicle characters of different mango varieties in eastern India particularly under red and lateritic zone of West Bengal. In this context the present study has been carried out to examine the morphological characters of different mango panicles under semi arid lateritic belt of eastern India, particularly the Birbhum district of West Bengal.

MATERIALS AND METHODS

The present experiment has been conducted during February to April in the year 2022 and 2023 selecting different mango plants from Rathindra Krishi Vigyan Kendra, Agricultural Farm, Horticultural Farm of Institute of Agriculture,Visva-Bharati, Sriniketan, West Bengal as well as farmers homestead garden.The location comes under semi arid lateritic belt of West Bengal under the Bolpur, Sriniketan Block of Birhum district, West Bengal. This geographical location is characterized by prolonged dry winter starting from second week of the December and continues up to second week of February which is followed by a mild spring season up to the March. Dry hot summer starts from first week of the April and characterized by very high temperature up to 45^{o}C degree and continues till mid of the June. Summer is also associated with heat wave and scorching sun. Soil condition is characterized by red and lateritic sandy loam having pH range of 5.5 to 6.5 with rich in iron and aluminium and low in organic matter content. The flowering of mango plants isconsiderablyaffected by the prevailing weather condition as well as the soil condition. In the present experiment the flowering of fifteen mango varieties particularly Bangalora, Banganpalli, Alphanso, Ratna, Sindhu, Bombay Green, Vastara, Dasheri, Amrapali, Mallika, Swarnarekha, Meghlanthan, Safdar Pasand, Himsagar and Langra, taking three different plants in each, have been studied by selecting ten panicles from each plant for two years (2022 and 2023). With respect to different morphological parameters of panicle, flower distribution and methods of recording observations were as follows:

Length of panicle : Length of pinnacle of mango varieties has been recorded in full bloom stage with a measuring scale starting from the apical portion of the chute and up to the tip of the panicle. Length of panicle was measured in both the years and was expressed in centimetre.

Number of rachis per panicle : The branches of the panicle are known as the rachis and the total count of rachis has been recorded at full bloom stage of the panicle in both the years.

Duration of flowering : To determine the duration of flowering of mango in the panicles the difference of days counted against opening of first flower and last flower of the same pinnacle has been considered for both the years.

Panicle colour : As the colour of the panicle of different mango varieties are different,and then the visual colour has been recorded and noted against each variety which has been matched in both the years.

Determination of numbers of male and hermaphrodite flowers : Male flowers of mango is characterized by absence of small globular ovule and female flowers of mango are characterized by green or creamy or whitish green coloured ovule with obliquely placed ovary in the flowers. To count of male and hermaphrodite flowers from a single selected panicle were observed by covering the entire panicle with perforated polythene bags followed by counting the dropped as well as attached fully opened male and hermaphrodite flowers. After counting the male and hermaphrodite flowers total number of flowers have been determined for by adding the numbers for respective mango varieties in both the years.

Percent of hermaphrodite flowers: Percent of hermaphrodite flowers has been calculated by dividing the total number of hermaphrodite flowers by total number of flowers (sum of male and hermaphrodite) and multiplying it by 100.

Sex ratio: Sex ratio of mango panicles of different varieties was determined by calculating

the ratio of male and hermaphrodite flowers simply by dividing the total number of male flowers by total number of hermaphrodite flowers for each pinnacle of respective mango varieties in both the years.

Statistical analysis : Statistical analysis of the collected data with respect to different panicle parameters of fifteen mango varieties in both the years (2022 and 2023) has been arranged for ANOVA under randomized block design (RBD) considering the varieties as treatments and three plants of each varieties as replications (Gomez and Gomez, 1984). Ten panicles under each replication have been considered as the single sample of each replication. The data collected in both the years have been subjected to statistical analysis and pooled data along with critical difference and standard error of mean is cited in the tables.

RESULTS AND DISCUSSION

The statistical analysis of the observations of the present experiment has been presented in Table 1 and 2 as well as graphical representations of the parameters are presented in figure 1, 2 and 3.

Length of panicle : Length of panicle of different mango varieties varied significantly in both the years of experiment as well as in the pooled data (Table 1 and figure 1). The maximum length of panicle (43.1 cm) was noted in mango variety Ratna which was closely followed by Himsagar that produced panicle of 38 .8 cm lengths. On contrary the mango varieties have shown minimum length of panicle ranging from 20.3 cm to 23.9 cm in Swarnareka,Vastara, Amrapali, Bombay Green and Banganpalli mango varieties.

The variation in the length of panicles of mango varieties in the present experiment may be due to their genetic makeup. Azam *et al*. (2018) reported the range of different mango varieties as 17.25 to 34.55 cm under Sabour, Bhagalpur, Bihar condition. Vidyashree *et al*. (2021) have reported the length of panicle of some mango varieties ranged from 29.5 to 38.3 cm under Bagalkot, Karnataka. This variation of result on panicle length in various reports may be due to the variation in the varieties. Thus the finding of Azam *et al*. (2018) and Vidyashree *et al*. (2021) has conformity with the findings of the present experiment.

Numbers of rachis per panicle : In the present study the mango varieties have also shown variation in the numbers of rachis present in the panicles (Table 1 and Figure 1). Highest number of rachis in a single panicle was noted in the variety Ratna (65.6) which was statistically *at par* with Himsagar mango variety that has produced 60 .1 rachis per panicle as on the pooled data of both the years. Lowest number of rachis per panicle of different mango varieties have been observed in Bombay Green and it was 25.9. Number of rachis per panicle was also lower in Safdar Pasand that is (27.7), Swarnarekha (29.1) and Mallika (30.6). More or less similar trend has been observed in both the years with respect to number of rachis in the panicles of different mango varieties.

Branching habit of panicles of different mango varieties in the present experiment noted considerable variation in number of rachis which is completely a cause of genetic variation of mango varieties. Moreover the data on panicle length has a good positive relation with the rachis number of the panicle and higher the panicle length resulted greater number of rachis. Similar findings havealso been reported by Shu (1999).

Flowering duration : The pooled data of both the years with respect to flowering duration of different mango varieties navigates the significant difference within themselves (Table 1 and Figure1). Significantly highest flowering duration *i.e.*, 19.9 days has been observed under SafdarPasand. Higher flowering duration has also been noted inMallika,Swarnarekha, Amrapali, and Dasheri varieties which have been ranged from 16.0 to 17.3 days. Lowest flowering duration was noted in Bangalora variety which was statistically *at par* with Ratna and shown flowering duration 10.1 days and 11.8 days respectively.

Flowering duration of fifteen mango varieties in the present experiment varied from 10.1 to 19.9 days and this might be due to the genetic makeup of the mango varieties which lead to maintaining a steady state of production of flowering responsible enzymes for certain period of flowering (Nampila *et al*, 2014; Chalak *et al*., 2022). Batten and McConchie (1995) also explained the variation of production of florigenic substances and gibberellins in different quantities by different mango and litchi cultivars that caused variation in flowering

Table 1: Length of panicle, number of rachis per panicle, duration of flowering and panicle colour of different mango varieties

Variety	Length of panicle (cm)			No. of rachis/panicle			Duration of flowering (days)			Panicle colour
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	
Bangalora	24.7	26.4	25.5	26.4	30.6	28.5	10.2	9.9	10.1	Lightpink
Banganpalli	23.2	24.7	23.9	46.9	44.8	45.9	11.8	12.2	12.0	Light pink
Alphanso	26.6	24.7	25.7	37.5	34.7	36.1	14.6	13.5	13.8	Greenish
Ratna	44.6	41.7	43.1	61.8	69.4	65.6	11.4	12.1	11.8	Deep purple
Sindhu	34.2	35.1	34.7	56.7	51.6	54.2	13.9	14.2	14.1	Pink
Bombay Green	22.3	24.4	23.4	24.3	27.5	25.9	12.2	11.8	12.0	Light pink
Vastara	19.6	21.2	20.4	34.1	32.8	33.5	14.6	15.5	15.1	Pink
Dasheri	25.7	26.2	25.9	33.0	31.7	32.4	15.7	16.3	16.0	Greenish
Amrapali	20.5	21.8	21.2	36.8	32.3	34.6	16..3	16.8	16.6	Light pink
Mallika	26.7	25.2	25.9	28.9	32.2	30.6	17.7	16.9	17.3	Greenish pink
Swarnarekha	19.5	21.0	20.3	30.4	27.8	29.1	16.1	18.0	17.1	Pinkish
Meghlanthan	35.2	36.6	35.9	42.6	42.0	42.3	15.5	16.4	16.0	Greenish pink
SafdarPasand	22.5	32.5	27.5	29.3	26.1	27.7	20.2	19.5	19.9	Pinkish
Himsagar	35.5	42.0	38.8	64.5	55.7	60.1	13.6	13.9	13.8	Light pink
Langra	28.7	31.5	30.1	39.2	35.4	37.3	16.3	15.9	16.1	Greenish
SE±m	**1.29**	**1.43**	**1.37**	**1.71**	**1.66**	**1.75**	**0.60**	**0.59**	**0.62**	**NA**
CD(0.05)	**3.88**	**4.31**	**4.12**	**5.14**	**4.98**	**5.26**	**1.81**	**1.76**	**1.85**	**NA**

Table 2: Number of male flowers, hermaphrodite flowers, percent of hermaphrodite flowers and male-hermaphrodite flower ratio of different mango varieties:

Variety	No. of male flowers			No. of hermaphrodite flowers			Percent of Hermaphrodite flowers			Male and hermaphrodite ratio		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Bangalora	445.2	395.4	420.3	58.6	40.2	49.4	11.6	9.2	10.4	7.59	9.83	8.71
Banganpalli	842.5	814.8	828.6	55.8	46.8	51.3	6.2	5.4	5.8	15.09	17.41	16.25
Alphanso	1342.3	1305.4	1323.8	72.1	69.6	70.9	5.1	5.0	5.1	18.61	18.75	18.68
Ratna	2009.1	2103.4	2056.2	34.6	37.2	35.9	1.7	1.7	1.7	58.06	56.54	57.30
Sindhu	362.8	314.6	338.7	186.3	213.4	199.8	33.9	40.4	37.1	1.91	1.47	1.69
Bombay Green	376.6	351.2	363.9	36.5	41.2	38.8	8.8	10.4	9.6	10.31	8.52	9.42
Vastara	373.2	346.3	359.8	111.4	119.1	115.3	22.9	25.5	24.2	3.35	2.91	3.13
Dasheri	389.3	374.5	381.9	241.0	237.8	239.4	38.2	38.8	38.5	1.61	1.57	1.59
Amrapali	312.7	321.5	317.1	127.5	116.5	122.0	28.9	26.5	27.7	2.45	2.75	2.60
Mallika	398.5	378.0	388.3	79.2	75.4	77.3	16.5	16.6	16.5	5.03	5.01	5.02
Swarnarekha	111.6	124.8	118.2	24.8	30.8	27.8	18.2	19.8	19.0	4.50	4.05	4.28
Meghlanthan	435.3	429.6	432.5	69.6	64.9	67.3	13.8	13.1	13.5	6.25	6.61	6.43
SafdarPasand	111.7	96.4	104.0	18.5	19.6	19.0	14.2	16.9	15.6	6.03	4.91	5.47
Himsagar	119.1	103.5	111.3	23.8	27.6	25.7	16.6	21.0	18.8	5.00	3.75	4.38
Langra	206.3	231.0	218.6	325.8	302.6	314.2	61.2	56.7	58.9	0.63	0.76	0.69
SE±m	**14.1**	**13.3**	**13.5**	**3.93**	**4.00**	**3.86**	**1.50**	**1.41**	**1.43**	**0.50**	**0.48**	**0.50**
CD(0.05)	**42.3**	**39.8**	**40.5**	**11.8**	**12.0**	**11.6**	**4.52**	**4.25**	**4.30**	**1.52**	**1.46**	**1.51**

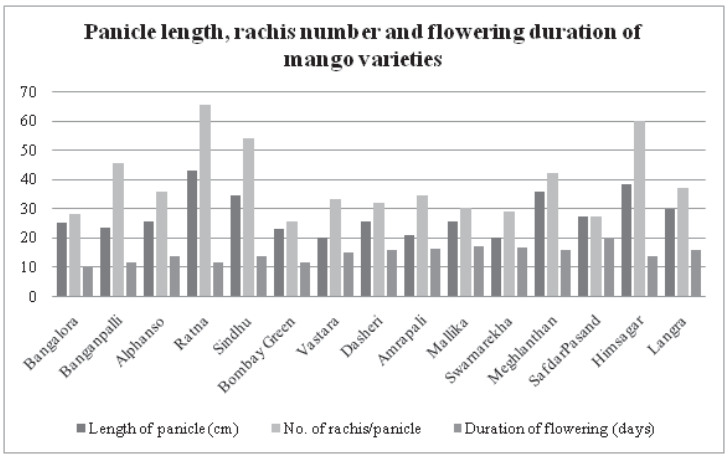

Fig. 1: Length of panicle, number of rachis per panicle and duration of flowering and panicle colour of different mango varieties

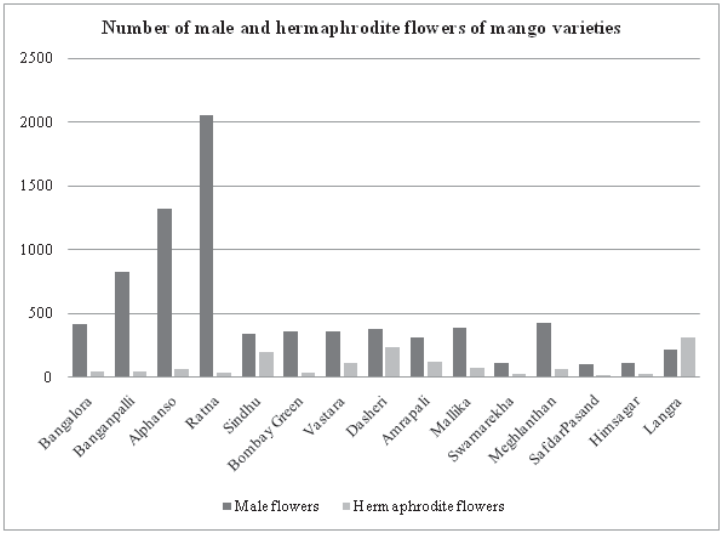

Fig. 2 : Number of male flowers and hermaphrodite flowers of different mango varieties.

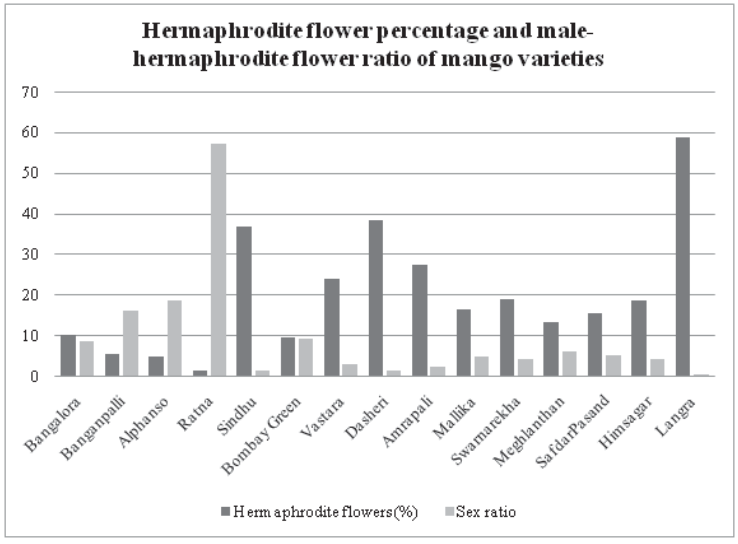

Fig. 3 : Percent of hermaphrodite flowers and male-hermaphrodite flower ratio of different mango varieties.

duration. Kumar *et al*. (2017) has reported range of flowering duration of mango varieties under western Uttar Pradesh condition as 11.33 to 19.00 days which has close proximity to the findings of the present experiment.

Colour of panicle: Mango varieties in the present study shown significant variation in their panicle (Table 1). Mainly the main stem and the branches or rachis are pigmented in mango panicles. Accordingly the panicle colors were noted. Light pink colouredpanicle have been observed in Bangalora, Bombay Green, Amrapali, Himsagar mango varieties. Greenish colour in the panicles has been noted in Alfonso, Dasheri and Langra varieties. Sindhuand Vastara have shown pink coloured panicles while Swarnarekha represented pinkish panicles. Light pink colored panicle was noted in Himsagar mango variety. On the other hand greenish pink colored panicle has been observed in Mallika and Meghlanthan mango varieties.

Synthesis of different pigments particularly anthocyanin in the panicles of mango cause the variation of panicle colour. This character is governed by some genes which are present in some varieties and sometimes they are absent and thus the presence or absence of colouration in the panicle of the mango results (Koirala *et al*., 2020). The variation of panicle colour in the present experiment is also due to the variation of their genotypic characters. Kumar *et al*. (2018) has also reported pinkish green, greenish pink, light green and light pink colour in various mango varieties.

Number of male flowers per panicle: Average number of male flowers per panicle under fifteen different mango varieties in the present experiment has been significantly varied in both the years as well as in pooled data (Table 2 and Figure 2). A huge variation has also been observed in the average number of male flowers present per panicle under the present experiment. Significantly highest number of male flowers per pinnacle (2056.2) has been noted in the mango variety Ratna. Alphanso mango variety has produced second highest number of male flowers per pinnacle (1323.8). Lowest number of male flowers was noted in SafdarPasand mango variety (104.0 numbers of male flowers) which was closely followed by Himsagar (111.3) and Swarnarekha (118.2) with respect to average number of male flowers per panicle.

The huge variation of number of male flowers of mango varieties in the present experiment (104.0 to 2056.2) was might be due to the variation of genetic components. Moreover, the varieties considered in the present experiment are diverse i. e. North Indian, South Indian, West Indian as well as hybrids. Thus the genetic variation is very common for this reason. Kishore *et al*. (2015) also found such huge variation in number of flowers in different mango varieties and that has been ranged from 384.67 to 2395.60.

Number of hermaphrodite flowers per panicle: The variation in the number of hermaphrodite flowers per panicle of fifteen different mango varieties noted ranged from 19.0 to 314.2 (Table 2 and Figure 2). Significantly highest number of hermaphrodite flowers was observed in the mango variety Langra while it was lowest under SafdarPasand. Mango variety Dasheri has also exhibited higher number of hermaphrodite flowers (239.4) and similar observation was noted in case of mango variety Sindu (199.8). On contrary, lower production of hermaphrodite flowers was observed under Himsagar as well as Swarnarekha variety with average hermaphrodite flowers of 25.7 and 27.8 respectively.

The sex differentiation of mango panicle depends on variation in the production of plant hormones and many other biomolecules which are determined and governed by genotypes of mango. Thus, genotypic variation causes difference in production of perfect flowers (Devenport, 2007). Vidyashree *et al*. (2021) has found 125 to 246 numbers of hermaphrodite flowers in some varieties and they have also mentioned that the variation was due to the genetic composition as well as weather condition prevailed during the flowering of mango varieties.

Percentage of hermaphrodite flowers: Significantly higher proportion of hermaphrodite flowers was noted under the mango variety Langra in both the years (Table 2 and Figure 3). It is evident from the pooled data that 58.9 % hermaphrodite flowers were produced by Langra variety mango. Variety Dasheri and Bombay Green have also produced higher proportion of hermaphrodite flowers in both the years as 38.5 and 37.1% respectively. Mango variety Ratna has exhibited significantly lowest proportion of hermaphrodite

flowers in both the years as well as in pooled data (1.7%). Variety Banganpalli and Alphanso have also been recorded lower proportion of hermaphrodite flowers in their panicles as 5.8 and 5.1% respectively.

Kishore *et al*. (2015) has reported the range in number of perfect flowers of different mango varieties as 3.39 to 34.03. The range of variation of percentage of hermaphrodite flowers as differed from the findings of Kumar *et al*. (2014) might be due to the variation in the genotypes as well as the prevalence of climatic condition.

Male and hermaphrodite ratio: Male and hermaphrodite ratio of different mango varieties in the present study has shown significant variation and it ranged from 0.69 to 57.30 (Table 2 and Figure 3). The mango variety Ratna has exhibited maximum male and hermaphrodite ratio. On contrary Langra has recorded lowest male and hermaphrodite ratio. Low male and hermaphrodite ratio was also noted in Dasheri, Sindhu, Amrapali, and Vastara mango varieties and they exhibited the ratio of 1.59, 1.69, 2.60 and 3.13.

In the present study the varieties with higher production of perfect flowers like Langra, Dasheri, Sindhu, Amrapali, and Vastara have shown very narrow male and hermaphrodite ratio which indicated a very good proportion of perfect flowers and better fruit set. On contrary Ratna, Alphanso, Banganpalli have exhibited lower proportion on perfect flowers and thus very high male and hermaphrodite ratio*i.e.*, higher population of male flowers per panicle. The attributed cause might be the genotypic variation, prevalence of climatic condition, growing zone as well as the influence of soil condition (Reddy and Sweety, 2018; Kumar *et al*., 2014; Abourayya *et al*., 2011).

CONCLUSION

In the present experiment, significant variations on various morphological characters of panicle and flowering pattern have been observed in fifteen selected mango varieties. The maximum length of panicle was noted in mango variety Ratna (43.1 cm) with maximum numbers of rachis (65.6). Highest flowering duration has been observed under SafdarPasand (19.9 days) and lowest in Bangalora (10.1 days). Mainly the main stem and the branches or rachis are pigmented in mango panicles as pink, light pink, pinkish green, greening pink, green etc. Maximum male flowers per pinnacle (2056.2) have been noted in the mango Ratna and minimum in Safdar Pasand (104.0). Number of hermaphrodite flowers per pinnacle of fifteen different mango varieties varied from 19.0 (in Langra) to 314.2 (in Safdar Pasand). Mango variety Langra has produced maximum hermaphrodite flowers (58.9 %) while lowest production of perfect flower was noted in Ratna (1.7%).

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Morpho-biochemical characterization of pomelo (*Citrus grandis* L.) accessions and assessment of bioactive compounds under western part of West Bengal

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ABSTRACT

Rich genetic base of Pomelo (Citrus grandis L.*) in India as a whole and Eastern India in particular, made wide variation in their fruit morphology, quality and presence of bioactive compounds. Thus the present study has been undertaken to characterize twelve pomelo accessions selected from different locations of Birbhum distrct which comes under western dry tract of West Bengal during the year 2023 at Department of Horticulture & Postharvest Technology, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal (India). Wide fruit morphological variation with respect to fruit length (14.2 to 25.0cm), fruit diameter (14.1 to 23.5) and rind thickness (1.15 to 2.36cm) were observed within the studied pomelo accessions. Considerable wider ranges of fruit weight (478.7 to 1323.6g), pulp weight (326.2 to 1051.5g), number of segments (13.6 to 18.0) have also been noted. Mean value of number of seeds and 10 seed weight was 46.18/fruit and 3.17g respectively which exhibited the range of 27.5 to 61.7/fruit and 2.22 to 4.79g respectively. Juice content varied from 48.7 to 65.1 ml/100g fruit pulp with 58.23 ml/ 100g as mean value. Moderate to high TSS (7.5 to 12.4°Brix), good range of total sugar (5.2 to 7.7%) and reducing sugar (3.0 to 4.6%) have been noted from different pomelo accessions. Mean value of acidity was 0.87% and TSS-acidity ratio was ranged from 8.06 to 16.37. Richness of the fruit in ascorbic acid content was noted (31.9 to 49.9 mg/100g pulp) along with high to moderate antioxidation capacity (30.8 to 65.4 DPPH IC_{50}). Pomelo fruits were rich in flavonoid content (3.2 to 7.2 mgRE/g) with high total phenolics (272.9 to 412.0 µgGAE/g) and diverse anthocyanin content (5.3 to 48.5 mg/100g).*

***Keywords*:** Bioactive compounds, diversity, fruit morphology, pomelo accessions, quality parameters

INTRODUCTION

Citrus grandis L. (syn. *Citrus maxima* L.) is commonly known as pomelo, is a citrus fruit native to Southeast Asia. This popular fruitbelongs to the order Sapindales under the family Rutaceae and genus *Citrus* (Rouseff *et al*., 2009; Hung *et al*., 2020; Zhao *et al*., 2019) and very closer but different from grapefruit (Ahmed *et al*., 2018; Gupta *et al*., 2021). It is a large, evergreen tree with a rounded canopy. Its glossy, dark green leaves are ovate to elliptical, with winged petioles (Jayaprakash *et al*., 2017). The tree bears large, pear-shaped fruits with thick, yellow to pale green rind, often with a slightly rough texture. The flesh ranges from pale yellow to pink or red, depending on the variety, and is segmented like other citrus fruits.Fruits consist of a thick, spongy rind with a dimpled texture, protecting the juicy segments inside (Roy and Saraf, 2006). The segments are surrounded by a membranous layer called the albedo, which separates them from the bitter, white pith.Seeds are typically large, round, or deltoid and white to creamy white in colour. They are found within the juicy segments of the fruit, embedded in the flesh and monoembryonic in nature (Glabasnia *et al*., 2018).Pomelo is rich in essential nutrients and offers several health benefits. It is low in calories (100g serving of pomelo only provides about 38 calories) and contains no cholesterol or saturated fats. It is an excellent source of vitamin C and contain significant amounts of potassium, vitamin A, dietary fiber, and antioxidants such as flavonoids and limonoids (Huang *et al*., 2021; Nadi

et al., 2019; Wang *et al*., 2017). It supports immune function, aid digestion, promote skin health, and help reduce the risk of chronic ailments like cardiovascular diseases (CVD) and cancer of different types (Fan *et al.*, 2019; Arora *et al*., 2018; Gualdani *et al*., 2016).

In Southeast Asian countries like Thailand, Vietnam, and Malaysia, pomelo displays notable diversity in its varieties, farming methods, and cultural significance. Thailand, renowned for its "Siamese Ruby" pomelo, boasts a wide array of pomelo cultivars, each distinguished by unique traits such as size, color, taste, and scent (Tian *et al*., 2007). This fruit holds cultural importance in Vietnam, often featuring in traditional celebrations and rituals. Vietnamese varieties like "PhucTrach" and "Da Xanh" are valued for their sweet taste and fragrant aroma. Malaysia, with its varied climates, supports various pomelo cultivars like "Buntong" and "Jelai," adapted to different ecological conditions (Montoya *et al*., 2019). Farming techniques for pomelo vary across these countries, ranging from small-scale family orchards to large commercial plantations, reflecting local agricultural customs and preferences. The diversity of pomelo in Southeast Asia not only enhances the region's culinary diversity but also contributes significantly to its agricultural sector and biodiversity conservation endeavors (Mohammad *et al*., 2021; Kore and Chakraborty, 2015; Corazza-Nunes *et al*., 2002). Ongoing efforts in research and conservation aim to preserve and utilize this diversity for sustainable pomelo cultivation and genetic enhancement, ensuring the fruit's continued prominence in the region.

In India, pomelo showcases significant diversity in its varieties and cultivation regions. Various cultivars such as Chakkorta, Bathike and Mysore Bitter are cultivated across the country, each offering unique flavors, sizes, and qualities (Sharma *et al*., 2015). Pomelo cultivation is prominent in states like Maharashtra, Karnataka, Tamil Nadu, Kerala, Bihar, West Bengal, Assam, Odisha etc. where diverse agro-climatic conditions support its growth. Additionally, local farming practices and preferences contribute to the richness of pomelo diversity in India along with the other minor or underutilized fruits (Mukherjee *et al*., 2023; Nandi *et al*., 2019). This diversity not only enriches the country's citrus industry but also provides opportunities for culinary innovation and sustainable agricultural practices (Maya *et al*., 2012).

Western dry tract of West Bengal within the lateritic belt of Chhotonagpur plateau region of Eastern India particularly the Birbhum district has wide range of diversity of pomelo with respect to their shape, size, surface characteristics, quality parameters and bioactive compounds. However, a very few of the pomelo genotypes have been studied and reported so far as scientific documents. Thus the present research has been carried out to characterize the available local pomelo accessions with respect to fruit morphological, biochemical and bioactive compound diversity under western dry tract of West Bengal.

MATERIALS AND METHODS

The present study was conducted during August 2023 to December 2023 selecting twelve different pomelo plants located different villages like Surul (23°39′N; 87°39′E),Supur (23°37′; 87°41′), Ruppur (23°39′; 87°27′), Raipur (23°37; 87°36′), Ballavpur (23°41′; 87°38′), Moldanga (23°40′; 87°39′), Bahadurpur (23°39′; 87°37′), Mahidapur (23°39′; 87°38′), Binuria (23°38′; 87°40′), Saldanga (23°39′; 87°25′), Kartikdanga (23°37′; 87°38′) and Deuli (23°36′; 87°38′) of Bolpur Sriniketan Block, Birbhum, West Bengal. Pomelo plants selected under the present study have aged between 10 to 20 years and were in full bearing stage under mostly at household gardens. The passport data of the plants were also collected. This area undergoes an extended period of arid winter, stretching from the second week of December to the second week of February, followed by a gentle spring lasting until March. The dry and hot summer season begins in the first week of April, featuring extremely high temperatures reaching up to 45°C, and persists until mid-June. Summers are marked by heatwaves and intense sunlight. The soil in this region is typified by red and lateritic sandy loam, with a pH range of 5.5 to 6.5, abundant in iron and aluminum, and with low organic matter content. The five mature ripe fruits of different selected pomelo plants have been collected and brought to the laboratory of the Department of Horticulture & Postharvest Technology for recording observations with respect

to fruit morphological, biochemical as well as quantification of bioactive compounds. The following procedure was adopted for recording the observations:

Fruit morphological parameters:

Fruit length and diameter: Fruit length and diameter of five pomelo fruits was recorded by placing the fruits in a plain surface and having vertical and horizontal arrangement of a measuring scale respectively and measurement was taken in centimeter up to the top level of the fruits.**Rind thickness:** As the fruit is hesperidium, the thickness of outer flavedo and albedo was measured as rind thickness by digital verneer caliper and expressed in centimeter. **Fruit weight and pulp weight:** Fruit weight and pulp weight of pomelo fruits were measuredwith digital balance and expressed in gram by measuring the whole fruit and only the pulp respectively. **Number of segments:** Total number of the segments in pomelo fruits has been counted by making horizontal section of each fruit. **Number of seeds per fruit**: Seeds of pomelo fruits counted separately for each fruit and the average was calculated for each accession. **Juice content**: Volume of juice was measured from hundred gram of pulp from every pomelo fruits and expressed in milliliter.

Fruit biochemical parameters

Total soluble solids (TSS in ^{o}Brix): Total soluble solids of pomelo fruits were measured by digital TSS meter (Model: ATAGO PAL-1, 3810, Japan) taking few drops of juice in the glass plate of TSS meter at ambient temperature. TSS was expressed in degree brix.

Total sugar and reducing sugar: The total sugar content of the fruit juice was measured by titrating it after hydrolysis with HCl against Fehling 'A' and Fehling 'B' solutions, with methylene blue serving as an indicator. The results were expressed as a percentage (A.O.A.C., 2018). Similarly, the reducing sugar content was determined by titrating the diluted juice against Fehling 'A' and Fehling 'B' solutions, also using methylene blue as an indicator, and reported as a percentage (A.O.A.C., 2018).

Acidity: The total acidity of the diluted fruit juice was assessed by titrating it against a 0.1 N NaOH solution, employing phenolphthalein as an indicator. The findings were presented as a percentage of the fruit's fresh weight (Ranganna, 1986). **TSS-Acidity ratio**: Ratio of total soluble solids and acidity of pomelo fruits juices were determined by simply dividing the total soluble solids content by acidity of the respective fruit juices. **Ascorbic acid content**: The ascorbic acid content of the fruit was assessed using the 2,6-dichlorophenol indophenol dye titration method recommended by Ranganna (1986), with the findings presented as mg per 100 g of fruit.

Determination of bioactive compounds

Antioxidant (DPPH IC_{50}) : Antioxidant activity was measured using 2,2- Diphenyl Picrylhydrazyl (DPPH) free radical inhibition assay (Jumina *et al*., 2019; Alanon *et al*., 2011; Dewanto *et al*., 2002). The fruit juice (0,5,10,25 and 50 µl/ml) was mixed with DMSO solution and ethanol for shaking and after that absorbance was taken at 517 nm in UV visible spectrophotometer (LABMAN, Model LMS PUV 1200). Linear plot of percent inhibition concentration of analyzed Jews has been prepared to find out the IC_{50} of each juice sample collected from the pomalo fruits.

Flavonoid (mgRE/g): For determination of the flavon compounds the juice were placed in beaker with 100 ml ethanol and covered with aluminum foil and placed in water bath at 80^{o}C for three hours after that the whole solution was filtered and allowed to evaporate into dryness at 60^{o}Cto get the solids. 0.05 gram of solids wire mixed with 5% sodium nitrite 10% aluminum nitrate and sodium hydroxide solution for final aliquot to be taken for absorbance at 500 nm while other component mixtures except sample are taken as blank. Flavonoid content was expressed in milligram of rutin equivalent per gram of sample (He *et al*., 2008).

Total phenolics (µgGAE/g): Total phenolic content was estimated by Folin Ciocalteu's method. 1 ml of aliquots and standard gallic acid (10, 20, 40, 60, 80, 100 µg/ml) was positioned into the test tubes and 5 ml of distilled water and 0.5 ml of Folin Ciocalteu's reagent was mixed and shaken. 1.5 ml of 20 % sodium carbonate was added and allowed to incubate for 2 hours at room temperature. Absorbance was measured at 750 nm using UV

visible spectrophotometer (LABMAN, Model LMS PUV 1200) after appearance of intense blue color considering gallic acid as standard (Dewanto *et al*., 2002). The phenolic contents were expressed as mg of gallic acid equivalent weight (GAE)/100 g).

Anthocyanin content (mg/100g): For determination of anthocyanin content pomelo juice was mixed with acidic ethanol and stirred for one hour in magnetic stirrer.Dilution of the mixture was done in volumetric flask by using buffers. The absorbance of the ethanolic extract was measured (LABMAN, Model LMS PUV 1200) at 520 nm as well as 700 nm using distilled water as blank (Nile *et al*., 2015).Anthocyanin pigment concentration was calculated and expressed as equivalent of cyanidine 3 glucoside at mg/100g.

Statistical analysis: Statistical analysis of the collected data with respect to different parameters of morphological, biochemicalparameters along with bioactive compounds have been subjected tomean variance analysis considering the each plant as sources of variation and five fruits from each plant as a single sample (Gomez and Gomez, 1984; Frans *et al*., 2021). The analysis of variance (ANOVA) is prepared for each parameter and cited in the tables. The Box-Whisker plot (Tukeys Honestly Significant Different Test or Tukeys HSD test) for all the parameters were prepared to compare the degree of diversity of characters within the pomelo accessions (PA) under the present study (Nanda *et al*., 2021).

RESULT AND DISCUSSION

Fruit morphological parameters

The mean variance analysis of different fruit morphological parameters is presented in Table 1 and the distribution pattern of the parameter quartiles is also presented by Box-Whicker plots (Figure 1, 2 and 3).

Fruit length of twelve different pomelo accessions (PA) has been ranged from 14.2 to 25.0 cm with a mean fruit length of 19.15cm. Pomelo accession PA 12 has shown lowest fruit length while PA 5 exhibited highest fruit length. **Fruit diameter** of different pomelo accessions was measured from 14.1 to 23.5 cm in PA1 and PA 5 respectively with a mean diameter of 17.68 cm. The **rind thickness** of pomelo accessions was varied from 1.15 to 2.36 cm with a mean value of 1.94 cm. PA 1 has exhibited exceptionally thin rind and on the other hand PA 11 has shown thickest rind. Pomelo accessions like PA 11, PA 4, PA 10 have recorded good fruit size in the present study (23.9cm x 21.8cm, 23.6cm x 19.3cm, 22.0cm x 19.5cm in length and diameter). Lower rind thickness was also noted in PA 12, PA 2 and PA 6 (1.81cm, 1.84cm and 1.86cm).

Significantly highest **fruit weight** (1323.6g) was noted in PA 5 and very low fruit weight (478.7g) was observed in PA 12, although the mean fruit weight was moderate (876.34g). Higher fruit weight has also been recorded in PA 4, PA11 and PA 10 (1158.4g, 1132.5g and 1094.8g). **Pulp weight** of different pomelo accessions was varied significantly and the range of pulp weight was measured from 326.2 to 1051.5g. Maximum fruit pulp content was noted in PA5 and minimum in PA 12. Pomelo accessionsPA 11, PA 4 and PA 10 has also possessed higher pulp weight (889.4g, 845.8g and 825.6g).

Significant variation in the **number of segments** of pomelo fruits was noted in the present study and a range of 13.6 to 18.0 numbers of segments was counted for twelve different accessions. Maximum segment was noted in PA 3 and minimum in PA 12 with a mean of 15.70 segments. PA 9 and PA 2 has shown lower number of segments (13.7 and 14.1). **Number of seeds** of different pomelo accessions in the present study has been ranged from 27.5 to 6 1.7. The smallest fruit of PA 12 has exhibited lowest number of seeds while PA10 possessed highest number of seeds, although the average number of seeds of twelve different pomelo accessions was 46.18. Size of the seeds of pomelo accessions varied significantly in the present study and **10 seed weight** was ranged from 2.22 to 4.79 g with a mean value of 3.17 g.lower seed weight was also counted in PA 10 and PA 9 (2.24g and 2.41g/10 seeds). **Juice content** of pomelo fruits was extracted from 100 gof pulp and the volume of the juice has been varied widely from 48.7 ml in PA 9 to 65.1 ml in PA 6.PA 12 and PA 4 has observed as higher juice yielder (61.8ml and 63.8ml/100g pulp).

The comparative length of Box-Whisker plot diagram (Figure 1) clearly denotes the wider variation of fruit length moderate variation of fruit diameter and very low variation in rind thickness of twelve pomelo accessions. On the other side the

Table 1:Fruit morphological characters of pomelo accessions under western dry tract of West Bengal

Pomelo accessions	Fruit length (cm)	Fruit diameter (cm)	Rind thickness (cm)	Fruit weight (g)	Pulp weight (g)	No of segments	No of seeds/fruit	10 seed weight (g)	Juice content (ml/100g pulp)
PA 1	16.5	14.1	1.15	814.3	684.0	15.2	29.6	3.56	51.4
PA 2	15.7	16.4	1.84	704.5	534.1	14.1	31.2	3.23	56.0
PA 3	21.3	18.3	2.02	936.4	714.6	18.0	48.8	2.75	57.9
PA 4	23.6	19.3	2.21	1158.4	845.8	16.3	56.7	2.22	63.8
PA 5	25.0	23.5	1.99	1323.6	1051.5	17.8	59.5	2.53	61.5
PA 6	17.6	16.4	1.86	759.9	637.2	14.9	42.3	4.48	65.1
PA 7	15.5	15.0	2.11	596.2	418.6	15.7	49.1	3.78	57.0
PA 8	19.1	17.6	1.89	875.1	678.7	14.8	41.3	3.46	53.8
PA 9	15.4	14.7	1.87	641.7	499.5	13.7	48.0	2.41	48.7
PA 10	22.0	19.5	2.17	1094.8	825.6	16.5	61.7	2.24	62.5
PA 11	23.9	21.8	2.36	1132.5	889.4	17.8	58.4	2.63	59.2
PA 12	14.2	15.6	1.81	478.7	326.2	13.6	27.5	4.79	61.8
Mean	**19.15**	**17.68**	**1.94**	**876.34**	**675.43**	**15.70**	**46.18**	**3.17**	**58.23**
SD	**3.84**	**2.92**	**0.30**	**258.52**	**209.05**	**1.59**	**12.00**	**0.86**	**5.09**
CV	**20.07**	**16.50**	**15.58**	**29.50**	**30.95**	**10.12**	**25.99**	**27.17**	**8.73**
Range	**14.2 - 25.0**	**14.1 - 23.5**	**1.15 - 2.36**	**478.7 - 1323.6**	**326.2 - 1051.5**	**13.6 – 18.0**	**27.5 - 61.7**	**2.22 - 4.79**	**48.7 - 65.1**

Table 2: Fruit biochemical parameters and bioactive compounds of pomelo accessions under western dry tract of West Bengal

Pomelo accessions	Biochemical parameters						Bioactive compounds			
	TSS (°B)	Total sugar (%)	Reducing sugar (%)	Acidity (%)	TSS-Acidity ratio	Ascorbic acid (mg/100g)	Antioxidant (DPPH IC_{50})	Flavonoid (mgRE/g)	Total phenolics (µgGAE/g)	Anthocyanin content (mg/100g)
PA 1	8.5	5.4	3.5	0.95	8.94	34.7	56.7	3.8	384.5	22.6 (P)
PA 2	7.5	5.2	3.4	0.93	8.06	32.5	60.2	3.2	376.8	35.2 (P)
PA 3	11.7	7.0	4.6	0.89	13.14	46.2	37.5	5.7	321.5	41.1 (P)
PA 4	12.4	7.5	4.4	0.85	14.58	31.9	48.9	4.6	362.2	11.7 (W)
PA 5	11.1	7.7	4.5	0.78	14.23	42.6	32.7	6.9	272.9	48.5 (P)
PA 6	8.3	6.0	3.7	0.86	9.65	38.3	59.8	4.2	298.7	39.6 (P)
PA 7	8.9	6.4	3.2	0.98	9.08	35.9	65.4	3.8	401.5	6.8 (W)
PA 8	9.2	6.7	3.6	0.87	10.57	40.7	41.5	4.9	356.7	38.5 (P)
PA 9	9.1	6.0	3.5	0.94	9.68	36.1	45.6	3.7	324.2	41.3 (P)
PA 10	11.3	7.2	4.3	0.69	16.37	41.5	35.4	7.2	294.6	32.6 (P)
PA 11	9.5	6.9	4.0	0.75	12.66	49.9	30.8	5.6	345.1	5.3 (W)
PA 12	8.7	6.3	3.0	0.91	9.56	31.8	51.6	3.7	412.0	45.2 (P)
Mean	**9.68**	**6.53**	**3.81**	**0.87**	**11.38**	**38.51**	**47.18**	**4.78**	**345.89**	**30.70**
SD	**1.55**	**0.79**	**0.54**	**0.09**	**2.70**	**5.81**	**11.75**	**1.31**	**44.25**	**15.24**
CV	**15.98**	**12.07**	**14.09**	**10.10**	**23.72**	**15.09**	**24.91**	**27.53**	**12.79**	**49.64**
Range	**7.5 - 12.4**	**5.2-7.7**	**3.0-4.6**	**0.69-0.98**	**8.06 – 16.37**	**31.9 -49.9**	**30.8 - 65.4**	**3.2-7.2**	**272.9-412.0**	**5.3-48.5**

(P: Pink fleshed and W: white fleshed pulp, noted on parentheses of anthocyanin content of fruits).

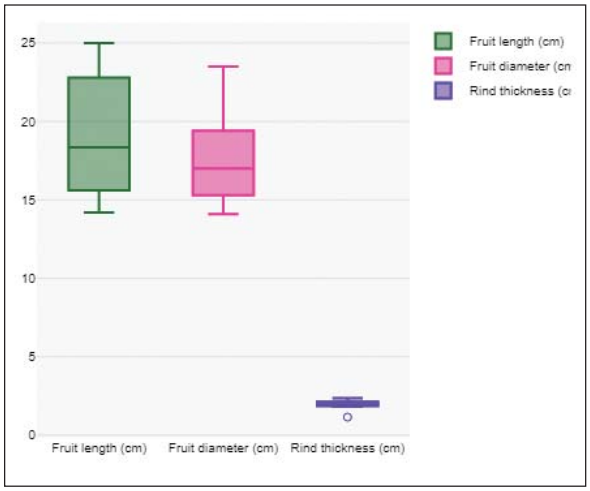

Fig. 1: **Box-Whisker plot of fruit length (cm), fruit diameter (cm) and rind thickness (cm) of different pomelo accessions.**

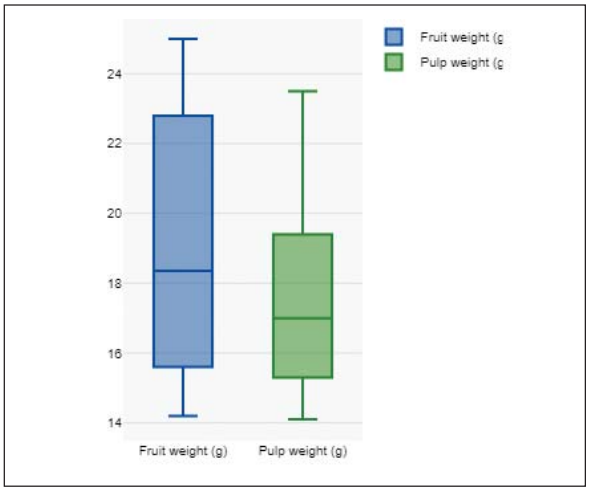

Fig. 2: **Box-Whisker plot of fruit weight (g) and pulp weight (g) of different pomelo accessions.**

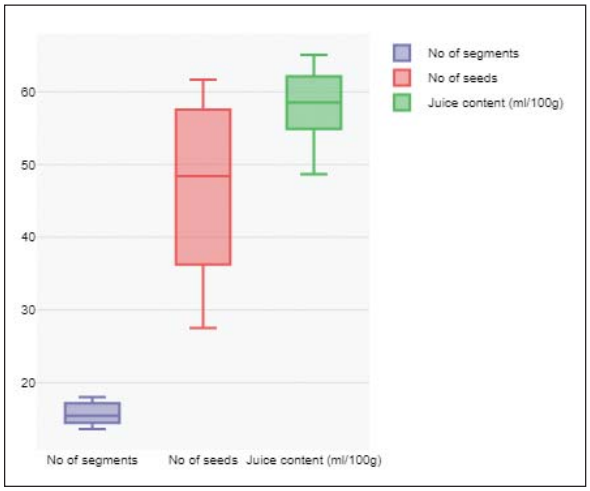

Fig. 3: **Box-Whisker plot of number of segments, number of seeds and juice (ml/100g) of different pomelo accessions.**

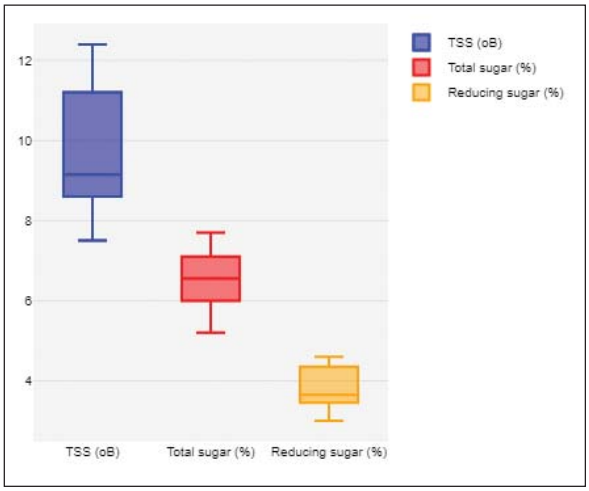

Fig. 4: **Box-Whisker plot of number of TSS (oBrix), total sugar (%) and reducing sugar (%) of different pomelo accessions.**

tall Box-Whisker plot diagram (Figure 2) express very high variation of fruit weight and pulp weight of different pomelo accessions where the pomelo accessions under lowest quartiles of both the parameters has closer value and most wide variation of fruit weight of pomelo accessions in 2nd upper quartile but first upper quartile in pulp weight. Number of segments in the pomelo fruits under present experiment has exhibited narrow variability while the number of seeds has shown very high variability and juice content of the fruits recorded moderate variability (Figure 3). The pomelo accessions fall under lower two quartile of Box-Whisker plot of both the number of seeds and juice content has significant variation. Angami *et al*. (2022) has found variability in pomelo genotypes in fruit morphological characters like fruit weight (567.52 – 1581.48 g), number of segments per fruit (13.00 - 114.33), peel thickness (1.22 - 3.26 cm), juice percent (14.40 - 20.54) etc.and these finding has conformity with the present findings.Pan *et al*. (2021) studied the fruit morphological variation of pomelo genotypes under northern China condition and found great variation in fruit length (14.05 to 20.7 cm), fruit width (13.12 to 19.56cm), fruit weight (264.63 to 1730.98g) and

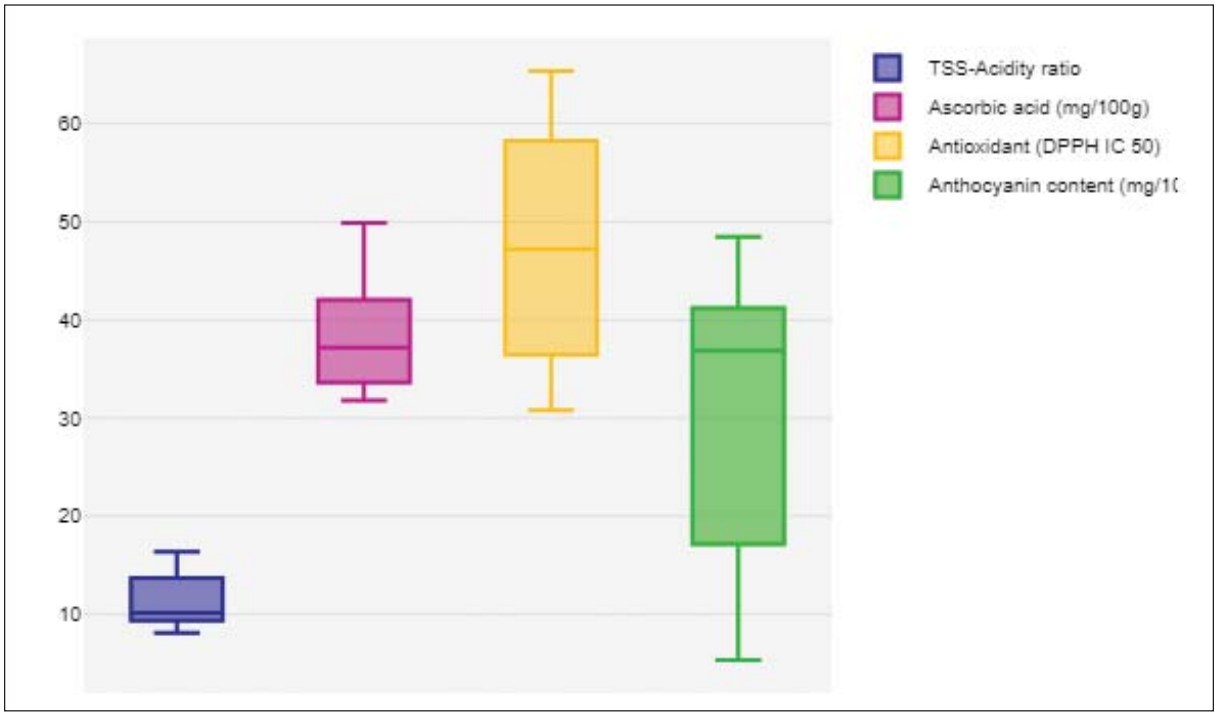

Fig. 5: **Box-Whisker plot of number of TSS-acidity ratio, ascorbic content (mg/100g), antioxidant capacity (DPPH IC50) and anthocyanin content (mg/100g) of different pomelo accessions.**

pulp weight (210.25 to 1257.27g), peel thickness (0.46 to 2.43cm)which has also in line with the results of the present experiment. More or less similar report have been referred by Bankar *et al*. (2021) who has found significant variation in fruit morphology with respect to fruit length (12.55 to 20.76cm), fruit weight (492.2 to 1036.4g), pulp weight (164.29 to 620.89g) and number of seeds 40.67 to 840. Hossain *et al*. (2018) has found the heaviest and lightest fruits in genotype Hybrid (1283.33 g) and Accession-52 (300 g), while the maximum weight of non-edible portion (463.33 g), pulp to peel ratio (3.97), thickness of pulp (11.50 cm), amount of juice (366.67 ml), number of seeds (114) and weight of seeds (58 g) in genotype Hybrid. Above scientific reports on the variability of morphological parameters of pomelo genotypes has the conformity with the findings of the present experiment and the variation is mainly due to the genetic variation and differences in growing condition.

Fruit biochemical parameters

The mean variance analysis of different fruit biochemical parameters is presented in Table 2 and the distribution pattern of parameter quartiles is also presented by Box-Whicker plots (Figure 4 and 5).

Total soluble solids content of different pomelo accessions was significantly varied from 7.5° to 12.4°Brix which was highest in PAS 4 and lowest in PA 2. Higher TSS was also recorded in PA 3, PA 10 and PA 5 (11.7, 11.3 and 11.1°Brix respectively). Mean value of TSS was 9.68°Brix. A considerable numbers of pomelo accessions have scored higher total sugar content like PA 5 (highest), PA 4, PA 10 and PA 3 (7.7,7.5,7.2 and 7.0% of total sugar) with a mean value of 6.53%. Similarly, pomelo accessions like PA 3, PA 5, PA4 and PA 10 exhibited with greater quantity of reducing sugar (4.6, 4.5, 4.4 and 4.3%) with a mean value of 3.81.

Titrable acidity of the pomelo fruits were varied widely with a range of 0.69 to 0.98% as citric acid equivalent. PA 10, PA 11 and PA 5 were under the low acid group with acidity of 0.69, 0.75 and 0.78% respectively. On contrary PA 7, PA 1, PA 2 and PA 12 were recorded under high acid group (0.98, 0.94, 0.93 and 0.91% acidity respectively).

TSS-acidity ratio of pomelo fruits under the present study was varied from 8.06 to 16.37 with a mean value of 11.38. Pomelo accession PA 10 has possessed highest TSS-acidity ratio and some other accessions like PA 4, PA 5, PA 3 and PA 11 have

also recorded higher TSS-acidity ratio (14.58, 14.23, 13.14 and 12.66 respectively). On contrary, lower TSS-acidity ratio was noted in PA 2 (lowest), PA1, PA 7, PA 12, PA 6 and PA 9 with value of 8.06, 8.94, 9.06, 9.56, 9.65 and 9.68 respectively.

Pomelo accessions in the present experiment have shown a wide range of **ascorbic acid content** in their pulp (31.9 to 49.9 mg/100g). Highest ascorbic acid content was recorded in the fruits of PA 11 and lowest in PA 4 with mean value of 38.51 mg/100g. Higher ascorbic acid content in pomelo fruits under the present study was recorded in PA 3, PA 5, PA 10and PA 8 with a value of 46.2, 42.6, 41.5 and 40.7 mg/100g of pomelo pulp.

Box-Whisker plot of TSS signifies very high variability of pomelo accessions where the accessions under upper second quartile have shown wider variation and third quartile has very closer value of TSS (Figure 4). The interpretation of Box-Whisker plot with respect to the total sugar and reducing sugar signifies low-moderate variability of pomelo accessions (Figure 4). The variation of pomelo accessions in view of TSS-acidity ratio was very narrow and out of which the accessions at the lower quartile has the closer value (Figure 5). The analysis of the result with respect to the ascorbic acid content of pomelo accessions have exhibited moderate variability and out of which the upper first quartile accessions have possessed greater variability and narrow in lower quartile. Angami *et al*. (2022) have found wider variation in different fruit quality aspects of pomelo genotypes under Arunachal Pradesh condition and they found variability in TSS (7.50 - 10.75 ºB), titratable acidity (0.39 - 1.71 %), ascorbic acid (27.57 - 48.28 mg/100 ml), total sugar (5.53 - 9.85 %) and total phenols (2.01 - 3.31 mg/100 ml) and this findings are in line with the findings of the present experiment. The report of Pan *et al*. (2021) regarding the variation of pomelo genotypes under northern China condition with respect to fruit biochemical parameters like TSS (9.4 to 12.42ºBrix), ascorbic acid content (34.79 to 84.58mg/100g), total sugar (6.13 to 9.47 g/100g) etc. has similarity with the result of present research. Similarly the wider variability in fruit biochemical parameters were reported by Bankar *et al*. (2021) in TSS (8.56 to 12.51ºBrix), total sugar (2.46 to 3.88%), reducing sugar (1.71 to 2.13%), acidity (0.43 to 1.02%) and ascorbic acid content (48.39 to 58.46 mg/100g). A greater variability in fruit quality of pomelo genotypes has also been reported by Hossain *et al*. (2018) under Bangladesh condition and Li *et al*. (2019) in China condition. Thus the findings of these fruit quality aspects of pomelo genotypes support the findings of the present experiment. In all these reports as well as in the findings of the present experiment, the variation of fruit quality parameters is due to the wider genetic makeup as well as the differences in growing conditions of pomelo genotypes.

Bioactive compounds

The mean variance analysis of different fruit biochemical parameters is presented in Table 2 and the distribution pattern of parameter quartiles is also presented by Box-Whicker plots (Figure 5).

Antioxidant activity of twelve different pomelo accessions in terms of DPPH IC_{50} value has been ranged from 30.8 to 65.4. Lower the IC_{50} value navigates higher antioxidant content of the fruit pulp. Thus PA 11 has been observed as potential pomelo accession for highest antioxidant activity with lowest IC_{50} value and on the other hand PA 7 possessed lowest content of antioxidant due to the highest IC_{50} value of DPPH. Some other potential pomelo accessions with respect to higher antioxidant content are PA 5, PA 10 and PA 3 with DPPH IC_{50} value of 32.7, 35.4 and 37.5 respectively.

Flavonoid is one of the most important bioactive compounds present in pomelo and in the present experiment it has been observed that the accessions of pomelo fruits have exhibited a significant variation in flavonoid content. Highest flavonoid content (7.2 mgRE/g) was recorded in PA 10 and lowest in PA 2 (3.2 mgRE/g). The pomelo accessions namely PA 5 and PA 11 also possessed higher flavonoid content of 6.9 and 5.6 mgRE/g.

Phenolic compounds are also considered as important bioactive compound which has antioxidation capacity as well many other positive cellular functions. The pomelo fruits of twelve different accessions possessed significant variation and a range of 272.9 to 412.0 µgGAE/g total phenolics in the fruit pulp (of pomelo accessions PA 5 and PA 12) with a mean value of 345.89 µgGAE/g. On the other hand very high phenolics

also responsible for development of oxidized polyphenols resulting into brownish or bluish black colour development of the cut fruit pieces.

Difference in fruit pulp colour of different pomelo accessions in the present study has resulted wide variation in **anthocyanin content** of pulp (Table 2). White fleshed accessions (W) expressed very low anthocyanin content like PA 11, PA 7 and PA 4 (5.3, 6.8 and 11.7 mg/100g). On the other hand, higher pulp anthocyanin content have been observed frompink fleshed pomelo accessions (P) like PA 5, PA 9 and PA 3 (48.5, 41.3 and 41.1 mg/ 100g). The mean anthocyanin content of pomelo accessions were 30.70 mg/100g.

The analysis of variability of pomelo accessions in the present study in respect of antioxidant activity has a clear long range and most of all the accessions are distributed equally within the range (Figure 5). Yin *et al.* (2023) has reported the amounts of the total phenols ranged from 5.428 - 11.97 mg/ 100 g EP and the amounts of the total flavonoid ranged from 47.12 - 135.9 mg/100 g EP in pomelo genotypes. Additionally they reported that the DPPH IC_{50} antioxidant activity of water extracts of pomelo was ranged from 13.8 to 77.6 mg/ml. Anagami *et al*. (2022) has found the range of phenolic compounds in pomelo genotypes as 2.01 - 3.31 mg/100 ml). This report has similarity with the findings of present experiment. Deng *et al*. (2022) has evaluated the flavonoid profiles of different pomelo genotypes and found wider variations from 13.4 to 193.3 mg CE/100 g FW. They have also reported the phenolics content of pomelo genotypes 91.8 to 170.9 mg GAE/100g FW and Anh *et al.* (2021) have found total phenolic and total flavonoid contents of the pomelo extracts under optimal condition as 16.79 mg GAE/g and 10.69 mg RE/g, respectively. Thus these findings have the conformity with the findings of present research. Nishad *et al*. (2018) reported antioxidant activity of pomelo accessions as 2.16–4.04 ìmol TE/ml, total phenol from 22.18 to 48.0 mg GAE / 100ml. Bioactive Flavonoids, Antioxidant Behaviour and cytoprotective effects of dried Grapefruit have been studied by JiajiaYina *et al*. (2023), Yin *et al*. (2023), Vazquez *et al*. (2016), and they have reported that pomelo has considerable potential as a source of natural bioactive flavonoids with outstanding antioxidant activity which can be used as agents in several therapeutic strategies. The findings of such all the scientist are in line with the results of the present study. The variation in the quantification of bioactive compounds is mainly due to the genetic differences of pomelo genotypes.

CONCLUSION

Wide fruit morphological variation with respect to fruit length (14.2 to 25.0cm), fruit diameter (14.1 to 23.5) and rind thickness (1.15 to 2.36cm) were observed within the studied pomelo accessions. Considerable wider ranges of fruit weight (478.7 to 1323.6g), pulp weight (326.2 to 1051.5g), number of segments (13.6 to 18.0) have also been noted. Juice content varied from 48.7 to 65.1 ml/ 100g fruit pulp with 58.23 ml/100g as mean value. Moderate to high TSS (7.5 to 12.4^{o}Brix), good range of total sugar (5.2 to 7.7%) and reducing sugar (3.0 to 4.6%) have been noted from different pomelo accessions. Mean value of acidity was 0.87% and TSS-acidity ratio was ranged from 8.06 to 16.37. Richness of the fruit in ascorbic acid content was noted (31.9 to 49.9 mg/100g pulp) along with high to moderate antioxidant content (30.8 to 65.4 DPPH IC_{50}) and rich in flavonoid content (3.2 to 7.2 mgRE/g). High total phenolics (272.9 to 412.0 µgGAE/g) and diverse anthocyanin content (5.3 to 48.5 mg/100g) has also been noted in pomelo fruits. In conclusion, among the pink fleshed pomelo accessions PA 5 has possessed higher fruit size better fruit quality and rich in bioactive compounds. On contrary PA 11 was found best within white fleshed pomelo.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Influence of indole butyric acid on root and shoot growth in dragon fruit (*Selenicereus undatus*) stem cuttings

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ABSTRACT

To study influence of indole butyric acid (IBA) for enhancing root and shoot growth of dragon fruit stem cuttings and optimise the concentration of IBA, 0, 1000, 2000, 4000, 6000 and 8000 ppm were used to treat the stem cuttings planted in polybags as well as field experiment (raised bed planting). Polybags filled with sandy loam soil from ravine bed mixed with farm yard manure (FYM) and without FYM and raised beds were prepared in native murrum soil filled with FYM. Results revealed that the application of IBA @6000 ppm enhanced root and shoot growth of dragon fruit at 20 and 60 days after planting (DAP) in both the growing medium as well as in the field. Root length (34.50 ± 1.25 cm), numbers of roots (25.20 ± 1.52), fresh (10.81 ± 0.70 g) and dry weight of roots (5.16 ± 0.49 g)as well as shot growth represented by number of new shoots, shoot weigh on fresh and dry basis etc. were found greater with application of IBA @6000 ppm at 60 DAP; in soil with FYM medium. Similar trend was also observed in cuttings planted in polybags filled with soil without FYM and in the field experiment where application of IBA @6000 ppm found at par with 8000 ppm. IBA @ 6000ppm treatment also resulted in to sprouting of cuttings in 16-17 days compared to control where it took 19-20 days under the experiments. Therefore, IBA@6000 ppm is optimum for enhancement of adventitious root and shoots growth of dragon fruit stem cuttings.

***Keywords*:** Dragon fruit, Indole butyric acid, propagation, stems cutting

INTRODUCTION

Dragon fruit plant (*Selenicereus undatus* [Berger] Britton & Rose) is fast growing; perennial epiphyte, produces beautiful flowers and fruits (Britton and Rose, 1963). It has enormous economic and medicinal importance due to richness in vitamins and minerals, and essential fatty acids. Therefore, it is considered as wholesome and remunerative fruit crop. Wider climatic and edaphic adaptability, hardy nature, less water and fertilizer requirement offers abundant opportunities for extending its cultivation particularly under degraded lands (Kakade *et al*., 2020). Government of India is also planned to expand its area to almost 50000 hectare in the country in coming five years. In this connection, availability of good quality planting material with well-developed root and shoot growth will be crucial.

Dragon fruit is largely propagated through stem cutting of 10-60 cm length. Stem cuttings can be planted in polybags as well as in raised beds to develop nursery. In dragon fruit, root and shoot growth increases with size of cutting (Gehlot *et al*., 2014; Kakade *et al*., 2019). However, growers prefer medium sized owing to ease of handling and transportation. Therefore, in order to enhance root and shoot growth in medium sized cuttings, application of rooting hormones under nursery is found to be easiest way. Auxins derivatives have relatively greater impact than others and among auxins, higher efficiency and stability of IBA is very well proven (Zimmerman and Wilcoxon, 1935; Nordstrom *et al*., 1991), therefore, it is widely used for developing adventitious rooting in plants (Chander and Kumar, 2023). Wide range of

concentrations of IBA *i.e*., from 50-10,000 ppm has been reported in different plants (Rahbin *et al*., 2012; Khajehpour *et al*., 2014). However, 300 ppm and 10 mM concentration reported by Rahad *et al*. (2016) and Elobeidy (2006) respectively in dragon fruit plant. These contradictory findings could be due to species variation, media composition, types of propagation material and growth regulators etc. used while multiplication. Since IBA concentration can influence the rooting of dragon fruit cutting, its low or high levels may inhibit the rooting as observed in other crops (Sulusoglu and Cavusoglu, 2010). Therefore, in view of above facts, an experiment has been undertaken to determine the optimum concentration of IBA for dragon fruit propagated through stem cutting in polybag as well as raised bed in field conditions with respect to root and shoot growth.

MATERIALS AND METHODS

Pot and field experiment was conducted during the year 2018-19 and 2019-20 at ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Vasad, Anand (Gujarat) and ICAR-National Institute of Abiotic Stress Management, Baramati, Pune (Maharashtra) which falls under semi-arid ago-ecological regions of western India. One year old medium sized stem cuttings of 20-25 cm and 15-20 cm length selected from healthy white fleshed dragon fruit (*S. undatus*) plants in the month of June and kept for callusing in shade for a week. Before planting, basal part (3-4 cm) of cuttings was dipped for 10 seconds in 0, 1000, 2000, 4000, 6000, and 8000 ppm IBA. Post application of IBA, cuttings were planted in polybags of size (30 × 12 cm) filled with only soil and soil + FYM @ 3:1 ratio, and also in the raised beds at uniform planting depth. Polybags were transferred under shade net having 50% shade efficiency. Soil used while filling the bags was sandy loam, well drained having organic carbon, pH and electrical conductivity of 0.3%, 7.6 and 0.22 dS/m respectively. Whereas, in case of field experiment on raised beds, cuttings were planted in soil developed from basaltic rocks and it was porous, gravelly, and low in organic matter. Plants were uprooted at 20 and 60 DAP, and 100 DAP (days after planting) in case of polybag and raised bed field experiment respectively to measure root and shoot growth. Fresh weight of shoots and roots and length of new shoots and roots was measured with help of digital weighing balance and vernier calliper. Uprooted plants were then transferred to hot air oven (70°C) for 36-48 hours to assess the biomass on dry weight basis. This experiment was conducted in completely randomised design using 5 replications and analysis was performed using analysis of variance using SPSS (16.0) software and CD was compared at 5% level of probability.

RESULTS AND DISCUSSION

Average number of roots : The higher number of roots was obtained in cutting treated with IBA at 6000 ppm on par with 8000 and 2000 ppm at 20 DAP, whereas IBA @6000ppm has resulted in to increased roots at 60 DAP over control and other treatments in case of soil + FYM medium. IBA @6000 ppm also resulted in to highest number of roots (18.00 ± 0.95) as compared to other treatments except IBA @4000 ppm at 20 DAP, whereas IBA @6000ppm on par with IBA @8000ppm shower greater root numbers over control and other treatments at 60 DAP in soil medium (Table 1 &2). In case of field experiment, the degree of root formation in cuttings increased with higher IBA concentration and IBA @6000 ppm produced higher number of roots followed by IBA @8000 and 4000 ppm and lowest was recorded in Control (Table 5). IBA growth hormone has been extensively used as rooting hormone in agriculture to promote adventitious rooting in cutting (Braun and Wyse, 2019). Induction of adventitious rooting can be classified as three distinct stages: the root induction period, root initiation, and protrusion (Arya and Husen, 2022). Auxins primarily play a critical role at the induction stage; thus benefits adventitious rooting (Pincelli-Souza *et al*., 2024). In dragon fruit Seran and Thiresh (2015) also proposed 6000 ppm IBA for enhancing rooting with smaller cuttings. Findings of present experiment though agree with Seran and Thiresh (2015) but vary from Gehlot *et al*. (2014) and Rahad *et al*. (2016) who reported 10 mM and 300 ppm concentration in dragon fruit. This may be because

Table 1: Effect of IBA concentrations on root parameters of Dragon fruit at 20 DAP in Soil + FYM and soil medium

Treatments	Number of roots		Root length (cm)		Fresh weight of roots (g)		Dry weight of roots (g)	
	SFM	SM	SFM	SM	SFM	SM	SFM	SM
IBA@ 0ppm	8.40 ± 0.60^{c}	9.00 ± 0.40^{c}	2.42 ± 0.14^{c}	2.89 ± 0.18^{e}	0.82 ± 0.04^{d}	1.96 ± 0.11^{b}	0.35 ± 0.24^{d}	0.79 ± 0.06^{b}
IBA@1000ppm	13.80 ±0.73^{b}	10.20 ± 0.73^{c}	2.92 ± 0.05^{c}	4.12 ± 0.07^{d}	1.39 ± 0.07^{c}	1.47 ± 0.02^{c}	0.98 ± 0.08^{b}	1.06 ± 0.43^{a}
IBA@2000ppm	14.40 ±0.60^{ab}	10.80 ± 1.20^{c}	3.78 ± 0.12^{b}	5.32 ± 0.31^{c}	2.24 ± 0.04^{b}	1.20 ± 0.04^{d}	1.24 ± 0.02^{a}	0.63 ± 0.08^{c}
IBA@4000ppm	9.00 ±0.95^{c}	16.20 ± 0.74^{a}	1.80 ± 0.07^{d}	5.60 ± 0.09^{c}	1.45 ± 0.03^{c}	1.69 ± 0.04^{c}	0.75 ± 0.03^{c}	0.82 ± 0.02^{b}
IBA@6000ppm	16.80 ±0.74^{a}	18.00 ± 0.95^{a}	4.82 ± 0.09^{a}	7.02 ± 0.26^{a}	2.34 ± 0.68^{b}	2.10 ± 0.08^{b}	1.18 ± 0.05^{a}	1.14 ± 0.91^{a}
IBA@8000ppm	16.20 ±1.53^{ab}	13.80 ± 0.74^{b}	5.16 ± 0.21^{a}	6.42 ± 0.09^{b}	3.06 ± 0.08^{a}	2.63 ± 0.12^{a}	1.32 ± 0.07^{a}	0.87 ± 0.04^{b}

Values are means ± standard error of five replicates. Means followed by same letter are not significantly different from each other at 5% significant level. Values in parenthesis are transformed values.
SFM: Soil + FYM medium; SM: Soil medium

Table 2: Effect of IBA concentrations on root parameters of Dragon fruit at 60 DAP in Soil + FYM and Soil medium

Treatments	Number of roots		Root length (cm)		Fresh weight of roots (g)		Dry weight of roots (g)	
	SFM	SM	SFM	SM	SFM	SM	SFM	SM
IBA@ 0ppm	13.20 ± 0.74^{c}	12.60 ± 0.60^{cd}	7.80 ± 0.58^{d}	10.34 ± 0.45^{c}	2.54 ± 0.32^{d}	7.27 ± 0.52^{d}	0.81 ± 0.10^{c}	1.90 ± 0.20^{d}
IBA@ 1000ppm	12.60 ± 1.47^{c}	15.60 ± 1.47^{bc}	16.60 ± 0.25^{c}	18.80 ± 1.24^{ab}	6.70 ± 0.77^{c}	9.30 ± 0.22^{c}	3.00 ± 0.35^{b}	3.11 ± 0.47^{c}
IBA@ 2000ppm	17.40 ± 0.60^{b}	10.20 ± 0.73^{d}	19.70 ± 1.04^{bc}	18.70 ± 1.16^{ab}	7.59 ± 0.71^{bc}	6.45 ± 0.06^{d}	3.38 ± 0.52^{b}	3.71 ± 0.31^{bc}
IBA@ 4000ppm	11.40 ± 1.12^{c}	12.00 ± 0.95^{d}	16.30 ± 1.50^{c}	15.54 ± 0.74^{b}	8.91 ± 0.32^{b}	6.36 ± 0.22^{d}	4.40 ± 0.59^{ab}	3.02 ± 0.34^{c}
IBA@ 6000ppm	25.20 ± 1.52^{a}	21.00 ± 1.64^{a}	34.50 ± 1.25^{a}	20.62 ± 1.63^{a}	10.81 ± 0.70^{a}	13.72 ± 0.35^{a}	5.16 ± 0.49^{a}	4.31 ± 0.40^{ab}
IBA@ 8000ppm	15.00 ± 1.34^{bc}	18.00 ± 0.94^{ab}	21.90 ±1.57^{b}	20.00 ± 0.82^{a}	7.82 ± 0.29^{bc}	11.06 ± 0.21^{b}	3.96 ± 0.42^{ab}	4.98 ± 0.20^{a}

Values are means ± standard error of five replicates. Means followed by same letter are not significantly different from each other at 5% significant level.
SFM: Soil + FYM medium; SM: Soil medium

Table 3: Effect of IBA concentrations on shoot parameters of Dragon fruit at 20 DAP in Soil+FYM and Soil medium

Treatments	No. of new shoots		Shoot length (cm)		Fresh weight of shoots (g)		Dry weight of shoots (g)		Days to sprout (number)	
	SFM	SM	SFM	SM	SFM	SM	SFM	SM	SFM	SM
IBA@ 0ppm	(0.71) ± 0.00^{a}	(0.71) ± 0.00^{a}	0.71 ± 0.00^{a}	0.71 ± 0.00^{a}	91.80 ± 1.30^{d}	101.36 ± 7.50^{c}	8.73 ± 0.25^{b}	11.40 ± 0.34^{bc}	19.20 ± 0.37^{a}	18.20 ± 0.37^{a}
IBA@ 1000ppm	(0.71) ± 0.00^{a}	(0.81) ± 0.10^{a}	0.71 ± 0.00^{a}	0.94 ± 0.23^{a}	91.33 ± 4.10^{d}	99.38 ± 4.72^{c}	8.64 ± 0.19^{b}	10.06 ± 0.44^{c}	18.40 ± 0.25^{ab}	17.80 ± 0.38^{ab}
IBA@ 2000ppm	(0.71) ± 0.00^{a}	(0.71) ± 0.00^{a}	0.71 ± 0.00^{a}	0.71 ± 0.00^{a}	115.15 ± 4.25^{bc}	115.38 ± 4.82^{bc}	8.04 ± 0.31^{b}	13.05 ± 0.44^{b}	18.00 ± 0.32^{bc}	17.00 ± 0.31^{bc}
IBA@ 4000ppm	(0.81) ± 0.10^{a}	(0.71) ± 0.00^{a}	0.94 ± 0.23^{a}	0.71 ± 0.00^{a}	105.16 ± 3.91^{cd}	127.80 ± 6.51^{ab}	10.05 ± 0.30^{a}	15.79 ± 0.23^{a}	18.20 ± 0.37^{bc}	16.80 ± 0.37^{bcd}
IBA@ 6000ppm	(0.71) ± 0.00^{a}	(0.81) ± 0.10^{a}	0.71 ± 0.00^{a}	0.99 ± 0.40^{a}	135.83 ± 2.94^{a}	146.74 ± 7.08^{a}	10.12 ± 0.31^{a}	16.34 ± 0.67^{a}	17.00 ± 0.32^{d}	15.80 ± 0.37^{d}
IBA@ 8000ppm	(0.71) ± 0.00^{a}	(0.71) ± 0.00^{a}	0.71 ± 0.00^{a}	0.71 ± 0.00^{a}	124.04 ± 2.03^{ab}	128.52 ± 7.16^{ab}	10.01 ± 0.26^{a}	15.78 ± 0.53^{a}	17.40 ± 0.25^{cd}	16.20 ± 0.40^{cd}

Values are means ± standard error of five replicates. Means followed by same letter are not significantly different from each other at 5% significant level. Values in parenthesis are transformed values.
SFM: Soil + FYM medium; SM: Soil medium

Table 4: Effect of IBA concentrations on shoot parameters of Dragon fruit at 60 DAP in Soil+FYM and Soil medium

Treatments	No. of new shoots		Shoot length (cm)		Fresh weight of shoots(g)		Dry weightof shoots(g)	
	SFM	SM	SFM	SM	SFM	SM	SFM	SM
IBA@ 0ppm	1.40 ± 0.25^{bc}	1.20 ± 0.20b	7.76 ± 0.27^{b}	6.12 ± 0.17^{c}	137.22 ± 1.08^{c}	122.22 ± 1.42^{c}	10.90 ± 0.60^{c}	11.92 ± 0.50^{b}
IBA@ 1000ppm	1.40 ± 0.25^{bc}	1.20 ± 0.20b	10.48 ± 0.37^{a}	5.50 ± 0.45^{c}	136.39 ± 4.85^{c}	127.40 ± 1.18^{c}	13.50 ± 0.35^{b}	14.49 ± 1.26^{ab}
IBA@ 2000ppm	1.80 ± 0.20^{ab}	0.80 ± 0.20b	10.68 ± 0.65^{a}	2.76 ± 0.34^{d}	186.72 ± 2.35^{abc}	168.30 ± 2.14^{ab}	14.75 ± 0.66^{b}	12.98 ± 0.96^{b}
IBA@ 4000ppm	1.00 ± 0.00^{c}	1.00 ± 0.00b	11.88 ± 0.61^{a}	5.66 ± 0.50^{c}	160.11 ± 2.22^{bc}	162.80 ± 1.79^{ab}	13.46 ± 0.91^{b}	14.84 ± 0.61^{ab}
IBA@ 6000ppm	2.40 ± 0.55^{a}	1.80 ± 0.20a	11.56 ± 0.49^{a}	12.46 ± 0.92^{a}	204.48 ± 2.04^{ab}	197.72 ± 2.49^{a}	19.52 ± 0.27^{a}	16.91 ± 1.17^{a}
IBA@ 8000ppm	1.80 ± 0.45^{ab}	0.80 ± 0.20b	10.86 ± 0.64^{a}	9.78 ± 0.45^{b}	228.00 ± 1.95^{a}	160.90 ± 8.45^{ab}	21.19 ± 0.72^{a}	16.49 ± 1.21^{a}

Values are means ± standard error of five replicates. Means followed by same letter are not significantly different from each other at 5% significant level.
SFM: Soil + FYM medium; SM: Soil medium

Table 5: Effect of IBA concentrations on root and shoot parameters of Dragon fruit at 100 DAP under raised bed field experiment

Treatments	Number of roots	Root length (cm)	Fresh weight of roots (g)	Dry weight of roots(g)	No. of new shoots	Shoot length (cm)	Fresh weight of shoots (g)	Dry weight of shoots (g)	Days to sprout (Number)
IBA@ 0ppm	20.88 ± 1.07^{d}	14.30 ± 1.10^{b}	13.50 ± 0.77^{c}	1.35 ± 0.24^{d}	2.40 ± 0.60^{a}	17.50 ± 0.76^{b}	56.61 ± 1.40^{d}	4.63 ± 0.15^{c}	19.60 ± 0.50^{b}
IBA@ 1000ppm	32.80 ± 0.66^{c}	27.54 ± 0.46^{a}	21.70 ± 1.29^{b}	2.13 ± 0.15^{c}	2.40 ± 0.40^{a}	19.50 ± 0.57^{ab}	71.86 ± 1.61^{bc}	6.14 ± 0.14^{b}	17.80 ± 0.86^{a}
IBA@ 2000ppm	34.00 ± 0.70^{c}	27.50 ± 0.47^{a}	23.18 ± 0.95^{ab}	2.43 ± 0.17^{c}	2.20 ± 0.37^{a}	19.70 ± 0.56^{a}	72.50 ± 2.50^{bc}	6.21 ± 0.17^{b}	17.60 ± 0.50^{a}
IBA@ 4000ppm	36.80 ± 0.66^{b}	29.10 ± 1.00^{a}	23.99 ± 1.40^{ab}	3.16 ± 0.18^{ab}	2.60 ± 0.50^{a}	20.38 ± 0.89^{a}	76.02 ± 1.40^{ab}	6.64 ± 0.11^{a}	19.20 ± 1.52^{b}
IBA@ 6000ppm	39.40 ± 0.50^{a}	31.32 ± 0.71^{a}	26.12 ± 1.05^{a}	3.36 ± 0.22^{a}	2.80 ± 0.37^{a}	21.70 ± 0.87^{a}	78.52 ± 1.24^{a}	6.92 ± 0.07^{a}	17.20 ± 0.37^{a}
IBA@ 8000ppm	37.00 ± 0.70^{b}	34.68 ± 6.21^{a}	21.16 ± 0.79^{b}	2.63 ± 0.17^{bc}	2.20 ± 0.20^{a}	20.70 ± 0.49^{a}	70.47 ± 1.45^{c}	6.15 ± 0.12^{b}	17.20 ± 0.49^{a}

Values are means ± standard error of five replicates. Means followed by same letter are not significantly different from each other at 5% significant level.
SFM: Soil + FYM medium; SM: Soil medium

correlation between primordial division in root initiation and endogenous or exogenous auxins may result in to increase of rooting at different concentrations.

Average root length : Higher root length was obtained with IBA 8000 ppm on par with 6000 ppm at 20 DAP. However, at 60 DAP highest root length (34.50 ± 1.25 cm) was observed with IBA @6000 ppm followed by IBA @8000 ppm and lower values were reported in control and lower concentrations of IBA in case of soil + FYM medium. IBA @6000 ppm on par with IBA @8000 ppm, showed greater root length at 20 DAP and 60 DAP over control where lowest root growth was observed in soil medium (Table 1 &2). Root length after 100 DAP was also varied significantly with different treatments in field experiment too. Longest root length was obtained in IBA @8000 ppm on par with IBA @6000 ppm, whereas shortest was observed from control with no IBA treatment under field experiment (Table 5). IBA plays significant role in enhancing rooting process (root hair elongation, later root development and formation of adventitious roots) by involving in physiological process of cell division, cell enlargement and interaction with other hormones through different mechanisms (Zimmerman and Wilcoxon, 1935; Gehlot *et al*., 2014). Madhavan *et al*. (2021), Sabatino *et al*. (2014), Rahbin *et al.* (2012) and Shiri *et al.* (2019) reported enhancement of root length with the use of IBA in grapes, night jessamine (*Cestrum nocturnum*), silver germander (*Teucrium fruticans*) and *Duranta errecta* respectively. In Dragon fruit, Seran and Thiresh (2015) observed longest root length in cutting treated with 8000 ppm and 6000 ppm IBA.

Fresh and dry weight of roots : Higher fresh and dry weight of roots was also recorded with IBA @8000 ppm followed by 6000 ppm whereas; it was least in control at 20 DAP. However at 60 DAP, IBA @6000 ppm followed by IBA @8000 ppm produced roots with greater root biomass on fresh and dry weight basis in soil + FYM medium. Similarly, in soil medium also IBA at higher concentrations 6000 and 8000 ppm performed better in producing greater root biomass while

lower root biomass was recorded in lower concentrations of IBA and in control at 20 and 60 DAP under pot experiment (Table 1 & 2). Similarly, in field experiment too, higher concentration produced maximum root biomass on fresh and dry weight basis *i.e.,* IBA @6000 ppm, followed by IBA 8000 ppm and lowest were recorded in control treatment i.e. no IBA (Table 5). IBA is effective in enhancing rooting percentage; root length thus ultimately causes enhanced root biomass in plants (Sabatino *et al.,* 2014; Madhavan *et al.,* 2021). Further, higher rooting and dipper roots may results in higher absorption of nutrients from the soil which results in better root growth. In the present experiment also IBA enhanced root percentage and root length which resulted in to higher root biomass. Enhancement of root biomass with the help of IBA has been reported by Kaur and Kaur (2016) in pomegranate, Rahbin *et al.* (2012) in night jessamine (*Cestrum nocturnum*). Whereas, in dragon fruit enhanced root biomass with use of IBA has been observed by Seran and Thiresh (2015).

Days to sprout : IBA treatments significantly helped to reduce number of days required for sprouting of cuttings in pot experiment under both the mediums and also in the field experiment. IBA @6000ppm on par with 8000ppm helped cuttings to sprout in 16-17 days compared to control where it took 19-20 days (Table 3 & 4). Similar trend was observed in the raised bed field experiment, where IBA @6000 and 8000 ppm produced sprouts in 17 days whereas it took 19-20 days in control with no IBA application (Table 5). The application of IBA assists in reducing the number of days required for sprouting by promoting deeper and more extensive root development. Enhanced rooting enables more efficient uptake of water and essential nutrients from the soil, providing the necessary resources for faster plant growth and development. This accelerated resource acquisition leads to a quicker initiation of sprouting. The beneficial effect of treating cuttings with IBA for reducing the number of days to sprouting has been corroborated by Patil *et al.* (2017), demonstrating that IBA treatment effectively speeds up the sprouting process by enhancing root formation and nutrient uptake efficiency.

Average number of shoots : IBA did not influence the formations of new shoots at 20 DAP under both soil mediums in the present experiment. However, at 60 DAP, IBA significantly influenced formation of new shoots. Numbers of new shoots were also observed highest in IBA @6000 ppm on par with 8000 ppm, which varied significantly from other treatments under both the mediums (Table 3& 4). Whereas, IBA treatments had non-significant effect of number of shoots produced in cuttings in field experiment. IBA is known to play a significant role in enhancing adventitious rooting in plants. This enhancement in rooting is crucial as it allows plants to better acquire water and essential nutrients from the soil, leading to increased sprouting and shoot formation. Research has demonstrated the effectiveness of IBA in promoting higher shoot formation in various plant species. For instance, Seran and Thiresh (2015) reported improved shoot formation in dragon fruit, while Madhavan *et al.* (2021) observed similar results in grapes. The application of IBA not only boosts root development but also supports the overall growth and productivity of the plants, highlighting its importance in horticultural practices.

Average shoot length : IBA @6000 ppm significantly improved shoot length which varied from other treatments. However, all IBA treatments showed significantly higher shoot length over control in soil + FYM medium and IBA @6000 ppm also improved shoot length in soil medium also. Lowest shoot length was reported in the control with no IBA treatment (Table 3& 4). In field experiment, highest shoot length was recorded in cuttings treated with IBA @6000 ppm followed by 8000ppm while minimum length of shoots was recorded in control with no IBA treatment (Table 5). Shoot growth, including sprouting and subsequent development, is directly proportional to the rooting rate and the hormonal levels in the plant. The exogenous application of IBA in this experiment not only elevated the hormonal levels but also enhanced rooting, consequently leading to increased shoot growth. Khajehpour *et al.* (2014) and Rahman *et al.* (2002) reported that branch length in olive increased at a hormone level of 3000

ppm, while the shortest branch length was observed in the control treatment. Further, Khadr *et al.* (2020) also observed enhancement of shoot length in carrot with IBA application. Similarly, Seran and Thiresh (2015) observed the greatest shoot length with the application of IBA at 6000 ppm. IBA facilitates cell elongation, resulting in enhanced shoot length, as evidenced in dragon fruit in the present experiment (Frick and Strader, 2018).

Fresh weight and dry weight of shoots : Application at 6000 ppm IBA on par with 8000 ppm has resulted into maximum increase in fresh weight of shoots. However, least increment was observed in control and 1000 ppm IBA. Similar trend was also observed in dry weight of shoots at 20 DAP. Whereas at 60 DAP, IBA @8000 ppm on par with 6000 ppm resulted in highest increase in fresh weight of shoots and lowest was recorded in control and 1000 ppm IBA. IBA @6000 ppm on par with 8000 ppm produced shoots with greater biomass on dry weight basis in soil + FYM medium and lower biomass reported in control. Similar observations were also recorded in soil medium and IBA at higher concentrations (6000 and 8000ppm) performed better compared to control (Table 3&4). In field experiment too, the highest shoot fresh weight (78.52g) was seen in dragon fruit cuttings treated with IBA 6000 ppm and it was lowest in control (56.61g) (Table 5). Similar trend was observed in case of dry weight of shoots in field experiment. The enhancement of shoot biomass with the application of Indole-3-butyric acid (IBA) can be attributed to several key physiological effects of this hormone. Higher shoot biomass results from increased sprouting, the emergence of new shoots, and an expanded leaf area. Studies have confirmed similar outcomes in various plants, such as carrot (Khadr *et al.,* 2020). The application of IBA, particularly at a concentration of 3000 ppm, has been shown to significantly enhance root fresh weight, with the lowest root biomass observed in untreated control plants (Khajehpour *et al*., 2014). This increase in root biomass facilitates the uptake of more water and essential nutrients from the soil, providing the necessary raw materials for photosynthesis. Enhanced photosynthetic activity leads to greater production of shoot growth-promoting hormones (Ghanem *et al*., 2011) and supports quicker adaptation and overall plant vigour. Furthermore, Seran and Thiresh (2015) reported that applying IBA at a concentration of 6000 ppm in dragon fruit resulted in higher shoot biomass on both a fresh and dry weight basis. IBA is known to promote the development of shoot initials and their subsequent growth, as demonstrated in citron (Kako Al-Zebari and Al-Brifkany, 2014). Thus, the application of IBA enhances root development, which in turn boosts water and nutrient uptake. This leads to increased photosynthetic efficiency and hormone production, ultimately resulting in greater shoot biomass.

CONCLUSION

The results of present pot and field experiment showed that, IBA@6000 ppm on par with 8000 ppm performed better in root and shoot growth improvement, reducing number days to sprout in dragon fruit stem cuttings compared to lower concentrations of IBA or no IBA. Therefore, application of IBA @6000 ppm can be used for multiplying stem cuttings of dragon fruitby nurserymen and growers.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Impact of microbial consortia on the physico-chemical and biological properties of soil in jamun (*Syzygium cumini* L.) cv. Goma Priyanka

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ABSTRACT

An experiment was conducted on recently planted Jamun cv. Goma Priyanka orchard at the Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar, Rajasthan with a view to investigate the impact of microbial consortia on the physico-chemical and biological properties of the soil in Jamun (Syzygium cumini L.) cv. Goma Priyanka. It was observed that the treatment $T_9(M_3T_3)$- (Azospirillum, PSB, KSB, VAM and Trichodermaharzianum) (100g)was found better in improving the soil parameters including organic carbon percentage, available N, P and K content of soil and soil microbial population was found significantly superior over other treatments. Like-wise, soil pH and electrical conductivity also had significant moderation under this treatment. The treatment $T_8(M_3T_2)$ - (Azospirillum, PSB, KSB, VAM and Trichodermaharzianum) (75g) was in next order in its impact on vegetative growth and developmental parameters of jamun plant besides better soil parameters of the orchard under the study.

***Keywords*:** Biological Properties of soil, microbial consortia, physico-chemical properties of soil, *Syzygium cumini.*

INTRODUCTION

Only by using inexpensive, environmentally safe nutrient sources can achieve long-term sustainability in agriculture. In this sense, biofertilizers are crucial in maintaining soil health and crop productivity more effectively. According to Yadav and Chandra (2012), biofertilizers are rhizosphere microorganisms that have been inoculated to increase plant growth and nutrition and decrease the requirement for N and P fertilizers, hence increasing grain output.Since then, biofertilizers have gained acceptance as significant nutrient inputs under both the organic management approach and the integrated nutrient management plan. Now, a variety of other microorganisms have been discovered and are being used commercially as microbial inoculants, the journey that began with Rhizobium has been expanded. On the other hand, frequent inputs of phosphate-solubilizing biofertilizers, mycorrhizal-biofertilizers, Rhizobium, Azotobacter and Azospirillum have been acknowledged.The microbial formulation protects plants from plant diseases, decreases the demand for soluble minerals and fertilisers with nitrogen, releases important plant nutrients and so lessens the need for chemical pesticides and fertilisers.

Two or more microbial populations coexisting in harmony is known as a microbial consortium. Microbial consortia are superior to single species, or “superbugs,” in a number of ways, including robustness, efficiency and modularity. In their native environments, microorganisms coexist in groups and some even help plants. Microbes in tiny consortia have been shown to improve defensesignaling cascades, which in turn leads to increased transcriptional activation of many metabolic pathways (Kumar and Jagadeesh, 2016).

When incorporated into soil, microbial consortia—which are composed of many microorganisms—are certain to have a synergistic effect. The consortiums could include A gram-

negative motile bacterium called *Azospirillum* fixes atmospheric nitrogen and makes it available to plants in a non-symbiotic way. This process can replace between 50 and 90 percent of the nitrogen fertilizer that plants need. Similar to this, fumaric acid, succinic acid, acetic acid, gluconic acid, lactic acid and other organic acids are secreted by Phosphate Solubilizing Bacteria (PSB). These organic acids aid in the soil's solubilization of insoluble tricalcium phosphate and rock phosphate, enabling crop plants to use it. For faster crop growth, the insoluble form of potassium can be mobilised with the aid of potassium-solubilizing bacteria (KSB). They can withstand a large range of soil pH and temperature, cut the cost of applying potash by 50–60% and increase crop production and growth by 20–30%. The *vesicular-arbuscularmycorrhiza* (VAM) consortia, which are endomycorrhiza fungi, are well known for their effects on phosphate uptake. Additionally, by associating with plant roots, these fungi can assist citrus plants manage water stress through stomatal regulation. Vesicular *Arbuscular Mycorrhiza* (VAM) develops a symbiotic relationship with the host plant, improving soil fertility, plant health and nutrient absorption while also promoting plant development (Ramasamy *et al*., 2011). The consortia that include the bio-fungicide *Trichoderma harzianum* are made up of free-living fungus that is widespread in the ecosystem of soil and roots. This fungus protects plants from most soil-borne illnesses, such as root rot, damping off and wilting, while also encouraging plant growth. Microbial consortiums have a variety of uses, including rhizosphere bioremediation of pesticides, bio-fertilizers, bio-control agents against diseases, soil reclamation and efficient breakdown of organic wastes. Despite the fact that several strains of plant growth-promoting rhizobacter (PGPR) and its consortia have demonstrated their ability to promote plant growth and enhance productivity in field conditions across a variety of crops, farmers have not been as inclined to utilise these products owing to a lack of awareness and a lack of access to high-quality consortia. It is suggested to assess microbial consortiums in jamun against the backdrop of their effectiveness in multidirectional aspects of plant growth, such as nutrient mobilisation, disease management, stress management and the biodegradation of organic waste, among many other things. Additionally, consortiums are economical to utilise since they combine fungi and rhizobacteria in a synergistic manner. The crop jamun is greatly neglected and there has been very little research done on microbial consortiums in this crop. Thus, it was suggested that an experiment be conducted to determine how microbial consortia affect the growth and development of jamun.

MATERIALS AND METHODS

The current study was carried out in the recently planted Jamun cv. Goma Priyanka orchard at the Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar, Rajasthan during 2019 and 2020. The Jhalawar district is situated between 23°4' and 24°52' N Latitude and 75°29' to 76°56' E Longitude. Zone V agro-climatically, the district is called the Humid South Eastern Plain. The area receives 954.7 mm of rain on average. Summertime temperatures range from 43 to 48°C, while wintertime lows are between 1.0 and 2.6°C.

Before the experiment started, soil samples were randomly taken from various locations inside the experimental site at a depth of 0 to 30 cm in order to evaluate the physico-chemical characteristics of the soil there. A representative sample was made and mechanical, physical and chemical analyses were performed on it. The experiment site's soil has a texture similar to clay loam (black cotton soil).

Three types of microbial consortia symbionts with each other and having ability to survive at high temperature which prevails in Jhalawar condition were used. These microbial consortia were obtained from Department of Microbiology, University of Horticultural Sciences, Bagalkot, Karnataka. Each consortia had mixture of equal weight of respective microbial strain.

The details regarding microbial consortia and their doses is furnished as under microbial consortia

- **M1**
  - *Azospirillum*
  - Phosphate Solubilising Bacteria (PSB)
  - Potassium Solubilising Bacteria (KSB)

- **M2**
  - *Azospirillum*
  - Phosphate SolubilisingBacteri (PSB)
  - Potassium Solubilising Bacteria (KSB)
  - vesicular-arbuscularmycorrhiza (VAM)
- **M3**
  - *Azospirillum*
  - Phosphate Solubilising Bacteria (PSB)
  - Potassium Solubilising Bacteria (KSB)
  - vesicular-arbuscularmycorrhiza (VAM)
  - *Trichoderma harzianum*

Treatment details

Treatment notation	Treatment content	Treatment notation	Treatment content
T_0 (Control)	No application of Microbial consortia	T_6 (M_2T_3)	Microbial consortia 100g
T_1 (M_1T_1)	Microbial consortia 50g	T_7 (M_3T_1)	Microbial consortia 50g
T_2 (M_1T_2)	Microbial consortia 75g	T_8 (M_3T_2)	Microbial consortia 75g
T_3 (M_1T_3)	Microbial consortia 100g	T_9 (M_3T_3)	Microbial consortia 100g
T_4 (M_2T_1)	Microbial consortia 50g		
T_5 (M_2T_2)	Microbial consortia 75g		

Each consortia was used at the rate of 50, 75 and 100g. These doses were denominated as T_1, T_2 and T_3 as detailed as under:T_1: 50 g,T_2: 75 g and T_3: 100 g.

The treatments were applied during last week of March, 2019 after recording initial (base) growth and development parameters of plants as well as soil parameters. Observations recoded were soil pH, electrical conductivity, bulk density, soil particle density, porosity, soil organic carbon, available N,P and K content in the soil and soil microbial population count during monsoon and post-monsoon period.

Soil pH was determined from 1: 25 soil to water Suspension by dipping the combined electrode (glass electrode plus calomel electrode) of a digital pH meter as described by Jackson (1973). Electrical conductivity (ds m^{-1}) of soil was determined with the help of Systronic Conductivity Meter-306 using 1**:**2.5 soil**:** water suspension ratio (Jackson 1973). Organic carbon (%) was determined by following Walkley and Black wet oxidation method (Black 1965). Bulk density of soil (Mg m^{-3}) of 0-15 cm depth was determined. The core sampler was pressed in the soil for enough depth to fill the core. Carefully removed the sampler and trimmed the soil extending out of the core with a sharp knife. Soil was oven dried at 105^0C to a constant weight, cooled and weighed. Soil volume was taken equal to inner volume of core sampler. Bulk density was calculated using the following formula and expressed as mg/ m^3 as suggested by Piper, (1950). Bulk density = Mass of oven dry soil/ Volume of soil including pore space.

To calculate soil particle density, the mass and the volume of the solid particles in a soil sample was measured. For this purpose soil sample was put in a flask with distilled water. The soil/ water mixture was then boiled to remove all air from the sample. After the mixture was cooled, water was added to the mixture to obtain a specified volume. The mass of this mixture was then measured. The mass of the water is then subtracted from the mass of the soil and water. The particle density was calculated from the mass of the solid particles in a specified volume. Particle Density = Mass of dry soil /Volume of soil particles only (air removed) (g/cm^3) (Arya *et al*., 1981). The Porosity (%) was calculated at end of experiment as per the formulae Porosity (%) = 1- Bulk density X 100 Particle density (Hao *et al*., 2008).

Available nitrogen (kg ha^{-1}) was determined by alkaline permanganate (0.32% KMnO4) method (Subbiah and Asija, 1956). Available phosphorus (kg ha^{-1}) was determined by extracting the acid soil P in dilute acid fluoride (Bray and Kurtz, 1945) phosphorus in the extract was determined calorimetrically at 660 nm as described by Black (1965). Available potassium (kg ha^{-1}) was estimated on Systronics Flame Photometer-128 using neutralnormal- ammonium acetate (NH_4OAc, pH 7.0) as per procedure given by Jackson (1973). Soil microbial population was measured by standard serial dilution and plate count method Wollum (1982).

The data recorded for the evaluation of different parameters was statistical analyzed using standard procedure for ANOVA of Randomized Block Design in order to test the significance of experimental results with three replication. The analysis of variance was done by the method suggested by Fisher (1954) and using analysis as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

In present study, all recorded parameters (Table 1, 2 and 3) for soil nutrient status was found significantly influenced by applied consortia of different plant growth promoting rhizobacteria. Data as regard to the effect microbial consortia on soil parameters like soil pH (7.49), electrical conductivity (0.32 dS m^{-1}), bulk density (NS), particle density (NS) porosity (NS), organic carbon (0.71%), N (342.42 kg ha^{-1}), P (28.82 kg ha^{-1}), K(305.62 kg ha^{-1}) and microbial population were observed comparatively better in treatment $T_9(M_3T_3)$- (*Azospirillum,* PSB, KSB, VAM and *Trichoderma harzianum*) (100g). The improvement in physico-chemical properties of soil in treatment T_9 (M_3T_3)-(*Azospirillum,* PSB, KSB, VAM and *Trichoderma harzianum*) (100g)might be attributed to increased organic matter status of the soil and improved soil physical structure (bulk density, porosity) as cited by Gogoi *et al.* (2004). Relatively better soil pH in this treatment may be due to perhaps better production of various organic and inorganic acids produced by micro-organisms. In general microbial sources have tendency to keep the soil pH in neutral range.

In the present study, electrical conductivity (EC) of the soil decreased with the application of increasing doses of different microbial sources. Sharma *et al.* (2017) recorded that by application of *Azospiriflum* 50 g + PSB 50g + VAM 20 g significantly decreased soil electrical conductivity in custard apple. Srivastava *et al.* (2019) observed decrease in soil electrical conductivity with the application of 25% vermicompost + microbial consortium which corroborates the present findings.

The increased in available nitrogen and phosphorus content as observed in the experiment in $T_9(M_3T_3)$- (*Azospirillum,* PSB, KSB, VAM and *Trichoderma harzianum*) (100g) may be due to better response of it over other treatments in increased biological nitrogen fixation and phosphate solubilization. Some bacteria have the ability to solubilize inorganic P due to chelation, exchange reaction, phosphate production and excretion of organic acids that have moderating effect on soil pH and in rendering the insoluble phosphate into soluble form. Generally, the solubility of calcium phosphates and magnesium also increases with decreasing pH. The increase in potassium content under microbial consortium was better in treatment in $T_9(M_3T_3)$- (*Azospirillum,* PSB, KSB, VAM and *Trichoderma harzianum*) (100g) which may be due to comparatively better dissolution rate of silicates and minerals which releases K, production of enzymes like chitinase and cellulases that causes breakdown of minerals and, increased root exudation accompanied by accelerated microbial proliferation and respiration which may lead to O_2 depletion in the rhizosphere and facilitate denitrification specifically. These findings were in agreement with the work of Sharma *et al*. (2017), Dutta and Kundu (2012), Esitken *et al*. (2010), Srivastava *et al*. (2019) and Hussain *et al.* (2017).

The results of present study inferred that the applied treatment T_9 (M_3T_3)- (*Azospirillum,* PSB, KSB, VAM and *Trichoderma harzianum*) (100g) perhaps had stimulating effect on micro-organisms growth in soil as well as root. Application of different microbial consortia had significant increased the total rhizobacterial counts on nutrient agar. The increase in rhizobacterial counts may be

Table 1: Effect of microbial consortia on soil pH, EC, N, P_2O_5 and K2O of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during growth period, 2019-20

Treatments	Soil parameters				
	pH	EC(dS m^{-1})	N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})
Initial value	7.75	0.45	312.62	21.14	278.32
T_0 (Control)	7.86	0.43	325.74	23.37	283.74
T_1 (M_1T_1)	7.64	0.41	327.73	25.71	290.67
T_2 (M_1T_2)	7.62	0.40	331.80	24.31	293.41
T_3 (M_1T_3)	7.59	0.37	336.15	26.42	292.60
T_4 (M_2T_1)	7.63	0.40	334.41	24.31	289.74
T_5 (M_2T_2)	7.52	0.39	329.60	25.82	294.80
T_6 (M_2T_3)	7.51	0.36	336.17	27.51	298.30
T_7 (M_3T_1)	7.53	0.38	331.42	26.14	294.43
T_8 (M_3T_2)	7.55	0.35	341.10	27.45	301.40
T_9 (M_3T_3)	7.49	0.32	342.42	28.82	305.62
SEm (±)	**0.04**	**0.01**	**1.54**	**0.34**	**1.41**
CD (5%)	**0.13**	**0.04**	**4.58**	**1.39**	**4.19**

Table 2: Effect of microbial consortia on soil OC, BD, PD and porosity of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during growth period, 2019-20

Treatments	Soil parameters			
	Organic carbon (%)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)
Initial value	0.49	1.38	2.66	48.12
T_0 (Control)	0.53	1.38	2.65	47.92
T_1 (M_1T_1)	0.57	1.37	2.66	48.49
T_2 (M_1T_2)	0.60	1.35	2.65	49.05
T_3 (M_1T_3)	0.63	1.33	2.64	49.62
T_4 (M_2T_1)	0.59	1.36	2.67	49.06
T_5 (M_2T_2)	0.65	1.34	2.69	50.18
T_6 (M_2T_3)	0.69	1.30	2.64	50.75
T_7 (M_3T_1)	0.62	1.33	2.66	50.00
T_8 (M_3T_2)	0.68	1.29	2.64	51.13
T_9 (M_3T_3)	0.71	1.26	2.63	52.09
SEm (±)	**0.003**	**0.012**	**0.005**	**0.057**
CD (5%)	**0.021**	**NS**	**NS**	**NS**

due to favourable environmental conditions for growth and their rapid multiplication rate as created by plant growth promoting rhizobacteria in soil. The results of present study are in agreement with the observations of Kumar and Shweta (2013) and Dutta and Kundu (2012).

Moreover, it is well recognised that the rhizosphere is a zone with elevated microbial and, by extension, enzyme activity. This could be because of the high concentration of readily degradable substrates in root exudates, which promotes the growth of microorganisms in the rhizosphere and helps plants develop their own unique microflora that may work in harmony with them (Bais *et al.*, 2006). Thanks to ideal soil moisture and temperature conditions that correlate with increased microbial activity and decomposition, the microbial population was

Table 3: Effect of microbial consortia on soil microbial population of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during growth period, 2019-20

Treatments	Bacteria ($x10^6$ cfu/g soil)	Fungi ($x10^4$ cfu/g soil)	Bacteria ($x10^6$ cfu/g soil)	Fungi ($x10^4$ cfu/g soil)
Initial (Pre monsoon)	**3.4**	**2.3**	**—-**	**—-**
Season	**Monsoon**		**Post monsoon**	
T_0 (Control)	2.50	1.80	2.00	1.20
T_1 (M_1T_1)	4.50	3.20	4.10	2.90
T_2 (M_1T_2)	4.80	3.90	4.40	3.10
T_3 (M_1T_3)	5.20	4.10	4.90	3.80
T_4 (M_2T_1)	4.80	3.80	4.50	3.20
T_5 (M_2T_2)	5.40	4.20	4.80	3.90
T_6 (M_2T_3)	5.80	4.80	5.20	4.00
T_7 (M_3T_1)	5.00	4.10	5.00	3.70
T_8 (M_3T_2)	6.20	4.70	5.50	4.30
T_9 (M_3T_3)	6.70	4.90	5.80	4.50
SEm (±)	**0.04**	**0.03**	**0.04**	**0.03**
CD (5%)	**0.13**	**0.11**	**0.12**	**0.10**

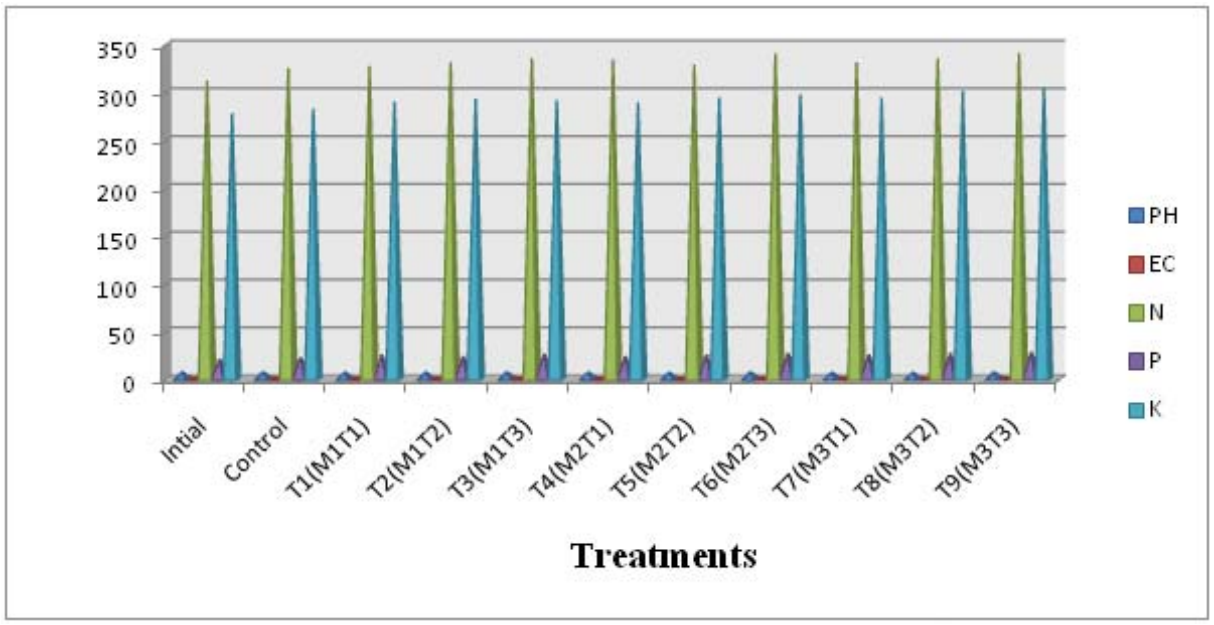

Fig. 1: Effect of microbial consortia on soil pH, EC, N, P2O5 and K2O of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during growth period, 2019-20

observed in the current experiment to be higher during the monsoon season than during the post-monsoon season (Table 3 and Figure 3a & b). Conversely, low ambient temperatures and increased physiological water stress which are otherwise essential for microbial growth and activity may be the cause of the lowest population counts throughout the winter. Tangjang and Arunachalam (2009) have also reported similar research findings.

CONCLUSION

Based on the findings of the experiment it is evident that the application of treatment T9 (M3T3)

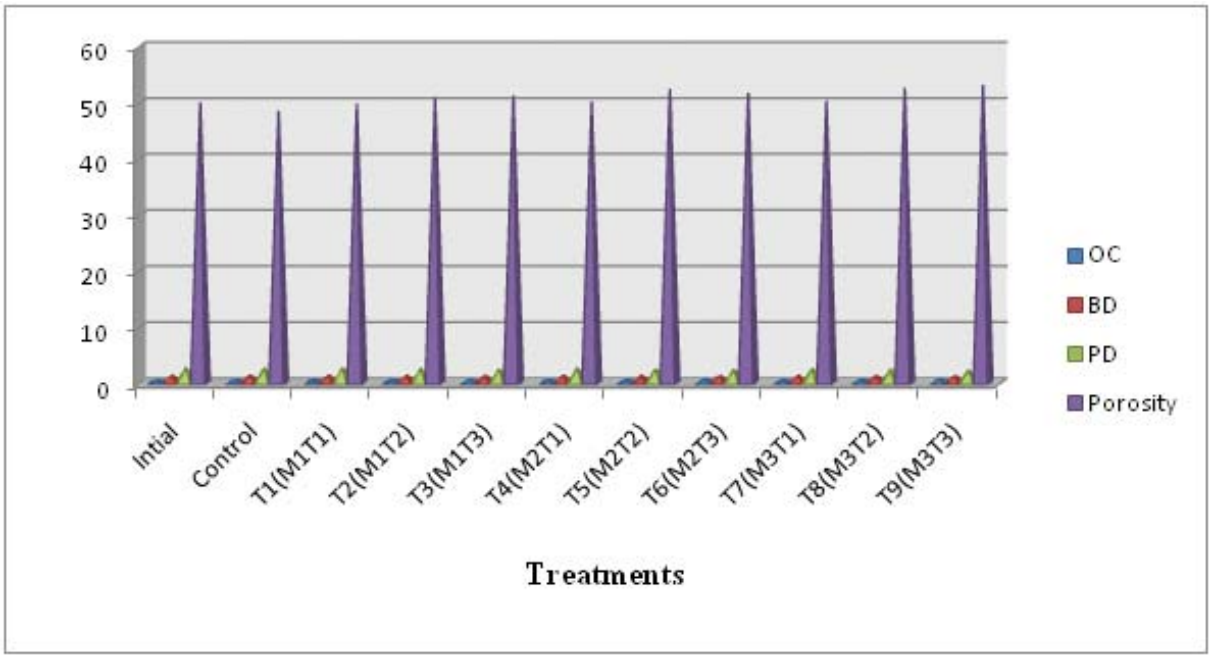

Fig. 2: Effect of microbial consortia on soil OC, BD, PD and porosity of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during growth period, 2019-20

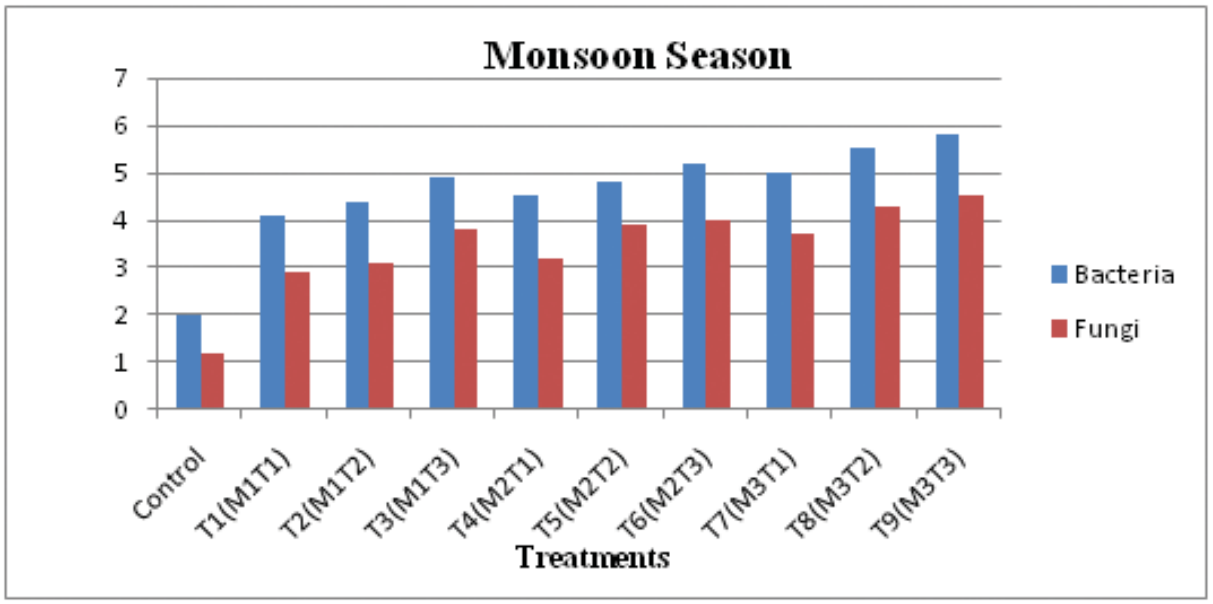

Fig. 3a: Effect of microbial consortia on soil microbial population of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during monsson season of growth period, 2019-20

- a combination of Azospirillum, PSB (Phosphate Solubilizing Bacteria), KSB (Potassium Solubilizing Bacteria), VAM (Vesicular ArbuscularMycorrhiza) and *Trichoderma harzianum* (100g) significantly enhanced various soil physicochemical and biological properties. Specifically, T9 (M3T3) demonstrated superior effects compared to other treatments across these parameters. Consequently, the results suggest that the application of T9 (M3T3) - a blend of *Azospirillum*, PSB, KSB, VAM and *Trichoderma harzianum*(100g) - in Jamun (*Syzygium cumini* L.) cv. GomaPriyanka cultivation is beneficial for improving plant growth and development characteristics, alongside enhancing soil parameters essential for establishing a robust plant framework and maintaining soil health.

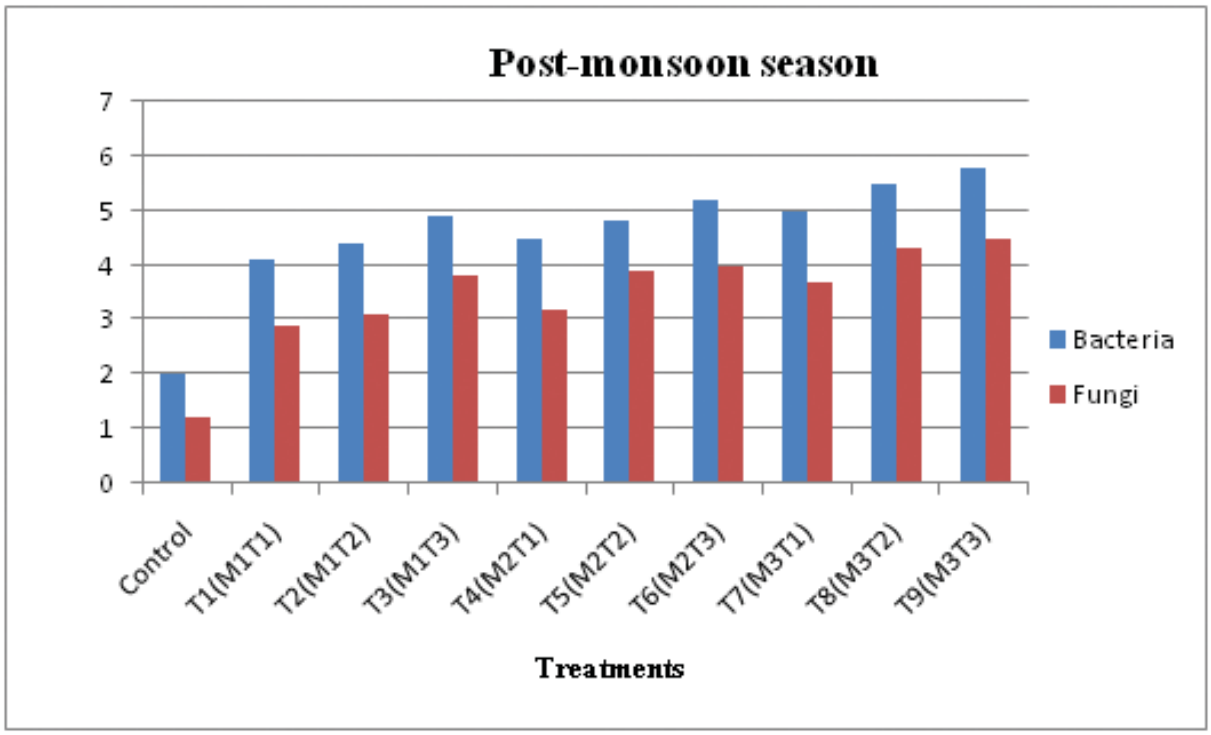

Fig. 3b : Effect of microbial consortia on soil microbial population of Jamun (*Syzygium cumini* L.) cv. Goma Priyanka during post-monsson season of growth period, 2019-20

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Screening of rhizosphere microorganisms for antagonism against *Alternaria alternata* (Fr.) Keissler causing Alternaria leaf blight of Isabgol *(Plantago ovate)*

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ABSTRACT

Isabgol (Plantago ovata) is a crucial medicinal plant valued for its high soluble fiber content, benefiting digestive health and cholesterol management. However, Alternaria leaf blight, caused by Alternaria alternata, poses a significant threat to Isabgol cultivation, impacting both yield and quality and necessitating effective disease management strategies. The experiment was conducted at the Department of Plant Pathology, College of Agriculture, Bikaner, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, in dual culture techinique under controlled conditions to screen rhizosphere microorganisms for their antagonism against Alternaria alternata in Isabgol. The result showed that the significant variation in the reduction mycelial growth of pathogen in the presence of various microorganisms. Among all the tested antagonists, Trichoderma viride was the most effective, with maximum 83.9% mycelial growth inhibition of pathogen followed by Colletotrichum lindemuthianum (79.73%), Trichoderma harzianum (76.01%), Aspergillus flavus (73.98%), Rhizoctonia solani (72.16%), Fusarium spp. (71.30%), Trichoderma spp. (67.55%), Aspergillus parasiticus (67.23%) and Colletotrichum gloeosporioides (66.95%). These findings indicated that certain rhizosphere microorganisms possess substantial potential as bio control agents against A. alternata, and an environmentally friendly alternative to chemical control.

***Keywords*:** *Alternaria alternata*, *in vitro*, Isabgol, microorganism, mycelial growth, Screening

INTRODUCTION

Plantago ovata commonly known as 'Psyllium' in English and 'Isabgol' in Hindi belongs to the family of *Plantaginaceae*. It has gained a reputation as a naturally occurring medicinal herb. It is believed to have originated in Persia and introduced in India. It is predominantly grown in India, Pakistan, Bangladesh, Persia, Mexico and Mediterranean regions due to its seed mucilage, pharmaceutical, cosmetics and food grade properties. The genus Plantago includes over 200 species cultivated globally, but only 10 are commonly found in India. Among these, blond psyllium (*Plantago ovata* Forsk.), known for its high-quality husk.

India is dominating the world market in production and export of psyllium husk powder. It provides approximately 80% of psyllium husk powder in the world market. About 90-95% of India's isabgol production is exported. The area under isabgol cultivation in India is 4.5 lakh hectares with a production of 4.32 lakh metric tonnes (Anonymous, 2024).

Isabgol is cultivated under Rabi season and easily grown under hot weather and saline soil consitions but require cool and dry weather during its crop season. It takes roughly 120 days to mature (November to Feb-March) (Jat *et al.*, 2015). Psyllium is a naturally occurring substance that is water soluble and it has been traditionally used in

Indian and Chinese herbal medicine to treat various conditions such as skin irritations, high blood pressure, constipation, diarrhoea, chronic dysenteries of amoebic and bacilliary origin and ulcerated surface of intestinal mucosa (Fernandez., 2006). The swelling and gelatinous mass properties of psyllium make it suitable for use in specific drug delivery systems as well as absorption. Psyllium has also been reported to possess cholesterol-lowering abilities and wound healing properties (Taneja *et al*., 1989 and Tomar *et al.*, 2010).

One of the primary factors diminishing Isabgol yield is the attack of diseases such as leaf blight (*Alternaria alternata*), wilt (*Fusarium* sp.), damping off (*Pythium ultimum*), and downy mildew (*Peronospora plantaginis*), as reported by Patel *et al*. (1984), Russel (1975), Kapoor and Choudhary (1976), and Richardson (1990), respectively. Among these, leaf blight caused by *Alternaria alternata* has emerged as a particularly serious issue in recent years. It has been found that downy mildew affected crops are more prone to be attacked by *Alternaria alternata*. This disease causes considerable damage every year and sometimes becomes very severe, resulting the total yield loss. Leaf blight in psyllium affects the crop at all stages of growth. Initially, infected plants develop small spots with a loss of chlorophyll. These spots gradually expand, covering larger areas, and the affected portions change color from light brown to dark brown and black. Necrosis of the affected areas also occurs (Patel *et al*., 1984; Meena and Maharshi, 2013b).

The necrotrophic nature of *Alternaria* species often results in significant damage to plants and their harvest, with seedlings rarely surviving an attack (Humpherson-Jones, 1985; Rimmer and Buchwaldt, 1995; Mamgain *et al*., 2013; Dhaka *et al*. 2022b). *Alternaria* is easily identifiable by its conidia, which are large, ovoid to obclavate, dark-colored (melanized), and multicellular with both longitudinal and transverse septations (Barnett, 1998). These conidia are produced in chains, broadest near the base, and tapering gradually to an elongated beak (Dube, 2013). It is known that members of the genus *Alternaria* produce a variety of phytotoxic metabolites that affect many of the plants on which the fungi grow on (Bruce *et al.* 1984). These phytotoxins have a wide range of impacts on metabolism and biological processes include tenuazonic acid (TA), alternariol, alternariol monomethyl ether (AME), alternaric acid, altenuene, altenuic acid, tentoxin, AK-toxin and AAL-toxin (Nishimura and Kohmoto, 1983). Therefore, this study aims to identify and evaluate the efficacy of various rhizosphere microorganisms in inhibiting the growth of *Alternaria alternata*, with the ultimate goal of developing effective biological control strategies for managing Alternaria leaf blight in Isabgol.

MATERIALS AND METHODS

All microorganism isolated from the rhizosphere of Isabgol were evaluated for their ability to show antagonistic effect against *Alternaria alternata* by Dual Culture Technique. Fungal microorganisms were screened for their antagonistic activity in dual culture on PDA in Petri plates (Johnston and Curl, 1972). Both microorganisms and pathogen were inoculated at the same time and 5 mm bit of young vigorously growing cultures were placed at the opposite points in Petri plates 40 mm apart from each other. In three replicates and incubated at 25± 2° C. The interactions were observed up to seventh day of incubation between rhizosphere fungal and bacterial microflora and the pathogen. In case of control, the Petri dishes were inoculated with mycelial disc of the test pathogen only. The mycelial growth of test pathogen was measured after 7 days of inoculation. Per cent growth inhibition was calculated by using the formula given by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where, I = Inhibition per cent

C = Colony diameter (mm) in control plate

T = Colony diameter (mm) in treated plate

RESULTS AND DISCUSSION

Rhizosphere/rhizoplane microorganisms of Isabgol

A total of 17 fungi and 3 bacteria were isolated from rhizosphere /rhizoplane of Isabgol plants (Table 1). Fungi isolated were *Rhizoctonia solani, Drechslera spp, Aspergillus glaucus, Claviceps purpurea, Alternaria solani, Aspergillus flavus, Fusarium spp., Sclerotium rolfsii , Aspergillus parasiticus, Sclerotia sclerotiorum, Colletotrichum lindemuthianum, Aspergillus nidulans, Colletotrichum gloeosporioides,*

Table 1: Microorganism isolated from the rhizosphere and rhizoplane of Isabgol

S. No.	Microorganisms isolated	S. No.	Microorganisms isolated
1.	*Rhizoctonia solani*	12	*Aspergillus nidulans*
2	*Drechslera spp*	13	*Xanthomonas spp.*
3	*Aspergillus glaucus*	14	*Colletotrichum gloeosporioides*
4	*Claviceps purpurea*	15	*Trichoderma viridae*
5	*Alternaria solani*	16	*Trichoderma harzianum*
6	*Aspergillus flavus*	17	*Pseudomonas fluorescens*
7	*Fusarium spp.*	18	*Bacillus subtilis*
8	*Sclerotium rolfsii*	19	*Aspergillus niger*
9	*Aspergillus parasiticus*	20	*Trichoderma spp.*
10	*Sclerotia sclerotiorum*	21	Control
11	*Colletotrichum lindemuthianum*		

Table 2 : Effect of microorganisms on the growth of *Alternaria alternata* in culture

S. No.	Microorganisms	Mycelial growth (mm)*	Mycelial growth inhibition (%)	Effect on pathogen
1	*Rhizoctonia solani*	25.05 (30.02)	72.16	+
2	*Drechslera spp*	33.42 (35.30)	62.86	-
3	*Aspergillus glaucus*	37.42 (37.69)	58.42	-
4	*Claviceps purpurea*	42.28 (40.54)	53.22	+
5	*Alternaria solani*	54.53 (47.58)	39.41	-
6	*Aspergillus flavus*	23.41 (28.91)	73.98	-
7	*Fusarium spp.*	25.83 (30.53)	58.42	-
8	*Sclerotium rolfsii*	37.10 (37.51)	58.77	+
9	*Aspergillus parasiticus*	29.49 (32.87)	67.23	-
10	*Sclerotia sclerotiorum*	32.26 (34.59)	64.15	+
11	*Colletotrichum lindemuthianum*	18.24 (25.26)	79.73	+
12	*Aspergillus nidulans*	35.69 (36.66)	60.34	-
13	*Xanthomonas spp.*	32.18 (34.54)	64.24	-
14	*Colletotrichum gloeosporioides*	29.74 (33.03)	66.95	-
15	*Trichoderma viridae*	14.49 (22.36)	83.9	+
16	*Trichoderma harzianum*	21.59 (27.67)	76.01	+
17	*Pseudomonas fluorescens*	44.19 (41.64)	50.9	-
18	*Bacillus subtilis*	39.35 (38.83)	56.27	-
19	*Aspergillus niger*	33.42 (35.30)	62.86	+
20	*Trichoderma viridae*	29.20 (32.68)	67.55	+
21	Control	90.00 (71.53)	0.0	
	S.Em±	**0.460**		
	CD (*p=0.05*)	**1.318**		

*Mean of three replications

Figures in parentheses are angular transformed values

+ = Microorganism over grew on pathogen (*A. alternata*) slightly

- = no effect on pathogen (*A. alternata*)

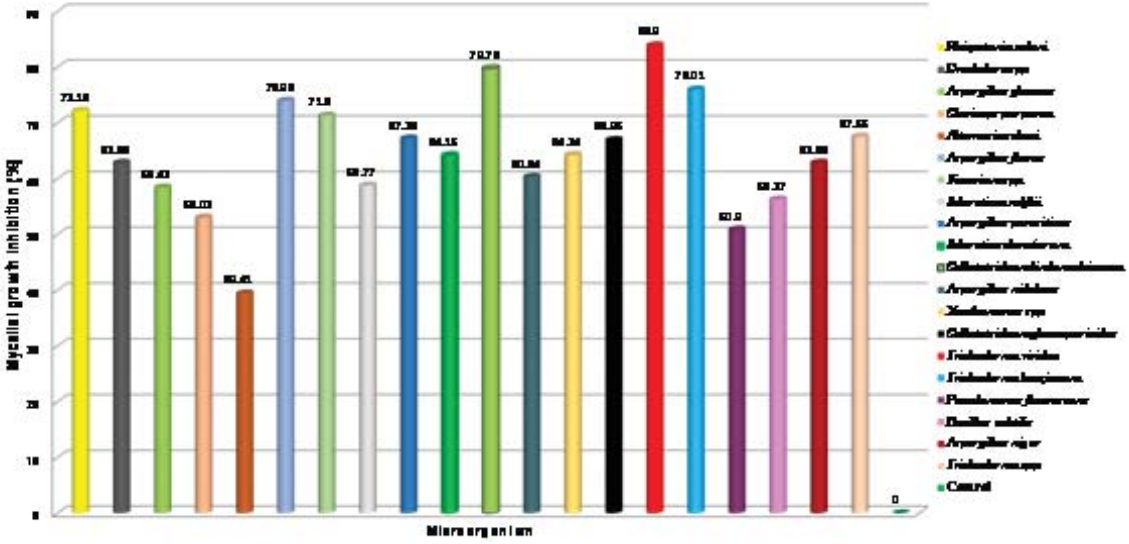

Fig. 1 : Screening of rhizosphere/rhizoplane microorganism for antagonism against pathogen

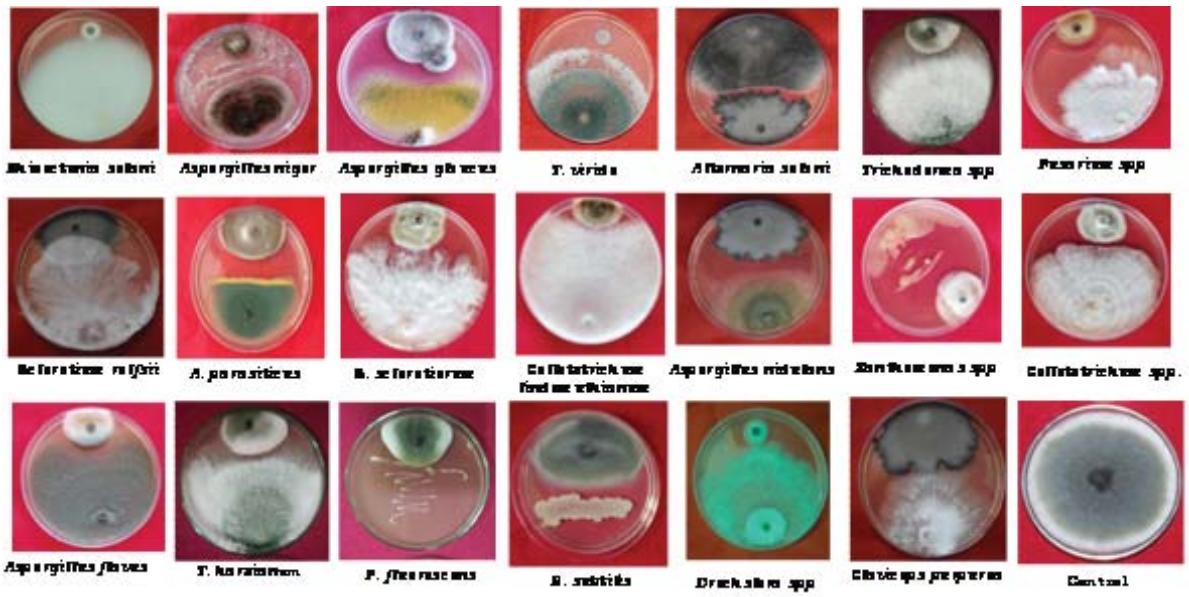

Plate 1 : Screening of rhizosphere/rhizoplane microorganism for antagonism against pathogen

Trichoderma viridae, *Trichoderma harzianum*, *Aspergillus niger, Trichoderma* spp. Bacteria were identified as *Bacillus subtilis*, *Xanthomonas* spp. and *Pseudomonas fluorescens*.

Antagonistic effect of rhizosphere/rhizoplane microorganisms on pathogen *in vitro*

All the microorganisms isolated from the rhizosphere/rhizoplane of Isabgol were tested for their antagonistic effects against *A. alternata* by dual culture and streak plate method in case of fungi and bacteria respectively. Observations on types of interactions started from 2nd day of inoculation and continued up to 7th day. Results are summarized in (Table 2, Fig. 1 and Plate 1)

Results showed a significant variation in the reduction of the growth of the pathogen in the presence of microorganisms (Table 2). Among the

antagonists, *Trichoderma viride* (83.9%) was found to be the most effective by recording the maximum inhibition of mycelial growth of the pathogen followed by *Colletotrichum lindemuthianum* (79.73%), *Trichoderma harzianum* (76.01%), *Aspergillus flavus* (73.98%), *Rhizoctonia solani* (72.16%), *Fusarium* spp. (71.30%), *Trichoderma* spp. (67.55%), *Aspergillus parasiticus* (67.23%) and *Colletotrichum gloeosporioides* (66.95%).

These fungi gave more than 65 per cent growth inhibition. Their growth rate was very fast and arrest and overgrew the pathogen within 7 days of incubation. Rest of the fungi was also antagonistic to pathogen but in their presence the growth inhibition of the *A. alternata* was less than 65 per cent and transparent inhibition zone was formed in two fungus between antagonistic fungi and the pathogenic fungus. The antagonists either overgrew the pathogen or just met at the margin. The three bacteria also inhibit the growth of the pathogen. Therefore, except the *Trichoderma harzianum, Fusarium oxysporium. Rhizoctonia solani, Trichoderma virens* and *A. niger* all other microorganism were discarded and not used in disease control studies.

Ngo *et al.* (2021) discovered that *A. candidus* and *A. montenegroi*, isolated from a marine environment, exhibit biocontrol potential for the first time. While various secondary metabolites and their biological activities have been documented from *A. candidus*, there is limited information on its efficacy in controlling plant diseases. Additionally, Choudhary *et al*. (2021) found that both *T. viride* and *T. harzianum* are highly effective in reducing the radial growth of *Alternaria solani*. All microorganisms isolated from rhizospheric soil show potential growth when treated with *Trichoderma* and other bioagents (Saran *et al*., 2021; Bairwa *et al*., 2022; Jangir *et al.*, 2022; Terki *et al*., 2023).

Although various workers have reported formation of clear cut inhibition zones by these soil microbes due to antibiosis or by the production of lytic enzymes (Wright, 1956; Smith, 1957; Papavizas, 1985; Upadhyay and Rai, 1987; Dhaka *et al*., 2022b). Philip *et al.* (2024) reported that *Trichoderma afroharzianum metabolites* inhibit *A. alternata* growth and induce tomato defense-related enzymes.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SHORT COMMUNICATION

Medicinal plants used by the tribal communities of Bandarban Hill District, Bangladesh

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ABSTRACT

Tribal communities in hilly areas of Bangladesh are mainly depend on herbal treatment for their illness and primary health care. The purpose of the present study was to document significantly distinguishable medicinal plants and their ethnopharmacological applications used by the tribal communities of Bandarban Hill District. During this expedition, a total of 244 ethnomedicinal plants have been recorded and documented which belonged to 86 plant families. Euphorbiaceae was found to be the largest plant family represented by 17 plant species, followed by Asteraceae, Rubiaceae, Fabaceae, Acanthaceae, Apocynaceae, Lauraceae and Verbenaceae. Herbs (35%) were found to be the most used plant, followed by shrubs (28%), trees (21%), climbers (13%) and fern (3%). For the treatment of different ailments, leaves were the most used dominant plant parts (42%), followed by roots (21%), whole plants (10%), bark (6%), stem (5%), fruit (4%), rhizome (4%), flower (4%), seed (2%), latex (1%) and tuber (1%). Out of 11 different forms of treatments for different diseases, the most common form was juice, followed by paste, decoction, fluid extraction, pill, powder, poultice, chewing raw, curry, infusion and fermented plant materials.Through this investigation, 102 diseases or illnesses were recorded which have been treated by medicinal plant species. The most commonly treated diseases was skin diseases for which 23 plant species were used followed by fever (22 species), stomachache (21 species), coughs (20 species), headache and dysentery (18 species each), menstruation problem and asthma (17 species each), wound and jaundice (16 species each), gastric and constipation (15 species each).

***Keywords*:** Ailments, Bandarban, Boiddays/ Kabiraj, medicinal plants, traditional knowledge

INTRODUCTION

Since ancient times, the main constituents of several traditional medicines have been plants, plant parts and plant products of all types, especially those with therapeutic qualities (Motaleb *et al.*, 2013). It is estimated that Bangladesh is home to about 6,500 species of higher cryptogams and phanerogams, of which over 500 species have medicinal value (Rahman *et al*., 2022).The natural forests of Bangladesh were rich with diverse plant species (Hossain *et al*., 2013; Mukul *et al*., 2018). Compare to any other areas in Bangladesh, Bandarban is one of the richest areas in terms of flora (Motaleb *et al*., 2013).Ethnomedicinal knowledge is essential for identifying plants as therapeutic agents (Balick, 1990). Plants contain novel drug compounds and aid in the discovery of economically important plant-based drugs (Cox and Balick, 1994).

Chowdhury *et al*. (1996) documented 42 folk formularies that have long been used in Bangladesh to treat dysentery and diarrhea. Alam *et al*. (1996) documented 143 folk formularies against 53 common diseases in another study. Information about 69 medicinal plants utilized by tribal peoples in the Chittagong Hill Tracts is provided by Yusuf *et al*. (2007). Rahman (2010) states that the majorities of the country's tribal groups live in hilly areas and rely mostly on herbal medicine for their basic medical needs. Motaleb *et al*. (2013) provide

information on 116 medicinal plants used by the traditional herbal practitioners of Thanchi upazila of Bandarban. According to Alam *et al*. (2022a) a total of 129 plant species belonging to 63 families have been traditionally used for medicinal purposes by the ethnic community residing in Thanchi upazila of Bandarban hill district to treat a variety of illnesses. According to Mohiuddin *et al*. (2012), the Marma, Bwam, Murang, and Tanchangya tribes in the hill regions of Bandarban have been using 70 plant species from 36 families, which are regarded as ethnomedicinal. Alam *et al*. (2022b) report that 81 plant species, belonging to 42 families, were used for ethnomedical purposes by the Marma people of Rowangcharri upazila in Bandarban hill district.

Traditional *healers-treat-patients* with medicinal plants are considered experts in plant knowledge and preparation in disease-treating formulations. This valuable indigenous knowledge is dwindling as modern health care systems emerge in hilly areas (Rahman *et al*., 2003). For scientists searching for new drugs, ethnomedical information regarding the uses of medicinal plants might be a useful source (Ghiselin and Landa, 2005). The knowledge of majority of the *Boiddays* (physician/ healer) is unrecorded and vanishes after they leave the workforce. A written language or script regardingthe use of medicinal herbs is absent from the majority of ethnic tribes. People living in contemporary societies are unaware of this knowledge system. As a result, this age-old medicinal knowledge is rapidly dwindling. While a few older men and women in the community are aware of the benefits of using medicinal herbs. To preserve and make use of biological resources, indigenous knowledge needs to be recorded (Tugume *et al*., 2016). However, there is very little information available on the ethnomedicinal plants used by tribal communities in Bandarban hill district. The current study was undertaken to document ethnomedicinal knowledge and plant parts application for curing various ailments by the ethnic communities of Bandarban hill district.

A series of investigations were conducted in the tribal regions of the Bandarban hill district over a span of three years from 2019 to 2021. During the study, we conducted visits to nine tribal paras located in three upazilas within the Bandarban district to collect ethnomedicinal plants. The study was conducted within the Marma, Tripura, Chakma and Tanchangya communities. Local herbal healers called Kabiraj/Boiddays and senior citizens were involved in collecting information about medicinal plants. With the help of herbal healers from the nearby forest areas, plant specimens were gathered for the study during various seasons, along with the relevant data. To ensure the accuracy of the information gathered, it was cross-checked on location. Documentation has been created through the random conduction of interviews with old men and women as well as traditional health practitioners. A digital voice recorder was used to record and document the interview process, which involved selecting open-ended and semi-structured question formats. The accuracy of the data on each plant was verified through multiple interviews. Documentation gathered on the aforementioned local names, plant parts utilized, application techniques, illnesses for which the formulations were applied and dosages. During the data collecting and sharing process, an interpreter who had translated the native language into Bengali was involved. The authors identified the common plant samples during the fieldwork and the remaining unkown species were identified with the assistance of plant taxonomists from the Bangladesh National Herbarium, Dhaka, and the Forest Botany Division of the Bangladesh Forest Research Institute, Chattogram. The voucher specimens were deposited at the Bangladesh Forest Research Institute's herbarium.

During the research work, a total of 244 ethnomedicinal plants were documented, belonging to 86 distinct families. Euphorbiaceae is the largest family represented by 17 species, followed by Asteraceae (15), Rubiaceae (14), Fabaceae (12), Acanthaceae (9), Apocynaceae (9), Lauraceae (8) and Verbenaceae (8). Wheras, there are 45 families has only one species each (Table 1).

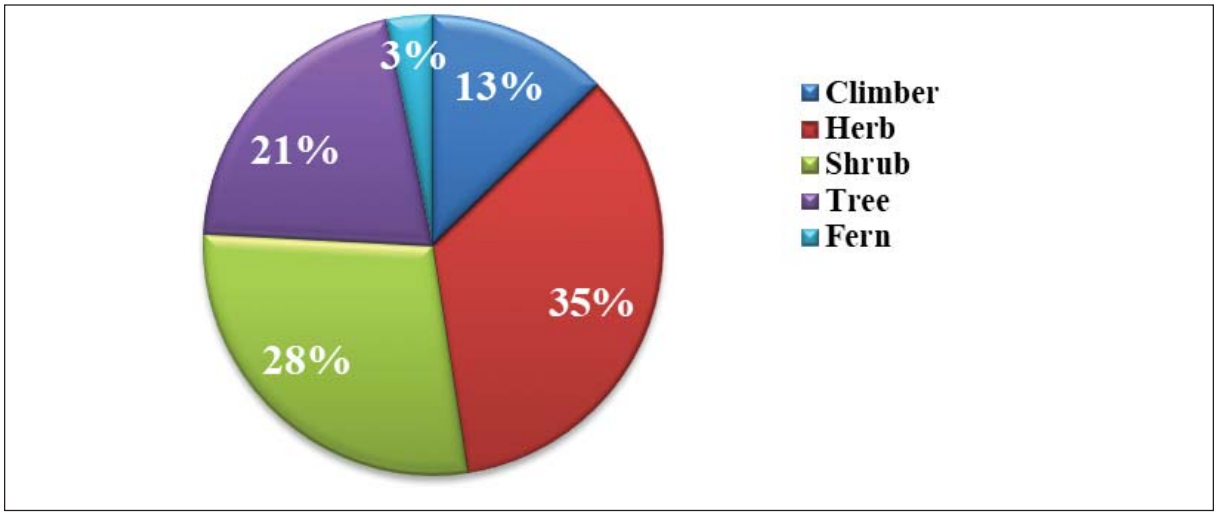

Fig. 1: Habit form of ethnomedicinal plants used by the herbal practitioner

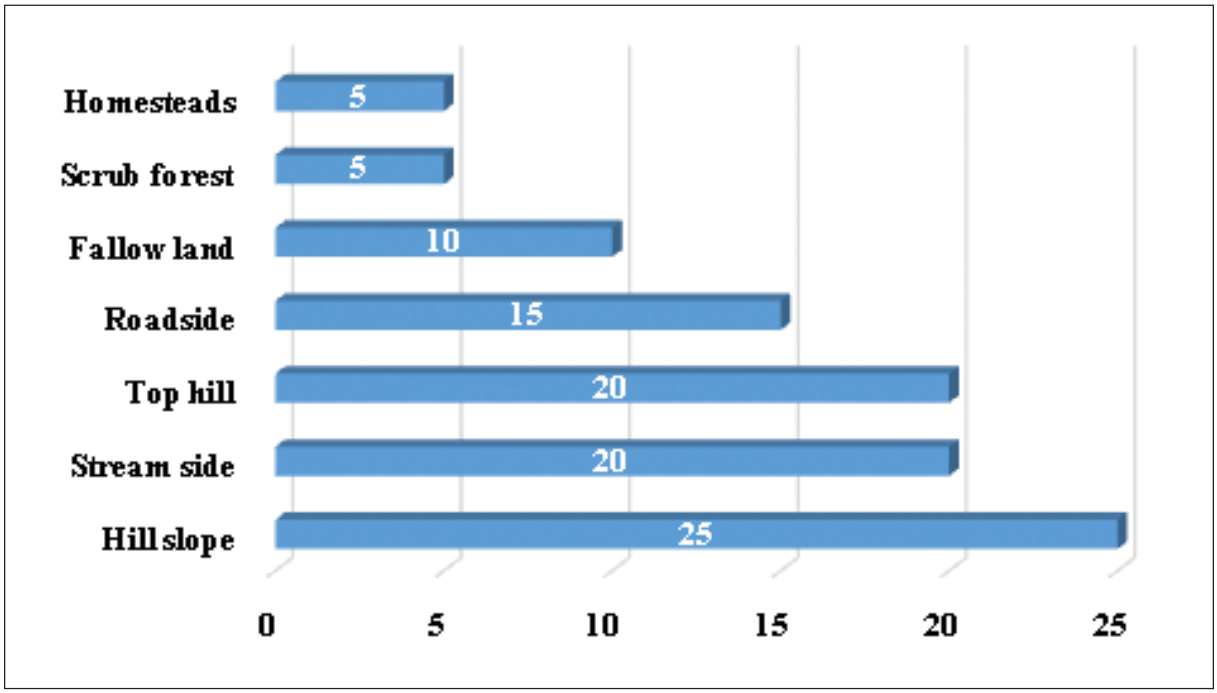

Fig. 2 : Habitat diversity of the ethnomedicinal plants

Based on habit, 35% (85 species) were herbs, 28% (69 species) were shrubs, 21% (51 species) were a tree, 13% (31 species) were climbers and 3% (8 species) were ferns. Herbs and shrubs account for 52% of medicinal plants in South India (Rawat and Garg, 2005). The distribution of plants in different habit form are shown in Figure 1.

Out of two hundred forty four ethnomedicinal plants, 29 (12%) species were common in three areas; 43 (18%) species were found exclusively in Bandarban Sadar, 26 (11%) were found in Rowangchhari and 34 (14%) were found in Thanchi upazila. Some new medicinal plant uses were also reported that had not previously been mentioned

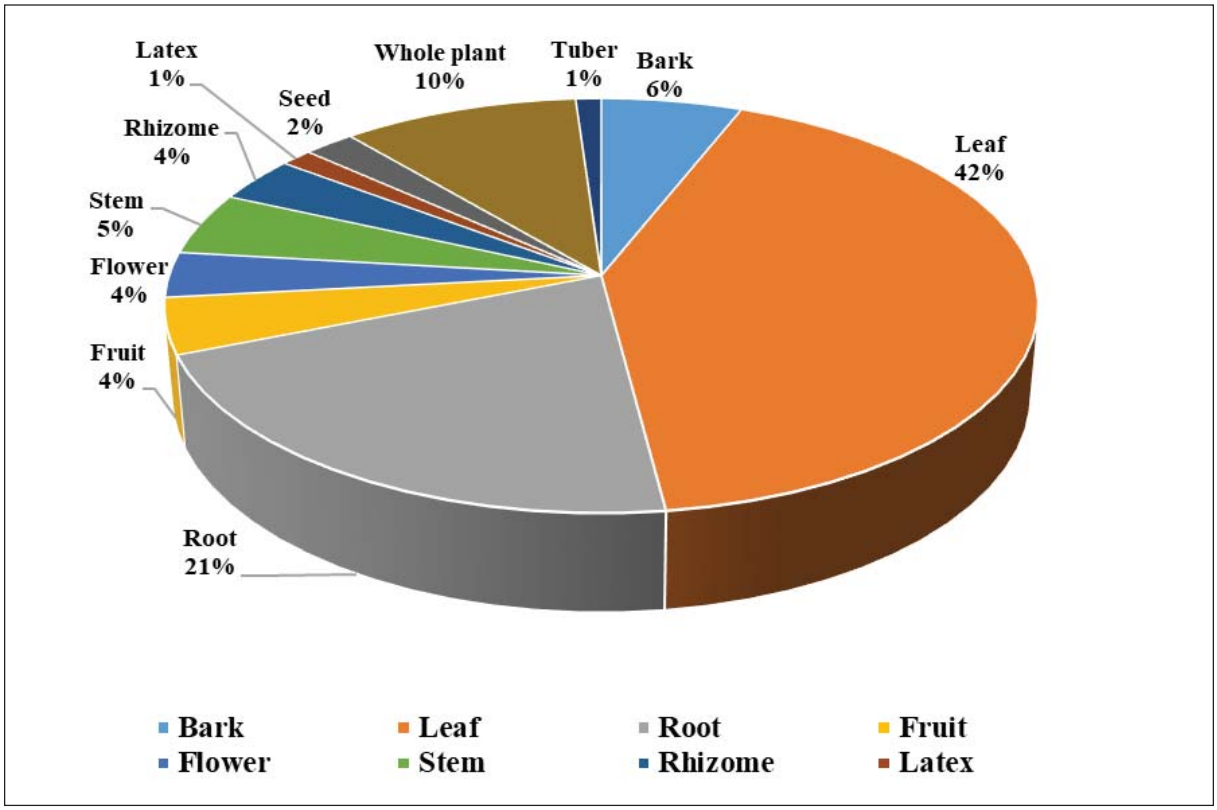

Fig. 3 : Proportion of different morphological parts used as herbal medicine

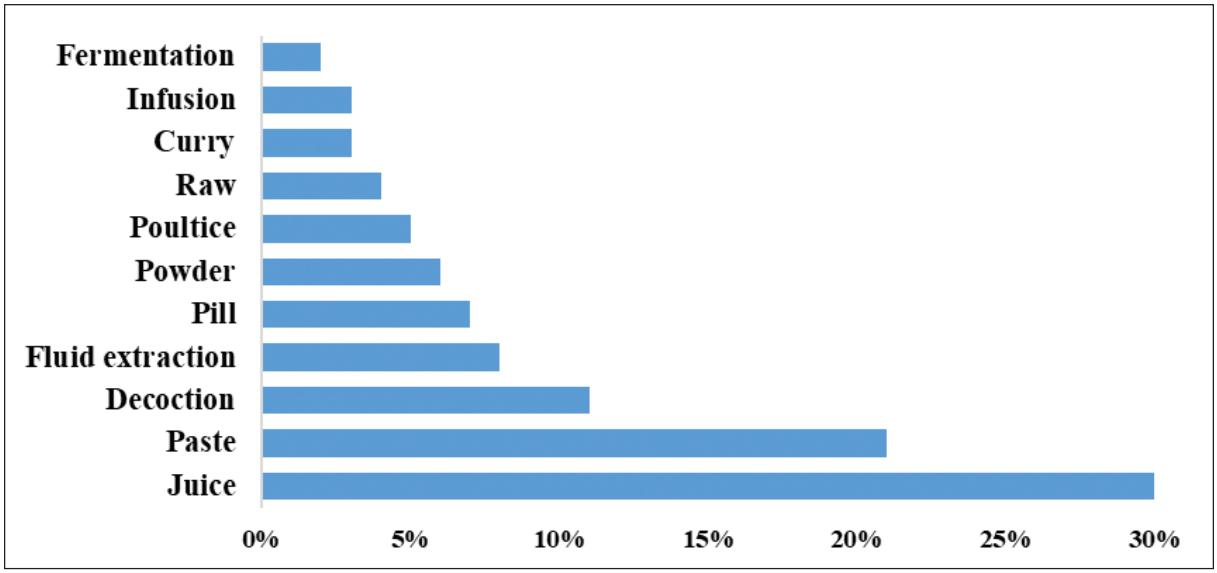

Fig. 4 : Mode of preparation used in herbal medicine formulation

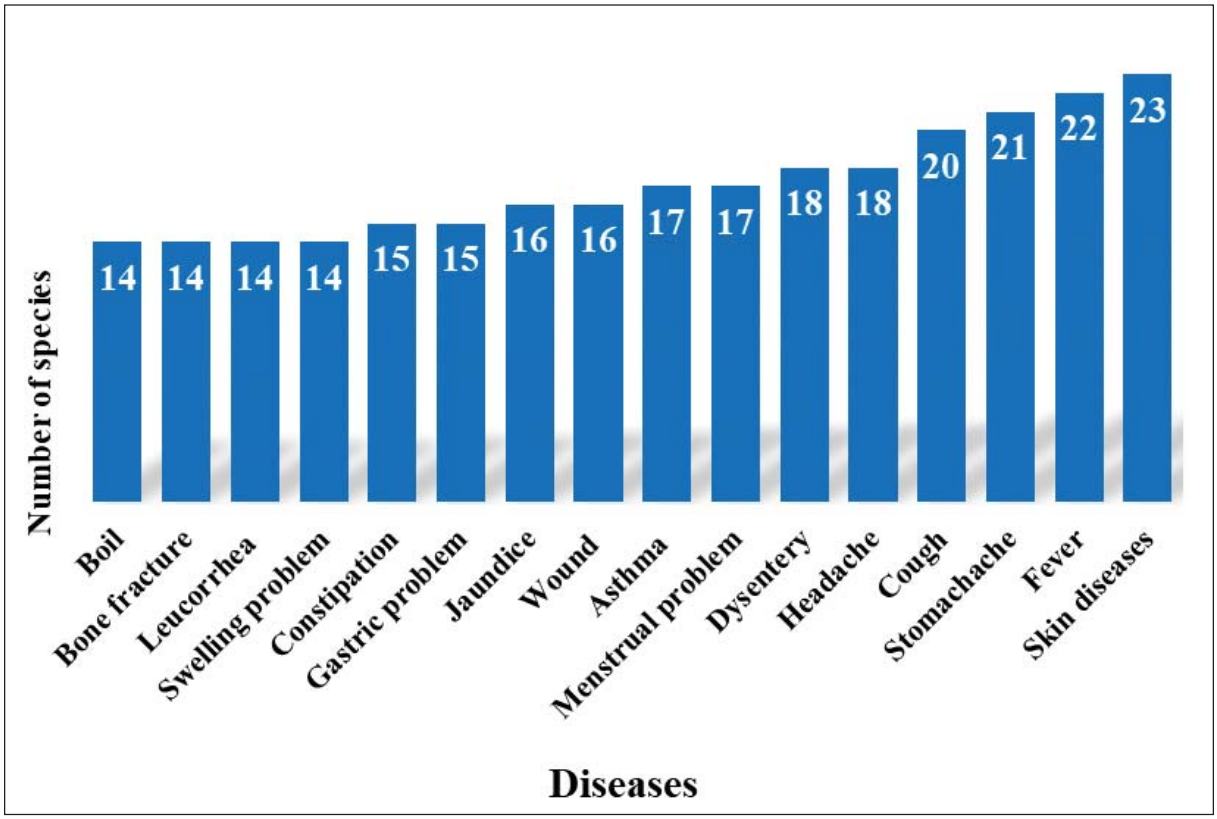

Fig. 5 : Number of species to treat different diseases

in Bangladesh. The widely used medicinal plants may draw the attention of phytochemists and pharmaceutical researchers to determine the active component of the plant for the production of new medicines.

Information about the habitat of ethnomedicinal plants of any species is essential for the conservation of the species. The habitat diversity of the ethnomedicinal plant sample reveals that 25% of the plants grow on the hill slope, 20% of the plants grow near the streamside (jhiri), 20% of the plants grow on the top of the hill, 15% of the plants grow on the roadside, 10% of the plants grow in the fallow land, 5% of the plants grow in the scrub forest and 5% of the plants grow in the homesteads (Figure 2).

The study reveals that the herbal practitioners of Bandarban hill district uses 11 different parts of the plants for the treatment of different ailments. Leaves were the most dominant plant parts (42%), followed by roots (21%), whole plants (10%), bark (6%), stem (5%), fruit (4%), rhizome (4%), flower (4%), seed (2%), latex (1%) and tuber (1%) (Figure 3). Herbal practitioners commonly favor the leaves and flowering components of the plant due to their convenient collecting process and widespread availability (Baydoun *et al.*, 2015; Giday *et al.*, 2003) In addition, the leaves are the most active part of the plant in terms of metabolite production and photosynthesis (Ghorbani, 2005). The use of plant parts affects plant populations. The use of whole trees with roots reduces the abundance of those plants in the area. For small populations and local plants, this practice has become more serious. More than 100 medicinal plants are extracted destructively from the Thar Desert in India (Bhattacharyya *et al.*, 2006). But regrettably, due to deforestation, jhum farming, illicit cutting, burning, and over exploitation of the resources, medicinal plants are becoming increasingly scarce, and wild plant populations are fast dwindling. So along with the use of medicinal plants, emphasis should be placed on their conservation.

Herbal practitioners informed that most of the medicine is used orally and in some cases is used

Table 1: List of recorded medicinal plant species in Bandarban Hill District, along with their family, local name, habit, parts used and ailments

Scientific name	Family	Local name	Habit	Parts used	Ailments
Abelmoschus hostilis Wall.	Malvaceae	Kantabhendi	Shrub	Root	Insect bite
Abelmoschus moschatus Medik.	Malvaceae	Mushakdana	Herb	Leaf, root and seed	Snake bite, cough, fever, anemia and throat pain
Abroma augusta (L.) L.f.	Sterculiaceae	Ulatkambol	Shrub	Leaf, root and stem	Paralysis, leucorrhoea, gonorrhea and fever
Abrus precatorius L.	Fabaceae	Kunch	Climber	Leaf and seed	Abortion, leprosy and asthma
Acalypha hispida Burm.f.	Euphorbiaceae	Lal hatisur	Shrub	Leaf	Leprosy, sores and skin rash
Achyranthes aspera L.	Amaranthaceae	Apang	Herb	Whole plant	Carbuncle, body pain, constipation and gynecological complexity
Acorus calamus L.	Araceae	Bach	Herb	Whole plant	Headache, cough and pneumonia
Actinostemma tenerum Griff.	Cucurbitaceae	Golapata	Herb	Flower and leaf	Abdominal pain and hydrocele
Adenosma indianum (Lour.)	Scrophulariaceae	Barakesuti	Herb	Leaf	Asthma
Adiantum caudatum L.	Adiantaceae	Fern	Fern	Leaf	Excessive bleeding after child birth and anorexia
Aegle mermelos (L.) Correa	Rutaceae	Bel	Tree	Leaf, root and fruit	Weakness, dysentery constipation and headache
Aerva sanguinolenta (L.) Blume	Amaranthaceae	Nuriya	Herb	Leaf	Piles, stop bleeding, burning urination and stomachache
Agave cantala Roxb.	Agavaceae	Bombai agar	Herb	Leaf	Joint pain
Ageratum conyzoides L.	Asteraceae	Fulkuri	Herb	Leaf	Cutting wounds, oedema, sneezing, hiccup and headache
Alangium salvifolium (L.f.)Wangerin	Alangiaceae	Ankor kanta	Tree	Bark, leaf and fruit	Piles, leprosy, rheumatic pain and lumbago
Allophyllus cobbe (L.) Raeusch.	Sapindaceae	Aitachita	Shrub	Root and leaf	Wound, skin diseases, hydrocele and rheumatic pain
Alocasia acuminata Schoot	Araceae	Pata bokakachu	Herb	Rhizome and stem	Skin diseases and earache
Aloe vera (L.) Burm. f.	Aloeaceae	Grita kumari	Herb	Leaf	Eczema, menopause problem and paralysis
Alpinia conchigera Griff.	Zingiberaceae	Konchi elachi	Herb	Rhizime	Gastric pain, dyspepsia, stomach pain and diarrhoea
Alstonia scholaris (L.) R. Br.	Apocynaceae	Chhatim	Tree	Stem bark, leaf and latex	Rheumatic pain, gout and skin diseases
Amaranthus spinosus L.	Amaranthaceae	Katanotey	Herb	Whole plant	Chicken pox, fever, vomiting and burning urination
Amomum aromaticum Roxb.	Zingiberaceae	Labongha elachi	Herb	Rhizome	Asthma, gastric and indigestion
Amorphophallus bulbifer (Roxb.) Blume	Araceae	Jongle ol	Herb	Bulbil	Insect bite
Anacardium occidentale L.	Anacardiaceae	Kajubadam	Tree	Leaf and fruit	Diarrhea, skin infection, burns and eczema
Andrographis paniculata (Burm.f.)	Acanthaceae	Kalomegh	Herb	Whole plant	Dysentery, acidity, worms and stomach problem
Angisopteris evecta (G. Forst.) Hoffm	Marattiacaeae	Dhekia Shak	Fern	Leaf and rhizome	Carbuncle, wound, knee pain and tumor
Anisomeles indica (L.) O. Kuntze	Lamiaceae	Gobura	Herb	Whole plant	Oedema, evil spirit, anorexia and mouth abscess
Anogeissus acuminata Roxb.	Combretaceae	Itchri	Tree	Leaf	Diarrhea, dysentery and anemia
Ardisia humilis Vahl.	Myrsinaceae	Ban jam	Shrub	Leaf and root	Muscle pain, snake bite and heal sores
Argyreia nervosa Burm. f.	Convolvulaceae	Bara dudhi	Climber	Leaf	Increase sexual capacity

Scientific name	Family	Local name	Habit	Parts used	Ailments
Aristolochia indica L.	Aristolochiaceae	Iswarmul	Climber	Root, leaf and seed	Stomachache, cough, joint pain and anemia
Asparagas racemosus Willd.	Liliaceae	Shotomuli	Climber	Tuber	Fever, cough, general weakness and gonorrhea
Azadirachta indica A. Juss.	Meliaceae	Neem	Tree	Leaf and root	Scabies, chest pain and itching
Baliospermum solanifolium (Burm. f.) Suresh	Euphorbiaceae	Danti	Shrub	Leaf, bark and root	Rheumatic pain, enlarged spleen and burning sensation
Barleria lupilina Lindl.	Acanthaceae	Kanta bishalla	Shrub	Leaf	Skin diseases and itching
Bauhinia acuminata L.	Caesalpiniaceae	Shet kanchan	Tree	Leaf, root and bark	Epilepsy, jaundice and leprosy
Bauhinia purpurea L.	Caesalpiniaceae	Raktakanchan	Tree	Bark	Diarrhea, ulcer, dropsy and rheumatism
Begonia roxburghii A. DC.	Begoniaceae	Gonirakto	Herb	Whole plant	Stone in urinary tract, intestinal worms and jaundice
Blumea balsamifera (L.) DC.	Asteraceae	Nagor chandal	Shrub	Leaf	Gout, oedema, leg pain, cough and chronic eye diseases
Boerhavia diffusa L.	Nyctaginaceae	Punarnava	Herb	Whole plant	Epilepsy, abdominal pain, anemia and renal disorder
Bombax ceiba L.	Bombacaceae	Shimul	Tree	Gum, root and flower	Diarrhea, leucorrhoea, dysentery and gonorrhea
Breynia retusa (Dennst.) Alston	Euphorbiaceae	Silpati	Shrub	Leaf and stem	Conjunctivitis, ulcer and toothache
Bridelia retusa (L.) A. Juss.	Euphorbiaceae	Kata koi	Tree	Root	Cough, fever and leucorrhoea
Bryophyllum pinnatum (Lamk.) Oken	Crassulaceae	Pathorkuchi	Herb	Leaf	Whooping cough, pneumonia, burn problem, blood dysentery and cold
Buddleja asiatica Lour.	Buddlejaceae	Badbhota	Shrub	Leaf	Rheumatism and pneumonia
Byttneria pilosa Roxb.	Sterculiaceae	Harjora lata	Climber	Leaf and root	Bone fracture, boils and dandruff
Calotropis gigantea (L.) Drynad.	Asclepiadaceae	Akanda	Shrub	Leaf and latex	Bone fracture, oedema, malarial fever, ringworm, pain and cough
Campanumoea lancifolia Roxb.	Campanulaceae	Atosigede	Herb	Leaf	Chicken pox
Canna indica L.	Cannaceae	Kalaboti	Herb	Rhizome and leaf	Dropsy, dyspepsia and abdominal pain
Cardiospermum halicacabum L.	Sapindaceae	Lataphatki	Climber	Whole plant	Whooping cough, chicken pox, healing wounds and asthma
Catharanthus roseus (L.) G. Don	Apocynaceae	Nayan tara	Herb	Leaf and root	Diabetic, dysentery, asthma and cancer
Celosia cristata L.	Amaranthaceae	Morogphul	Herb	Root, flower and stem	Irregular menstruation, piles, body swollen, leucorrhoea and measles
Centella asiatica (L.) Urb.	Apiaceae	Thankuni	Herb	Leaf	Blood dysentery, indigestion, conjunctivitis and insomnia
Christella dentata (Forssk.) Brownsey	Thelypteridaceae	Bish dhekia	Fern	Whole plant	Chronic leukemia
Chromolaena odorata (L.) R.M.king & H. Rob.	Asteraceae	Bara shialmuti	Herb	Whole plant	Cough, gastric and healing wound
Cinnamomum tamala (Buch.-Ham)	Lauraceae	Tejpata	Tree	Leaf	Cough, cardiac weakness and sexual weakness

Scientific name	Family	Local name	Habit	Parts used	Ailments
Cissus adnata Roxb.	Vitaceae	Bhatia-lota	Climber	Root and leaf	Paralysis and hypochondria
Cissus javana DC.	Vitaceae	Rangila lata	Climber	Leaf	Enlarge liver
Cissus quadrangularis L.	Vitaceae	Harjora	Climber	Whole plant	Bone fracture, cancer and ulcer
Cissus repens Lam.	Vitaceae	Marmaria lata	Climber	Leaf	Jaundice and boils
Clausena heptaphylla (Roxb.) Wight & Arn.		Rutaceae	Pan mouri	Shrub	leaf and root Cancer, fever, hysteria and mental disorder
Clerodendrum indicum (L.) Kuntze	Verbenaceae	Bamunhatti	Shrub	Leaf and root	Fever, gynecological complexity, rheumatic pain and cough
Clerodendrum viscosum Vent.	Verbenaceae	Bhat	Shrub	Leaf	Abdominal pain, boils, impotence and itching
Clerodendrum wallichii Merr.	Verbenacaeae	Tara tabah bhat	Shrub	Root and leaf	Fever and skin allergy
Clitoria ternatea L.	Fabaceae	Aparajita	Climber	Whole plant	Menopause, cough, diarrhoea, leprosy and boils
Coccinia grandis (L.) Voigt	Cucurbitaceae	Telakucha	Climber	Leaf	Diabetes, skin eruptions and hypertension
Coix lacryma-jobi L.	Poaceae	Tosbi dana	Shrub	Root and seed	Strangury, menstrual complaints and urinary tract inflammation
Commelina benghalensis L.	Commelinaceae	Dholpata	Herb	Leaf	Malnutrition, leprosy and sores
Commelina diffusa Burm. f.	Commelinacaeae	Monayna kanshira	Herb	Whole plant	Anemia and leucorrhoea
Conyza semipinnatifida Wall.	Asteraceae	Adha conyza	Herb	Leaf	Boils
Costus speciosus (J. Koenig) Sm.	Costaceae	Keu	Herb	Whole plant	Jin assor, Indigestion, paralysis and earache
Crateva magna (Lour.) DC.	Capparaceae	Barun	Tree	Stem bark and root	Rheumatic pain and contraceptive
Crotalaria pallida Aiton	Fabaceae	Jhunjhuni	Shrub	Root and leaf	Stomachache, piles and prostate enlargement
Croton bonplandianus Baill.	Euphorbiaceae	Nakphul	Herb	Whole plant	Gastric ulcer, abdominal pain and eczema
Croton tiglium L.	Euphorbiaceae	Jamalgota	Tree	Seed	Tumor, scabies and asthma
Curculigo orchioides Gaertn.	Hypoxidaceae	Talmuli	Herb	Tuber	Lumbago, menorrhagia, leucorrhoea and impotence
Curcuma caesia Roxb.	Zingiberaceae	Kalo holud	Herb	Rhizome	Diarrhea, blood dysentery, headache and tonsilitis
Curcuma longa L.	Zingiberaceae	Halud	Herb	Rhizome	Wound healing, dysentery, bone fracture and stomachache
Cuscuta reflexa Roxb.	Cuscutaceae	Swarrnalata	Climber	Whole plant	Jaundice, constipation, stomachache, liver diseases, body pain and anorexia
Cyathula prostrata (L.) Blume	Amaranthaceae	Shyontula	Herb	Root and leaf	Gastric, oedema and pneumonia
Cycas pectinata Buch.-Ham.	Cycadaceae	Cicas gaas	Palm	Leaf, fruit and flower	Asthma, breast tumor and menstruation problem
Cyclea barbata Miers	Menispermaceae	Thangbandri	Climber	Leaf and root	Easy delivery, body pain and epilepsy
Cymbopogon citratus (DC.) Stapf	Poaceae	Lebugandhi ghas	Herb	Leaf	Nasal congestion, cough and tuberculosis
Cyperus rotundus L.	Cyperaceae	Mutha	Herb	Whole plant	Cough, dyspepsia and stomach complaints
Datura metal L.	Solanaceae	Dhutra	Shrub	Leaf and fruit	Headache, skin diseases, dislocated bone and tumor
Dendrobium aphyllum (Roxb.)	Orchidaceae	Fasiarium	Herb	Leaf	Deformed head and abdominal pain
Dendrocnide sinuata (Blume) Chew	Urticaceae	Sutra	Tree	Leaf and root	Appendicitis, body pain and swollen limb
Desmodium gangeticum (L.) DC.	Fabaceae	Salpani	Shrub	Root	Asthma, headache and whooping cough

Scientific name	Family	Local name	Habit	Parts used	Ailments
Desmodium triquetrum (L.) DC.	Fabaceae	Kising sina gach	Shrub	Root and leaf	Asthma, jaundice, bone fracture and tuberculosis
Dillenia pentagyna Roxb.	Dilleniaceae	Hargaza	Tree	Bark	Blood dysentery, diarrhea and tuberculosis
Dioscorea bulbifera L.	Discoreaceae	Banalu	Climber	Tuber	Enlarged spleen, syphilis and dyspepsia
Diplazium esculentum (Retz.) Sw.	Athyriaceae	Dheki shak	Fern	Leaf	Swollen knee and allergy
Dracena spicata Roxb.	Asparagaceae	Kadorateng gach	Shrub	Stem	Evil spirit
Drymoglossum piloselloides (L.)	Polypodiaceae	Pasha dhekia	Fern	Whole plant	Liver inflammation, asthma and knee pain
Eclipta prostrata (L.) L.	Asteraceae	Kalokeshi	Herb	Whole plant	Resists hair fall, constipation and boils
Elatostema papillosum Wedd.	Urticaceae	Silajhara	Herb	Leaf and root	Abscess, pneumonia and paralysis
Emilia sonchifolia (L.) DC *ex* DC	Asteraceae	Sadusi	Herb	Leaf	Eye inflammations, night blindness and joint pain
Entada rheedii Spreng.	Mimosaceae	Gilagach	Climber	Whole plant	Skin diseases, bowel complaints and wound healing
Eupatorium triplinerve Vahl	Asteraceae	Ayapan	Herb	Leaf	Ulcer and stomachache
Euphorbia hirta L.	Euphorbiaceae	Dudhiya	Herb	Whole plant	Bronchial affections, dysentery and piles
Euphorbia nerifolia L.	Euphorbiaceae	Mansa	Shrub	Root and leaf	Snake bite, bronchitis, cough and asthma
Ficus hispida L.f.	Moraceae	Kakdumur	Tree	Fruit and root	Stop vomiting, epilepsy and menstrual hemorrhage
Flemingia macrophylla(Willd.) Merr.	Fabaceae	Bara salphan	Shrub	Leaf and root	Polio and irregular menstruation
Flemingia stricta Roxb.	Fabaceae	Charchara phan	Shrub	Leaf and root	Stop bleeding, digestive problem and chest pain
Flueggea virosa (Roxb. *ex* Willd.)	Euphorbiaceae	Khaukra	Shrub	Root	Burning eye, small pox and gonorrhea
Gmelina arborea Roxb.	Verbenaceae	Gamari	Tree	Leaf and flower	Gonorrhea, anemia, burning sensation and scabies
Gouania tiliaefolia Lam.	Rhamnaceae	Harjen gagota	Shrub	Leaf	Sores
Grewia nervosa (Lour.) Panigrahi	Tiliaceae	Asar	Tree	Leaf	Bone fracture and hair tonic
Gynura nepalensis DC.	Asteraceae	Diabetes plant	Herb	Leaf	Headache, mums, body pain, oedema and fever
Hedyotis thomsoni Hook. f.	Rubiaceae	Taso wpangpai	Herb	Whole plant	Wound healing
Heliotropium indicum L.	Boraginaceae	Hatisur	Herb	Leaf	Stop bleeding, bone fracture and night blindness
Hibiscus rosa-sinensis L.	Malvaceae	Jaba	Shrub	Flower, root and leaf	Excessive menstruation, urinary tract, piles and boils
Holarrhena antidysenterica (L.) Wall. *ex*A. DC.		Apocynaceae	Kurchi	Tree	Bark Threadworm, abdominal pain, dysentery, mouth sore and asthma
Homalomena aramatica (Spreng.) Schott	Araceae	Gandhobi kochu	Herb	Leaf and rhizome	Piles, insect bite and blood dysentery
Hoya parasitica (Wall. *ex* Hornem.)	Asclepiadaceae	Serapatahoya	Creeper	Leaf	Ear abscess, paralysis, headache and arthritis
Hydnocarpus kurzii (King) Warb.	Flacourtiaceae	Chalmugra	Tree	Bark and seed	Tumor, fever, leprosy and skin diseases
Hymenodictyon orixensis (Roxb.) Mabb.	Rubiaceae	Bhui-kadam	Tree	Leaf and bark	Ham, snake bite, jaundice and paralysis
Ichnocarpus frutescens (L.) W. T Aiton.	Apocynaceae	Syamalota	Climber	Leaf	Stop bleeding, fever and ham
Imperata cylindrica (L.) Raeusch.	Poaceae	Ulu	Herb	Whole plant	Burning urination and fever
Ipomoea mauritiana Jacq.	Convolvulaceae	Bhuikumra	Climber	Tuber	Syphilis and sexual disabilities
Ixora coccinea L.	Rubiaceae	Rangan	Shrub	Root and flower	Hiccup, fever, leucorrhoea and dysmenorrhea

Scientific name	Family	Local name	Habit	Parts used	Ailments
Ixora cuneifolia Roxb.	Rubiaceae	Beophul rangan	Shrub	Root and leaf	Cholera, gallstone and tonsillitis
Ixora nigricans R. Br. ex Wight & Arn.	Rubiaceae	Kuthi rangan	Shrub	Root	Diarrhea
Jasminum sambac (L.) Aiton	Oleaceae	Beli	Shrub	Leaf and root	Fever, abdominal pain and urinary tract infection
Jatropha gossypifolia L.	Euphorbiaceae	Laljeol	Shrub	Leaf and root	Fistula, hydrocele and excessive menstruation
Justicia adhatoda L.	Acanthaceae	Basok pata	Shrub	Leaf	Cough, fever and asthma
Justicia gendarussa Burm. f.	Acanthaceae	Jagatmadan	Shrub	Leaf	Tumor, body pain and leucorrhoea
Kaempferia galanga L.	Zingiberaceae	Sugandi bach	Herb	Leaf and rhizome	Headache and flatulence
Lantana camara L.	Verbenaceae	Guayganda	Shrub	Leaf	Tetanus
Laportea interrupta (L.) Chew	Uritaceae	Chutra	Herb	Leaf and root	Muscular pain, asthma and boils
Leea aequata L.	Leeaceae	Kakjangha	Shrub	Root and leaf	Carbuncle, rheumatism and sores
Leea indica (Burm. f.) Merr.	Leeaceae	Dubjat	Shrub	Leaf	Jaundice and bone fracture
Lepisanthes senegalensis (Poir.) Leenh.	Sapinadiceae	Gotaharina	Tree	Leaf	Leucorrhoea
Leucas zeylanica (L.) W. T. Aiton	Lamiaceae	Shetadrone	Herb	Whole plant	Fever, gout and blistery
Leucus aspera (Willd.) Link.	Lamiaceae	Dondakolos	Herb	Whole plant	Tonsillitis, cough and headache
Lippia alba (Mill.) N.E.Br. *ex* Britton	Verbenaceae	Vui okra	Shrub	Leaf	Diarrhea, stomachache and bronchitis
Litsea glutinosa (Lour.) C. B. Rob.	Lauraceae	Menda	Tree	Bark, leaf and root	Joint pain, blood dysentery and tumor
Lygodium altum (C. B. Clarke) Alderw.	Schizaeaceae	Dheki shak	Fern	Whole plant	Swallowness of leg and headache
Lygodium flexuosum (L.) Sw.	Schizaeaceae	Kuttijurkha	Fern	Leaf	Toothache, dental carries and mumps
Maesa indica (Roxb.) A. DC.	Myrsinaceae	Ramjoni	Shrub	Root and leaf	Fever, body pain and paralysis
Maesa ramantacea (Roxb.) A. DC.	Myrsinaceae	Maricha	Tree	Leaf, stem and flower	Headache, cutting wound and urine infection
Mangifera indica L.	Anacardiaceae	Aam	Tree	Bark, fruit and latex	Dysentery, constipation, urinary discharge and sole healing
Maranta arundinacea L.	Marantaceae	Ararut	Herb	Rhizome	Cough and urinary problem
Melastoma malabathricum L.	Melastomaceae	Ban-tezpata	Shrub	Root and leaf	Toothache, boils, dysentery, gynecological problem and ulcer
Merremia vitifolia (Burm.f.) Hallier f.	Convolvulaceae	Kormolata	Climber	Leaf and root	Injury, inflammation and stomachache
Mesua ferrea L.	Clusiaceae	Nageshwar	Tree	Seed and flower	Nasal polyp, weakness, leucorrhoea and piles
Micromelum minutum (J. G.Forst.) Wight & Arn.		Rutaceae	Dulia	Tree	Leaf and bark Teeth decay, evil spirit and headache
Microsorum punctatum (L.) Copel.	Polypodiaceae	Gucha patra	Fern	Leaf	Knee pain and stomach pain
Mikania cordata (Burn. f.) B.L.Rob.	Asteraceae	Refuzi lata	Herb	Whole plant	Stop bleeding and wound healing
Mimosa pudica L.	Mimosaceae	Lajjaboti	Shrub	Whole plant	Abscess, filaria, measles, pyorrhea and hydrocele
Molineria capitulata (Lour.) Herb.	Hypoxidaceae	Sotipata	Herb	Root	Stop bleeding, hernia and stop vomiting
Molineria recurvata (W.T.Aiton) Herb.	Liliaceae	Satipata	Herb	Leaf and root	Stop bleeding and bone fracture
Morinda angustifolia Roxb.	Rubiaceae	Daruharidra	Tree	Root, leaf and stem	Urinary tract infection, tetanus and jaundice
Morinda persicifolia Buch.-Ham.	Rubiaceae	Cefo bena	Shrub	Root and leaf	Irregular menstruation and jaundice

Scientific name	Family	Local name	Habit	Parts used	Ailments
Moringa oleifera Lam.	Moringaceae	Sajna	Tree	Leaf, bark, root and fruit	High blood pressure, cough, rheumatism, flatulence, joint pain, liver diseases and menstrual pain
Mucuna pruriens (L.) DC.	Fabaceae	Alkushi	Herb	Leaf and root	Bone fracture, stop bleeding and cholera
Murraya koenigii (L.) Spreng.	Rutaceae	Kariphuli	Tree	Leaf	Dysentery, eruptions and stop vomiting
Murrya paniculata (L.) Jack.	Rutaceae	Kamini	Tree	Leaf	Toothache and tooth decay
Musa paradisiaca L.	Musaceae	Kola	Herb	Flower and fruit	Dysentery, menorrhagia, indigestion and constipation
Mussaenda macrophylla Wall.	Rubiaceae	Baropata muchenda		Shrub	Root Diarrhea
Mussaenda roxburghii Hook. f.	Rubiaceae	Silchaonri	Shrub	Leaf and flower	Breast pain, headache and fever
Naravelia zeylanica (L.) DC.	Ranunculaceae	Chagol-boti	Climber	Leaf	Gastric problem
Nelsonia canescens (Lam.) Spreng.	Acanthaceae	Paramul	Herb	Leaf	Boils, asthma and body pain
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Kadam	Tree	Leaf	Enlarge liver
Ocimum americanum L.	Lamiaceae	Bon tulsi	Herb	Leaf	Bronchitis, abdominal pain and nose bleeding
Ocimum gratissimum L.	Lamiaceae	Ram tulsi	Shrub	Leaf	Burning urination, skin diseases and flatulence
Ocimum tenuiflorum L.	Lamiaceae	Kalo tulsi	Shrub	Leaf	Cold, cough, influenza and gastric problem
*Ophiorrhiza trichocarpa*Blume	Rubiaceae	Karphagandhali	Herb	Leaf	Jaundice
Opuntia dillenii (Ker-Gwal.) Haw.	Cactaceae	Phanimansa	Shrub	Stem	Impotence, inflammation and dandruff
Oroxylum indicum (L.) Kurz	Bignoniaceae	Khona	Tree	Bark and leaf	Headache, body pain, hydrocele and jaundice
Oxalis corniculata L.	Oxalidaceae	Amrul	Herb	Whole plant	Fever and dysentery
Paederia foetida L.	Rubiaceae	Gandhabhaduli	Climber	Leaf	Stomach disorder, gout, constipation and urticaria
Passiflora foetida L.	Passifloraceae	Jumkolata	Herb	Leaf and root	Asthma, hysteria, menopause and ringworm
Pedilanthus tithymaloides (L.) Poit.	Euphorbiaceae	Rangchita	Shrub	Leaf	Bone fracture, body pain and eczema
Peperomia pellucida (L.) Kunth	Piperaceae	Luchi pata	Herb	Whole plant	Allergy, eye inflammation and insect stings
Peristylus constrictus (Lindl.) Lindl.	Orchidaceae	Bhuinora orchid	Herb	Leaf	Gonorrhea and earache
Persicaria hydropiper (L.) Delarbre	Polygonaceae	Biskatali	Herb	Leaf	Joint pain, carbuncles and stomach pain
Phyllanthus emblica L.	Euphorbiaceae	Amloki	Tree	Fruit	Anorexia, dyspepsia, flatulence and hair fall
Phyllanthus niruri L.	Euphorbiaceae	Bhuiamla	Herb	Whole plant	Stomachache, tetanus, gonorrhea and vomiting
Phyllanthus reticulatus Poir.	Euphorbiaceae	Chitki	Shrub	Leaf and root	Boils, diabetes and malaria
Phyllanthus urinaria L.	Euphorbiaceae	Andha ghas	Herb	Root	Urinary tract infection
Physalis minima L.	Solanaceae	Fotka	Herb	Whole plant	Easy delivery and insomnia
Piper longum L.	Piperaceae	Pepul	Climber	Leaf and fruit	Breast pain, delivery pain and chronic bronchitis
Plumbago indica L.	Plumbaginaceae	Raktachita	Shrub	Leaf	Hyper acidity, leprosy, snakebites contraceptive and jaundice

Scientific name	Family	Local name	Habit	Parts used	Ailments
Plumbago zeylanica L.	Plumbaginaceae	Shetchita	Shrub	Leaf and root	Piles, blood dysentery, arthritis contraception and irregular menstruation.
Plumeria rubra L.	Apocynaceae	Kat-golap	Tree	Bark	Facial paralysis, constipation and piles
Polyalthia longifolia (Sonn.)Thw.	Annonaceae	Debdaru	Tree	Bark	Fever
Polygala chinensis L.	Polygalaceae	China-dudhi	Herb	Leaf	Jaundice, chronic bronchitis and catarrhal affection
Portulaca oleracea L.	Portulacaceeae	Nune	Herb	Whole plant	Dyspepsia and sore in mouth
Pouzolzia zeylanica (L.) Benn.	Urticaceae	Kullaruki	Herb	Whole plant	Stomachache, snake bite and dysmenorrhea
Premna esculenta Roxb.	Verbenaceae	Lalong	Shrub	Leaf	Headache, abdominal pain and urinary problem
Prismatomeris tetrandra Roxb.	Rubiaceae	Katmali	Tree	Leaf	Sore throat
Pseuderanthemum carruthersii (Seem.)	Acanthaceae	Gollackchanda	Shrub	Root	Evil spirit and insect bite
Pseudoelephantopus spicatus (Juss. *ex* Aubl.)		Asteraceae	Kukurgihba	Herb	Whole plant Skin diseases
Psychotria adenopyhlla Wall.	Rubiaceae	Baro bhuta	Tree	Root	Indigestion and tetanus
Pueraria peduncularis (Benth.)	Fabaceae	Pendun kunch	Climber	Leaf	Tuberculosis
Pueraria tuberosa (Willd.) DC.	Fabaceae	Botrajineem	Climber	Leaf and flower	Stop bleeding and leprosy
Rauvolfia serpentina (L.) Benth. *ex* Kurz	Apocynaceae	Sarpagandha	Shrub	Root and leaf	Hypertension, constipation, and schizophrenia
Rauvolfia tetraphylla L.	Apocynaceae	Bara chadar	Shrub	Root	High blood pressure, dysmenorrhea, chest pain and excessive menstruation
Ricinus communis L.	Euphorbiaceae	Bherenda	Shrub	Leaf and seed	Constipation, anal fistula and mental disorder
Rungia pectinata (L.) Nees	Acanthaceae	Pindi	Herb	Leaf	Chicken pox and body pain
Sansevieria roxburghiana Schult. & Schult. f.		Agavaceae	Gorachaka	Herb	Rhizome Gonorrhea, glandular enlargement and bone pain
Saraca asoca (Roxb.) Willd.	Fabaceae	Asok	Tree	Bark, leaf and flower	Dysmenorrhea, irregular menstruation and dysentery
Schefflera elliptica (Blume) Harms	Araliaceae	Dahina kath	Shrub	Leaf and root	Insomnia, tumor, bone dislocation and hiccup
Scoparia dulcis L.	Scrophulariaceae	Bandhane	Herb	Whole plant	Breast pain, gallstone, earache and jaundice
Senna alata (L.) Roxb.	Caesalpiniaceae	Dadmardhan	Shrub	Leaf	Ringworm, eczema, hookworm and constipation
Senna hirsuta (L.) H.S. Irwin and Barneby		Caesalpiniaceae	Gandhosena	Shrub	Leaf and root Snake bite, blood purify and boils
Senna tora (L.) Roxb.	Caesalpiniaceae	Chakunda	Shrub	Leaf	Insanity, cough, eczema and ringworm
Sida acuta Burm. f.	Malvaceae	Ban methi	Shrub	Leaf, root and stem	Acne, blistery, early delivery and abscess
Sida rhombifolia L.	Malvaceae	Lal berela	Shrub	Leaf and root	Pain, quick delivery, burning urination and carbuncle
Smilax zeylanica L.	Smilaceae	Kumari lata	Climber	Root and stem	sores, general weakness and gonorrhea
Solanum lasiocarpum Dunal	Solanaceae	Kantha sola	Shrub	Leaf and root	Irregular menstruation and leucorrhoea
Solanum torvum Sw.	Solanaceae	Tit Begun	Shrub	Leaf and root	Haemorrhage, ear pain, leucorrhoea and tonsillitis
Solanum violaceum Ortega	Solanaceae	Brihati begun	Shrub	Leaf and fruit	Stop vomiting, intestinal worms and gastric problem

Scientific name	Family	Local name	Habit	Parts used	Ailments
Sonchus wightianus DC.	Asteraceae	Ban palang	Herb	Leaf	Pneumonia and swellings
Spilanthes calva DC.	Asteraceae	Marhatinga	Herb	Leaf	Knee pain, epilepsy, allergy and snakebite
Staurogyne argentea Wall.	Acanthaceae	Chemdima	Herb	Leaf	Jaundice, cancer, gout and body pain
Stephania japonica (Thunb.) Miers	Menispermaceae	Akanadi manik	Climber	Leaf and root	Hydrocele, irregular mensuration and constipation
Sterculia villosa Roxb.	Sterculiaceae	Udal (B)	Tree	Leaf	Burning urination, obesity and impotency
Stereospermum colais (Buch.-Ham.)	Bignoniaceae	Dharmara	Tree	Bark	Intestinal worms
Suregada multiflora (A. Juss.) Baill	Euphorbiaceae	Maricha	Tree	Leaf and root	Rheumatism, pneumonia, cough and fever
Synedrella nodiflora (L.) Gaertn.	Asteraceae	Relanodi	Herb	Leaf	Eczema, urticaria and stomachache
Syzygium cumini (L.) Skeels	Myrtaceae	Kalojam	Tree	Bark	Jaundice and dysentery
Tabernaemontana divericata (L.) R. Br.	Apocynaceae	Tagar	Shrub	Leaf and stem	Bronchitis, rheumatic pain and abdominal pain
Tabernaemontana recurva Roxb. *ex* Lindl.	Apocynaceae	Baka tagar	Shrub	Leaf	Insect bite and acidity
Tamarindus indica L.	Caesalpiniaceae	Tentul	Tree	Leaf and fruit	High blood pressure, weakness, inflammatory swelling and sore throat
Terminalia arjuna (Roxb. *ex* Dc.) Wight &Arn	Combretaceae	Arjun	Tree	Bark	Leucorrhoea and cardiac weakness
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Bahera	Tree	Fruit	Cough, piles and anorexia
Terminalia chebula Retz.	Combretaceae	Horitaki	Tree	Fruit	Leucoderma, constipation, flatulence and diarrhea
Tetrastigma bracteolatum (Wall.)	Vitaceae	Golgoli lata	Climber	Root	Wounds
Thunbergia grandiflora (Roxb. *ex* Rottl) Roxb.	Acanthaceae	Neel lata	Climber	Leaf	Leucorrhoea, eye diseases and hysteria
Tinospora cordifolia (Willd.) Miers	Menispermaceae	Guloncho	Climber	Stem and root	Syphilis, gonorrhea, gastric and scabies
Tournefortia viridiflora Wall.	Boraginaceae	Tiaturni	Shrub	Leaf	Eczema
Trema orientalis (L.) Blume	Ulmaceae	Jigni	Tree	Leaf, bark and root	Toothache, stomachache, muscular pain and epilepsy
Trichosanthes tricuspidata Lour.	Cucurbitaceae	Makal	Climber	Leaf and fruit	Allergy, hemicrania and earache
Typhonium trilobatum (L.) Schott	Araceae	Ghet kochu	Herb	Leaf and root	Gastric, wound healing and liver diseases
Uraria crinita L. DC.	Fabaceae	Bilai lengur	Shrub	Root and leaf	Tetanus, evil spirit and hysteria
Vernonia cinerea (L.) Less.	Asteraceae	Kukshim	Herb	Leaf	Fever and headache
Vitex negundo L.	Verbenaceae	Nishinda	Tree	Leaf	Abdominal pain, black fever, cough and asthma
Wedelia chinensis (Osbeck) Merr.	Asteraceae	Kesraj	Herb	Whole plant	Uterine haemorrhagia and menorrhagia
Woodfordia fruticosa (L.) Kurz.	Lythraceae	Dhaiphul	Tree	Flower	Skin diseases, dysentery and stop bleeding
Xanthosoma violaceum Schott	Araceae	Dudhkachu	Herb	Rhizome and leaf	Stop bleeding, rheumatic pain and itchy skin
Zingiber capitatum Roxb.	Zingiberaceae	Jongly ada	Herb	Rhizome	Gastric, indigestion and chronic dysentery
Zingiber montanum (J. Koenig.) Link	Zingiberaceae	Bonada	Herb	Rhizome	Gastric, stomachache and constipation

externally and they use drugs in 11 different forms to treat different diseases. The most common form was found in juice, followed by paste, decoction, fluid extraction, pill, powder, poultice, chewing raw, curry, infusion and fermentation (Figure 4).

According to Nadembega *et al*. (2011), the decoction is one of the most common forms of herbal formulations in traditional herbal drugs because it is very simple to prepare ethnomedicine by simply mixing plant parts with boiling water. However, in CHT most common form herbal formulation is juice. It is done by grinding the plant parts in stone and squeezing them to extract the juice. It may be due to their local adaptation to the harsh situation of the Chittagong Hill Tracts and the tradition they inherited from their predecessor.

From this investigation, 102 illnesses or symptoms that the herbalist treated were documented and it was found that fourteen species (Figure 5) are used for the treatment of the following diseases: boils, bone fractures, leucorrhea, rheumatic pain and swelling problems (14 species each), constipation, gastric problems (15 species each), jaundice and wounds (16 species each), asthma and menstrual problems (17 species each), dysentery and headache (18 species each), cough (20 species), stomachache (21 species), fever (22 species) and skin diseases (23 species). The herbal healers also reported that rheumatic pain, constipation, gastric problems, dysentery, cough, stomachaches, fever and skin diseases are the common diseases that occur among the tribal people of the Bandarban Hill District. Sumbul *et al*. (2011) state that *Myrtus communis* has been used to treat gastric ulcers, rheumatism, diarrhea, vomiting, haemorrhages, fever and dysentery.*Solanum nigrum* is used to treat hypertension, according to Abe and Ohtani (2013). The entire *Cynodon dactylon* plant is used to cure diabetes and tuberculosis, according to Dulla and Jahan (2017). According to Alam *et al*. (2022), *Calotropis gigantea* has been used to treat cough, oedema, ringworm, malaria, bone fractures and discomfort.

CONCLUSION

The utilization of medicinal plants by the indigenous people residing in the Bandarban hill district for the treatment of several human ailments has been observed. The documentation of indigenous traditional knowledge regarding medicinal plants is imperative to prevent its permanent loss within the community. In order to ensure the preservation and sustainability of medicinal plants, it is imperative to promptly undertake measures encompassing both in-situ and ex-situ conservation approaches. When scientific research is done properly, new substances that can be utilized to cure both old and new diseases may be discovered. A well planned educational and awareness building campaign involving local herbal healers and religious leaders should be implemented to raise awareness about the benefits of ethnomedicinal plants and sustainable ways to harvest plants for disease treatment now without endangering their availability for future use. The research work should be extended to other parts of the hill district to find any previously unidentified medicinal plants that have been utilized for ages to treat a variety of difficult ailments.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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