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Research Review

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Recent trends in development and utilization of non-traditional ornamental plants — a review

T Janakiram[1], V Aparna[*] and P Sunitha

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ICAR-Central Plantation Crop Research Institute, Kasaragod 671 124, Kerala, India

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ABSTRACT

Non-traditional ornamentals are under-utilized and un-explored plant species or relatives of commercially important crops having attractive ornamental plant characteristics, but its potential ornamental value is not fully realized and primarily not recognized or treated as an ornamental/floriculture crops. A number of commercially important fruit crops, plantations, vegetables, spices, and aromatic have a huge number of wild relatives, which cannot be grown directly as an economic crop but carry the genetic richness in them. Some of these wild species have attractive plant features with beautiful flowers, fruits and foliage appears unusual from their commercial counterpart. In recent years many of the novel ornamental types from the wild are recognized and domesticated for ornamental gardening, after improving their vegetative and reproductive traits. Therefore, current knowledge on identification, genetic richness, variability, and improvement of non-traditional ornamental species of banana, pomegranate, ginger, pineapple, cabbage, and kale are discussed.

Key Words: Banana, Cabbage, Ginger, Kale, Non-traditional ornamentals, Pineapple, Pomegranate

The demand and use of non-traditional ornamental plants have been increasing in recent years, making the development of such ornamental types of an alternative for different floricultural segments. Non-traditional ornamentals include attractive plant species of any of the commercial crops or weeds having appealing vegetative growth or reproductive growth or both, also accepted by the wide number of consumers as an ornamental. Recently, several wild relatives of fruits, vegetables and spices were widely used as ornamental plants due to its uniqueness, originality as well as durability of the crop species. Besides, its use as cut flowers, they also offer different landscaping or gardening purposes especially for potted plants, living fences, background and foreground plantings, borders, and focal points as well.

In recent times, numbers of species have been identified from the wild (Singh *et al.*, 2020; Janakiram *et al.*, 2013; for ornamental use and improvement was done using various breeding methods such as selection, mutation breeding and hybridization (Janakiram and Sane, 2011; Janakiram and Meenakshi, 2008) for obtaining more attractive plant features. Marker technologies have been employed for identifying the variability (Aparna *et al.*, 2019; Aparna *et al.*, 2020; Aparna *et al.*, 2020a). Physiology was studied and agronomic practices were standardized for various wild ornamental species (Sabu *et al.*, 2011). In the present paper, recent developments in some of the non-traditional ornamentals were discussed hereunder.

Ornamental Bananas

Banana is known as a commercial fruit crop and a staple food for millions of people in theworld, there are several wild bananas as well,bear no commercial or nutritionally important fruits which are important as an ornamental due to its attractive colorful inflorescences, foliage and seeded mini fruits. Banana family Musaceae is having three genera, *i.e., Musa, Musella* and *Ensete*. Genus, *Musa* contains four sections, *Eumusa, Rhodochlamys, Australimusa* and *Callimusa* of which, sections *Eumusaand Australimusa* comprises number of species which are most important as commercial fruit and fiber producers and species from sections, *Rhodochlamys* and *Callimusa* had more characteristic features like ornamental plants rather

*Corresponding author : aparna.cpcri@gmail.com

[1] Vice-Chancellor, Dr Y.S.R. Horticultural University, Venkataramannagudem 516 105, Andhra Pradesh, India

than fruit bearers. Important ornamental species from section *'Rhodochlamys'* are *Musa velutina, M. aurantiaca, M. laterita, M. ornate, M. siamens, M. rosea, M. manni, M. rubra* and *M. sanguine* distributed mainly in South-East Asian countries. Plants from this section were able to withstand the seasonal drought and suitable for background planting and indoor gardening. Species such as *M. coccinea, M. beccarii, M. campestris* and *M. violascens* are potential ornamental species from section *Callimusa* suitable for container planting in indoors and background planting, group planting for outdoor gardens (Aparna, 2019).

Genera *Musella* contain most fascinating species, *Musellala siocarpa* (Sam *et al.,* 2017) have unique plant characteristics, and the plant is < 60 cm in height with persistent leaf sheaths on pseudo stem and bears erect, 20-25 cm long inflorescence having bright colourful bracts on top of it. Before the opening of the inflorescence plant looks similar to a lotus flower due to this plant gets one of its names 'lotusbanana'. It grows usually in high mountain regions up to an altitude of 2500 m and tolerates free zing temperatures. The *Musella* can be grown ideally in pots due to its extra dwarf nature. They also look beautiful alongside water bodies or running water in gardens and as a corner plant in lawns with luxurious vegetative backgrounds (Aparna, 2019).

Species from genus *Ensete* are gained much attention recently as ornamental besides its major utility as commercial food crop with root as an economic part. A plant from this genus gives beautiful ornamental look due to their bunchy leaf crown with the swollen base of the pseudo stem,there are a number of dwarf species in this genus resembles to cycads in appearance. Species such as *Ensetesuperbum (Rock banana), Ensete ventricosum, Enseteperrieri etc.* can be used as a focal plant or center plant in the garden, also suitable for group planting (2-3 plants together) in lawns or on grassy mounds (Aparna, 2019).

In the last decade, large numbers of wild banana species with ornamental value have been identified by many researchers worldwide, especially in South-East Asia. A rare wild banana species *M. rubinea* belongs to section *Rhodochlamy s* having ornamental potential was discovered by Häkkinen and Teo in 2008. Intersectional hybrid, *Musa* × *georgiana* Rich. H. developed from the cross *'Musa balbisiana* (section-Musa) × *Musa velutina'* (section-*Rhodochlamys*) was identified and described for ornamental utility and fruiting as well (Wallace and Häkkinen. 2009). Recently, Smisha and Sabu (2017a, b) developed two new interspecific hybrids, Musa × calicutensis and *Musa*× *parahaekkinenii* from crosses *Musa haekkinenii* × *Musa beccarii* and *Musa coccinea* × *Musa haekkinenii* for ornamental use. Species *M. velutina* subsp. *Markkuana* (Sabu *et al.,* 2013), *M. sabuana* (Prasad *et al.,* 2013), *M. velutinavar. Variegate* (Joe *et al.,* 2014a), *M. arunachalensis* (Sreejith *et al.,* 2013), *M. cylindrical* (Joe *et al.,* 2014b), *M. balbisiana* var. *Elavazhai* (Joe *et al.,* 2014c) were discovered recently in India were suggested for ornamental gardening. Swangpol *et al.* (2017) discovered three new banana species, *Musa siamensis, M. serpentina* and *M. nanensis* having decorative potential. Joe and Sabu (2016) suggested some of the native wild species of India such as *Ensete glaucum, E. superbum, Musa arunachalensis, M. aurantiaca, M. chunii, M. laterita, M. mannii, M. markkui, M. ornate, M. rubra, M. sanguinea, M. velutina, M. velutina* subsp. *Markkuana* and *M. velutinavar.* variegate for ornamental utility in different landscape purposes (Joe and Sabu, 2016) after characterization and evaluation. Souza *et al.* (2012) confirmed the ornamental utility of banana accessions from sections *Rhodochlamys* and *Callimusa* and *Eumusa* based on morphological characterization and grouped the accessions (*e.g.* landscape plants, cut flowers, potted plants, and male inflorescence mini fruits) for landscaping. Santos-Serejo *et al.* (2012) developed 42 hybrids with ornamental banana accession of that, four lines (RM09, RM38, RM37 and RM33) were selected and recommended ornamental use (cut flowers, mini fruits, or landscaping plants) after screening procedure was done for plant growth characteristics and disease resistance. Thirugnanavel *et al.* in 2018 characterized and studied the diversity of five wild ornamental bananas and three hybrid seedlings. Likewise, numbers of studies have been conducted and explorations were done to maximize the utilization of bananas for landscaping.

Flowering Pomegranates

Punica granatum L. (2n=2x=16, 18) is oldest known nutritionally important edible tree species originating in Central Asia. Genus *Punica* also has important ornamental types besides economically important fruiting forms and some of them are equally performing well as dual-purpose varieties. Important ornamental types of *Punica* are 'Nana' and 'Double flower'.

The Nana or Dwarf form of pomegranate is also called as Japanese dwarf pomegranate (*Punica granatum* var. *nana*; 2n=2x=16). As the name implies *'Nana'* type have miniature and compact plant form, with 50-70 cm height; the plant has smaller leaves, miniature flowers and fruits are borne abundantly (Jalicop, 2007). The *Nana* plants are comparatively hardy in nature, easily adaptable to wider climatic conditions and extensively used as an ornamental. Recently, attempts have been made to transfer the important traits like bacterial blight resistance and moisture stress tolerance

from *'Nana'* to the commercial fruit cultivars (Jalikop *et al.*, 2003). A dwarf F1 hybrid *'Amlidana'* was also developed by crossing the *'Nana'* with commercial pomegranate cv. Ganesh for utilizing the crop for *anardana* purpose. Saho *et al.* (2003) developed a colchicine induced tetraploids forms of nana having larger flower forms than usual types.

The double-flowered types (*Punica granatum* var. Double flower; 2n=2x=18) possess large flowers with numerous petals, a homeotic transition of stamen into petals have led to the development of double-flowered forms in pomegranate, as a result, these double flower types became completely sterile and do not able to set fruits and on own self. However, functionally sterile flowers also may set fruits when those are pollinated manually (Jalikop, 2007) these forms bears larger juicy fruits with a low acid content, absence of spines and weaker sucker growth. These additional traits make the large flower forms suitable for gardening. Wang (2003) described a double-flowered dual-purpose variety *'Mudanhua'* possesses the best fruiting and flowering traits. Feng *et al.* (1998) identified double-flowered selections, i.e., Honghuachongbai and Baihuachongbai with good ornamental and fruiting qualities in China. Ashton (2006) described nearly 25 ornamental pomegranate varieties of different geographical origins having different flower forms, colours, and plant growth characteristics.

Ornamental Gingers

Ornamental gingers comprise a diverse and versatile group of plants belong to family Zingiberaceae there are about 53 genera and 1377 species reported so far (Kong *et al.*, 2010). Gingers are grown widely under tropical and sub-tropical regions of the world, and they add beauty to the gardens with their wider coloured blooms, flower forms and lush green foliage without much maintenance. In recent years, ornamental zingers are gaining much attention for gardening and cut flower markets especially ingenera like *Alpinia* (Shell Ginger), *Boesenbergia* (Island Purple Ginger), *Curcuma* (Hidden Ginger), *Etlingera* (Torch Ginger), *Globba* (Dancing Ladies), *Hedychium* (Butterfly Ginger), *Kaempferia* (Peacock Ginger), *Larsenianthus* (Praying Mantis Ginger) and *Zingiber* (Shampoo Finger) *etc*. (Sabu, 2006).

After realizing their economic potential, number of studies have been initiated for collection, characterization, diversity studies and domestication of wild ginger species in India and abroad (Prabhu *et al.*, 2014); in the process three new genera (*Plagiostachys, Stahlianthus* and *Larsenianthus*) and 9 species of gingers have been identified in India (Sabu, 2006) and large ginger repository with over 180 species and 2000 accessions of live plants from India and other Exotic origins with horticultural importance and ornamental potential are maintained in the Calicut Botanical Garden, India. A number of studies have been initiated for improvement of ornamental gingers using mutational breeding (Sakhanokho *et al.*, 2012; Prabhu *et al.*, 2015). *In vitro* and *in vivo* propagation methods are standardized (Illg and Faria, 1995; Nissar *et al.*, 2008) off-season cultivation (Ruamrungsri *et al.*, 2007; Thomas *et al.*, 2010; Prabhu *et al.*, 2014) and agronomic cultivation techniques are developed for number of ornamental ginger species (Sabu *et al.*, 2011).

Ornamental Pineapples

Pineapple is a perennial monocot belongs to the family Bromeliaceae with 56 genera and 2921 species (Luther, 2002). This is a commercial fruit crop and a decorative plant as well because of its unique growth habit with a rosette of strap-like colourful leaves. Moreover after attaining the reproductive growth, ornamental quality of the plant is enhanced by its colourful multiple fruits with a crown. Pineapple is more familiar as a pot plant and live fence in the gardens and the fruit is also popular as a decorative element in flower arrangements and used with floral decorations. In the recent years, demand for other ornamentally valued pineapple products is growing especially as cut stems (budorinfructescence), mini fruits and these products are well accepted in the market due to their exotic appearance with pleasing colours and prolonged postharvest life (Pereira et al., 2018). For the production of cut stems, the stem must be uniform with a minimum length of at least 30 cm and fruits should have balanced crown / syncarp ratio close to one or less than that (Souza *et al.*, 2012).

Number studies have been conducted in pineapples for screening and selection of ornamental types suitable for different landscape uses from its large germplasm (Souza *et al.*, 2006). Brazil is the primary centre of origin for Ananas having largest germplasm. A Brazilian Agricultural Research Corporation 'Embrapa Cassava and Fruits' has the largest ex-situ collection of 743 of the *Ananas* and other Bromeliaceae members. From 616 accessions of pineapple germplasm in Embrapa Cassava and Fruits, 84 genotypes were characterized with ornamental potential to develop potted plants, cut flowers and for gardens and squares; also, some of them were identified as parents for development of ornamental types, numerous crosses were performed, and new ornamental hybrids developed (Souza *et al.*, 2009). In Australia during 1995, a breeding programme was operated using a combination of parental lines such as *Ananascosmosus* var. *cosmosus, A. cosmosus* var. *bracteatus, A. cosmosus*

var. *ananassoides* FRF.223, *A. cosmosus* var. *Erectifolius* Selvagem 6 and *Ananasmacrodonates* I.26-803 and produced 4700 seedlings over three generations; From this several selections have been made for cut flower markets and gardens having characteristics like pink and red syncarp, dark red-brown foliage and dwarf clumping growth habit (Sanewski, 2009). Souza *et al.* (2012) identified different accessions from *A. cosmosus* var. *erectifolius*, *A. cosmosus* var. *bracteatus*, *A. macrodonates* and *A. cosmosus* var. Ananassoides for landscaping, cut flower, mini fruits, potted plants, and hedges. Fusarium resistant ornamental pineapple hybrids were also developed by Souza *et al.* (2014) for gardening and cut flowers purpose. Junior *et al.* (2016) developed two ornamental pineapple hybrids (PL01 and PL04) suitable for landscaping and cut flower purpose. Plant characteristics like stem sinuosity and black coloured fruits also preferred over normal types for cut flowers. Lima *et al.* (2017) characterized and selected 26 new pineapple hybrids for the production of cut stems and other landscape uses with emphasis on stem sinuosity and nearly black coloured fruits.Intra and interspecific hybrids and Intergeneric hybrids involving *Anonas* and other genera such as *Aechmea, Cryptanthus* and *Neoreglia* are performed, and resultant crosses were exclusively used for ornamental use (Grant, 1998).

Ornamental Cabbage and Kale

The ornamental cabbage (*Brassica oleracea* var. *capitata*) and kale (*Brassica oleracea* var. *acephala*, Brassicaceae) have become increasingly popular as ornamentals in the garden which are widely accepted and cultivated by flower enthusiasts for different landscaping purposes primarily of its colourful long-lasting rosette foliage. Kales produces colourful leaves in tight rosettes with deeply cut curly, ruffled, or frilled leaves but cabbages yield globe-shaped heads with broad, flat leaves having contrasting colours in inner and outer portions. Both the crops grow approximately 15 inches tall and one foot wide. Ornamental kales and cabbages are grown in late fall, winters, and spring and resistant to the low temperatures highly suitable for short boarders (foreground planting) and containers as a potted plant. Number of commercial ornamental varieties of kale and cabbages with varied colours are available globally. Experiments were conducted by a number of researchers using plant growth regulators to produce dwarf phenotypes with intensified coloursand to control the plant height during late fall and in early winters (Mello *et al.*, 2012; Gholmpour *et al.*, 2012; Gibson and Whipker. 2000). Whipker *et al.* (1998) provided knowledge on cultivation and maintenance of ornamental cabbage and kale crops along with its varietal wealth.

CONCLUSION

The use of non-traditional ornamentals not only adds additional beauty to the gardens but also conserves the diversity of a number of crop species by adding the valuable germplasm to the gardens as ornaments for a variety of landscape uses. A number of non-traditional ornamental species were discovered and domesticated by the researchers especially in tropical crops species like banana, ginger, pineapple *etc*. Numbers of commercial varieties are already available in the market in crops like cabbage, kale, pomegranate *etc*. and these are widely used by the gardeners. The works on improvement and cultivation aspects of these non-traditional crops are intensified in the recent years for encouraging its dual utility, these ornamentals are highly prized in the market also carries valuable alleles of their respective commercial crops.

In addition to discussed plant material there are several thousand species of herbs, shrubs and trees which are important as ornamentals or amenity species, some of these are commercially traded by nurseries or garden centres. Conservation of such material are therefore of considerable importance for the maintenance of diversity. Particularly for ornamentals, only a few *in situ* experiments have been attempted. For rare and endangered species, gene sanctuaries, repositories or micro reserves are established in some cases but their viability is still untested. Use of combined conservation approaches (*in situ* and *ex situ*) facilitates the availability of the wild material to extend its improvement and popularization of these wild ornamentals in non-traditional areas or outside their ecosystems. It is also apparent that conventional breeding strategies of selection and propagation have been effectively utilized in the crop improvement programmes of these wild ornamentals. Application and use of molecular marker technologies, development of genetic maps, implementation of genomics-based advancements, is severely lacking in these crops. It is anticipated that application of these novel technologies would greatly enhances the development of new and elite varieties and hybrids of non-traditional ornamentals.

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Essentiality of seed standards for cultivation of medicinal plants — a review

Manish Das* and A P Trivedi[1]

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Horticultural Science Division, Indian Council of Agricultural Research
Krishi Anusandhan Bhawan-II, New Delhi 110 012, India

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ABSTRACT

Seeds play a critical role in agriculture, serving as the primary unit of plant propagation. Seed quality parameters of a notified variety of crops have been published through gazette notification from time to time and compiled. Indian Minimum Seed Certification Standards are available for about 150 crops grown in India. However, no such seed standards have been formulated for medicinal and aromatic plants grown by farmers in India. Therefore, quality of seed made available to farmers cannot be regulated as envisaged under Seeds Act. Several attempts have been made to formulate seed standards and seed testing protocols for important medicinal crops cultivated by farmers. Those studies/attempts were made on different seed parameters of the seeds of the species at different centres, viz. IARI, New Delhi; DMAPR, Anand, Gujrat and IIHR, Bengaluru. For seed lot size and sample size, seeds indicated weights of lots which was derived from a nominal thousand seed weight for each species expected to be adequate for the majority of samples tested. Working sample for purity analysis considered was the weight of 2,500 seeds and working sample for count of other species was the weight of 25,000 seeds. For example, maximum weight of lot for *Plantago ovata* would be 10,000 kg for which submitted sample would be 50 g and it would be 5 g for working sample for purity analysis and 50 g for working sample for count of other species. In this study further pure seed (PSD) was defined based on ISTA (2003) and ISTA (2012), for example, in *Lepidium sativum*, PSD number is given as PSD 11 which states that in the seed a portion of testa is attached in which seeds and pieces of seed entirely without testa are regarded as inert matter. In *P. ovata*, pure seed (minimum) is 98% in both foundation and certified seed, of which 2% is inert matter. In this case total weed seed could be 10/kg, other crop seed 10/kg and germination should be 85% (minimum) with maximum moisture 10%. Likewise, seed standards and seed testing protocols of all the medicinal species taken from time to time have been standardized which would prove useful for seed quality assurance in medicinal plant sector. Further, it would be used towards notification of a variety under Seeds Act and also for the conservation of germplasm in gene/seed bank.

Key Words: Germination, Medicinal plants, Plantago ovata, Seeds, Seed standard

Medicinal and aromatic plants (MAPs) are an essential part of traditional health care systems which provide a critical source of income for many rural communities, especially landless poor and marginalized farmers. MAPs are also inextricably linked to the region's natural biodiversity which are increasingly threatened by various environmental, socio-economic and institutional issues. With growing health consciousness there is an increasing demand for herb based diet supplements that has potential to develop innumerable products to provide livelihood to many stakeholders. Such concerns and issues are however addressed through a variety of programmed activities and projects promoted by several national, international, regional and non-governmental organisations. Therefore, it is important to integrate the medicinal plants to harness the potential towards gain for the benefit of mankind. Further, there is an urgent need to focus on conservation and sustainable use of medicinal plant populations and bringing it under cultivation harnessing the potential of seed standards.

SEEDS: ESSENTIAL COMPONENT

Medicinal plants play an important role in human life since they are employed as raw materials for the

*Corresponding author : manishdas50@gmail.com
[1] ICAR-DMAPR, Anand, Gujarat, India

extraction of active constitution in pure form, as precursor for synthetic vitamins and steroids, and as preparations for herbal and indigenous medicines. The first step towards domestication and mass-production is to acquire healthy seeds with high germination. Germination of a seed in a laboratory test is the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable condition in soil.

Seeds are considered a major source of food therefore, all information concerning their nutritive value, chemical composition during storage, retention of viability is very important (Bewley and Black, 1995). Plant physiologists have used seeds to study the influence of various environmental factors *e.g.* temperature, moisture, oxygen, light and other factors on germination and seedling emergence in crop plants like potato, chickpea, wheat, mungbean and mustard (Das *et al.* 1999, 2001, 2002, 2003; Das and Singh, 2000). Due to their necessity in human life, also farmers and horticulturists are interested in the factors related to seed germination. Much emphasis is laid upon high-quality seed having excellent genetic potential and good germination and vigorous seedling growth. Recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds.

A seed is an embryonic plant enclosed in a protective outer covering known as the seed coat. Seed is a material which is used for planting or regeneration purpose. Scientifically Seed is a fertilized matured ovule with seed coat.

It is a characteristic of spermatophytes (gymnosperm and angiosperm plants) and the product of the ripened ovule which occurs after fertilization and some growth within the mother plant. The formation of the seed completes the process of reproduction in seed plants (started with the development of flowers and pollination), with the embryo developed from the zygote and the seed coat from the integuments of the ovule.

Seed has been an important development in the reproduction and spread of gymnosperm and angiosperm plants, relative to more primitive plants such as ferns, mosses and liverworts, which do not have seeds and use other means to propagate themselves. This can be seen by the success of seed plants (both gymnosperms and angiosperms) in dominating biological niches on land, from forests to grasslands both in hot and cold climates.

Functional Aspect of Seed

- The main function of seeds is reproduction in which plants perpetuate themselves, mainly sexually.
- The seed is widely used in the deliberate production of seedlings, known as plant propagation. In addition, this organ also serves as a diaspore or dispersal unit of many plants.
- Many seeds are equipped with adaptations which ensure or enhance dispersal such as dust-like and balloon seeds, wing-like appendages, hairs, parachutes, feathers and hooks, and water repellent surfaces.
- Seeds protect young plants while they are being moved to a new location; they also aid in the growth of the new plant by providing nutrients until it is established enough to grow on its own.
- Some seeds also attract animals that help move the seeds or have adaptations that aid in there dispersal by wind or water.
- Some seeds also prevent the embryo from growing until the environment is suitable for plant growth.
- Most seeds are not dormant, but are in a quiescent state, needing water and the right temperature for cellular growth. Seeds are dormant embryos and a food reservoir called the endosperm. Their function is to remain dormant until they have relocated and the annual growing season comes around.

Bottlenecks in Cultivation of Medicinal Plants

Rural farming in particular faces constraints associated with the processing of medicinal plants which may result in reducing their competitiveness in global markets and which have to be remedied are:

- Poor agricultural practices.
- Poor harvesting (indiscriminate) and post-harvest treatment practices.
- Lack of research on development of high-yielding varieties, domestication etc.
- Poor propagation methods.
- Inefficient processing techniques leading to low yields and poor quality products.
- Poor quality control procedures.
- High energy losses during processing.
- Lack of current good manufacturing practices.
- Lack of R & D on product and process development.
- Difficulties in marketing.
- Lack of local market for primary processed products.
- Lack of trained personnel and equipment.
- Lack of facilities to fabricate equipment locally.
- Lack of access to latest technological and market information.
- No seed standards developed.

Journey to Seed Testing Protocols

Seed testing protocols are methodologies standardized for measuring the seed quality parameters *viz*. physical purity, genetic purity, germination, seed moisture and seed health. Seed testing is also essential for assessing the quality of seed before it is sown. Seed is a living biological product and its behaviour cannot be predicted with the certainty that characterizes the testing of inert or non-biological material. Therefore, the method used must be based on the knowledge of germination ecology of a species so that the results are reproducible in different laboratories of the country or world. For conducting a reliable germination test, we need to identify a suitable substrate / media *e.g.* paper (top of the paper or between paper), sand, soil, agar-agar or vermiculite *etc.*

Identification of optimum temperature for conducting the germination test is also important as the germination capacity or the speed of germination may vary from species to species depending upon the prevailing temperature. Test duration for a crop / species also needs to be identified as the test duration may vary from few days to months or years. Seeds of many species require pre-treatments (physical or chemical) for germination because of various types of dormancy *viz*. physical dormancy, physiological dormancy, morphological dormancy, combinational dormancy *etc*.

Many kinds of seeds require light for germination or light may have inhibitory or promontory effect on germination. Seed testing protocols for majority of species (*viz.* cereals, millets, pulses, vegetables, forage crops, range grasses, range legumes *etc.*) are available in International Rules for Seed Testing (International Seed Testing Association (ISTA), Switzerland) published every year and updated regularly by incorporating the new methodologies / new crops. However, seed testing protocols for majority of Indian medicinal and aromatic plants are yet to be standardized for incorporation in the ISTA Rules and also for the determination of germination capacity by various State Seed Testing laboratories for implementing the legislation pertaining to seeds of medicinal and aromatic plants.

Path Finding to Seed Quality and Seed Standards

The standard for judging seed quality (viability) is always a germination test under optimum conditions. Temperature, media and light are the critical factors affecting seed germination. Optimum temperature varies with ecotype; at this temperature, seeds are biochemically active, and any fluctuation above and below it, retards the rate of biochemical activity, which in turn results in inhibition or slowing of the rate of germination (Bewley and Black 1995; Phartyal *et al.*, 2002). Germination of seed is the initial and most critical step in the propagation or laboratory testing of seed for certification. Reports regarding the germination behaviour of some medicinal plant species are available (Thakur and Thakur 2006, Nautiyal *et al.* 1987, Nautiyal *et al.* 2002, Butola and Badola 2004; Mehta and Raina, 2016; Smitha and Das, 2016; Das, 2016), however, the work on germination behaviour and seedling vigour of Artemisia annua L has not been attempted seriously till date accept a few (Al-Quadan *et al.,* 2014).

The study on germination behaviour of some related medicinal herbs indicated the late, erratic and poor germination with substantial loss of viability of seeds (Thakur *et al.* 2004, Das 2016, Smitha and Das, 2016). In order to encourage the successful commercial cultivation of this species by seeds, a systematic study on germination behaviour and seedling vigour is essential which are of paramount importance for formulation of seed quality parameters (seed standards) and standardizing the methodology for evaluating seed quality parameters for Seed Quality Assurance in medicinal and aromatic crops. These seed quality parameters known as Seed Standards have been notified for more than 95 crops. However, no such standards of seed quality parameters are available for medicinal crops and hence this study was under taken to fulfil this gap.

Indian Minimum Seed Certification Standards (IMSCS) are seed quality parameters and consist of following parameters.

Genetic Purity

Genetic purity means trueness-to-type of the seed lot. It is important to assure the genetic identity which makes cultivars distinct. Genetic purity is best evaluated through a field trial in which the percentage of off-types in a seed lot is determined. Seed breeders have to conduct variety trials each season to evaluate the genetic quality of contract lots; ideally, the seed lot is evaluated in comparison to the parent seed lot and competitors' lots of the same variety. The results of these variety trials are made available to the grower, this information is used as a tool to guide on-farm selection of the plants in the seed crop so the seed produced from that crop is true-to-type. The breeder seed should be of the highest genetic purity. In the foundation and certified seed classes, the genetic purity standards are lower to those of breeder seed. The Genetic purity of the breeder seed should be maintained through maintenance breeding programme. The responsibility of the maintaining genetic purity of breeder seed lies with the plant breeder who has evolved the variety; while the genetic purity of foundation and certified seed classes is ensured through seed certification.

Physical Purity

Physical purity consists of seed purity in a lot. The physical purity of seed determines the percentages by weight of pure seed, other crop seed, weed seed, and inert matter in a sample. Seed company has to define the purity standard for a particular seed crop. These tests are performed by a registered seed technician at a certified lab. The results of purity analysis reflect the physical quality status of seed lot. Pure seed definition for a large number of crops is given in ISTA Rules published periodically. In the present bulletin pure seed is being defined for 25 medicinal species based on ISTA (2003) and ISTA (2012). The components of physical purity analysis as per IMSCS (Indian Minimum Seed Certification Standards) include: pure seed, inert matter, other crop seed, weed seed, objectionable weed seed. In many crops, Other Distinguishable Varieties (ODV) is also the component of physical purity according to IMSCS.

Seed germination : Germination testing is important for knowing the planting value of seed. In addition, the laboratory germination results are also required for comparing the performance potential or superiority of the different seed lots. The germination results are used for seed rate for sowing and, labelling for Seed Certification purposes.

Factors Affecting Seed Quality

Seed vigour, viability, and the presence of seed borne pathogens and other microorganisms are the attributes which affect the seed performance in the field.

Viability testing : Viability testing determines the percentage of live seeds in a sample that have the potential to produce normal seedlings under favourable germination conditions. All seeds sold commercially be tested by a certified lab within six months of sale and must meet minimum germination standards that are set for each major crop group. This test is useful as it measures the percent live seeds in a sample regardless of the seeds' dormancy status. The test can be performed in 24 to 48 hours.

Vigour testing : Vigour testing moves beyond a simple assessment of germination by evaluating how quickly seed germinates and whether the germinating seeds and developing seedlings are "normal" and robust in the early stages of growth. Vigour tests measure the potential for rapid, uniform emergence of seeds under a wide range of field conditions.

Seed health : Seed borne disease testing indicates whether your seed carries diseases that will have a significant impact on the health and productivity of the crop. Seed borne inoculum may give rise to progressive disease development in the field and reduce the commercial value of the crop. Imported seed lots may introduce diseases into new region. Tests to meet quarantine requirement may therefore be necessary. Seed health testing may elucidate seedling evaluation and cause of poor germination or field establishment and thus supplement germination testing. Seed health test results can / may indicate the necessity to carry out seed treatment in order to eradicate seed-borne pathogens or to reduce the risk of disease transmission.

Moisture content : Moisture content of the seed is one of the most important factor influencing the seed vigour and viability. In an organized seed programme, the measurement of moisture content determines the decision-making policies pertaining to the harvesting, threshing, processing and marketing of seeds. It is therefore, essential that moisture content should be in accordance to the requirement of seed storage behaviour and desiccation and chilling sensitivity / tolerance of a species.

Outcome

Seed certification is an important mechanism for ensuring seed quality and should be understood by growers, buyers, and users of seed. Seed classes indicate how many generations a given seed lot is removed from the plant breeder or institution that was the source of the variety; these classes provide the distributer or buyer information about the history and quality of a seed lot.

- **Breeder** seed is seed produced by the originating plant breeder
- **Foundation** seed is seed produced from breeder seed and is controlled by license from that source.
- **Certified** seed is produced from either breeder seed or foundation seed, and is at most two generations from foundation seed.

Certified seed crops must pass both field inspection and laboratory analysis. The field must be planted from the proper class of seed, have appropriate isolation, and are free of problem weeds and diseases. After harvest, a sample of the seed crop must be sent to an official seed certification laboratory for germination and purity analyses. The seed must meet the standards set by the seed certification agency.

Seed that has passed the field inspection and the laboratory analysis can be tagged as certified seed. In addition to the Certified tag there must also be an analysis tag with information on Name of crop variety and Physical purity (percent pure seed, other seed, inert matter, weed seeds, germination).

Institutional Research

Seeds play a critical role in agriculture and allied activities by serving as the primary unit of plant

propagation. Seed quality parameters of a notified variety of crops have been published through gazette notification from time to time and compiled. Till to date Indian Minimum Seed Certification Standards (IMSCS) are available for about 150 crops grown in India. However, no such seed standards have been formulated for medicinal and aromatic plants grown by farmers in India and quality of seed made available to the farmers cannot be regulated as envisaged under Seeds Act. Therefore, an attempt was made to formulate seed standards and seed testing protocols for 25 important medicinal crops cultivated by the farmers of the country. In this study physical purity, genetic purity, germination capacity, moisture content and seed health status of the seeds of the species were carried out at three different centres, viz. IARI, DMAPR and IIHR (Parihar *et al.,* 2013).

For seed lot size and sample size, seeds indicated weights of lots which was derived from a nominal thousand seed weight for each species which is expected to be adequate for the majority of samples tested. Working sample for purity analysis was the weight of 2,500 seeds and working sample for count of other species was the weight of 25,000 seeds. For example, maximum weight of lot for Plantago ovata would be 10000 kg for which submitted sample would be 50 g and it would be 5 g for working sample for purity analysis and 50 g for working sample for count of other species. In this study further pure seed (PSD) was defined based on ISTA (2003) and ISTA (2012), for example, in Lepidium sativum, PSD number is given as PSD 11 which states that in the seed a portion of testa is attached in which seeds and pieces of seed entirely without testa are regarded as inert matter.

Since it is not possible to give seed standards of all the 25 species in this summary, however, as an example in *P. ovata,* pure seed (minimum) is 98% in both foundation and certified seed, of which 2% is inert matter. In this case total weed seed could be 10/kg, other crop seed 10/kg and germination should be 85% (minimum) with maximum moisture 10%. Likewise, seed standards and seed testing protocols of all the 25 medicinal species have been standardized which would prove useful for seed quality assurance in medicinal plant sector, notification of a variety under Seeds Act and also the conservation of germplasm in gene/seed bank (Table 1 and 2).

A study was carried out at ICAR-Directorate of Medicinal and Aromatic Plants Research (DMAPR) with an objective to evaluate seed germination of three very important medicinal species *viz*. *Plantago ovata* L, *P. indica* L, and *Lepidium sativum* L (Asalio) for standardizing efficient germination procedure and to determine minimum seed standards (Das, 2016a). In the study, effect of different temperatures (15, 20, 25 and 30°C) and storage duration from 7 months to 3 years old seeds was evaluated including freshly harvested seeds on germination. Results revealed that seed germination was >95% at 20ºC in 7 months old seeds of all the species. However, it varied with storage duration with time taken for germination *i.e.* first count and final count was on 2nd and 6th day, respectively at 20°C. Seed germination more than 80% could also be recorded upto a storage limit of 24 months excluding first three months after the harvest. Among the species, *P. indica* exhibited decreased germination after this storage duration at 20°C, while, >95% of seed germination could be recorded in 7-8 months old seeds after harvest in all the species irrespective of temperatures indicating that there was physiological

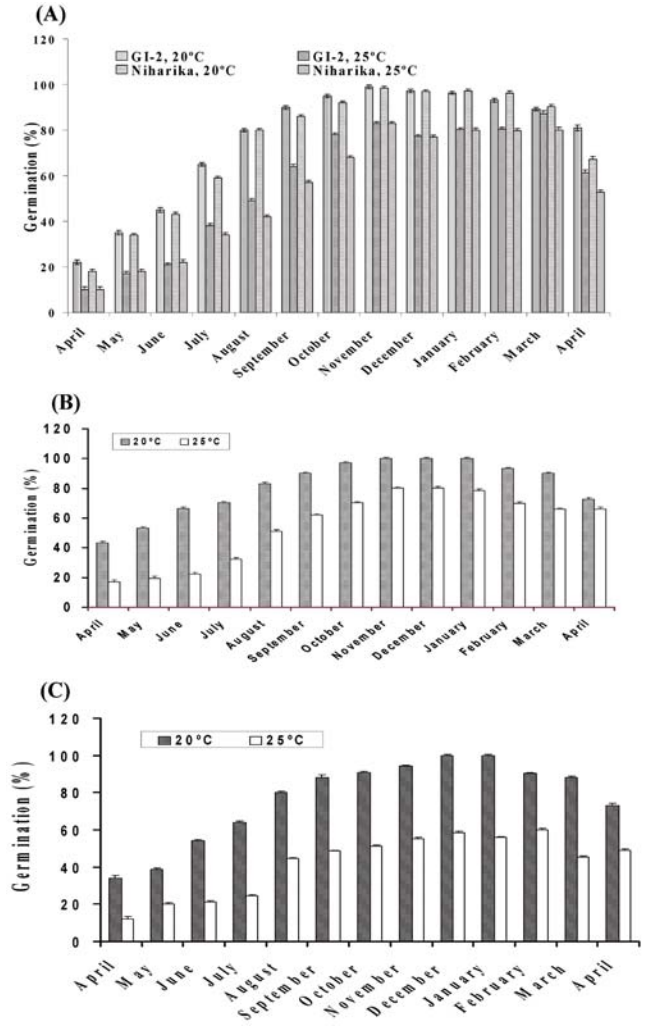

Fig. 1: Time course of seed germination (%) in (A) *Plantago ovata* vars. GI 2 and Niharika, (B) *P. indica* and (C) *Lepidium sativum* from the month of harvest (April) to a period of 12 months at every one month interval at 20 and 25ºC, Data are mean value of (n=4) ±SEm.

Table 1. Minimum seed standard for foundation seed of medicinal plants

Medicinal plant	Pure seed minimum (%)	Maximum inert matter (%)	Other crop seed maximum	Total weed seed	Objectionable weed seed	Germination minimum (%)	Moisture minimum (%)	Moisture for vapour-proof containers (maximum) (%)
Andrographis paniculata (Burm £.) Wall ex Nees	98.00	2.00	10/kg	10/kg	None	75.00	10.00	8.00
Aegle marmelos (L.) Corr	98.00	2.00	None	None	None	70.00	8.00	6.00
Abelmoschus moschatus Medik	99.00	1.0	None	None	None	65.00	10.00	8.00
Berberis aristata DC	98.00	2.00	None	None	None	70.00	8.00	6.00
Bixa orelien a L.	98.00	2.00	None	None	None	70.00	12.00	8.00
Cannabis sativa L.	98.00	2.00	10/kg	10/kg	None	60.00	8.00	6.00
Catharanthus ~resus (L.)	98.00	2.0	10/kg	10/kg	None	60.00	8.00	6.00
Carum carvi L.	97.00	3.0	10/kg	10/kg	None	50.00	8.00	6.00
Cassia angustifolia Vahl	96.00	4.00	5/kg	5/kg	-	85.00	10.00	8.00
Clitoria ternatea L.	98.00	2.0	5/kg	5/kg	None	75.00	10.00	8.00
Desmodium gangeticum (L.) DC	98.00	2.00	10/kg	10/kg	None	70.00	10.00	8.00
Hibiscus sabdariffa L.	99.00	1.00	None	None	None	65.00	10.00	8.00
Lawsoni inermis L.	97.00	3.00	None	None	None	85.00	10.00	8.00
Lepidium sativum L.	98.00	2.00	10/kg	10/kg	None	80.00	8.00	6.00
Mucuna puriens L.	98.00	2.00	None	None	None	75.00	12.00	10.00
Nigella sativa L.	98.00	2.00	10/kg	10/kg	None	85.00	8.00	6.00
Ocimum tenuiflorum L.	98.00	2.0	10/kg	10/kg	None	65.00	10.00	8.00
Ocimum basilicum L.	98.00	2.00	10/kg	10/kg	None	75.00	10..00	8.00
Plantago ovata L.	98.00	2.0	10/kg	10/kg	None	85.00	10.00	8.00
Psoralia corylifolia L.	98.00	2.00	10/kg	10/kg	None	70.00	12.00	8.00
Rauwolfia serpentina (L.) Benth ex Kurz	98.00	2.00	0/kg	None	-	35.00	12.00	10.00
Ruta graveolens L.	98.00	2.00	10/kg	10/kg	None	70.00	10.00	8.00
Silybum marianum (L.)	98.00	2.00	10/kg	10/kg	None	70.00	10.00	8.00
Solanum nigrum L.	98.00	2.00	5/kg	-	-	70.00	8.00	6.00
Withania somnifera (L.) Dunal	98.00	2.00	5/kg	None	-	78.00	8.00	6.00

Table 2. Seed testing protocol of medicinal plants

Medicinal plant	*Media	Temperature (°C)	1st count	Final count	Pre-treatment /additive/other
Andrographis paniculata (Burm £.) Wall ex Nees	TP	20-30	8-9	12	Hot water followed by H_2O_2 treatment
Aegle marmelos (L.) Corr	BP	30	12-16	21	Leaching in water
Abelmoschus moschatus Medik	BP	25-30	6	10-13	Hot water or H_2SO_4 treatment
Berberis aristata DC	BP	20-30	10-12	15	
Bixa orelien a L.	TP	20-30	9	12	H_2SO_4 scarification
Cannabis sativa L.	TP	20-30	4	7	
Catharanthus roseus (L.) G. Don	TP, BP	20-30	4-6	14	GA_3
Carum carvi L.	TP	20-30	7-10	21-28	Pre-chilling or GA_3 co-applied
Cassia angustifolia Vahl	BP	25	7	14	Hot water or H_2SO_4 treatment
Clitoria ternatea L.	BP	20-30	6	9	H_2SO_4 scarification
Desmodium gangeticum (L.) DC	TP	25	6-8	12	H_2SO_4,Hot water
Hibiscus sabdariffa L.	TP	20-30	4-6	14	Hot water or H_2SO_4 treatment
Lawsoni inermis L.	TP	20-30	7-8	14	Leaching
Lepidium sativum L.	TP	20-30	4	10	Pre-chilling
Mucuna puriens L.	BP	25	3-5	14	H_2SO_4,Hot water
Nigella sativa L.	TP,BP	20-30	7-10	21	Pre-chilling, GA_3
Ocimum tenuiflorum L.	TP	20-30	7	14	Light for 8 hrs/day GA_3 co-applied
Ocimum basilicum L.	TP	20-30	7	14	Light for 8 hrs/day GA_3 co-applied
Plantago ovata L.	TP	20.0	4	6	Pre-chilling or GA_3 co-applied
Psoralia corylifolia L.	TP,BP	25	6	8	H_2SO_4 scarification
Rauwolfia serpentina (L.) Benth ex Kurz	BP	20-30	18	28	Soaking of seed in GA_3 for 5-6 days
Ruta graveolens L.	TP	25	6	8	H_2SO_4 scarification
Silybum marianum (L.) Gaertn	BP	20-30	5-7	21	Pre-chill
Solanum nigrum L.	TP	20.0	7	12	Pre-chilling or GA_3/KNO_3 co-applied
Withania somnifera (L.) Dunal	TP	20-30	9	12	Leaching in water for 1-2 days

*TP= top of the paper method: BP=rolled towel method

dormancy initially in these species. Time course on germination rate reveals that germination usually increased linearly with storage time over a period of 12 months from the month of harvest up to a peak in the month (>95%) of its sowing (October, both *Plantago* and *Lepidium* species) to an optimum and then decreases linearly (Fig. 1). Results also revealed that data on storage-dependent changes in seed germination and their responsiveness to temperature of Isabgol species and *L. sativum* are of potential implication for propagation of these plant species.

A study was carried out at ICAR-Directorate of Medicinal and Aromatic Plants Research (DMAPR) with an objective to evaluate seed physiology parameters and seed germination of an important medicinal species *viz*. sweet wormwood (*Artemisia annua* L.) for standardizing efficient germination procedure and to determine minimum seed standards. In the study, effect of different temperatures (20, 25 and 30°C) and storage duration from harvest to 6 months old seeds was evaluated on germination. Results revealed that seed germination was >60% at 25ºC in 3 months old seeds reaching a maximum of 66%. However, it varied with storage duration and temperatures. Time taken for germination *i.e.* first count and final count was on 1st and 9th day, respectively at 20°C and 25°C. Seed germination was maximum at 25°C with 66%. Seed physiology parameters were evaluated after a complete sieving of seeds which could be achieved after 5th sieving following harvest (Fig. 2). Study has made it possible to develop a seed standard protocol under laboratory condition with a package of seed sieving to get pure seed (Das, 2016b).

Road Map for Medicinal Plants

- Conservation: In situ and *Ex situ*.
- Variety Evaluations: New varieties have to be evaluated before they are released to farmers for commercial use.
- Performance Trial has to be carried out.

- Standards for samples have to be evaluated.
- Experimental set up has to be designed for standards.
- Developing Good agricultural practices (GAP)
- Observation and scoring have to be done for
  - Special tests
  - DUS Tests
  - Categories of variety
  - Varietal description for Quantity and
  - Quality for germination (vigour), health, genetic purity, moisture uniformity & size, physical purity
  - Traceability
  - Treated, packed, labelled.

CONCLUSION

In future seed certification will play an important role in medicinal plant cultivation as GAP certification is going to be more acceptable. The success of seed certification will depend on how effectively we are defining minimum seed standards of the MP varieties keeping DUS parameters in view as an essential component of PPVFR Act. So far whatever we have utilized in the MP sector, is far from the vast wealth, nature has preserved for the mankind. More need to be done utilizing the vast resource that we have.

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Production factors affect post-harvest performance of tuberose (*Polianthes tuberosa*) — a review

Krishan Pal Singh[1], Shyama Kumari[2*] and Subhashish Sarkhel[2]

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[1]*ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India*

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ABSTRACT

Tuberose (*Polianthes tuberosa* L.) is popular flower crop due to its exquisite beauty and strong fragrance. However, as a potential ornamental plant resource, it has not been well commercialized. This crop has the potential to develop and expand the ornamental horticultural industry if properly managed and exploited. Tuberose longevity and quality are influenced by production and post- production factors. The production factors provide an excellent opportunity to overcome all the imbalances of post-harvest management. Therefore, all important aspects of production factors of tuberose cultivation for better understanding and future strategies for improved flower quality and Post-harvest life have been discussed. These information are important for both farmers and distributors.

Key Words: Flower quality, Post-harvest management, Production factors, Tuberose, Vase-life

The external appearance, quality and longevity of tuberose (*Polianthes tuberosa* L.) plants depend upon the conditions of cultivation, proper harvesting time and post-harvest handling. The appearance of fresh flowers is a primary criterion in making purchasing decisions. Product appearance is characterized by size, shape, form, colour, condition and absence of defects (Ebrahimzadeh *et al.*, 2008). Post-harvest life of cut flowers and other ornamental plants is very much influenced by several pre- harvest factors like genetical, temperature, light, soil, nutrient, season, relative humidity, CO_2 enrichment, chemical applications, irrigation, pests and diseases (Bhattacharjee and De, 2005). These factors are related to the level of carbohydrate reserves in plant and also with vase-life. Pre- harvest conditions affect quality of cut flowers (30-70%) (Halevy and Mayak, 1979).

USES AND MARKETS

Tuberose has a great economic potential for cut flower trade and essential oil industry (Anwar *et al.*, 2014). Tuberose is native to Mexico and recently it has been placed under the family Asparagaceae (Naga Lakshmi *et al.*, 2020). It is one of the most popular commercial flower crops in tropical and sub-tropical areas of the world including India. It blooms profusely during summer and rainy seasons (Singh *et al.*, 2010). The loose flowers emit a delightful fragrance and are the source of tuberose essential oil. The serene beauty of the flower is because of its tall and straight spikes, bright white flower, sweeten of blooms and delicacy of fragrance (Kumari, 2010). Among the commercial flowers cultivated in India, tuberose is extensively cultivated in an area of 7.77 thousand ha with a total production of 40.22 thousand tonnes in Assam, Maharashtra, Gujarat, Haryana, Karnataka, Andhra Pradesh, Tamilnadu, West Bengal, Uttar Pradesh, Uttarakhand and Orissa (Naga Lakshmi *et al.*, 2020).

There are up to 30 flowers in a spike and length of rachis varies between 14-28 cm, depending upon the size of bulb. Tuberose spikes bear 10-20 pairs of florets which open acropetally. The waxy white flower spikes of single as well as double flowered tuberose with sweet lingering fragrance are excellent for floral arrangement having great demand in metropolitan cities and used for flower pot in offices and bungalows while loose flowers are used in floral works, making garlands, veni, essential oil extraction, decoration for motorcars and 'mandaps' on the occasion of marriage ceremonies. It is also suitable for garden decoration and landscaping and grown in pots, rockery and hangers from ancient times. Commercial production

*Corresponding author : shyamabau@gmail.com
[2] Dr Kalam Agricultural College, Kishanganj, Bihar Agricultural University, Sabour, Bihar, India

for tuberose cut-flower has increased incredibly since it can be grown in the field under minimal management practices. Expansion may however be hampered by poor post-harvest life of the tuberose inflorescence (Naidu and Reid, 1989).

PRE-HARVEST FACTORS AFFECTING POST-HARVEST QUALITY

Genetical : Flower longevity and quality may be varies due to differences in anatomical, physiological, physical, biochemical and genetic makeup among varieties. Cut flower longevity depends on carbohydrate reserves of flowers, osmotic concentration and pressure potential of petal cells, stomata functioning, differences in number of thick walled supporting cells in the xylem element and phloem fiber and presence/absence of a complete ring of secondary thickening in flower peduncles, differences in the diffusive resistance of leaves in the field, lignifications, level of plant hormones, susceptibility to diseases and insects. (Singh *et al.,* 2001). Cultivars with long vase-life of cut flowers are very important on commercial point of view, which facilitates their easy transportation to distant market including export. Singh (2017) reported that Arka Suvasini and Arka Vaibhav were most promising genotype based on overall yield and quality parameters and can be recommended for future commercialization.

Cultural Practices

Good cultural practices reduce injury and losses during harvesting and postharvest handling procedures (Ebrahimzadeh *et al.*, 2008). Mineral nutrition, foliar feeding, irrigation and growth regulator sprays were found to influence longevity and post-harvest quality of cut flowers. For proper growth with high yield it is better to choose a place having plenty of sunlight. A porous sandy loams or loams soil rich in organic matter having pH range 6.5-7.5 with good aeration and drainage are ideal. In India, the commercial cultivation of tuberose is mainly confined to warm, humid areas with temperature between 15-35°C. Planting bulbs of 3.0-3.5 cm diameter, depth 4 cm and spacing 25 cm × 25 cm has been recommended for obtaining highest yield of spikes and bulbs in tuberose cv 'Single' at BSI, Howrah (Bose *et al.,* 2002). In India, tuberose is generally planted in February-April (plains) and April-May (hills) (Sadhu and Bose, 1973).

Planting of tuberose bulbs in March recorded more number of leaves and number of spikes/m^2 under Kalyani, West Bengal conditions. Planting at spacing of 30 cm × 30 cm recorded higher plant height, maximum number of leaves/clump, spikes/plot and longer flowering duration with better post harvest characteristics (Biswas *et al.,* 2002). Nagaraju *et al.* (2004) revealed that post harvest parameters like water balance, maximum % of fully opened florets/spike, fresh weight and vase life were significantly superior when larger bulbs (>4 cm) and wider spacing (30 × 30 cm) were adopted.

Irrigation

Soil moisture affects growth and flowering in tuberose. It is suggested to irrigate before planting to provide optimum moisture for sprouting and further irrigation should be avoided until the bulbs have sprouted. Too much soil moisture at the time of sprouting results in the rotting of bulbs and similar condition during flowering adversely affects the development of spikes and flowers (Bose *et al.,* 2002). Moisture stress increases the rate of transpiration over the rate of absorption and affects both yield and quality of floral crops by decreasing cell enlargement. A short period of severe moisture stress is more harmful to plant growth than a prolonged duration of moderate stress. Stress at the bud initiation stage or flower opening stage reduces the yield and quality of flowers and causes leaf and flower senescence through its effects on photosynthesis, stomatal closure, protein synthesis and cell division. Too much and too frequent irrigation reduces the grade, stem length, fresh weight and number of flowers/ plant. Decreased water supply in the final period of cultivation decreases bract to leaf area ratio and decreases quality (Bhattacharjee and De, 2005).

Environmental Factors

Light : It regulates chlorophyll synthesis, phototropism, respiration and stomatal opening. Most of the commercial flowers need high light intensity (3,000-8,000 f.c.). Absorption of red light (625-700 nm) through phytochrome is essential for carbohydrate production which determines the longevity of cut flowers. Cut flowers having comparatively higher amounts of stored carbohydrates show longer vase-life. Decrease in available solar radiant energy before harvest reduces the post harvest life of cut flowers. Low light intensity causes excessive elongation of flower stems and delays stem hardening. Colour intensity of petals depends upon the availability of carbohydrates in surrounding tissues. High light intensity on the day prior to harvest increases plant temperature which, in turn, decreases the sugar level in the flowers (Bhattacharjee and De, 2005).

Temperature : Temperature affects all types of physiological and biochemical processes related to plant growth and yield. Tuberose requires 20-30°C temperature for proper growth and flowering. Higher temperature during field conditions decreases vase-life and quality because stored carbohydrates are

quickly depleted during respiration and plant transpires at a faster rate.

Nutritional Factors

A good and balanced nutritional regime results in the best quality cut flowers with an extended post harvest life (Balas *et al.*, 2006). An adequate supply of nutrients during the growth of the plant is necessary to ensure quality flowers. Fertilization practices have a major impact on the post harvest life of cut flowers and post production performance of ornamental plants (Bhattacharjee and De, 2005).

Nitrogen: It is essential for synthesis of amino acids, purines, pyrimidines, chlorophyll and coenzymes. The relative amount of nitrogen to carbohydrates in plant indicates the ratio between proteins and stored carbohydrates and affects growth and flowering. There is a positive and significant correlation between N supply during cultivation and the keeping quality of interior decorating plant. Tuberose, if fertilized with excessive N makes flower spike quite tall and soft, making it vulnerable to wind and the plant became more susceptible to disease and pest.

The flower quality is also adversely affected (Sadhu and Bose, 1973). Singh and Uma (1996) found that the best tuberose quality and quantity (yields) were obtained at 03 split applications of 250 kg/ha N fertilizers (at basal, 60 and 90 days after planting). Singh and Uma (2013) observed that 100-150 kg N/ha in cv. Pearl Double and 150-200 kg N/ha in cv. Suvasini marginally improved majority of the growth and floral parameters. Dahal *et al.* (2014) reported that 03 equal split doses of nitrogen, 33% N basal + 33% N at 50 days after planting + 33% N at 70 days after planting are appropriate for commercial cultivation of tuberose. Eidyan *et al.* (2014) observed longest vase life with a combination of 150 mg L-1 N, 2% (w/v) iron sulfate and 0.1% (w/v) citric acid. N fertigation increased all vegetative growth indices, including flower stalk length, inflorescence length, number of florets and vase life at 150 mg L-1 N.

Phosphorous : It is essential for nucleic acids, co-enzymes, phospholipids and phytic acid. Phosphorus combines with organic compound, forming stable high energy complexes such as ADP and ATP which supply resistance during trapping, transportation and energy for enzymatic reactions. It eases bud break, maturation and necessary for the development of sturdy and healthy plants (Bhattacharjee and De, 2005).

Potassium : It regulates photosynthesis and respiration, carbohydrate metabolism and the translocation of inorganic and organic substances in plants. It is the primary activator of several enzymes. Potassium is the most available cellular cation and neutralizes soluble and macromolecular anions of the cytoplasm at higher concentrations. Plants grown with insufficient amount of K yielded small sized flowers (Bhattacharjee and De, 2005).

Other Nutrients

Mostafa *et al.* (1996) reported that foliar spray of boron + 300 ppm phosphorus increased floret and spike dry weight, number of florets/spike, number of bulbs, bulblets and fresh weight of bulbs, bulblets in tuberose. Sharga (1999) suggested that 16 foliar sprays should be applied in tuberose after a month of vegetative growth at fortnightly intervals. Each spray comprised urea (0.783 kg), diammonium hydrogen orthophosphate (1.5 kg) and potassium citrate (0.875 kg) with spreader at 0.1% per 400 liters of deionized water/acre. This promoted vegetative growth in terms of lengthier and sturdier spike with more bulbs and bulblets/clump and better flowering, both qualitatively and quantitatively.

Patel *et al.* (2017) found that foliar application of $FeSO_4$ @ 2.0 % + 0.1% C.A and $ZnSO_4$ @ 0.5% + 0.1% $CaCO_3$ significantly maximum growth parameters in respect of plant height, number of leaves/ plant, fresh weight and dry weight of plant, florets diameter and vase-life of spike in tuberose cv. Prajwal. Sharifi and Naderi (2019) studied the impact of feldspar, talc, dolomite and tuff minerals @ 10, 20 and 40% incorporated with garden soil and manure and reported that the use of talc, dolomite and feldspar at the ratio of 40% as Mg and K supplying minerals can improve growth and biochemical parameters of the tuberose. Shahjahan *et al.* (2016) reported that large size bulb (2.6-3.0 cm) and 10 t ha^{-1} poultry litter is best for growth, bulb and flower production in tuberose.

Season: Synthesis of more amounts of carbo-hydrates during the day time and its utilization through translocation and respiration in the night is responsible for the variation in the longevity of cut flowers. Roses and tuberose shows longer keeping quality in winter under ambient conditions than in summer (Bhattacharjee and De, 2005). Seasonal differences in the flower quality arise due to either effects of temperature or light or both, possibly affecting the water status of the plant (Harkess and Hanan, 1988). Stability in relation to the longevity in a variety for different seasons is essential for quality (De Gelder, 1989).

Carbon dioxide : It is easy to produce good quality plant materials, early flowering, more flowering, increased yield, rapid crop growth and development at higher levels of CO_2. CO_2 enrichment increases photosynthesis by increasing carboxylation of RUBP and decreasing photo respiration (Bhattacharjee and De, 2005). CO_2 enrichment increases the number of

leaves / plant, stem thickness in gerbera, rooting % in chrysanthemums, number of lateral shoots in roses, carnation and gypsophila and number of flowers in carnation and roses (De *et al.*, 1998).

Use of Agrochemicals

Pre-harvest application of agrochemicals such as BA, IAA, GA_3, growth retardants like B-9, CCC, A rest and Phosphon D have been reported to improve quality and longevity of flower crops. GA_3 increases fresh weight of flowers, the length to diameter ratio of the bud, elongation of the flower pedicel and the receptacle of bud (Grzeszkiewicz and Treder, 1989), neck length of flowers (Nagarajaiah and Reddy, 1986), flower diameter (El-Shafie *et al.*, 1980) and advances flowering in roses. Application of GA_3, Cycocel, B9, Ethrel and NAA increases the number of florets / spike and longevity of tuberose. Soaking of tuberose bulbs with GA_3 (200 ppm) and thiourea (2000 ppm) for 06 hours increases number of flowers and quality (Hatibaruah *et al.*, 1997).

Growth retardants improve the keeping quality of flowers by retarding stem elongation, increas-ing green colour of leaves, producing xanthophylls, reducing air pollutants, improving flower quality and regulating harvesting time (Bhattacharjee and De, 2005). Chemical growth retardants like phosphon-D, CCC, SADH and ancymidol have been reported to regulate stem length, increase leaf thickness, stress tolerance and improve leaf colour. Kanani and Nazarideljou (2017) evaluated pre-harvest foliar application of a Phenylalanine Ammonia-Lyase (PAL) promoter (methyl jasmonate [MeJA]) and a PAL inhibitor (α-aminooxi-E-phenyl propionic acid [AOPP]) on physiological parameters, floral scent and longevity of cut tuberose and found that flowers of AOPP-treated plants lasted longer than those treated with MeJA.

Bohra and Nautiyal (2019) emphasized about integrated nutrients management for sustainable production of tuberose with improved vegetative, floral as well as yield-attributing traits. Babarabie *et al.* (2019) found that treatment of tuberose with gamma-aminobutyric acid (GABA) and salicylic acid during growth can improve its post-harvest quality. Naga Lakshmi *et al.* (2020) reported that GA_3 at 100 ppm and 200 ppm concentrations significantly increased spike quality and yield in tuberose cv. Prajwal. Jain *et al.* (2015) found that application of atrazine (1.0 kg / ha) + rice residue (5t / ha) resulted in better weed control, higher growth, flowering and bulb yield in tuberose cv. Prajwal

Pests and Diseases

Export quality plants and flowers should be free from pests and diseases. Both pests and diseases injure leaves and flowers and ultimately deteriorate the quality. Damaged tissues causes by them show wilting and produce ethylene (Nowak and Rudnicki, 1990) which causes early senescence as well as petal and leaf fall. Microbes like *Botrytis*, *Alternaria*, *Puccinia*, *Cryptosporella*, *Actinonema* and *Diplocarpon* stimulate ethylene production in plant tissues. Vascular diseases of floral crops hinder transport, affect their post harvest life and quality. Fungi like *Pythium* and *Rhizoctonia* cause stem or root rot of flowering and foliage plants and affect their post harvest quality (Bhattacharjee and De, 2005).

CONCLUSION

For best quality tuberose production, advanced production technologies should be taken into consideration. Improved cultivars, proper cultural practices, plant growth regulators, drip irrigation, nutrient and plant protection management are major horticultural interventions which influence plant health and flowering, and ultimately post-harvest value. Flower quality should be the major concern for export market, particularly spike length, number, size, shape of florets, weight, length of flower heads etc. Tuberose is a suitable flower crop for sustainability of small holdings, as it is well adapted to varied topography and agro-climatic condition. It provides ample opportunity for livelihood security particularly in the tropical and sub tropical areas. As the strength of a building lies in its foundation so it is very important to develop pre harvest package technology for the cut flower tuberose and brought to the doorsteps of the stake holders to minimize the post harvest losses for maintaining physical quality and flower longevity for ultimate users.

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Effect of bat guano and rabbit urine liquid fertilizers on growth physiognomies of *Spinacia oleracea* under hydroponics

Gumisiriza Ssentambi Margaret[1*], Mbega Ernest[1], Ndakidemi Patrick[1] and Kiriba Deo[1,2]

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[1]*The Nelson Mandela African Institution of Science and Technology. School of Life Sciences and Bioengineering, P.O. Box 447, Arusha, Tanzania*

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ABSTRACT

This pilot research study assessed the effect of bat guano and rabbit urine as organic nutrient sources for growing *Spinacia oleracea* (spinach) under a non-circulating hydroponic system. Three treatments; bat guano (5 g/L of water), rabbit urine (50 ml/L of water) and a commercial hydroponic fertilizer as the positive control were tested. Three-week-old spinach seedlings were transplanted into a small net cup fitted on a 4-litre bucket. Data collected on plant height, root length and number of leaves was analyzed using Origin Pro software. Single factor ANOVA results showed no significant difference in the height of spinach grown using bat guano, rabbit urine and commercial hydroponic fertilizer solutions ($P<0.05$). A significant difference was observed on the length of the root and number of leaves among the three hydroponic solutions ($P<0.05$). Results showed that both bat guano and rabbit urine have the potential to be used in hydroponic spinach production.

Key Words: Hydroponics, Kratky method, Organic farming, Soilless farming, Sustainable agriculture

Organic materials play a huge role in providing both micro and macro elements to plants both under soil and soilless culture (Said *et al.,* 2018). Animal manures such as; poultry droppings and cow dung are used with the aim of maintaining nutrient availability both in soil and soilless farming systems (Samkeliso *et al.,* 2020; Wagaw, 2016). However, the utilization of animal waste in hydroponic farming such as; bat guano and rabbit urine for farming purposes is still minimal yet animal waste organic fertilizers are usable and biodegradable (Said *et al.,* 2018). Bat guanois one of organic sources rich in nitrogen (N), phosphorus (P) and potassium (K) alongside other plant nutrients with NPK ratio of 8-10%, 2.5-3.5%, 1.5% (Sothearen *et al.*, 2014). Tanzania has a couple of caves that are infested with bats and guano such as: Amboni cave in Tanaga, Uzungwa Scarp Forest Reserve located in South Central Tanzania (Liana and Francesco, 2011). Additionally, there are also a number of rabbit farmers in Tanzania who sell rabbit urine which is known to be rich with NPK (2.4-1.4-0.6) but the use of rabbit urine is still minimal (Said *et al.,* 2018) especially in soilless farming. Organic based soilless farming has the ability of producing quality leafy vegetables within urban centers with aptness for back-yard gardening and reducing food insecurity (Croft *et al.,* 2017). There are already positive results of animal waste fertilizers such as; goat manure on vegetable production under soilless farming (hydroponics) conditions (Arshad *et al.,* 2018). Thus there is a need to carry out more research into the utilization of other animal waste for cultivation of vegetables under hydroponics (Arshad *et al.,* 2018). Hydroponics has the capacity to produce crops and improve food security in areas with: non-arable fields and limited agriculture land (Gumisiriza *et al.,* 2020; Nicole, 2021). This experiment examined the effect of bat guano and rabbit urine on the growth of spinach under hydroponics as an alternative to the costly and less-readily available artificial hydroponic fertilizers in Tanzania and Africa.

MATERIALS AND METHODS

Rabbit urine was bought from a rabbit farmer near Nelson Mandela African Institution of Science and Technology (NM-AIST) at a cost of 4.3$ per litre. Bat guano was obtained at a free cost from a bat infested

*Corresponding author : m5gundas@gmail.com

[2] Tanzania Agricultural Research Institute, Department of Natural Resources Management, P.O. Box 6024, Arusha, Tanzania

Fig. 1: Preparation of nutrient solutions from animal waste (left) and lettuce production under kratky hydroponic system in the screen house (right).

area in Arusha region. The guano was mixed in tap water at a ratio of 5g: 1litre for 24 hand later filtered through a thin white cloth while rabbit urine was mixed in tap water at ratio of 1:20 (Fig. 1). Nutrient solutions were poured into small 4 litre buckets which had 2 holes drilled on each bucket cover. Non-circulating hydroponic system (Kratky method) which does not require timers, electricity and air pumps (Aatif *et al.*, 2014, Kratky, 2004) was used for the experiment. Three-week old seedlings of Spinach were bought from the seedlings market and their roots were gently washed using tap water to remove soil residues. These were transplanted into the different hydroponic nutrient solutions; (i) rabbit urine solution, (ii) bat guano solution and (iii) commercial hydroponic nutrient solution. Seedlings were supported by gravel stones in the hydroponic net cups. Gatit super start* from green life crop protection with NPK levels of 14-28-18% was used as the chemical hydroponic fertilizer and control. The experiment was assembled inside a screen house at NM-AIST, Arusha, Tanzania during July to September 2019 using the Completely Randomized Design (Fig. 1) with 8 replicates per treatment.

The data was collected four weeks after transplanting where 5 biological plant replicates were randomly selected per treatment and measurements taken on; plant height, length of roots and number of leaves per plant. This data was analyzed using one factor Analysis of Variance (ANOVA) with Origin Pro software. Where significant differences occurred, data was further subjected to the Fishers' Least Significant Difference test at 5% probability level.

RESULTS AND DISCUSSION

The electrical conductivity (EC) that indicates the strength of the nutrient solution and potential of hydrogen (pH) which determines the availability of nutrients were measured at four weeks after transplanting using a hand held Total Dissolved Salts (TDS) meter (Table 1) (Charoenpakdee, 2014).

There was a significant difference ($P<0.05$) in average length of the roots of spinach grown using bat guano as compared to rabbit urine and Gatit super start* nutrient solutions (Table 2). Spinach grown using Gatit super start* nutrient solution had average root length of 18.8 cm; rabbit urine fertilizer (17.2 cm); and bat guano (10.4 cm). There was no significant difference between spinach grown using rabbit urine (15 cm), Gatit super start* (18.6 cm) and bat guano solutions (13.2 cm) (Fig. 2).

Table 1. Characteristics of nutrient solutions 4 weeks after transplanting

Parameter	Treatments (hydroponic solutions)		
	Rabbit urine	Bat Guano	Gatit super start*
pH	7.9	7.1	6.2
EC (ppm)	562	615	707

Table 2. Effect of rabbit urine, bat guano and Gatit super start* on growth physiognomies of spinach under hydroponic farming.

Treatment	Number of leaves	Plant height (cm)	Length of the root (cm)
Bat guano	5.0 ± 0.4ab	13.2 ± 1.6a	10.4 ± 2.03b
Rabbit urine	4.0 ± 0.5b	15.0 ± 0.5a	17.2 ± 1.1a
Commercial fertilizer	6.8 ± 0.9a	18.6 ± 2.7a	18.8 ± 2.03a
		One Factor ANOVA F-statistics	
Treatments (fertilizers)	4.625*	2.22353ns	6.32203**

Values presented are means ±SE. Different letter within the same column are significantly different at p=0.05 as determined by Fisher's Least Significance Difference test.

*, **, *** show significant difference at p≤0.05; p≤0.01 and p≤0.001 respectively. ns means no significant difference.

The difference in length of roots under bat guano solution compared to rabbit urine could potentially be due to presence of high levels of nutrients in the guano since it was collected from inside a building and such bats often feed on insects. Insect feeding bats are known to have guano that is rich in NPK as compared to non-insect eating bats (Charoenpakdee, 2014).

The ANOVA results showed a significant difference (P<0.05) on number of leaves of Spinach grown in the three different hydroponic nutrient solutions (Fig. 3). Spinach cultivated in Gatit super start* hydroponic solution had the highest number of leaves (7), followed by bat guano hydroponic solution (5) and lastly rabbit urine hydroponic solution (4) as shown in Fig. 3. Similar significant effect of bat guano fertilizer on plant growth was noted by Sothearen *et al.* (2014). The low number of leaves under rabbit urine hydroponic solution could be due to high pH which

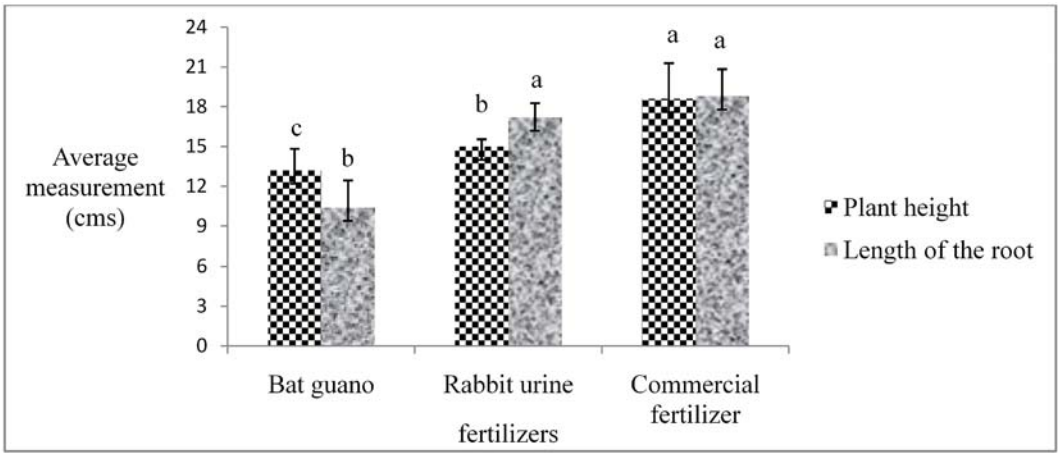

Fig. 2: Effect of hydroponic nutrient solutions on the length of the root and height of the plant. *Different letters on columns with a similar pattern show a significant difference at p=0.05 as determined by Fisher's Least Significance Difference test.

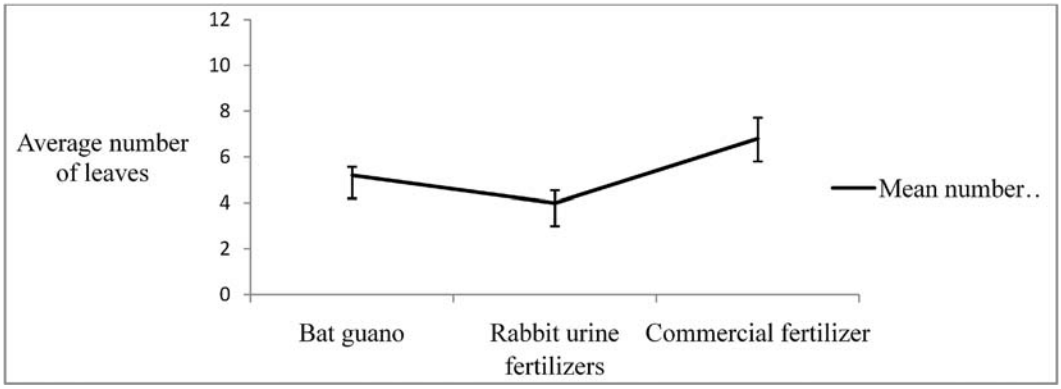

Fig. 3: Average number of leaves per treatment

can cause nutrient deficiencies (Aatif *et al.,* 2014).

CONCLUSION

Spinach grown using bat guano nutrient solution showed the best results in comparison to spinach grown using Gatit super start* since leaves are the edible part just like; bokchoy and lettuce (Hlophe *et al.,* 2019). Bat guano has sufficient levels of nitrogen, phosphorus and potassium alongside other micro nutrients needed for plant growth (Charoenpakdee, 2014).

Therefore, bat guano can be considered as an alternative low cost and organic fertilizer in comparison to synthetic commercial hydroponic fertilizers under hydroponic farming. However, a slow growth rate was noted for spinach grown in bat guano hydroponic solutions as compared to spinach grown using commercial fertilizer. The utilization of rabbit urine for hydroponic farming should not be ruled out because it also gave considerably good results in terms of yield. It should be considered in areas where farmers cannot easily access bat guano. More research is needed to identify adequate levels of rabbit urine and bat guano necessary to produce quality yield within the required growth period under hydroponic farming. Organic fertilizers play a critical role in reducing the costs associated with the expensive hydroponic fertilizers.

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Effect of banana (*Musa* spp.) intercropping with root and tuber crops

P R Manju[1*], S Swain[2], B K Pradhan[2], P B Pushpalatha[1] and P Patil[3]

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[1]*Banana Research Station, Kannara, Kerala Agricultural University, Thrissur, Kerala 680 652*

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ABSTRACT

A field experiment was conducted at the Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha to evaluate the performance of intercropping of banana cv. Champa with elephant-foot yam, ginger, turmeric, arrow root, colocasia and mango ginger during 2011-16. Growth and yield characters of banana did not show any significant difference among each other, indicating that cultivation of intercrops does not have any significant effect on them. Yield of intercrops varied from 13.29 tonnes/ha in elephant-foot yam to as high as 54.84 tonnes/ha in mango ginger. However, arrow root recorded maximum returns of ₹ 3.54 lakh/ha. Banana + arrow root combination recorded maximum total returns (₹ 8.21 lakh/ha), net profit (₹ 5.29 lakh/ha) as well B:C ratio (2.09). The effect of intercropping on incidence of Eumusae leaf spot showed that except colocasia, other intercrop combinations had significantly higher PDI than growing banana alone (PDI 8.75). The maximum PDI was recorded in banana + turmeric (27.50), followed by banana + mango ginger (26.25). Banana + arrow root recorded a moderate leaf spot incidence of 17.50 necessitating the application of suitable systemic/contact fungicide while growing arrow root as an intercrop in banana. Two pathogenic nematode species, *viz.*, reniform nematode, *(Rotylenchulus reniformis)* and root-knot nematode, *(Meloidogyne incognita)* were recorded. In none of the treatments, these two pathogenic nematodes were above the economic threshold level (ETL). The population of *Rotylenchulus* reniformis in banana + arrow root was 104 per 250 g soil, against ETL of 1000 young females per 250 g soil. Thus it is concluded that arrowroot can be taken as a remunerative intercrop in banana in Odisha..

Key Words: Intercrop, Benefit : cost ratio, Arrow root, Nematode, Eumusae, Root and tuber crops

Banana (*Musa* spp.) is one of the most important fruit crop in the world. The recommended spacing for banana variety Champa is 2 m × 2 m. The interspaces during the initial 4-5 months are ideal for growing suitable intercrops which do well under partial shade condition. However, studies on banana intercropping in Odisha is very limited. Hartley (2000) suggested desirable traits for crops suitable for growing as intercrops. They should be shade tolerant, not overgrow the main crop, should not host the same pests and diseases of the main crop. The cultural operations for the intercrop should not damage the main crop or promote soil erosion, its economic life should not exceed that of the main crop, and should be adapted to the same ecological conditions. In addition, the produce should have good storability and marketability. Considering all these factors, elephant-foot yam *(Amorphophallus campanulatus)*, ginger *(Zingiber officinale)*, turmeric *(Curcuma longa)*, arrow root *(Maranta arundinaceae)*, colocasia *(Colocasia esculenta)* and mango ginger *(Curcuma amada)* were evaluated to find most remunerative intercrop that could be cultivated along with banana in Odisha.

MATERIALS AND METHODS

The experiment was conducted at the Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha as part of ICAR - AICRP (Fruits) during 2011 - 2016 in Randomized Block Design with seven treatments and three replications : banana + elephant-foot yam, banana + ginger, banana + turmeric, banana + arrowroot, banana + colocasia, banana+ mango ginger and banana alone (control).

The varieties used for intercropping and their spacing are as follows.

*Corresponding author : manjupr.nair@gmail.com

[2] Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751 003

[3] ICAR-AICRP (Fruits), Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru 560 089

Crop	Variety	Spacing
Elephant foot yam	Gajendra	75 cm x 75 cm
Ginger	Suprava	20 cm x 30 cm
Turmeric	Surama	20 cm x 30 cm
Arrowroot	Khordha local	60 cm x 30 cm
Colocasia	Muktakeshi	60 cm x 20 cm
Mango ginger	Amba	20 cm x 30 cm

The cultural practices for main crop as well as intercrops were followed as per the standard package of practices and recommendations for the region. The plant height (cm), pseudostem girth (cm) and leaves per plant were recorded at bunching. TSS (°B), fruit acidity (%) and shelf life (days) were also observed after harvesting. Plant height was measured in centimeters using a measuring tape and scale from the base of the plant to the point of peduncle emergence. The maximum circumference of pseudostem at 10 cm height from the ground was recorded using measuring tape to get pseudostem girth (cm). While TSS / total soluble solids of the fruit was measured at ripening using a refractometer, fruit acidity was determined as per method of Ranganna (1997). Shelf-life was taken as the number of days from ripening to spoilage.

The data were analysed by analysis of variance (Panse and Sukhatme, 1967). Yield and economics of the main crop and the intercrops were calculated at harvesting. Economics of cultivation was calculated based on the cost of cultivation, gross returns and net returns.

The effect of growing intercrops on incidence of major pests and diseases in banana like Eumusae leaf spot and nematodes were also studied. Observations on YLS (youngest leaf spot) and percentage disease incidence of eumusae leaf spot were recorded. The disease severity index (PDI %) was calculated as per Gauhl's modification of Stover's severity scoring system (Gauhl et al., 1995; Carlier et al., 2002) using the formula:

$$\text{Infection index (PDI)} = \text{₹}nb / (N - 1)\ T \times 100$$

where, n = number of leaves in each grade, b = grade, N = number of grades used in the scale and T= total number of leaves scored.

Observations on nematode population, both beneficial and predatory were recorded by analyzing soil samples collected leaving 1 foot from the base of banana plants. In each treatment, a composite sample of 250 g was collected from each replication at harvesting.

RESULTS AND DISCUSSION

Biometrical parameters, yield and quality characters recorded during the study are presented in Table 1. Plant growth characters like pseudostem height, pseudostem girth and leaves per plant did not show any significant difference in treatments with intercrops compared to growing banana alone. Among the intercropping treatments, the bunch weight varied from 10.15 kg / plant in Banana + Ginger to 11.28 kg / plant in Banana + Colocasia, which was on par with control (10.12 kg / plant). The results suggest that intercropping did not had any significant influence on the growth and yield of banana. This could be due to the fact that more than 90% of the roots in banana extend within one meter from the plant, and about 70% of the root biomass is confined to the upper 20 to 40 cm of the soil (Turner and Rosales, 2003).

The intercrops selected were also shallow rooted and did not offer any serious competition for space and nutrition with the main crop. The spacing, inputs and other cultural requirements provided were sufficient to get a good yield, both for the main crop as well as the intercrops. The state of Odisha enjoys a tropical climate, characterized by high temperature, high humidity, medium to high rainfall and short and

Table 1. Biometrical observations of banana under intercropping

Treatment	Plant Height (cm)	Pseudo-stem Girth (cm)	Leaves / plant	Bunch Weight (kg/ plant)	Yield (tonnes/ ha)	TSS (°B)	Acidity (%)	Shelf-life (days)
Banana + elephant-foot yam	262.62	57.68	8.39	10.52	27.67	23.8	0.32	7.10
Banana + ginger	265.16	55.67	7.91	10.15	26.14	24.4	0.34	6.20
Banana + turmeric	260.69	59.92	8.17	10.39	27.05	24.0	0.31	6.90
Banana+ arrowroot	271.13	57.46	8.20	11.14	27.15	25.0	0.32	7.20
Banana+ colocasia	263.33	55.07	8.24	11.28	27.50	23.9	0.30	6.70
Banana + mango ginger	260.81	56.02	7.97	10.58	27.02	24.1	0.31	6.80
Control	257.29	52.62	8.12	10.12	26.65	24.2	0.33	7.30
SEm±	8.20	3.41	0.99	0.82	2.04	0.91	0.01	0.58
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	9.60	12.86	13.14	14.56	12.06	7.54	7.10	16.97

mild winters. According to National Informatics Centre, Odisha, marginal farmers in the state constitute more than 50% of the farmers, either own or rent a piece of land for cultivation. Hence besides enhancing production, increase in productivity per unit land area through intercropping hold the key to agricultural development.

Yield of intercrops varied from 13.29 tonnes / ha in elephant foot yam to as high as 54.84 t / ha in mango ginger (Table 2). However, returns was maximum for arrow root (₹ 3.54 lakh per hectare) and subsequently banana + arrow root combination recorded the maximum total returns (₹ 8.21 lakhs.) Among the intercrops, the cost of cultivation ranged from ₹ 78,250 / ha in arrow root to ₹ 90,050 in elephant-foot yam. The net profit was highest for banana + arrow root combination (₹ 5.29 lakh / ha), followed by banana + elephant foot yam (₹ 4.93 lakh / ha). Intercropping arrow root in banana had the highest B:C ratio of 2.09 (Table 3). Maximum returns over control was also recorded for banana + arrow root cropping system (₹ 3.80 lakh / ha).

The most positive thing is that in this intercropping system it is possible to get two separate yields form one plot and economically use the land resources. On critical evaluation of the characteristics of the root and tubers, it may be observed that root and tuber crops especially edible aroids and arrowroot are shade tolerant, most are shorter in stature and are comparatively tolerant to pests and diseases and do not harbor common pests and diseases.

Root and tuber crops are adapted to the same ecological conditions as that of banana and have shorter duration, their produce have fairly good storability and all of them have demand in local markets. Climatic conditions are also changing, and we are in need of new growing technologies that are more adaptable and sustainable. Arrow root is an under-exploited tuber crop, the rhizomes of which are valued as food stuff and a source of starch. Arrowroot starch is used for the preparation of bakery products especially biscuits, as a base for face powder, in the preparation of specialized glues and in the manufacture of carbonless paper for computer printouts. The starch possesses demulcent and anti-diarrhoeal properties and is used in the treatment of intestinal disorders which adds medicinal value to the crop. The crop comes up well under shaded conditions and no serious pests and diseases are noted in the crop. Extraction of starch can be done even in households by adopting a simple procedure. It serves as a raw material for cottage industry by unemployed women and rural youth (Swadija *et al.* 2013). It is in

Table 2. Yield and returns from banana based intercropping system

Treatment	Intercrop yield (tonnes/ha)	Return from intercrop (₹/ha)	Yield of Banana (tonnes/ha)	Return from banana (₹/ha)	Total Return (₹/ha)	Return over control (₹/ha)
Banana+elephant-foot yam	13.29	337290	27.80	457827	795118	353950
Banana+ ginger	22.12	272487	28.10	443585	691072	249900
Banana+ turmeric	22.91	267131	28.07	455380	722511	281344
Banana+ arrowroot	34.99	353681	26.35	467400	821081	379914
Banana+ colocasia	52.47	246935	29.52	479890	726825	285658
Banana+mango ginger	54.84	283102	28.00	460027	718880	277712
Control	-	-	29.00	441167	441168	-

Table 3. Economics of production per hectare for banana plus intercrop

Treatment	Cost of cultivation of intercrop (₹/ha)	Cost of cultivation of banana (₹/ha)	Total cost of cultivation (₹/ha)	Total return (₹/ha)	Net profit (₹/ha)	Benefit : Cost ratio
Banana+elephant-foot yam	90,050	1,91,457	2,81,507	7,95,118	4,93,473	1.16
Banana+ ginger	84,350	1,91,457	3,17,012	6,91,072	3,74,072	1.13
Banana+ turmeric	87,000	1,91,457	2,78,457	7,22,511	4,21,366	1.65
Banana+ arrowroot	78,250	1,91,457	2,69,707	8,21,081	5,28,686	2.09
Banana+ colocasia	80,250	1,91,457	2,71,707	7,26,825	4,32,480	1.20
Banana+mango ginger	83,750	1,91,457	2,75,207	7,18,880	4,21,010	1.14
Control	-	1,91,457	1,54,675	4,41,168	2,00,523	1.11

this context that the potential of this crop could be well exploited as an intercrop in banana.

Sarkar (2011) reported that intercropping pineapple with banana can help farmers to increase their income by nearly 40-45%. Studies conducted on the economic assessment of the intercropping system in Grand Naine banana indicated that banana with onion was the most profitable system under drip irrigation, which recorded higher banana equivalent yield, land equivalent ratio and net realization (Mahant *et al.,* 2012). Short duration pulse crops like soyabean and red gram can also be recommended in the interspaces of banana at 50 per cent reduced recommended dose of fertilizers to get more returns per unit area per unit time rather than growing banana as a sole crop (Hipparagi and Chinnappa, 2008).

Similar studies were conducted under the ICAR - AICRP (Fruits) at different agroclimatic zones of India with the objective of developing a more remunerative banana based cropping system using common economically important crops of the region. In Banana cv. Rajapuri, Onion (var. Arka Kalyan, B:C ratio - 3.29) as well as radish (var. Japanese White, B:C ratio - 3.10) can be recommended as suitable intercrops for Karnataka. Under irrigated conditions, cabbage (var. Golden Acre) and cauliflower (var. Maharani) are suitable intercrops in banana cv. Grand Naine in Gujarat. Bush type cowpea (var. Phule Pandhari) as well as greengram (var. J-781) and blackgram (var. TPU-4) performed well as intercrops in banana var. Grand Naine under irrigated conditions of Maharashtra.

In Assam, cultivating banana (var. Barjahaji) with intercrops like knol-khol (var. White Vienna), followed by elephant-foot yam (var. Kavvur) was found to be more remunerative (B:C ratio - 3.41) than growing banana as a sole crop. Under rainfed conditions of Kerala, turmeric (var. Sona, 12.3 tonnes / ha) performed as the best intercrop combination (B:C ratio 1.86) in banana cv. Nendran (28.2 tonnes / ha). In Andhra Pradesh, amaranth (B:C ratio 1.99) as well as carrot (B:C ratio - 1.78) can be cultivated as suitable intercrops in banana cv. Tella Chakkarakeli. Banana + cabbage (var. Green Express) is a remunerative banana based cropping system for West Bengal (B:C ratio - 2.20) (ICAR-AICRP Fruits, 2006).

Research in East Arica reveals that banana intercropped with coffee can increase plot revenue by more than 50% in both unfertilized and fertilized conditions.

Effect of intercropping on soil nutrient status showed that there was depletion in soil nitrogen and potassium as the crop reached harvest across all the treatments including the control. The reduction in soil available nutrients compared to initial status, particularly N and K in all the treatments might be due to the higher crop uptake than the quantity of nutrients applied. Potassium plays a major role in the translocation of photosynthates from the leaves to the roots and accelerates the process by contributing to the rapid cambial activity in the tuberous roots where starch is stored. All intercrops tried were root tubers with high K uptake, the reduction in available soil potassium was more pronounced in banana with intercrop, compared to banana alone.

Tropical tuber crops being high nutrient demanding, proper integrated management of the crop through the different approaches comprising major, secondary and micronutrients can definitely help in achieving the yield potential. Soil fertility can be replenished by incorporating back into the soil organic crop residues especially that of banana, as it is a good reservoir of nutrients. Banana intercropping can contribute to mitigation through storing an additional 15-30 tonnes of carbon per ha in the soil (Campbell *et al.,* 2014).

Eumusae leaf spot caused by *Mycosphaerella* spp., which occurs in all banana-growing regions of the world, is considered a serious threat to banana production as it causes major economic losses (Arzanlou *et al.,* 2008). The effect of intercropping on incidence of Eumusae leaf spot showed that except colocasia, all other intercrop combinations had significantly higher PDI than growing banana alone (PDI 8.75). The maximum PDI was recorded in banana + turmeric (27.50,) followed by banana + mango ginger (26.25). The most remunerative treatment combination, viz. banana + arrow root recorded a moderate leaf spot incidence of 17.50. Hence, application of suitable systemic / contact fungicide is recommended while growing arrow root as an intercrop in banana.

Nematodes play diverse roles as fungal-feeders, bacterial-feeders, omnivore-predators or plant-parasites in soil, making them valuable bioindicators for assessment of soil health (Ferris and Tuomisto, 2015). Cropping systems have been shown to have variable effects on soil nematode communities, and these changes can provide an insight into the functioning of the soil food web. Among all nematodes identified, reniform nematode, *(Rotylenchulus reniformis)* and root-knot nematode, *(Meloidogyne incognita)* are pathogenic and economic threshold level (ETL) for the same are 1000 young females and 250 J2 respectively per 250g of soil. In none of the treatments, both pathogenic nematodes were above the economic threshold limit.

As only the reniform nematode had maximum population of 104 / 250 g soil in banana + arrow root,

against the ETL of 1000 young females / 250 g soil, arrowroot can be taken as a safe intercrop in banana. Elephant-foot yam and colocasia can also be taken as intercrops as the predator nematode (*Mononchus* sp.) is found in these two associations. The predator nematodes feed upon the pathogenic nematodes. In mango ginger association, root-knot nematode is almost approaching the ETL and hence should not be taken as an intercrop in banana. In the control, no pathogenic nematodes were found. De Waele *et al.* (2006) reported that *Geophila repens, Arachis pintoi, Sorghum bicolor* and *Tagetes erecta* show promise as cover crops, rotation crops or intercrops in banana cv. Ecuador Dwarf (Cavendish group, AAA) that would not increase the population of banana nematode. Chitamba *et al.* (2013) evaluated legume intercrops on population dynamics and damage level of burrowing nematode *(Radopholus similis)* in banana and recommended sunhemp and cowpea for adoption by small holder banana farmers as an alternative to nematicide use.

CONCLUSION

Performance of six banana-based intercrop combinations showed that banana in association with arrowroot is the most remunerative with respect to the study also shows that intercropping arrowroot in banana does not pose any serious pest and disease threat to the main crop. Intercropping is becoming more popular and there are many combinations practiced worldwide.

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Assessment of morphological diversity in acid lime *(Citrus aurantifolia)* genotypes based on floral traits in Jammu region

Shilpy Kumari[1*], Akash Sharma[2], Parshant Bakshi[2], Romesh Salgotra[3], Manish Sharma[4], Vishal Gupta[2] and Gyanendra Kumar Rai[3]

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[1]*Division of Fruit Science, Faculty of Agriculture, SKUAST-J, Chatha, Jammu 180 009, JKUT, India*

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ABSTRACT

The survey was conducted on 70 seedlings of acid lime (*Citrus aurantifolia* Swingle) genotypes to find out the genetic divergence based on floral characteristics. The data did not reveal much variation in qualitative floral traits. All the seedlings flowered between February and March. The number of days to secondary flowering (163 days) were maximum in JMU-Lait (50) and JMU-Lait(53), and minimum (157 days) in JMU-Log(6), JMU-Log (7), JMU-Kat (14) and JMU-Gura (25). Pedicel length varied from 2.15 to 4.20 mm. The maximum pedicel length (4.20 mm) was in JMU-Sun (63), while minimum (2.15 mm) in JMU-Jib (36). The minimum petal length (11.02 mm) was in JMU-Log (5) and maximum (14.62 mm) in JMU-Uttar (18). The maximum petal width (5.12 mm) was in JMU-Nag (68) and minimum (3.19 mm) in JMU-Balli (27). Maximum number of flower buds/inflorescence (8.65) was in JMU-Nag (70) and minimum (3.62) in JMU-Log (4). Anther length (2.25 mm) was maximum in JMU-Nag (67) and minimum in (1.44 mm) in JMU-Log (1).

Key Words: Diversity, Floral characteristics, Genotypes, Indigenous, Morphology

Lime (*Citrus aurantifolia* Swingle) is the third most important citrus species in India after mandarin and sweet orange. In Jammu, lime (acid lime and sweet lime) accounts for an area of 4.97 thousand ha with a total production of 12.74 thousand Tonnes (DH, J&K, 2018). The study of genetic variability in citrus is critical for characteriz-ing germplasm, genetic erosion controlling and registration of new cultivars (Barkley *et al.*, 2006). Germplasm are being evaluated for development of varieties having desirable traits. An enormous vari-ability with respect to yield, qualitative and quantitative character in different fruit crops in tamarind (Sharma *et al.*, 2015). In different bael germplasm, Singh *et al.* (2018) studied morphological, floral, phenological and pollination behaviour. Characterization of acid lime genotypes based on floral morphology is of utmost importance for a citrus breeder. The synchronization and duration of flowering among lime genotypes, type of flowers, flower earliness, pollen viability etc. are few important aspects to plan breeding strategy for crop improvement. Genetic divergence of 50 mandarin genotypes through morphological characterization in Nagaland was estimated by Longkumer and Kabir (2014). Demir *et al.* (2015), Baswal *et al.* (2016) and Singh *et al.* (2016) also characterized lemon, grapefruit and mandarin genotypes, respectively. Due to long period of progressive evolution of citrus genus, it becomes difficult to ascertain centres of origin of most of the citrus cultivars because of natural hybridization. Both inter-specific and inter-generic hybrids have made the identification of citrus species more difficult (Tripathi *et al.*, 2018).

MATERIALS AND METHODS

Survey was done from major lime growing districts of Jammu province up to 800 m amsl, viz. Jammu (327), Samba (300), Kathua (307), Udhampur (755) and Reasi (466) m amsl, of Jammu purposely during 2017 and 2018 to select promising accessions among the

*Corresponding author : 0016.rsharma@gmail.com
[2] Advanced Centre for Horticulture Research, Udheywalla, SKUAST-Jammu 180 018, JKUT, India
[3] School of Biotechnology, Faculty of Agriculture, SKUAST-J, Chatha, Jammu 180 009, JKUT, India
[4] Division of Statistics and Computer Sciences, Faculty of Agriculture, SKUAST-J, Chatha, Jammu 180 009, JKUT, India

diverse acid lime (seedling) genotypes and assess variability on the basis of floral characteristics. Finally, plants of 70 acid lime genotypes with divergent characters were selected. Codes were allotted to each selection on the basis of their location and geo tagging was done on selected plants and the research work was carried out at Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and technology of Jammu, Chatha, Jammu.

Parameters related to flowering were recorded at full flowering stage by taking ten flowers randomly from each seedling grown lime genotype. Floral morphology was determined by taking the qualitative characters such as colour of open flowers, style shape, inflorescence type, stamina length, number of petals/flower, flowering period, date of flowering, date of end of flowering and number of days to secondary flowering and quantitative characters such as pedicel length (mm), petal length (mm), petal width (mm), number of flower buds/inflorescence, anther length (mm) were taken by using digital Vernier Calipers. The pollen viability (per cent) was determined by acetocarmine stain for pollen viability at full bloom which were calculated and was statistically analyzed with the help of INDOSTAT statistical package.

RESULTS AND DISCUSSION

The colour of open flowers was categorized as white, yellow, light yellow and purple. White coloured open flowers were observed in all 70 acid lime genotypes. Viable pollen was categorized as pollen sterile, sparse pollen, normal pollen and abundant pollen with sparse pollen observed in 36 and medium in 34 (48.57 per cent) genotypes. None of the seedling origin acid lime genotypes have pollen sterile and abundant pollen. Style shape was categorized as straight, arched and crooked. Straight style shape was found in 48 genotypes and rest of the 22 genotypes had arched shape of style. Inflorescence type was categorized as panicle, raceme and corymb. No variation was recorded in inflorescence type and raceme type of inflorescence was recorded in all genotypes. Stamina length was categorized into short, medium and long. Short stamina length was observed in all genotypes (Table 1). Baswal *et al.* (2015) recorded viability pollen percentage values ranged from 5.0 per cent for 'New Hall Navel' orange to 80.0 per cent for 'Mosambi' sweet orange. Demir *et al.* (2015) found maximum pollen viability in Meyer variety of lemon, while the minimum pollen viability was in Batem Sarisi lemon.

The genotypes flowers between February and March. The date of flowering varied from 26 February to 15 March. The mean time of flowering (26 February) was observed earliest in genotypes JMU-Sum (59) and JMU-Sum (60) and delayed flowering (15 March) in genotypes JMU-Gura (22), JMU-Godd (53) and JMU-Godd (54), whereas JMU-Log (1) and JMU-Log (4) were earliest to end its mean flowering season with 20 March and JMU-Godd (54) were last to end its flowering season with mean date 6 April. Number of days to secondary flowering (163 days) were maximum in JMU-Lait (50), JMU-Lait (53) and minimum (157 days) in JMU-Log (6), JMU-Log (7), JMU-Kat (14) and JMU-Gura (25).

Number of petals/flower were five in all genotypes. Similar observations were also reported by Dorji and Yapwattanaphun (2011). The variation in these characters may be due to differences in days and night temperature during growing period, and genetic make up of cultivars, along with various biotic and abiotic influences. Kinley and Chinawat (2011) reported maximum number of stamens in Tsirang and Dagana mandarin and minimum in Samtse mandarin. Baswal *et al.* (2015) also recorded number of stamens in Campbell Valencia cultivars of sweet orange, flowering initiation and full bloom period was the earliest in variety Early Gold (6 March and 18-25 March, respectively), while termination of flowering season was commenced firstly in Ruby Nucellar (30 March).

The pedicel length varied from 2.15 mm to 4.20 mm among different seedling originated acid lime genotypes. The pedicel length was maximum (4.20 mm) in JMU-Sun (63), followed by (4.19) in JMU-Lait (50), (4.17) in JMU-Kat (14) and JMU-Godd (52), while minimum (2.15 mm) was in JMU-Jib (36). The petal length (mm) showed significant differences among genotypes. The minimum petal length (11.02 mm) was in JMU-Log (5) and maximum (14.62 mm) in JMU-Uttar (18) with overall general mean of 12.46 mm (Table 1). The average petal width (mm) ranged from 3.19 mm to 5.12 mm with overall general mean of 4.13 mm. The maximum petal width (5.12 mm) was recorded in JMU-Nag (68) and minimum (3.19 mm) in JMU-Balli (27) with overall general mean of 4.13. The maximum petal length and petal width in Campbell Valencia and Cutter Valencia, maximum pedicel length in Cutter Valencia, cultivars of sweet orange reported by Baswal *et al.* (2015). The variation in plant growth characters in different genotypes may be attributed to genetic features of individual genotype and their adoptability to agroclimatic conditions (Kumar *et al.,* 2014). Acid lime usually produces a large number of flowers over the year. The floral load depends on cultivar, tree age and environmental conditions. In acid lime fruits are clustered in most of the time.

The data pertaining to number of flower buds/inflorescence revealed that maximum number of flower

Table 1. Floral characters of indigenous acid lime (*Citrus aurantifolia* Swingle) genotypes of Jammu region

Genotypes	Colour of open flower	Viable pollen	Style shape	Inflore-scence type	Stamina length	Flowering month, (2018)	Date of start of flowering, (2018)	Date of end of flowering, (2018)	Number of days to secondary flowering	Number of petals flower (mm)	Pedicel length (mm)	Petal length (mm)	Petal width (mm)	Number of flower buds/inflo-rescence	Anther length (mm)
JMU-Log(1)	White	Normal pollen	Straight	Raceme	Short	February	28 Feb	20 March	159	5.00	3.49	11.08	3.23	5.07	1.44
JMU-Log(2)	White	Sparse pollen	Straight	Raceme	Short	February	28 Feb	22 March	159	5.00	3.44	11.39	3.50	4.55	1.56
JMU-Log(3)	White	Sparse pollen	Arched	Raceme	Short	February	27 Feb	21 March	158	5.00	3.63	11.40	3.52	5.15	1.56
JMU-Log(4)	White	Sparse pollen	Arched	Raceme	Short	February	27 Feb	20 March	158	5.00	3.57	11.48	3.60	3.62	1.78
JMU-Log(5)	White	Sparse pollen	Straight	Raceme	Short	February	28 Feb	22 March	158	5.00	3.34	11.02	3.20	4.67	1.73
JMU-Log(6)	White	Sparse pollen	Straight	Raceme	Short	March	6 March	29 March	157	5.00	3.72	11.52	3.63	5.54	2.18
JMU-Log(7)	White	Sparse pollen	Straight	Raceme	Short	March	6 March	28 March	157	5.00	3.47	11.98	4.00	4.33	2.10
JMU-Log(8)	White	Normal pollen	Straight	Raceme	Short	March	8 March	1 April	159	5.00	3.08	11.69	3.75	5.63	2.17
JMU-Log(9)	White	Normal pollen	Straight	Raceme	Short	March	10 March	4 April	159	5.00	3.50	11.83	3.99	6.33	1.91
JMU-Bar(10)	White	Sparse pollen	Straight	Raceme	Short	March	6 March	29 March	158	5.00	3.89	11.40	3.51	5.29	1.80
JMU-Bar(11)	White	Sparse pollen	Straight	Raceme	Short	March	6 March	29 March	159	5.00	3.60	11.32	3.57	5.66	1.93
JMU-Bar(12)	White	Sparse pollen	Arched	Raceme	Short	March	8 March	31 March	160	5.00	3.12	12.34	4.16	5.19	1.96
JMU-Bar(13)	White	Normal pollen	Arched	Raceme	Short	March	8 March	30 March	160	5.00	4.13	12.00	4.24	4.67	1.99
JMU-Kat (14)	White	Normal pollen	Straight	Raceme	Short	March	6 March	27 March	157	5.00	4.17	12.30	4.08	5.91	2.25
JMU-Kat(15)	White	Sparse pollen	Straight	Raceme	Short	March	10 March	2 April	162	5.00	3.41	11.93	3.77	5.64	2.20
JMU-Kat(16)	White	Sparse pollen	Arched	Raceme	Short	March	10 March	3 April	162	5.00	3.48	12.15	4.66	4.59	2.23
JMU-Kat(17)	White	Normal pollen	Straight	Raceme	Short	March	12 March	4 April	160	5.00	3.43	14.45	5.00	5.22	1.90
JMU-Uttar(18)	White	Normal pollen	Straight	Raceme	Short	March	12 March	4 April	160	5.00	3.07	14.62	5.00	5.26	1.73
JMU-Uttar(19)	White	Sparse pollen	Arched	Raceme	Short	March	12 March	4 April	159	5.00	3.06	14.14	4.99	4.84	1.76
JMU-Uttar(20)	White	Sparse pollen	Arched	Raceme	Short	March	11 March	4 April	159	5.00	3.53	14.47	5.10	3.71	1.94
JMU-Uttar(21)	White	Sparse pollen	Straight	Raceme	Short	March	11 March	4 April	159	5.00	3.26	11.34	3.32	5.84	1.91
JMU-Gura(22)	White	Normal pollen	Straight	Raceme	Short	March	15 March	6 April	160	5.00	3.83	12.35	4.15	5.33	1.89
JMU-Gura(23)	White	Normal pollen	Straight	Raceme	Short	March	14 March	5 April	159	5.00	3.39	11.99	3.86	4.97	1.93
JMU-Gura(24)	White	Sparse pollen	Arched	Raceme	Short	March	14 March	5 April	158	5.00	3.21	11.78	3.75	5.53	1.93
JMU-Gura(25)	White	Normal pollen	Straight	Raceme	Short	March	13 March	2 April	157	5.00	2.52	11.51	3.63	5.46	1.97
JMU-Taror(26)	White	Normal pollen	Straight	Raceme	Short	March	10 March	1 April	161	5.00	2.37	11.17	3.31	6.69	2.18
JMU-Balli(27)	White	Sparse pollen	Straight	Raceme	Short	March	11 March	3 April	160	5.00	4.03	11.06	3.19	5.39	2.15
JMU-Balli(28)	White	Sparse pollen	Straight	Raceme	Short	March	11 March	3 Aril	160	5.00	4.15	12.83	4.45	5.52	2.15
JMU-Balli(29)	White	Sparse pollen	Straight	Raceme	Short	March	10 March	2 April	162	5.00	4.13	12.65	4.26	5.48	2.24
JMU-Balli(30)	White	Sparse pollen	Arched	Raceme	Short	March	10 March	1 April	162	5.00	2.25	12.02	4.00	3.93	2.20
JMU-Neeli(31)	White	Sparse pollen	Arched	Raceme	Short	March	9 March	31 March	161	5.00	3.94	12.17	4.26	5.63	1.69
JMU-Neeli(32)	White	Sparse pollen	Arched	Raceme	Short	March	8 March	31 March	160	5.00	2.57	12.25	4.19	3.65	1.63
JMU-Neeli(33)	White	Sparse pollen	Straight	Raceme	Short	March	9 March	30 March	160	5.00	2.98	12.10	4.25	4.62	1.67
JMU-Jib(34)	White	Sparse pollen	Straight	Raceme	Short	March	12 March	2 April	161	5.00	2.76	12.34	4.45	5.80	1.77
JMU-Jib(35)	White	Normal pollen	Straight	Raceme	Short	March	12 March	2 April	161	5.00	2.58	12.21	4.37	5.19	1.75
JMU-Jib(36)	White	Normal pollen	Arched	Raceme	Short	March	10 March	31 March	162	5.00	2.15	14.26	5.03	8.62	1.54
JMU-Jib(37)	White	Normal pollen	Straight	Raceme	Short	March	11 March	2 April	161	5.00	3.22	14.06	5.01	5.50	1.73

JMU-Jib(38)	White	Normal pollen	Straight	Raceme	Short	March	13 March	4 April	158	5.00	3.73	14.19	5.04	5.42	1.69
JMU-Tikri(39)	White	Sparse pollen	Straight	Raceme	Short	March	13 March	5 April	158	5.00	3.82	14.05	4.83	4.37	1.66
JMU-Tikri(40)	White	Sparse pollen	Straight	Raceme	Short	March	12 March	3 April	158	5.00	3.12	12.88	3.88	6.09	1.70
JMU-Pana(41)	White	Normal pollen	Arched	Raceme	Short	March	13 March	3 April	159	5.00	4.07	12.46	4.51	7.43	1.73
JMU-Pana(42)	White	Normal pollen	Arched	Raceme	Short	March	13 March	4 April	159	5.00	3.90	12.53	4.65	5.50	1.56
JMU-Pana(43)	White	Normal pollen	Straight	Raceme	Short	March	12 March	2 April	160	5.00	3.55	12.29	4.06	4.61	1.59
JMU-Pana(44)	White	Sparse pollen	Straight	Raceme	Short	March	12 March	2 April	160	5.00	3.96	12.48	4.09	5.75	1.59
JMU-Chet(45)	White	Normal pollen	Arched	Raceme	Short	March	14 March	5 April	162	5.00	3.65	12.11	3.34	6.29	1.53
JMU-Chet(46)	White	Normal pollen	Arched	Raceme	Short	March	12 March	3 April	160	5.00	3.85	11.85	3.38	5.45	2.00
JMU-Chet(47)	White	Sparse pollen	Straight	Raceme	Short	March	13 March	3 April	159	5.00	3.52	11.67	3.21	6.16	2.10
JMU-Chet(48)	White	Sparse pollen	Straight	Raceme	Short	March	13 March	2 April	159	5.00	3.38	11.13	3.29	5.46	2.13
JMU-Duggi(49)	White	Normal pollen	Straight	Raceme	Short	March	11 March	3 April	160	5.00	4.08	11.15	4.17	3.95	1.83
JMU-Lait(50)	White	Normal pollen	Arched	Raceme	Short	March	14 March	4 April	163	5.00	4.19	11.57	3.66	4.68	1.68
JMU-Lait(51)	White	Sparse pollen	Arched	Raceme	Short	March	14 March	4 April	162	5.00	4.16	11.63	4.19	5.40	1.87
JMU-Godd(52)	White	Sparse pollen	Straight	Raceme	Short	March	13 March	2 April	163	5.00	4.17	11.80	3.81	6.45	1.68
JMU-Godd(53)	White	Sparse pollen	Straight	Raceme	Short	March	15 March	6 April	162	5.00	3.67	11.44	3.37	5.57	1.99
JMU-Godd(54)	White	Sparse pollen	Straight	Raceme	Short	March	15 March	6 April	162	5.00	3.81	11.65	3.46	5.93	2.15
JMU-Godd(55)	White	Normal pollen	Straight	Raceme	Short	March	13 March	4 April	159	5.00	3.91	11.42	3.43	5.30	2.21
JMU-Godd(56)	White	Normal pollen	Arched	Raceme	Short	February	27 Feb	22 March	161	5.00	2.89	11.76	3.71	4.28	2.05
JMU-Sum(57)	White	Normal pollen	Straight	Raceme	Short	February	28 Feb	23 March	162	5.00	2.83	11.96	3.83	5.50	2.09
JMU-Sum(58)	White	Normal pollen	Straight	Raceme	Short	February	27 Feb	23 March	161	5.00	2.51	11.91	3.79	5.60	2.13
JMU-Sum(59)	White	Normal pollen	Arched	Raceme	Short	February	26 Feb	21 March	162	5.00	3.8	11.49	3.23	5.55	1.97
JMU-Sum(60)	White	Sparse pollen	Straight	Raceme	Short	February	26 Feb	21 March	162	5.00	3.04	11.90	3.79	5.47	1.93
JMU-Sun(61)	White	Sparse pollen	Straight	Raceme	Short	February	27 Feb	23 March	161	5.00	3.51	14.13	5.01	3.95	1.96
JMU-Sun(62)	White	Sparse pollen	Arched	Raceme	Short	February	28 Feb	24 March	160	5.00	3.95	14.04	4.97	5.38	1.53
JMU-Sun(63)	White	Normal pollen	Straight	Raceme	Short	March	9 March	31 March	161	5.00	4.20	14.17	5.06	4.79	1.67
JMU-Sun(64)	White	Normal pollen	Arched	Raceme	Short	March	9 March	31 March	161	5.00	4.16	14.31	4.89	5.69	2.18
JMU-Nag(65)	White	Normal pollen	Straight	Raceme	Short	March	9 March	31 March	161	5.00	4.11	14.19	5.04	8.61	1.91
JMU-Nag(66)	White	Normal pollen	Straight	Raceme	Short	March	10 March	1 April	162	5.00	3.90	14.27	5.11	5.88	2.19
JMU-Nag(67)	White	Normal pollen	Straight	Raceme	Short	March	10 March	1 April	162	5.00	3.86	14.39	4.95	4.89	2.25
JMU-Nag(68)	White	Normal pollen	Straight	Raceme	Short	March	10 March	1 April	162	5.00	3.75	14.33	5.12	5.32	1.67
JMU-Nag(69)	White	Normal pollen	Straight	Raceme	Short	March	9 March	2 April	160	5.00	3.99	14.29	5.01	5.76	1.91
JMU-Nag(70)	White	Normal pollen	Straight	Raceme	Short	March	9 March	2 April	160	5.00	4.01	14.21	4.79	8.65	2.18
General mean											3.52	12.46	4.13	5.42	1.90
±SE (m)											0.18	0.58	0.18	0.26	0.11
CV (%)											8.79	8.08	7.41	8.44	10.08
CD at 5%											0.50	1.62	0.51	0.74	0.31

buds/inflorescence (8.65) was recorded in JMU-Nag (70) which was statistically at par with (8.61) in JMU-Nag (65), (8.62) in JMU-Jib (36) and (7.43) in JMU-Pana (41), while minimum number of flower buds/ inflorescence (3.62) was found in JMU-Log (4). Maximum anther length (2.25 mm) was in JMU-Nag (67) and minimum length of anther (1.44 mm) in JMU-Log (1) with a mean value of (1.89 mm). Rocha *et al.* (1990) observed that in Orange trees, North part had highest number of flowers. Multitudes of factors were found to affect flowering.

Generally, in Citrus, in subtropical conditions greater accumulation of hours of low temperature (Valiente and Albrigo 2004), under tropical conditions 45-60 days of water stress (Lovatt *et al.,* 1984), type of flowering shoot (Garcia-Luis *et al.,* 1995) and bud competence (Monselise 1986) play a significant role in determining the extent of flowering and the floral load.

Therefore, Similarities were observed in floral qualitative characters among different acid lime genotypes. However, quantitative floral characters varied significantly among all genotypes. Thus, there was wide variation in floral morphological characters in acid lime genotypes and these variations are indicative of underlying genetic diversity. The study will help in identification of acid lime genotype for their suitability for specific floral trait for their better use in improvement programmes.

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Phenology and productivity of elephant-foot yam *(Amorphophallus paeoniifolius)* in relation to planting time under humid tropical conditions

S Sunitha*, V S Sathosh Mithra and J Sreekumar

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ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 695 017, Kerala, India

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ABSTRACT

Phenology and productivity of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] were studied by planting its varieties, Gajendra and Sree Padma, under humid tropical conditions of Kerala by planting them during February, March and April during 2014, 2015 and 2016 at ICAR-CTCRI, Thiruvananthapuram. Gajendra took 23-90 days for sprouting, 65-114 days for tuber initiation, 195-261 days for senescence, which lasted for 25-64 days, while Sree Padma took 22-64 days for sprouting, 69 days for tuber initiation, 195-263 days for senescence lasting for 28-64 days during different seasons. Active tuber development was noticed between 3 to 6 months after planting. Timely planting resulted in more and comparable tuber yield both in Gajendra and Sree Padma (27.8 and 27.2 Tonnes/ha). Delayed planting although resulted in early emergence and tuber initiation, senescence was also early, resulting in yield loss in both varieties.

KEY WORDS: Harvest index, Humid tropics, Phenology, Senescence, Sprouting

Elephant-foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is one of the major tropical tuber crops used as a starchy vegetable having high nutritive and medicinal values. There are five different phases identified in the generalized growth cycle of yams and aroids, first phase starting with root formation and sprouting, which may take 1-3 weeks. It is followed by rapid shoot and root development with corm initiation, which occurs in 3-10 weeks. Third phase with maximum root and shoot growth and rapid increase in corm size which lasts for 10-20 weeks and in the next phase, 20-30 weeks, coincides with rapid accumulation of dry matter in aerial parts with corm bulking. The last phase, during the senescence phase, continued increase in corm size occurs which may lasts for 30-40 weeks, after which the corms enter into dormancy (Onwueme and Charles 1994). The crop goes through all these phases during its life cycle but the exact duration varies with varieties and the climatic conditions. In the present study, an attempt was made to study the phenological expressions of elephant foot yam planted during different months under humid tropical conditions of Kerala, India, with particular emphasis to growth, corm yield and yield attributes.

*Corresponding author: sunitharajan1@rediffmail.com

MATERIALS AND METHODS

Field experiments were conducted at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, during 2014, 2015 and 2016. The location lies between 8.54° North latitude and 76.91° East longitude and comes under the humid tropical climatic zones of India with an altitude of 50 m above mean sea- level. Maximum temperature varied between 25-35°C and minimum temperature, 23-26°C having a relative humidity of 64-81%. The first, second and third season crop was planted during the first fortnight of February, March and April of consecutive years. The corms harvested and stored for two months were used for planting in all the seasons. The crop received 1518, 1330, and 1583 mm of rainfall during the three growing seasons respectively.

The soil was deep, well drained, sandy clay loam, moderately acidic in reaction. Available nitrogen and potassium were medium and phosphorus status was high. Two promising varieties, Gajendra, and Sree Padma, having a duration of 8-9 months, were used. Gajendra is a local selection from Kovvur area of Andhra Pradesh, the tubers are non-acrid, well shaped and generally devoid of cormels. Sree Padma has been developed by Central Tuber Crops Research Institute,

Trivandrum, The tubers are non acrid and generally have one mother corm and a few cormels.

The corm pieces of 500 g each were planted at a spacing of 90 cm x 90 cm with a gross plot size of 25 plants in three replications. The FYM and fertilizers were applied as 25 t FYM and 100-50-150 kg N, P_2O_5 and K_2O in two split doses, coinciding with 50% sprouting and one month thereafter, followed by earthing - up. Observations on number of days taken for first sprouting and 50% sprouting, corm emergence, days to crop senescence, and duration of senescence were recorded. Destructive sampling was done at monthly intervals from 3 months onwards up to senescence and the rate of corm bulking was assessed. Biometric parameters and dry- matter partitioning were also estimated at monthly intervals and the harvest index at senescence stage. Corm yield was recorded at harvesting stage from all the replications. The data over the seasons were analysed using 'R' package and the mean values were compared. The average value of three replicated values in each season were computed and were compared using standard error, and the error graphs were drawn.

RESULTS AND DISCUSSION

Sree Padma took more time for sprouting in all the seasons. Gajendra took 60, 32 and 19 days for initiation of sprouting of planted corms during the first, second and third season respectively. Sree Padma took 81, 64 and 22 days for initiating sprouting during the first, second and third seasons respectively. Gajendra took 90 days for achieving 50% sprouting during the first season, 78 and 44 days during second and third seasons respectively. The 50% sprouting in Sree Padma was achieved in 90 days during the first and second seasons and 40 days during the third season. Usually the crop is harvested during December-January for seed purpose and next planting is undertaken during February-March.

During this lean period, tubers undergo dormancy for 2-3 months. The time of emergence of leaf (sprouting) depends on dormancy status of planted corms and it starts sprouting with pre-monsoon showers during April-May or with the commencement of SW monsoon in June under rainfed conditions. About 75-80% of sprouting of planted corms and development of first leaf occurs during 2-3 months and this crop growth period requires adequate soil moisture through irrigation or rainfall. Sufficient moisture in planted zone with drip irrigation resulted in early sprouting, within 22 days in elephant - foot yam (Sunitha *et al.*, 2018). The corms also show tendency to sprout in storage once the dormancy period is over. The variation in days taken for emergence is mainly due to difference in time of planting from February, March and April. Delayed planting resulted in early sprouting, even with less rains during initial period, mainly due to termination of innate dormancy.

Number of leaves produced was more in Gajendra in all the seasons compared to Sree Padma. However, difference was not significant. Number of leaves also expressed an increasing trend up to 6 months during the first season in both varieties. Number of leaves declined in Gajendra from 5 months during second and third seasons. In Sree Padma, leaf number reduced from 6^{th} month during second season and 4^{th} month during third season. The number and size of leaves which develop during the growing season is dependent on quantity of planting material used, soil fertility, soil moisture and developing corm age. The 500 g corms were used as planting material with uniform nutrition under rainfed conditions. Water stress 4 and 6 months after planting resulted in maximum plants with one leaf and minimum plants with two leaves (Ravi *et al.*, 2015). Once sprouted, vegetative growth continues almost up to 4-5 months and then declines with corm development, unless sufficient soil moisture is present through irrigation or rainfall. Depending upon the rainfall, both the varieties performed equally good.

Leaf canopy started spreading once the petiole elongated, after three months and increased up to 6 months after planting when the corms were planted during February, thereafter slightly declined, but again increased during the first season in both the varieties. However, during second season, canopy spread showed a gradual increase up to 6-7 months and then declined. During third season also the values increased up to 5 MAP and then declined. The values were significantly high during the third season (CD-8.32) (Fig. 1). Once the sprout is initiated, further development of leaf is completed within 30 days provided sufficient soil moisture is available (Ravi *et al.*, 2011). Hence early sprouting in third season resulted in more canopy spread during initial months. After 4-5 months, first leaf senesce and second leaf emerges depending upon the soil moisture status. Sufficient rains received during 5 months after planting resulted in second leaf emergence and subsequent increase in canopy spread during the first season. Delayed senescence of first leaf or early emergence of second leaf is reported in elephant foot yam under irrigation (Sunitha *et al.*, 2018).

Leaf area index (LAI) followed a similar trend as the number of leaves. The LAI starting from 2.18 at 4 MAP reached a maximum of 4.14 at 6 MAP and then declined in Gajendra during the first season. Maximum LAI was recorded at 5 MAP and 4 MAP during the second and third season respectively. In Sree Padma also, LAI reached maximum at 6 MAP during the first

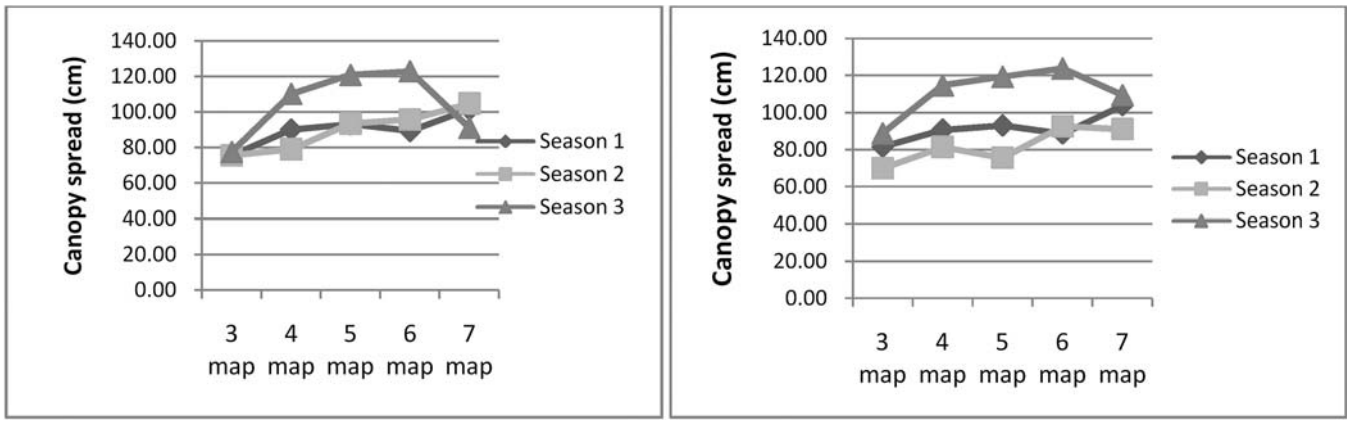

Fig. 1: Canopy spread in Gajendra and Sree Padma during different seasons

and second seasons. During the third season, LAI reached maximum at 5 MAP. Elephant foot yam has been reported to produce more number of larger leaves with adequate water availability than plants under stress (Santosa *et al.,* 2004). Well distributed rainfall received during early stages of second and third seasons resulted in high LAI values (Fig. 2).

Gajendra took 114 days for corm emergence during the first season whereas Sree Padma took 121 days. During second and third seasons, tuber emergence occurred in Gajendra in 90 days and 65 days and in Sree Padma, 98 days and 69 days respectively. In elephant- foot yam, new daughter corm gets initiated along with sprouting of planted corms, however the developing corms will be clearly visible only after shoot emergence. Early planting resulted in delayed sprouting after 60 and 81 days respectively in Gajendra and Sree Padma and consequently more time for new corm emergence during the first season. During third season, tuber emergence was found early within 65-69 days, indicating that physiological rest period highly influenced the emergence of tubers also irrespective of the time of planting.

There was significant difference in rate of tuber bulking among the three seasons. In general, after tuber initiation, tuber bulking started at a low pace during the initial stages. The rate of tuber development increased from 4 months after planting, reached the peak during 5th month period, when planting was undertaken during February and March. When planting was delayed to April, tuber bulking started 3 months after planting and continued upto 5-6 months. Then it started declining slowly. This trend was observed in both the varieties, with the values varying between the seasons. During the third season, bulking rate was comparatively higher during 3-4 months compared to the first two seasons. Towards maturity, bulking rate was less and during the third season, the rate was less in Sree Padma, compared to Gajendra. It can be inferred that the maximum tuber development occurs in elephant foot yam between 4-6 months of planting (Fig. 3). Higher dry-matter accumulation in elephant - foot yam corms compared to shoot and root at 3, 5 and 8 months after planting is reported (Nedunchezhiyan *et al.,* 2021). In elephant foot yam, initial establishment of canopy as well as corm

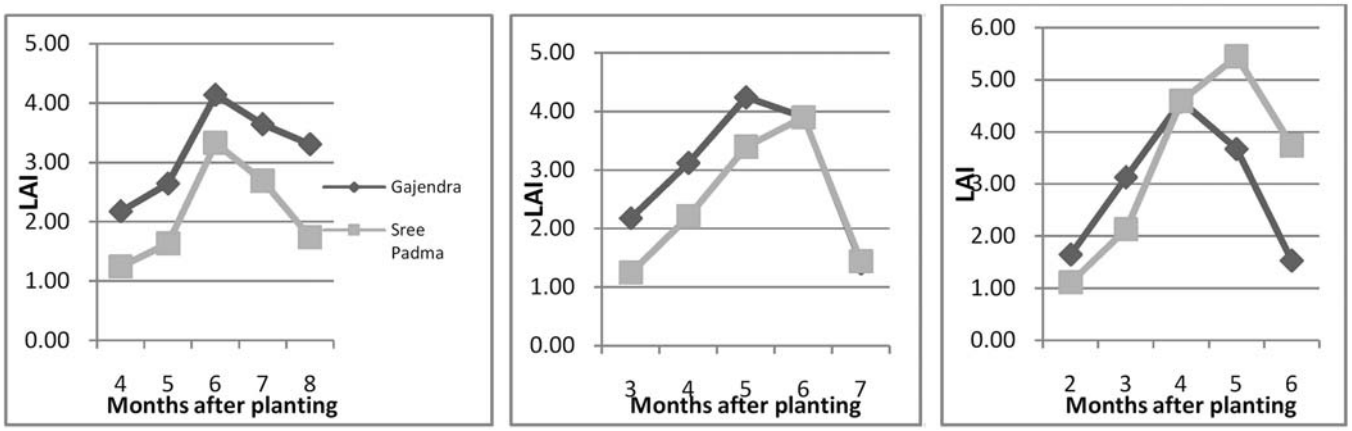

Fig. 2: Leaf area indices during different seasons

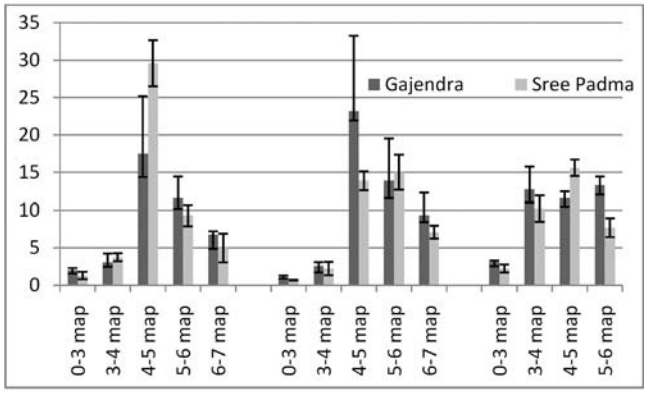

Fig. 3: Rate of tuber development during the 3 seasons

development phases of 4-6 months are reported to be critical with respect to moisture availability (Ravi *et al.,* 2015 and Sunitha *et al.,* 2018).

Harvest index did not show any significant variation among the varieties during three seasons. Harvest index of both the varieties was maximum during the third season and minimum during the second season. During the first season, Sree Padma recorded more harvest index value, but the difference was not significant. More than sprouting, soil moisture status influenced the development of leaf and initial establishment of the crop is sensitive to water deficit stress (Ravi *et al.,* 2011). During second season, the crop did not receive adequate rains for initial establishment for two months (Fig. 4).

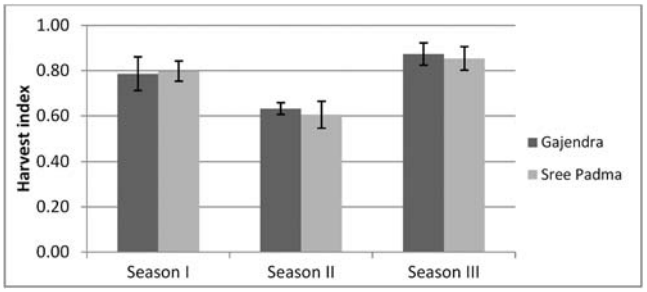

Fig. 4: Harvest indices of varieties at senescence stage during 3 seasons

Significant difference in days to senescence was observed only during the first season among the varieties (CD= 3.36). Days to senescence was found to be 244, 260 and 195 days in Gajendra and 230, 263 and 193 days in Sree Padma during first, second and third season respectively. During the third season where planting was delayed senesced early in both the varieties. Late planting results in early senescence in greater yam also (Sunitha et al., 2020). The crop enters dormancy earlier than usual when the rainy season is shorter than four months (Ravi *et al.,* 2011).

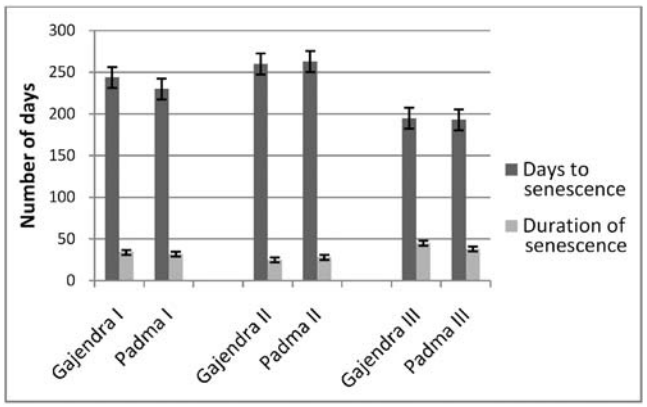

Fig. 5: Days to senescence and its duration during different seasons

The period of senescence varied from 25 to 45 days in Gajendra whereas in Sree Padma, the period ranged from 28 to 38 days. A significant difference among the varieties could be observed in duration of senescence during the third season (CD=2.87). The rate of senescence was found faster in Sree Padma. A negative correlation was found between days to senescence and duration of senescence. Earlier the senescence, more was the duration of senescence in both the varieties. Usually senescence starts by 7-8 months of planting after cessation of rains and with the withdrawal of rainy season during October - November. Hence delayed planting resulted in early senescence also. Consequently reduction in tuber yield could be noted for third season.

Per hectare corm yield varied from 25.02 to 31.06 tonnes / ha in Gajendra and 22.45 to 27.16 tonnes / ha in Sree Padma. There was no significant difference in corm yield between the varieties, but the values differed only with respect to seasons. The lowest corm yield was recorded during the second season in both the varieties (Fig. 6). The yield data indicated that the crop performed better during the first season of planting, followed by third season. February planting resulted in 15% yield increase in Gajendra and 3% increase in Sree Padma compared to April planting. March planting suffered yield loss of 24% in Gajendra and 21% in Sree Padma compared to February planted crop. In greater yam, delayed planting resulted in early emergence, tuber formation and senescence and recorded less tuber yield compared to normal season planting (Sunitha *et al.,* 2020). However in this study, delayed planting during April resulted in 9% and 17% increased corm yield compared to March planting. The rainfall was less during the second season. Poor establishment due to inadequate soil moisture resulted in poor growth and yield. Supplementary irrigation along with suitable water saving techniques such as

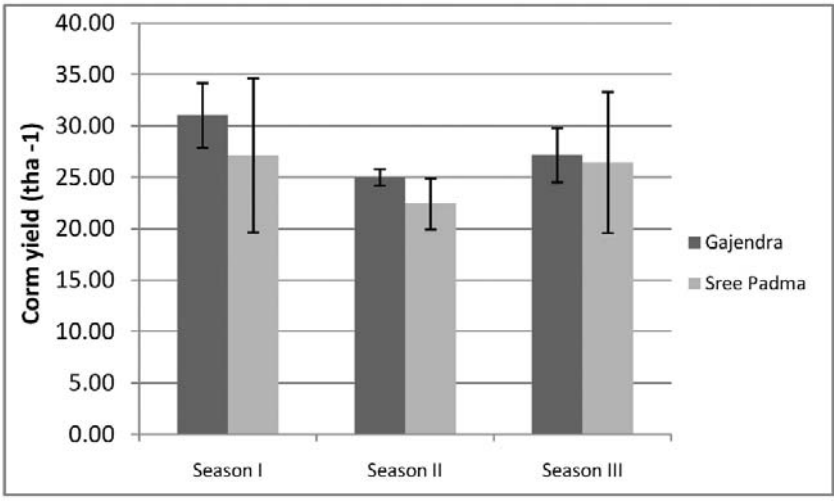

Fig. 6: Corm yield in different seasons of planting

porous ground cover mat can retain soil moisture for more period, thus enhances corm yield in elephant foot yam (Sunitha *et al*., 2019).

Elephant-foot yam is comparatively a long duration tuber crop having 8-10 months longevity. Time of planting of seed tubers is very important, and as per the performance of the crop, the most ideal time being February as the crop can utilize summer rains for sprout emergence, and both the monsoons, for canopy establishment and corm development. The crop takes 3-12 weeks for sprouting, 8-16 weeks for canopy establishment, 10-16 weeks for tuber emergence, 26-38 weeks for senescence under humid tropical conditions of Kerala. Delayed planting resulted reduction in vegetative phase of the crop and consequently in reduced tuber yield. Adequate soil moisture with rainfall or supplementary irrigation helps in proper establishment of canopy during 8-16 weeks and corm development during 12-24 weeks, ensuring high corm yield in elephant-foot yam.

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Effect of mineral boron sources on reproductive, yield and quality characteristics of mango (*Mangifera indica*)

Gopavaram Pavithra, Pauline Alila*, C S Maiti, A Sarkar and A K Sahu

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School of Agricultural Sciences and Rural Development, Nagaland University, Mediphema, Nagaland

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ABSTRACT

The experiment was conducted at Instructional Research Farm, School of Agricultural Sciences and Rural Development, Nagaland University, Nagaland during November 2017-August 2018 in a randomized block design with three replications and seven treatments of different boron sources, viz., Agricol 5 g, Agricol 10 g, Chemibor-P 5 g, Chemibor-P 10 g, Disodium Octaborate Tetrahydrate 5 g, Disodium Octaborate Tetrahydrate 10 g and the control (distilled water). The aqueous solution of boron was applied on the soil at two stages, i.e. before flowering and at pea-sized stage. Data were collected from N-E and S-W aspects of the tree canopy. The earliest panicle emergence, minimum number of days for 50% flowering (22.51 and 22.07), days to fruit set time (57.27 and 56.82) and days to harvesting from panicle initiation (168.26 and 168.00) were obtained with Agricol (5 g) on N-E and S-W aspects of the canopy respectively. Maximum fruit yield (46.2 and 45.92 kg/tree) significantly increased with Agricol (5 g) application. The number of hermaphrodite flower/panicle (208.55 and 207.71), sex ratio/panicle (0.66 and 0.61) and least fruit drop (51.23 and 50.50) were found maximum with application of DOT (5g). The pulp weight (153.23 and 152.04) and fruit quality parameters significantly increased with Agricol (5 g) application. The maximum fruit length (9.38 and 9.17 cm) and width were recorded with application of Chemibor-P and fruit bioactive compounds like vitamin C (65.31 mg/100g pulp and 65.64 mg/100g pulp) and beta-carotene (3330.55 µg/100g and 3315.18 µg/100g) were recorded maximum with application of DOT (10g) on north-east and south-west canopy of the plant. The lower concentrations of boron from various sources performed better in the present study.

Key Words: Flowering, Fruit yield and Fruit qualitative characteristics, Mango, Mineral boron

Organic boron sources like Agricol, Chemibor-P, Disodium Octaborate Tetrahydrate are recommended for soil application as they have higher solubility in soils of acidic pH. In a trial on peanuts conducted in Department of Plant Sciences, UC Davis, it was reported to enhance pod filling, thereby increasing the yield and the peanut productivity. In most of the crops, boron shows very poor phloem mobility and because of this boron in leaf tissue cannot be easily transported nor sufficiently to reproductive organs, i.e. buds, flowers, seeds, *etc.* Therefore, application of boron in moist soils at all stages of plant growth, particularly during reproductive growth (fruit setting) is critical in the supply of plant nutrition (Ulusik *et al.*, 2018). The paper elucidates the effect of boron from different organic sources on flowering, reproductive growth, yield and fruit characteristics of mango (*Mangifera indica* L.) cv. Amrapali.

*Corresponding author : paulinealila@gmail.com

MATERIALS AND METHODS

Uniform trees of mango cv. Amrapali (15 years old) were selected for the experiment. Common cultural practices were carried out in the field with application of manures and prophylactic measures against pest and diseases were carried out from time to time. There were seven treatments embedded in a randomized block design replicated thrice with three trees selected per treatment. The boron sources in the study were from Agricol which is a homogenized powder, dark to light grey in colour, and it is ideal for correcting boron deficiency in soils. Chemibor-P is in white granular form, Disodium Octaborate Tetrahydrate (DOT) is an odourless white coloured powder and having high solubility in the soil.

The treatments were : control (Distilled water), 5g Agricol (1% B), 10g Agricol (2.0% B), 5g Chemibor-P

(1.4% B), 10g Chemibor-P (3% B), 5g DOT (0.2% B), 10g DOT (0.6% B). The percentage of boron was calculated based on molecular weight of the compounds. These mineral boron sources were manufactured by Borochemie (India) Pvt. Ltd with class 1 trademark. The required quantity of different mineral sources of boron were weighed in a digital balance and dissolved in distilled water at 80±2°C). The aqueous treatment solutions were applied in two spilt doses, first dose was applied during November after fruit harvest of preceding year and the second dose was applied during March when fruits were at pea size stage. The soil at the drip zone was raked up and the solutions applied all around the plant till the soil was fully drenched.

The data were recorded on two aspects of plant canopy, *viz.* north-east and south-west. The date on bud emergence referred to as panicle initiation (PI) was scaly leaf protuberances observed from the swollen buds and daily tagged with the date for further studies. Fruits were harvested at maturity and brought immediately to laboratory for analyses. The physical parameters were recorded following standard procedure. TSS of fruit pulp was determined with ERMA hand Refractometer (0-32°Brix). Ascorbic acid was estimated by volumetric method using 2, 6-dicholorophenol-indophenol dye and expressed in mg / 100 g fresh weight of pulp (Rangana, 1999).

Titratable acidity (%) of mango pulp was determined using a known volume of filtered mango juice titrated with standard sodium hydroxide (0.1 mol L^{-1}) with phenol-phthalein as indicator (AOAC., 2006). Total sugars (%) were determined by taking a known quantity of mango pulp titrated with boiling Fehling's solution using methylene blue indicator, until a brick-red colour appeared (AOAC., 2006). The data obtained was statistically analyzed for analysis of variance (Cochran and Cox, 1992).

RESULTS AND DISCUSSION

Early emergence of panicle was observed with the application of Agricol (5 g) in N-E aspect of tree canopy, followed by S-W aspect and in the N-E aspects with application of DOT (5g). In general, trees applied with mineral boron showed advancement in panicle initiation as compared to the control. There was a significant variation in length of panicle on all days of with maximum length (36.66 cm and 36.27 cm) which was significantly highest over all other treatments with Disodium Octaborate Tetrahydrate (DOT) (5 g) treatment on both aspects of canopy respectively. The boron sources and concentrations also showed significant differences on all days. The effect of boron on panicle length may be due to action of boron on photo assimilates and protein synthesis, and trans-location to growing site which is the panicle on terminal portion of branches, thereby increasing length of panicle. Similar results were observed by Sarkar *et al.* (2015) in mango cv. Alphonso where foliar application of 0.5% borax recorded maximum panicle length (36.48 cm). Singroul (2016) also reported that application of 100% RDF+0.1% B on mango cv. Amrapali produced the maximum panicle length (36.67 cm).

Application of Agricol (5g) resulted in 50% flowering in three weeks time of panicle initiation (PI) as compared to six weeks in the control, followed by three and half weeks time duration with the application of Agricol at 10g and DOT at 5g in both aspects of tree canopy. There was significant variations on effect of boron sources on days to 50% flowering, while different concentrations of boron did not show any significant variations in S-W canopy but varied significantly on N-E aspect of the canopy. Boron regulates the RNA synthesis (Ram and Bose, 2000) which might have played vital role in increasing physiological activities leading to early initiation of flowering. The findings confirm to those of Gurjar *et al.* (2015) who observed that foliar application of 1% zinc sulphate, 1% iron sulphate and 0.5% borax in combination had influenced flowering in terms of minimum days (19.67) taken to 50% flowering. Patel (2016) also reported that soil application of RDF+200 g zinc sulphate+100g boric acid recorded minimum number of days (30.00) to 50% flowering in mango cv. Amrapali. Various treatments significantly advanced the days to full blooming. The number of days to full blooming (data not shown) also showed similar results with those of 50% flowering influenced by mineral boron applications.

The application of mineral boron caused a shift in number of male and hermaphrodite flowers in inflorescence. Number of male flowers / panicle was found more with the application of Chemibor-P in both concentrations and DOT at 10g in all canopy aspects of plants. Further, these treatments showed a reciprocal lower number of hermaphrodite flowers / panicle. There was a significant variation on the effect of boron sources on number of male and hermaphrodite flowers / panicle. However, different concentrations failed to reach the level of significance. Boron is essential for reproductive growth as it involves in metabolisam and protein synthesis which might be the reason for greatest number of male flowers / panicle. These findings corroborates with those of Singh and Maurya (2004) where foliar application of boric acid 0.2% on mango cv. Mallika recorded the maximum number of male flowers. The sex ratio per panicle was found to be least with the application of Chemibor-P with both concentrations, followed by DOT at 10g application on

all parts of the plant canopy. However, Dutta (2004) in mango cv. Himsagar and Negi *et al.* (2010) in Dashehari, hermaphrodite flowers increased with application of 3000 ppm and 200 ppm boric acid respectively as foliar application. The production of more number of hermaphrodite flowers may be due to boron activity in plants as it involves in protein synthesis and enhances the production and utilization of amino acids.

Fruit Setting

The days to fruit setting and harvest time from panicle initiation followed similar trend with days to 50% flowering where Agricol application at 5g minimized the time taken for fruit setting and harvesting as compared to the control (Table 1). Various concentrations did not have much effect on these parameters. The reduction in time taken for harvesting of fruits were at least about a month with the application of mineral boron. There was a drastic reduction in number of fruits / panicle from pea-sized stage to marble-sized stage in all treatments. The treatments with DOT with both concentrations and Chemibor-P (5g) resulted in more number of fruits retained at marble-sized stage. Foliar application of borax 0.5% recorded maximum number of fruit set at pea-sized stage (13.54) which reduced to 6.83 at marble-sized stage in mango cv. Alphonso (Gurjar *et al.*, 2015).

Sajid *et al.* (2010) reported that foliar application of 0.05% zinc + 0.04 % boron before flower initiation, after fruit setting and 40 days interval of second spray increased fruit setting in sweet orange cv. Blood Orange. The number of fruits / panicle at harvesting time also followed a more or less similar trend with DOT (5g) and Chemibor-P (5g) retaining the highest number of fruits / panicle. There was a significant variation on effect of boron sources on fruits retained per panicle. These findings confirm those of Yadav *et al.* (2011) where foliar application of borax 0.4% on guava cv. Lucknow-49 recorded maximum fruit retention percentage of 57.27% and foliar application of 0.5% borox on mango cv. Alphonso recorded maximum number (1.5) of fruits / panicle (Gurjar *et al.*, 2015).

There was maximum fruit drop in plants where no boron was applied. The least fruit drop was recorded in plants treated with DOT (5g) followed by Chemibor-P (5g). Different boron sources had significant effect on number of fruits retained per panicle while the concentration of boron did not vary significantly on fruit drop percentage on both aspects of tree canopy. The findings confirm the reports of Banyal *et al.* (2011) where spraying of borax 0.4% on litchi cv. Dehradun in mid February and first week of May as a foliar application showed lowest fruit drop (77.42%). Abhijith (2018) also recorded less fruit drop of 45.60% as against 79.63% in the control in aonla cv. NA-7 with the foliar application of micronutrients 0.5% zinc sulphate + 0.5% iron sulphate + 0.25% borax.

Yield Attributes

Various treatments significantly influenced the number fruits / tree. There was a significant variation on effect of boron sources on fruits retained per tree. The number of fruits / tree increased 60-100% with the boron application regardless of source or concentration as compared to the control plants (Table 2). The greatest yield (245.48 and 244.18 fruits / tree) on both canopy directions was obtained with application of DOT at 5g followed by 5g application of Chemibor-P (223.28 and 163.54 fruits / tree), while the control plants produced significantly the least number of fruits on both canopy

Table 1. Effect of different boron sources and canopy direction on fruit setting of mango

Treatment	Fruit /tree		Yield/plant (kg)		Fruit weight (g)		Fruit length (cm)	
	N-E	S-W	N-E	S-W	N-E	S-W	N-E	S-W
Control	104.38	104.04	11.30	10.95	118.57	118.67	5.43	5.42
Agricol (5 g)	219.35	193.08	46.24	45.92	211.49	207.80	9.01	8.98
Agricol (10 g)	192.38	222.11	41.22	40.72	203.56	203.07	6.76	6.69
Chemibor-P (5 g)	223.28	163.54	41.90	41.44	180.06	178.52	9.38	9.17
Chemibor-P (10 g)	189.53	189.12	25.87	25.39	159.28	158.69	7.45	7.39
D O T (5 g)	245.48	244.18	42.24	41.80	174.85	174.08	9.04	9.01
D O T (10 g)	189.53	189.62	31.36	31.04	166.75	163.91	7.74	7.63
S Em±	0.86	0.86	0.28	0.26	0.48	0.50	0.13	0.13
LSD (p=0.05)	3.11	3.12	1.02	0.95	1.75	1.81	0.48	0.48
Boron sources compared with control								
S Em±	0.86	0.86	0.30	0.28	0.52	0.54	0.14	0.15
LSD (p=0.05)	3.11	3.12	1.10	1.02	1.89	1.95	0.51	0.53
Concentration effect								
S Em±	0.46	0.46	0.16	0.15	0.28	0.29	0.08	0.08
LSD (p=0.05)	1.66	1.67	0.59	0.55	1.01	1.07	0.26	0.28

*DOT= Disodium Octaborate Tetrahydrate

directions (104.38 and 104.04 plants / tree).

The yield per plant was found to be significantly greater with the application of mineral boron as compared to control. The increase in yield per plant as compared with the control was fourfold in plants treated with Agricol 5g in both aspects of canopy. This was followed by the treatments of DOT (5g), Chemibor-P (5g), Agricol (10g). The treatments with DOT (10g) and Chemibor-P (10g) also brought about double yield / plant compared with the control.

Fruit weight was found to be significantly highest with the application of Agricol (5g) in all aspects of tree canopy. Chemibor-P (5g) recorded greatest fruit length and width which were statistically at par with treatments with DOT and Agricol at 5g for the fruit length while the fruit width did not show any significant differences. These positive effects on fruits could be due to promotion of starch formation followed by rapid transportation of carbohydrates activated by boron. These findings confirm the reports of Bhatt *et al.* (2012) who recorded maximum fruit weight (167.29 g) with spraying of 0.5% borax on mango trees during marble-sized stage of fruits. There was significant variations on effect of boron sources and concentrations on fruit weight and length but not in width. The findings corroborates with reports of Ali *et al.* (2014) in peach and Singh *et al.* (2018) in sweet orange cv. Mosambi.

Fruit Quality

TSS was recorded significantly highest in fruits treated with Agricol 5g followed by 10 g Agricol and DOT (5g) which were statistically same (Table 2). The acidity in fruits did not vary significantly amongst the treatments, however the lowest was obtained with treatment of 5g Agricol followed by 5g DOT. The control fruits registered highest acidity followed by 10g Agricol. The TSS-acid ratio did not show any particular trend but was found to vary significantly and lowest recorded in the control.

The increase in fruit TSS in treated plants might be due to the action of boron enhancing the conversion of complex polysaccharides into simple sugars. Such increase in fruit TSS has also been reported in Kinnow mandarin (Meena *et al.,* 2003), guava cv. Lucknow-49 (Yadav *et al.,* 2011) and pomegranate cv. Ardestani (Sohrab *et al.,* 2016). Reduction in acidity with boron application might be due to their utilization in respiration and rapid metabolic transformation of organic acids into sugars.

The greatest content of vitamin C and β-carotene were obtained with the application of DOT (10 g) which was significantly highest followed by 10 g Chemibor-P and 10g Agricol in vitamin C content while no definite trend in beta-carotene was found. Higher dose of mineral boron had a significant edge over lower doses in the vitamin C content. This is in concurrence with findings of Farooq *et al.* (2017) in mango cv. Langra where foliar application of 1% boric acid + 1.2% zinc sulphate recorded maximum amount of vitamin C (154.3 mg / 100g). The increase in ascorbic acid in the fruits could be due high content of sugars which invariably gets synthesized into ascorbic acid. Singh *et al.* (2013) found that foliar application of boric acid (0.02%) with sorbitol (2.0%) on mango recorded the maximum β-carotene (3.01mg / 100g). Sankar *et al.* (2015) found that foliar application of boric acid 0.02% recorded the maximum amount of carotenoids (12.34 mg / 100g).

Table 2. Fruit quality of mango cv. Amrapali as influenced by different sources of boron

Treatment	TSS (°Brix)		Acidity %		TSS - acid ratio		Vitamin C (mg/100g)		Beta carotene (µg/100g)	
	N-E	S-W	N-E	S-W	N-E	S-W	N-E	S-W	N-E	S-W
Control	17.43	17.50	0.33	0.31	38.41	41.73	25.29	24.61	1881.02	1851.18
Agricol (5 g)	21.75	22.04	0.17	0.17	84.49	65.5	54.26	53.57	3227.46	3149.11
Agricol (10g)	20.50	20.60	0.30	0.31	67.17	65.83	55.54	55.21	3015.99	2971.34
Chemibor-P (5 g)	19.82	19.90	0.25	0.24	63.95	82.59	54.66	53.99	2328.22	2245.24
Chemibor-P (10 g)	19.85	19.92	0.26	0.26	70.89	70.83	56.62	55.95	2015.50	1994.71
D O T (5 g)	20.24	20.32	0.20	0.19	75.04	72.00	55.96	55.31	2962.01	2936.01
D O T (10 g)	20.02	20.10	0.24	0.23	86.57	72.27	65.31	64.64	3330.55	3315.18
S Em±	0.10	0.10	0.03	0.03	0.80	0.81	0.16	0.17	1.60	1.44
LSD (p=0.05)	0.37	0.37	NS	NS	2.87	2.93	0.54	0.57	5.46	5.22
Boron sources compared with control										
S Em±	0.10	0.10	0.03	0.02	0.74	0.75	0.16	0.10	1.63	1.55
LSD (p=0.05)	0.32	0.32	NS	NS	NS	NS	0.58	0.34	5.90	5.64
Concentration effect										
S Em±	0.06	0.04	0.02	0.01	0.42	0.43	0.09	0.10	0.87	0.83
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.31	0.35	NS	NS

*DOT= Disodium Octaborate Tetrahydrate

CONCLUSION

The soil application of boron from various mineral sources on mango cv. Amrapali clearly resulted in positive effect on the advancement of reproductive growth as compared to the control plants. The different aspects of tree canopy did not show much variations on the parameters studied. Soil application of boron sources at pre-flowering and fruit setting at pea-sized stage influenced flowering and fruiting of mango with greatest number of flowers, more yield and lowest fruit drop (%) in mango.

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Techno-economic feasibility of tomato *(Solanum lycopersicum)* hybrids for year-round cultivation in Andamans, India

Shrawan Singh[1*], D R Singh[2] and Subhash Chand[3]

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ICAR-Central Island Agricultural Research Institute, Port Blair 744 105, India

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ABSTRACT

The experiment was conducted to investigate adaptation of tomato (*Solanum lycopersicum* L.) hybrids in different growing condition in tropical island and assess the techno-economic feasibility for year-round cultivation at CIARI, Port Blair, Andaman and Nicobar Islands, India during 2012-13 and 2013-14. Seven hybrids and three varieties were evaluated in three growing environments (open+dry season, open+rainy season and polyhouse+rainy season). Arka Rakshak (369.3 q/ha), Ayushman (351.6 q/ha) and Arka Samrat (339.3 q/ha) were consistent performer all the conditions with highest yield levels and they also had low incidence of bacterial wilt,i.e. 34.2%, 29.2% and 33.3%, respectively. Risk analysis using Likert scale score revealed that heavy rains, lack of suitable varieties and bacterial wilt are major risk in farmers' view. Accordingly, they ranked techno-economically feasible options and prominent were varieties/hybrids, polyhouse technology, grafting and raised beds for year-round production. The study will ensure year-round production of tomato locallyand also prospective areas of research for tomato cultivation in tropical islands.

Key Words: Economic feasibility, F_1 hybrids, High-value vegetables, Tropical islands

Vegetables show variation for relative adaptation to both biotic and abiotic stresses which emphasize evaluation of hybrids in new agro-ecological region (Chellemi *et al.* 1994). Protected cultivation showed great promise for vegetable production even in problematic environment and improve yield and quality (Singh, 2013; Sabir and Singh, 2013). Further, only indigenous vegetables, predominantly leafy types, are prevalent in rainy season and tomato production remain almost nil (Singh *et al.*, 2015a) and (Singh *et al.*, 2015b). Halder and Rai (2021) highlighted the potential threat due to emergence of new diseases in vegetable crops which also applies more categorically to island regions due to extremely congenial climate for diseases and pathogen. Effective options for bacterial wilt management in tomato for island situation were identified as grafting tomato on bacterial wilt resistant cultivated/wild brinjal for field condition or use of growing media (cocopeat : vermicompost: lime) in pot culture were already described by Singh *et al.* (2014) and integrated disease management options for field condition by Bhagat *et al.* (2015). The tropical ecology of Andaman and Nicobar Islands represent such a typical situation where evaluation of hybrids for their suitability and also techno-economic feasibility was required. Hence, trial was conducted for assessing the performance of hybrids by considering the local farmers' perceptions and all possible eco-friendly technological options (Singh *et al.*, 2015a). Therefore, study was aimed to identify suitable hybrids of tomato for dry and rainy seasons and also investigate the techno-economic suitability of protected cultivation of tomato during rainy season in tropical island ecosystem.

*Corresponding author : singhshrawan@rediffmail.com
[1] Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India.
[2] Chander Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India
[3] ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi, India

MATERIALS AND METHODS

Initially, 50 diverse genotypes/hybrids were tested in exploratory trial and seven hybrids and two varieties of normal tomato and one of cherry tomato from mainland India were selected for testing in three growing environments. Three hybrids namely Arka Ananya, Arka Rakshak and Arka Samrat were from

Indian Institute of Horticulture (IIHR), Bengaluru. Three common hybrids from private sector namely G 600 (from Golden Seeds), Lakshmi (Nunhem Seeds Pvt. Ltd.), Saktiman (Namdhari Seeds Pvt. Ltd.) and Ayushman (Seminis Pvt. Ltd.) were used in study. Arka Vikash from IIHR, Bengaluru, BT 1 from Orrisa University of Agriculture and Technology (OUA&T), Bhubaneswar and Cherry Tomato-1 a line (now as Pusa Cherry Tomato Selection-1) from Indian Agricultural Research Institute (IARI), New Delhi were also used in the study. These varieties / hybrids are developed for certain agro-climatic regions of mainland India but never tested in the island situation. In each environment, the varieties / hybrids were tested in complete randomized block design (RBD) with three replications.

The experiments were conducted during 2012-13 and 2013-14 at Garacharma Research Farm, Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands (India). The test environments were (i) open condition in dry season, (ii) open condition in rainy seasons and (iii) polyhouse during rainy season. For open field trials, raised beds alongwith plastic mulch, furrow irrigation and stalking of plants were opted as common factors for all genotypes. The polyhouse was naturally ventilated (40%), double span saw toothed structure and 200 ultra-violet (UV) stabilized LDPE sheet. Gutter and centre heights were 2 m and 3.5 m and provided with ridge and side ventilations by 40 mesh insect-proof (IP) net. Trial crop was grown in plots (3 m × 2.7 m) and each had three raised beds of 60 cm width at 30 cm apart and 15 cm height on upland terraces. Healthy seedlings (30 days) were transplanted on both sides of bed by leaving a space of 10 cm which made a spacing of 50 cm × 40 cm. Irrigation was done in furrows made between the beds. Well-decomposed FYM was applied @ 250 kg / 100 sq m during first ploughing. Nutrients were applied as per recommended dose @ 150 N; 60 P_2O_5 and 50 K_2O kg / ha was given. Half of N, full of K_2O and P_2O_5 appliedthe time of transplanting and remaining N was given at 30 and 60 days after transplanting.

Growth and yield parameters were recorded from five random plants in each plot. Incidence of bacterial wilt was observed plot-wise and calculated the disease incidence (DI) as DI (%) = (number of infected plants per plot / total number of plants per plot) *100. Incidence of blossom end rot (BER) on fruits recorded from five randomly tagged plants and calculated as percentage of total fruits harvested per plant and. Flower and fruit drop were also observed from these tagged plants. Economic analysis of different hybrids of tomato in open and polyhouse was done for B:C ratio and net return using market price in Port Blair.

We use the Likert scale for quantification of farmers perception on possible risks in off-season, (rainy season) tomato cultivation. The items measured using Likert type scale which is the most widely used approach to scaling responses in survey research and is often used interchangeably with rating scale. The scale is named after its inventor, psychologist Rensis Likert, and these were treated as continuous variable (Meuwssen *et al.*, 2001; Lien *et al.*, 2007). The five-point scale on sources of risks in cultivation of tomato during harsh climatic conditions as Strongly agree=5, agree=4, Neutral=3, not agree=2, strongly not agree=1. Techno-feasibility of the improved technologies for tomato cultivation was assessed using the view of the tomato growers in the islands during trainings and demonstration interactions. For this, a scale of 0 to 10 was given to score the technologies to counter each risk factor, wherein 0 stands for no role of the technology while 10 represent the complete solution for the risk factor.

The statistical analysis for ANOVA of the pooled data of 2012-13 and 2013-14 was done using OPSTAT software (http / / www.hau.ernet.in). The economic analysis was done using Microsoft Excel software.

RESULTS AND DISCUSSION

Out of ten varieties / hybrids, individual plant yield was highest in Arka Vikash (1314.5 g) followed by G-600 (1166.0 g) while minimum in Saktiman (675.0 g / plant) and BT-1 (690.0 g) (Table 1). Lakshmi was commonly grown tomato hybrids by the island farmers in open fields during dry season, its yield (209.7 q / ha) was significantly lesser than Arka Rakshak (377.9 q / ha), Ayushman (352.1 q / ha), Arka Samrat (337.8 q / ha), Arka Vikas (307.2 q / ha) and Arka Ananya (220.5 q / ha). G 600 is an indeterminant hybrid for protected cultivation but it also out yielded the popular hybrid Lakshmi by 41.5% yield advantage. Wide significant variation in yield and related traits was in agreement with previous report on different hybrids and varieties.

Ayushman (222.2 q / ha) and Arka Rakshak (205.1 q / ha) produced highest fruit yield in open condition during rainy season. However, upland location, raised beds and plastic mulching were pre-requisite because the pilot trial on same hybrids in flat land on the terraces was destroyed entirely in 2012-13 (data not presented). The harvesting period was less in rainy season in all the tomato hybrids in comparison to the dry season and protected environment. It was ranged from 25.0 days in Saktiman to 47.5 days in G-600 due to early crop loss due to heavy rains.

Further, yield of suitable tomato hybrids for polyhouse cultivation in rainy season was 84.4 q / ha in Cherry tomato to 239.2 q / ha in Arka Rakshak. The per plant yield was observed to be highest from G-600

Table 1. Performance of tomato hybrids during 2012-13 and 2013-14 (pooled data)

Variety	Variety/ Hybrid	Fruits / plant (No.)			Fruit weight (g)			Fruit yield / plant (g)			Fruit yield (q/ha)			Harvest period (days)		
		D+O	R+O	R+P	O+D	R+O	R+P	O+D	R+O	R+P	O+D	R+O	R+P	O+D	R+O	R+P
Cherry Tomato-1	Variety	129.3	60.0	68.3	9.8	8.5	9.5	695.5	360.5	716.5	151.6	48.7	84.4	96.3	45.0	46.8
G 600	Hybrid	33.3	18.8	26.5	39.0	37.8	39.5	1166.0	675.8	1558.4	296.8	85.9	119.0	102.5	47.5	49.3
Lakshmi	Hybrid	27.5	15.0	21.5	37.5	36.5	38.5	883.0	526.0	1194.4	208.6	64.6	171.0	47.5	26.3	27.3
Arka Ananya	Hybrid	26.3	12.3	17.0	37.0	35.8	39.0	868.0	413.8	924.8	219.0	77.5	103.8	63.8	32.0	42.5
Saktiman	Hybrid	17.0	13.0	21.5	44.5	40.0	41.0	675.0	505.5	1284.8	161.6	75.1	204.7	40.0	25.0	30.0
Arka Vikash	Variety	27.0	15.8	16.3	53.3	45.8	46.5	1315.5	713.0	1083.2	307.3	103.4	152.0	65.0	36.3	40.0
BT-1	Variety	18.3	12.0	18.8	42.5	36.3	37.5	690.0	423.0	1046.4	189.3	82.9	125.9	35.0	25.0	28.8
Ayushman	Hybrid	26.0	17.0	20.8	61.3	51.3	53.3	994.5	761.0	1271.2	351.6	222.2	235.6	92.5	43.8	47.5
ArkaRakshak	Hybrid	28.3	17.5	20.5	44.5	42.0	42.8	1148.5	693.0	1247.7	369.4	204.7	239.2	76.3	45.0	47.5
Arka Samrat	Hybrid	27.3	17.0	19.8	40.0	40.0	42.5	1013.0	659.0	1252.5	339.3	179.0	218.0	72.5	40.0	43.0
CD 0.05		10.8	10.5	7.1	5.2	6	4.5	234	230.2	257.4	87.8	53.5	86.5	12.1	11.7	7.4

D+O :dry season+open condition; R+O: rainy season+ open condition; R+P: rainy season+ polyhouse condition.

(1558.4 g) and Saktiman (1284.8 g), while it was 1271.2 g from Ayushman and 1252.5 g in Arka Samrat. Ayushman (351.6 q/ha), Arka Rakshak (369.4 q/ha) and Arka Samrat (339.3 qt/ha) and Arka Samrat (339.3 q/ha). The harvest period was maximum for G-600 (49.3 days) followed by Arka Rakshak (47.5 days) and Ayushman (47.5 days). It was minimum in Lakshmi (27.3 days) and BT-1 (28.8 days). Only three hybrids Arka Rakshak, Ayushman and Arka Samrat had significantly higher yield over the tomato varieties Arka Vikash and Laksmi. This could be due its better adaptive traits and higher yield per surviving plants upto harvesting stage.

The relative decrease in the yield obtained during rainy open condition was observed to be the maximum in G 600 (-71.1%), followed by Cherry tomato (67.9%) over the dry open condition (Fig. 1). The G -600 also had 149.4% low yield than its cultivation in open during dry season. The climatic condition of the islands was relatively favouruable during November - February for tomato cultivation in open condition also which allows proper fruit setting and good crop harvest. The yield reduction over different situation was relatively low in Arka Rakshak, Arka Samrat and Ayushman. All the tested hybrids and OP varieties showed significant increase in yield in polyhouse condition than in open condition during rainy season. The maximum increase was observed in Shaktiman (172.6%) followed by Lakshmi (164.7%). Although, yield in these hybrids was significantly low than Arka Rakshak, Arka Samrat and Ayushman. Because three hybrids performed well in all three seasons.

Higher percentage of plants survive till final economic harvest is important criteria for higher yield in challenge areas and overall mean value was observed to be highest in dry season (54.5±9.6%), followed by polyhouse in rainy season (44.9±11.5%) while minimum value was observed in open condition during rainy season (38.14.2%). Among the hybrids, Ayushman had maximum survival percentage (62.5%) and G 600 had only 363.6%. Other hybrids with high overall mean survival were Arka Rakshak (62.0%) and Arka Samrat (58.9%).

Bacterial wilt incidence was high in open rainy season trial (63.7±13.7%) followed by polyhouse in rainy season (56.2±11.6%) and Open in dry season (46.9±9.2%). The highest incidence was recorded in G-600 (66.4%) followed by Cherry tomato (64.5%) and Lakshmi (61.4%). Overall mean analysis showed that Ayushman (37.5%) and Arka Rakshak (38.1%) and Arka Samrat (41.1%) had minimum levels of bacterial wilt incidence. The Lakshmi had become the most popular hybrid in the Islands for its peculiar taste, suitability and abundant yield in dry season but this

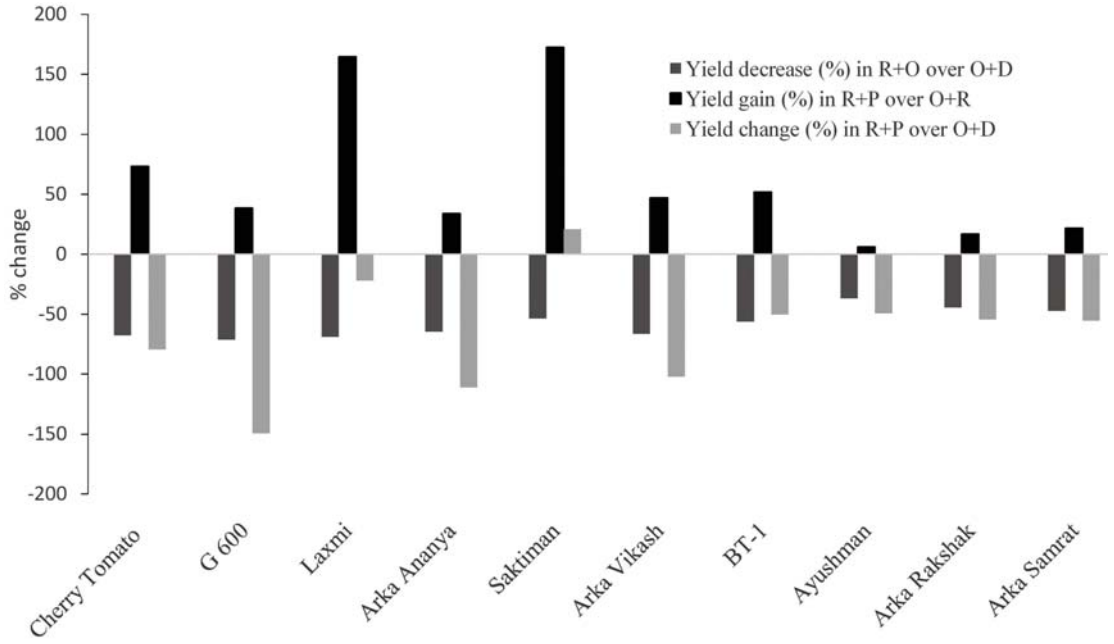

Fig. 1: Relative change in yield of tomato during rainy open and rainy polyhouse conditions over dry open condition

also had wilt incidence of 52.5% suggesting for search of alternative varieties / hybrids having wilt resistance and similar taste. However, in Neil Island, this hybrid stands to be most popular due to relatively low incidence of bacterial wilt (Bhagat *et al.* 2004) associated to relatively higher soil pH value and calcium content (Singh *et al.* 2014) andpresence of antagonistic bacteria of the island's soil (Amaresan *et al.,* 2013).

The upland soils of the islands are towards acidic in reaction and low in calcium content and further, uptake of Ca was by high humidity. This could be seen in high incidence of Ca deficiency associated disorder 'Blossom end rot' which ranged from 3.4-29.8% in open condition in dry season, 5.7-40.8% in polyhouse in rainy season and open rainy season 13.2-40.4%. Overall, tomato hybrids / varieties showed high incidence of blossom end rot (31.7±8.2%) while minimum in dry season (15.8±7.9%). Cherry tomato had minimum incidence among all the tested varieties / hybrids in all three growing conditions. Maximum incidence was in Shaktiman, Arka Vikas and Shaktiman, respectively.

The farmers perception / observations were found to be true for high incidence of flower and fruit drop in rainy season (62.0±4.5%) while in polyhouse condition it was 55.2±8.9%. Varieties / hybrids had significant difference in flower and fruit drop in polyhouse

Table 2. Economic analysis of tomato cultivation in Andaman and Nicobar Islands

Varieties	Gross return (₹, Lakh/ha)			Net return (₹, Lakh/ha)			B:C ratio		
	D+O	R+O	R+P	D+O	R+O	R+P	D+O	R+O	R+P
Cherry tomato	6.06	2.92	5.06	3.39	0.25	-1.56	2.27	1.09	0.76
G 600	4.45	4.30	7.14	1.78	1.62	0.52	1.66	1.61	1.08
Laksmi	3.13	3.23	10.26	0.45	0.56	3.64	1.17	1.21	1.55
Arka Ananya	3.29	3.88	6.23	0.61	1.20	-0.39	1.23	1.45	0.94
Saktiman	2.42	3.76	12.28	-0.25	1.08	5.66	0.91	1.40	1.85
Arka Vikash	4.61	5.17	9.12	1.93	2.50	2.50	1.72	1.93	1.38
BT-1	2.84	4.15	7.55	0.16	1.47	0.93	1.06	1.55	1.14
Ayushman	5.27	11.11	14.14	2.60	8.44	7.51	1.97	4.15	2.13
ArkaRakshak	5.54	10.24	14.35	2.87	7.56	7.73	2.07	3.83	2.17
Arka Samrat	5.09	8.95	13.08	2.41	6.28	6.46	1.90	3.35	1.98

Cost of cultivation for open dry and rainy season crops: ₹ 2.65 lakhs/ha; polyhouse rainy season: ₹ 6.62 lakh/ha. Tomato price: cherry tomato @ ₹ 60/kg; open dry season tomato @ ₹ 15/kg, open rainy season @ 50/ka and polyhouse rainy season @ 60/ka.

condition in rainy season while they had difference in other two conditions but it was not significant. Notably, it was also high in open condition during dry season (56.7±6.3%). Continuous high level of moisture in rainy season in open condition, lack of pollination activities in polyhouse condition and strong winds and occasional heavy rains by cyclones during reproductive stage of tomato crop were main factors for high flower and fruit drop in tomato during dry season. G 600 had minimum overall flower and fruit drop (49.2%) while it was maximum in Arka Ananya (62.8%) and Cherry tomato (62.7%). High humidity (>90%) and frequent heavy rains during in prolonged period of rainy season (May - November) in the Andaman Islands interfere with pollination activities and promote vegetative growth (Lawson and Rands, 2019). Regulated moisture condition by plastic mulching and proper stalking in open condition and ensuring adequate pollination measures inside the polyhouse are suggested measures for higher fruit setting and fruit retention in polyhouse tomato crop in the islands.

Tropical islands are having typical climatic conditions in terms of precipitations and weather parameters. Therefore, to make these islands self-sufficient in terms of local vegetable production varieties selection and suitable method of cultivation is the subject of important issue. Under this experiment, to counter these risks this study was planned and implemented. The economic analysis revealed that under dry condition the hybrids Arka Rakshak, Ayushman and G 600 have given better returns in the range of ₹ 2.41 to 2.87 lakh / ha / year (Table 2). However, other varieties / hybrids performed in same weather conditions but the net return ranged ₹ -0.25 to 1.93 lakh / ha / crop. The return from the Cherry tomato was ₹ 3.39 lakhs / ha in dry season while in rest of the season, its performance was not satisfactory due to poor fruit setting and high incidence of bacterial wilt. Further, preference of the Cherry tomato-1 was limited to hotels, tourists and premier consumers, hence it have limited requirement in the market. However, the prices remained higher than normal tomato.

During rainy season open conditions, Arka Rakshak, Ayushman, Arka Smarat performed better in terms of net returns were higher. However, others could not perform well. The possible reason was, high infestation of disease, rain damage, and varietal differences *etc*. This could be the reason for farmers are not interested to cultivate tomato in this season and as a result of this consumer have to pay high price during this season. During rainy season all the varieties performed well in protected cultivation due to crop protection from heavy rains. The net returns were very high for some of the promising varieties. The B:C ratio

Table 3. Risk associated with rainy season tomato cultivation in Andaman Islands defined by local farmers

Risks identified	Likert scale score						Risks aversion options						
	Average score	STD	High yielding varieties/ hybrids	Resistant varieties/ hybrids	Plant stalking	Rain-shelter/ poly-house	Grafting	Growing media	Raised bed	Plastic mulching	Insecti-cides	Upland sites
Crop damage by heavy rains	4.91	1.05	9.5	10.0	8.0	10.0	6.0	-	10.0	8.0	-	10.0
Low yield of varieties/hybrids	4.86	1.04	8.2	8.2	7.0	10.0	9.0	6.0	8.0	9.0	6.0	7.0
Bacterial wilt	4.08	0.91	7.4	10.0	6.5	-	10.0	8.0	8.0	7.0	2.5	9.0
Flower and fruit drop	3.96	0.75	7.6	9.0	7.0	7.0	3.0	3.0	6.0	3.5	3.4	4.5
Soil moisture (excess in rainy season and deficit in dry season)	3.8	1.00	5.1	7.4	6.0	9.0	7.0	5.4	9.0	7.0	-	8.0
Diseases and pests (other than bacterial wilt)	3.56	0.58	6.4	10.0	6.4	8.0	4.5	4.4	6.8	2.5	8.0	4.4
Fruit defects (cracking, rotting)	3.43	0.72	8.0	10.0	7.0	8.0	7.0	4.2	6.0	5.0	-	4.2
Flooding and submergence	3.28	1.07	7.6	8.0	6.5	6.0	8.0	2.6	7.0	-	-	10.0
Weed problem	3.14	0.95	10.0	9.0	5.0	6.0	2.0	3.0	7.0	6.0	-	5.0
Mean			7.8	9.1	6.6	8.0	6.3	4.6	7.5	6.0	5.0	6.9

Likert Scale defined as: strongly agree=5, agree=4, neutral=3, not agree=2, strongly not agree=1, STD is standard deviation of scores; Farmers observations recorded during interactions/trainings; -No score given.

also was worked out to see the direction on economic returns. It was found that BC ratio was more than one which indicate that these varieties are economical feasible for tropical islands. Only for few cases in rainy open conditions some varieties could not give positive BC ratio. The possible reason may be due to more damage and disease infestation during rainy season. This problem was checked through protected cultivation. Therefore, we received B:C ration more than one. Thus, tomato cultivation is possible during adverse conditions under protected cultivation in tropical islands.

The higher the Likert scale score value indicates that particular attribute is having higher impact on the tomato crops production in tropical islands (Table 3). Therefore, we observe that crop damage by heavy rains, lack of varieties for rainy season and bacterial wilt received more than four and higher standard deviation value. This implies that farmers perceived heavy rains, lack of variety and infestation of bacterial wilt are strongly agreed risks by majority of farmers while other risks like flower drops, disease and natural calamities are observed to medium level of risks since score value was less than four. Therefore, risks aversion eco-friendly technologies developed by the agriculture scientists need to be adopted. Hence, this will help in sustaining the off-season tomato cultivation in tropical Islands.

The techno-feasibility of the available option showed that the resistant varieties / hybrids (9.1) followed by rainshelter / polyhouse had overall maximum score (7.8) and raised bed (7.3) among the local farmers. Farmers had perception that resistant varieties could be feasible solution for crop losses due to heavy rains, bacterial wilt, diseases and pests and fruit defects as they scored maximum score (10) for them to consider as complete solution. Further, rainshelter / polyhouse were still considered as most effective way to protect crops from heavy rains and grafting for bacterial wilt.

CONCLUSION

Tomato cultivation could be an economically viable option to local growers in rainy season both in open and protected condition. However, it requires to select suitable hybrids (Arka Rakshak, Ayushman and Arka Samrat). The polyhouse cultivation was found to be economically viable with B:C ratio > 2.0 for only two hybrids Ayushman and Arka Rakhsak in islands.

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Effect of integrated nutrient management on coconut (*Cocos nucifera*) based cropping systems in south Gujarat

P P Bhalerao[1], H P Maheswarappa[2] and S Sumitha[3*]

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ASPEE College of Horticulture and Forestry, NAU, Navsari, Gujarat 396 450 , India

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ABSTRACT

An experiment was conducted on 27-year-old coconut (*Cocos nucifera* L.) garden to evaluate the productivity of coconut- based cropping system involving banana *(Musa sp.)*, elephant -foot yam (*Amorphophallus paeoniifolius* [Dennst] Nicolson), tannia (*Xanthosoma sagittifolium* L.) and turmeric (*Curcuma longa* L.) with three integrated nutrient management (INM) practices, viz., T_1- 75% of recommended dose of fertilizers (RDF) + 25% of N through organic recycling with vermicompost, T_2- 50% of RDF + 50% of N through organic recycling with vermicompost + vermiwash application + biofertilizer application + *in situ* green manuring (sunhemp), T_3- fully organic: 100% N through organic recycling with vermicompost + vermiwash application + biofertilizer application + *in situ* green manuring (sunnhemp) and green leaf manuring + composted coir pith, husk incorporation, and mulching with coconut leaves were imposed in coconut-based cropping system. For comparison, T_4- control: monocrop of coconut with recommended NPK was maintained. Four treatments were laid out in a block of 0.25 ha area each for five years (2015-16 to 2019-20). Results showed that yield under T_2 (146 nuts/palm) and T_3 (136 nuts/palm) were on par and differed significantly compared to monocrop (117 nuts/ palm). With respect to component crops yield, *viz.*, banana (8.27 t/ha), elephant- foot yam (13.90 t /ha), tannia leaves (65,605) and turmeric rhizome yield (12.06 t/ha) were higher under T_2 treatment. The maximum gross and net returns were recorded in T_2 (₹ 6,08,285 and ₹ 4,35,167) with BC ratio of 2.50, followed by T_1 (₹ 5,35,226 and ₹ 3,71,789) with BC ratio of 2.20.

Key Words: Coconut, Cropping system, Coastal, Productivity, Nut yield.

The area under coconut in Gujarat has increased from 15,978 ha in 2006-2007 to 26,911 ha in 2018-2019 with a productivity of 9,646 nuts/ha (CBD 2020). The economic returns from coconut plantations need to be augmented through coconut - based mixed cropping. A well-spaced coconut garden provides adequate inter and intra-row spaces where it is possible to grow a variety of useful seasonal, perennial and commercial crops (Nath *et al.*, 2019 and Shinde *et al.*, 2020). Adoption of coconut- based inter cropping is one of the means to effectively utilize the natural resources such as land, water, light and space. There are several reports to indicate the beneficial effects of such cropping systems Maheswarappa *et al.*, 2013). The productivity of land is increased in an intercropping system due to the yield of intercrops in addition to coconut yield (Maheswarappa and Sumitha, 2018). The selection and inclusion of crop components are influenced by climate and also by household preferences, and dietary habits. With this background, there is a gap in the research front about the impact of organic and integrated nutrient management practices under coconut-based cropping system. Hence, an experiment was conducted to evaluate the effect of integrated nutrient management practices on yield and economics of systems in South Gujarat.

MATERIALS AND METHODS

The experiment was conducted at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari during 2015-16 to 2019-20 in a 27-years-old hybrid coconut (D × T) garden spaced at 7.5 m × 7.5 m. The mean annual rainfall during 2015 - 2019 was about 1650 mm. The soil of

*Corresponding author : sumithasundaram12@gmail.com
[1] Asst. Professor, HRS, (ICAR-AICRP on Palms), ASPEE College of Horticulture and Forestry, NAU, Navsari, Gujarat.
[2] Project Coordinator (Palms) ICAR-CPCRI, Kasaragod, Kerala.
[3] Scientist, ICAR- CPCRI, Kasaragod, Kerala.

experimental site was dark greyish- black having clay in texture with medium fertility status. The pH was 7.9 - 8.1. Coconut- based cropping system with banana *(Musa sp.)* + elephant-foot yam (*Amorphophallus paeoniifolius* [Dennst.] Nicolson) + tannia (*Xanthosoma sagittifolium* L.) and turmeric (*Curcuma longa* L.) was initiated in coconut field during 2015 and managed with the INM package of practices. The crops grown with their mean population level over the experimental period are given in Table 1.

Integrated nutrient management (INM) practices;

T_1 75% of recommended dose of fertilizers (RDF) + 25% of N through organic recycling with vermicompost.

T_2 50% of RDF + 50% of N through organic recycling with vermicompost + vermiwash application + biofertilizer application + in situ green manuring with sunhemp.

T_3 **Fully organic :** 100% of N through organic recycling with vermicompost + vermiwash application + biofertilizer application + *in situ* green manuring with sunhemp and green leaf manuring (*Glyricidia* leaves) + composted coir pith, husk incorporation (once in three years) and mulching with coconut leaves.

T_4 **Control :** monocrop of coconut with recommended NPK and organic manure.

The quantity of different fertilizers and manures applied for different crops was as per the package of practice of NAU. Biofertilizer, i.e. *Azotaobacter* was applied in particular treatments with proper mention dose (109 cfu / g of carrier). Sunhemp was grown as green manure crop in coconut (basin), banana, turmeric (trench), tannia and EFY crops in system and was incorporated during June and September except turmeric (once in July). Quantity of recyclable biomass from the system was converted into vermicompost in the pits made for the purpose. The vermiwash was applied after diluting to 1:10 proportion as per the treatments to different crops. In addition to this *Glyricidia* leaves grown along the border were used as green manure crop and were applied for coconut and intercrops in the month of June and September. All the required inorganic and organic manures were applied in two equal split doses. Husk incorporation was followed before planting of crops and husk incorporated in the trenches was followed in each set of four coconut palms (once in 3 year). Dried coconut leaves were used for mulching in summer months (February-May) in order to reduce the evaporation of moisture from the soil.

The observation on number of functional leaves and annual production of bunches were recorded. The nuts were harvested periodically at maturity from July to June and pooled to get nut yield per palm per year. Copra content in a nut was recorded by drawing random sample of six nuts per treatment at each harvest, dehusking, separation of kernel from shell, drying in shade and averaging over harvests. Copra yield per palm was computed based on the copra content in the nut in each treatment.

The statistical design was non-replicated, whereas experimental block of each treatment was laid out in 0.25 ha coconut garden and intercropping with varieties of tuber, spices and fruit crop was adopted. The input cost mentioned includes labour (imputed and actual), fertilizer, plant protection measures, irrigation and other miscellaneous overhead charges. The market rates of various inputs and outputs (coconut and other crop produces) during different years were considered to work out the economics. As the experiment was laid out in a block of 0.25 ha area for each treatment, the weather parameters during the year influence the productivity of the system. Hence, in the analysis, year effect was taken as fixed effect in the ANOVA table, and treatment effect as error. The statistical analysis was performed using Statistical Analysis System 9.3 computer software (SAS Institute Inc., 1995). DMRT procedure was used at P=0.05 level to determine the significance among the treatments.

RESULTS AND DISCUSSION

The pooled data of five years from 2015-16 to 2019-20 showed that the number of leaves on the crown and annual leaf production of coconut did not differ significantly under coconut- based cropping system with INM practices. There was significant difference among the INM treatments in respect of nut yield and it was highest with the treatment T_2 (palms are treated with 50% RDF + 50% organic manures (146 nuts

Table 1. Crop species grown in coconut-based INM system

Crop	Variety /hybrid	Spacing	No. of plants/block	No. of plants/ha
Coconut	D x T	7.5m x 7.5 m	48	176
Banana	Grand Naine	3.5m x 2.7m	198	741
Elephant- foot yam	Gajendra	90 x 90 cm	387	5760
Tannia	Local	90 x 60 cm	582	8640
Turmeric	Sugandham	30 x 20 cm	5250	77766

palm^{-1}), followed by T_3 (136 nuts palm^{-1}) and significantly lower (117 nuts palm^{-1}) in monocrop (Table 2). Enhancement of coconut yield due to combined application of inorganic fertilizer and organic manure has been reported by previous workers in coconut (Shinde *et al.,* 2020; Farsanashamin and Anilkumar, 2016; Maheswarappa *et al.,* 2013; and Krishnakumar and Maheswarappa, 2010). With respect to copra content (g nuts^{-1}) and copra output (kg palm^{-1}), significant improvement was also observed under different INM practices, wherein T_2 registered the highest copra content (161.4 g nut^{-1}) and copra output (22.1 kg palm^{-1}) followed by T_3 (155.1 g nut^{-1} & 20.2 kg palm^{-1}) as compared to coconut monocrop. The results obtained are similar with the finding of Kalpana *et al.* (2008); Sahoo *et al.* (2004) and Venkitaswamy and Hameed Khan (2002). The improvement in nut yield of the main crop by intercropping is also supported by the findings of Nath *et al.* (2019); Bhalerao *et al.* (2016); Maheswarappa *et al.* (2013) and Basavaraju *et al.* (2011). Organic matter addition generated from each component crops act as barrier to loss of soil and moisture in surface runoff, facilitate nutrient addition and improve the microclimate. Also, air relative humidity will be higher and soil water availability for intercrops will be maintained at a higher level because of less evaporation from the soil with lower crop transpiration rates (Selva Rani *et al.,* 2019).

Tannia is cultivated for its edible leaves and corms and it was observed that number of leaves harvested per ha (65,605) was increased progressively with the application of 50% RDF + 50% organic manures (T_2) followed by application of 75% RDF + 25 % N through organic manures (56,069) (T_1). These results were in conformity with Susan John *et al.* (2013) who evolved an integrated nutrient management strategy for tannia and found the highest yield and net returns under intercropping in coconut with INM package.

Elephant-foot yam corm yield was varied significantly with INM practices (Table 3) and INM treatments T_2 recorded significantly the highest corm yield (13.90 t ha^{-1}) followed by T_1 (11.60 t ha^{-1}) compared to fully organic (T_3). Present results are in accordance with the finding of Maheswarappa *et al.* (2013) and Ravindran and Kabeerathumma, (1991).

Turmeric is being a long duration (8-9 months) and exhaustive crop and requires heavy nutrition for getting higher yield and quality. In present studies, the results revealed that the application of fully organic with recycling biomass + bio-fertilizer + mulching with coconut leaves + in-situ green manuring + glyricidia pruning's (T_3) was noted significantly the highest yield (13.14 t ha^{-1}) of rhizome. These results were in accordance with the findings of Dinesh *et al.* 2010 also reported that application of organic manures and biofertilizers improved soil fertility, which in turn

Table 2. Growth and yield of coconut as influenced by integrated nutrient management in coconut- based cropping system (pooled data 2015-16 to 2019-20)

Treatment	Number of functional leaves on crown	Annual leaf production (Number)	No. of bunches/ palm	Nut yield / palm/year	Nut yield/ ha	Copra content (g /nut)	Copra output (kg /palm)
T_1	33.8	12.3	12.3	125.4	22070	146.2	17.9
T_2	35.3	12.6	13.0	146.3	25498	161.4	22.0
T_3	33.9	12.1	12.3	136.8	24080	155.1	20.2
T_4	32.4	11.8	10.0	117.5	20680	141.5	16.6
Mean	33.88	12.25	12.45	131.52	23082	151.09	19.22
SEm. ±	1.02	0.09	0.29	7.26	529.44	4.26	1.21
CD (P=0.05)	NS	N.S.	1.03	22.91	1597.72	13.10	3.68

Table 3. Yield of component crops influenced by integrated nutrient management in coconut- based cropping system (pooled data 2015-16 to 2019-20)

Treatment	Banana (t/ha)	Elephant -foot yam (t/ ha)	Tannia (No. of leaves/ha)	Turmeric (t/ ha)
T_1	7.32	11.16	56069.20	10.96
T_2	8.27	13.90	65605.00	12.06
T_3	6.78	9.13	42178.20	13.14
Mean	7.46	11.40	54617.47	12.05
SEm. ±	0.39	0.27	724.12	0.34
CD (P=0.05)	0.78	0.78	2209.8	1.06

Table 4. Economics of coconut- based cropping system (mean of five years)

Treatment	Cost of cultivation (₹/ha)	Gross Return (₹/ha)	Net return (₹/ha)	BCR
T_1	1,63,437	5,35,226	3,71,789	2.20
T_2	1,73,118	6,08,285	4,35,167	2.50
T_3	1,86,714	5,83,872	3,97,158	2.10
T_4	99,879	2,44,296	1,45,417	1.40

Selling price: coconut = ₹ 12/nut, banana = ₹ 6/kg, turmeric = ₹ 25/kg, EFY = ₹ 20/kg, tannia = ₹ 0.50/leaf

improved the yield of turmeric.

The yield of banana variety 'Grand Naine' was influenced by INM treatments and T_2 recorded significantly higher yield (8.27 t / ha). Higher yield with INM practices under coconut- based cropping system has been reported by Maheswarappa *et al.* (2013).

The data on economics of INM (Table 4) revealed that the maximum gross and net returns were recorded in T_2 (₹ 6, 08,285 and ₹ 4, 35,167) with BC ratio of 2.50 followed by T_1 (₹ 5, 35,226 and ₹ 3, 71,789) with BC ratio of 2.20, whereas Treatment T_4 recorded the lowest gross income (₹ 244296). These results showed that crop diversification could help the farmers to realize better returns even if the price of one commodity gets reduced in any year. These results are in line with previous workers who observed the increased pecuniary income in the coconut-based intercropping systems (Naveen Kumar *et al.* 2017 and Maheswarappa *et al.* 2013). The use of inorganic and organic fertilizers in the form of integrated nutrition management in coconut fields, proved to be an important combination for sustainable productivity in coconut- based cropping system. Thus, it is concluded that use of organic manures, such as vermicompost, green manuring, and biofertilizers along with chemical fertilizer is essential to sustain the productivity over a period of time.

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Effect of FYM and gypsum on growth and yield attributing traits on radish *(Raphanus sativus)* using RSC water

Desh Raj Choudhary*, Avtar Singh, VPS Panghal and Vikash Kumar

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Department of Vegetable Science, CCS Haryana Agricultural University, Hisar

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ABSTRACT

The response of treatments comprising three levels each of farmyard manure (0, 10 and 20 tonnes/ha) and gypsum (0, 50 and 100% neutralization of RSC) were laid out in a factorial RBD with three replications in a net plot of 3.0 m × 3.0 m at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, during 2017-18 and 2018-19. The application of farmyard manure and gypsum individually and in combination significantly influenced growth, yield traits and seed yield of radish (*Raphanus sativus* L.) cultivar Punjab Safed. Among the interaction combinations, plant height at harvesting, number of pods/plant, pod weight, pod length, number of seeds/pod, seed recovery (%), seed yield (g/plot), seed yield (kg/ha), biological yield (q/ha) and harvest index (%) were significantly maximum in F_2G_2 treatment, where, farmyard manure was applied at the rate of 20 tonnes/ha in combination with 100% neutralization of RSC by gypsum during both the years.

Key Words: FYM, Gypsum, RSC water, Seed yield, Yield traits

The productivity of radish (*Raphanus sativus* L.) in India is very less which may be due to unavailability of quality water in arid and semi-arid regions. Further, ground water is either saline or alkaline and almost 60% of it as such is not suitable for irrigation (FAO, 2001). Salinity problem develops if salts accumulate in crop root zone to a concentration, which causes a great loss in crop yield (Pandian *et al.,* 2016). The long-term sodic water irrigation may adversely affect quality of seed, soil and microbial biomass carbon along with some physico-chemical properties of soil (Kaur *et al.*, 2008; Yadav *et al.,* 2016). Their repeated applications over the years enhance calcium deficiency and deteriorate soil physical condition due to the presence of sodium and magnesium in excess quantity (Satyavan *et al.*, 2006). Although, during emergency, such water could be used with special management practices depending upon the rainfall, crop to be grown and soil kind. Keeping in view, an experiment was conducted to see the effect of farmyard manure and gypsum with high RSC water on growth, yield traits and seed yield of radish.

*Corresponding author : desraj1992@gmail.com

MATERIALS AND METHODS

The experiment was conducted at Vegetable Research Farm of the Department of Vegetable Science, CCS HAU, Hisar, 215.2 m above mean sea level during 2017-18 and 2018-19. The soil was sandy loam with 19.6% clay and cation exchange capacity 9.3 C mol/kg in 0-30 cm layer. The experiment comprise three levels each of farmyard manure (0, 10 and 20 tonnes/ha) and gypsum (0, 50 and 100% neutralization of RSC) in a randomized block design (factorial) replicated thrice having plot sized 3.0 m × 3.0 m. The 45-day-old stecklings of radish cv. Punjab Safed were planted in December give year at a spacing of 60 cm (R×R) × 45 cm (P×P) comprising 33 plants/plot. The seedlings are prepared by cutting, two-thirds lower portion of root and shoot and one-third portion left. The seedling was treated with Carbendazim 0.2% per litre before planted in the field.

The data were recorded from five randomly selected plants from each treatment of each replication for plant height (cm) at harvesting, number of leaves/plant at harvesting, number of pods/plant, pod weight (g), pod length (cm), number of seeds per pod, seed recovery (%), seed yield (g/plot), seed yield (kg/ha),

Table 1. Effect of different levels and interaction between FYM and gypsum on growth, yield traits and seed yield of radish (pooled data)

Treatment	Plant height (cm) at harvesting	Number of leaves/plant at harvesting	Number of pods/ plant	Pod weight (g)	Pod length (cm)	Number of seeds/ pod	Seed recovery (%)	Seed yield (g/plot)	Seed yield (kg/ha)	Biological yield (q/ha)	Harvest index (%)
Farmyard manure											
F_0	122.47	1.93	241.97	0.12	4.80	4.43	78.07	215.89	239.88	23.47	9.67
F_1	129.50	2.31	368.79	0.14	5.23	5.06	84.29	321.31	357.01	31.74	10.71
F_2	135.39	2.66	394.82	0.16	5.78	5.69	88.29	449.17	499.07	35.87	13.08
SEm±	0.12	0.04	1.24	0.001	0.02	0.02	0.18	0.87	0.97	0.39	0.15
CD (p=0.05)	0.36	0.11	3.71	0.003	0.07	0.06	0.53	2.62	2.91	1.16	0.45
Gypsum											
G_0	121.36	1.78	234.59	0.11	4.53	4.23	76.44	185.56	206.17	22.29	8.91
G_1	131.91	2.46	375.37	0.15	5.46	5.30	85.74	363.92	404.36	33.77	11.32
G_2	134.08	2.67	395.62	0.16	5.81	5.64	88.47	436.89	485.43	35.02	13.23
SEm±	0.12	0.04	1.24	0.001	0.02	0.02	0.18	0.87	0.97	0.39	0.15
CD (p=0.05)	0.36	0.11	3.71	0.003	0.07	0.06	0.53	2.62	2.91	1.16	0.45
Interaction effect											
F_0G_0	115.45	1.47	216.20	0.09	4.25	3.57	68.89	118.67	131.85	19.81	6.58
F_0G_1	124.60	2.00	238.47	0.12	4.74	4.57	80.80	235.17	261.30	25.93	9.64
F_0G_2	127.36	2.33	271.23	0.14	5.40	5.17	84.52	293.83	326.48	24.67	12.78
F_1G_0	123.05	1.67	229.73	0.11	4.49	4.23	78.48	195.67	217.41	22.04	9.75
F_1G_1	131.68	2.53	429.27	0.15	5.48	5.37	86.10	347.43	386.04	35.19	10.66
F_1G_2	133.76	2.73	447.37	0.16	5.70	5.57	88.30	420.83	467.59	38.0	11.72
F_2G_0	125.58	2.20	257.83	0.13	4.85	4.90	81.95	242.33	269.26	25.02	10.39
F_2G_1	139.47	2.83	458.37	0.17	6.17	5.97	90.32	509.17	565.74	40.19	13.66
F_2G_2	141.12	2.93	468.27	0.18	6.32	6.20	92.59	596.0	662.22	42.41	15.18
SEm±	0.21	0.07	2.14	0.002	0.04	0.04	0.44	1.51	1.68	0.67	0.26
CD (p=0.05)	0.63	NS	6.43	0.005	0.13	0.11	0.92	4.54	5.04	2.0	0.78

F_0-no farmyard manure, F_1-10 tonnes/ha, F_2- 20 tonnes/ha; G_0- no gypsum, G_1 - 50% of gypsum, G_2-100% of gypsum, NS-non-significant

biological yield (q / ha) and harvest index (%). The data was averaged for computation on per plant basis and statistically analysed as per Gomez and Gomez (1984) using the statistical programme developed by O.P. Sheoran.

RESULTS AND DISCUSSION

The application of different levels of farmyard manure and gypsum had significant effect on vegetative growth, yield traits and seed yield of radish (Table 1). There was maximum plant height and number of leaves / plant at harvesting under 20 tonnes / ha farmyard manure (F_2), *i.e.* 135.39 cm and 2.66, respectively which was minimum under 10 tonnes / ha farmyard manure (F_1) and the control (F_0). This is might be due to application of farmyard manure which minimized the harmful effect of sodicity and increased the availability of nutrients. Similar trends were found during both the years of study. The results are in confirmation with those of Upadhyay *et al.* (2012) and Kumar *et al.* (2019).

The pooled data indicated more number of pods / plant (394.82), pod weight (0.16 g), pod length (5.78 cm), number of seeds / pod (5.69), seed recovery (88.29%), seed yield (449.17 g / plot), seed yield (499.07 kg / ha), biological yield (35.87 q / ha) and harvest index (13.08%) under 20 tonnes / ha farmyard manure (F_2) as compared to 10 tonnes / ha farmyard manure (F_1) and the control treatment (F_0). This might be due to that farmyard manure in general improved physical and chemical properties of soil. The results confirm the findings of Bilekudari *et al.* (2005) and Kaswan *et al.* (2017).

There was maximum plant height and number of leaves / plant at harvesting under 100% neutralization of RSC by gypsum (G_2), *i.e.* 134.08 cm and 2.67, respectively which was significantly more to 50% neutralization of RSC (G_1) and the control treatment (G_0). This might be due to that gypsum neutralized the sodicity effect of water. Same trends were found during both the years of study. The similar effects of gypsum have been reported by Kumar *et al.* (2017).

There were significantly maximum number of pods / plant (395.62), pod weight (0.16 g), pod length (5.81 cm), number of seeds / pod (5.64), seed recovery (88.47%), seed yield (436.89 g / plot), seed yield (485.43 kg / ha), biological yield (35.02 q / ha) and harvest index (13.23%) under G_2 treatment, where 100% neutralization of RSC was done by gypsum as compared to the control. The reason for such response might be due to that gypsum neutralized the sodicity effect of water increasing yield traits and seed yield. Same findings have also been reported by Singh *et al.* (2013) and Kumar *et al.* (2017).

The interaction combinations of farmyard manure and gypsum at different levels had significant effect on the plant height at harvesting, number of pods / plant, pod weight, pod length, number of seeds / pod, seed recovery, seed yield, biological yield and harvest index (Table 1). The significantly maximum plant height at harvesting (141.12 cm), number of pods / plant (468.27), pod weight (0.18 g), pod length (6.32 cm), number of seeds / pod (6.20), seed recovery (92.59%), seed yield (596.0 g / plot), seed yield (662.22 kg / ha), biological yield (42.41 q / ha) and harvest index (15.18%) were obtained in F_2G_2 treatment combination where farmyard manure was applied 20 tonnes / ha with 100% neutralization of water sodicity.

This might be due to that gypsum neutralized the sodicity effect of water and farmyard manure in general improved the chemical properties like pH, EC and ESP of soil. Higher harvest index indicated proportionally more increase in seed yield and straw yield due to higher translocation of photosynthates from source to sink. The results are in confirmation with the findings of Tripathi *et al.* (2013), Singh *et al.* (2013), Kaswan *et al.* (2017), Kumar *et al*. (2017) and Kumar *et al*. (2019).Positive response of organic manure, biofertlizers has been reported in gladiolus by Chakradhar *et al.* (20200 in gladiolus and Yadav and Kavita (2016) in cabbage.

CONCLUSION

Thus, it was concluded that application of 20 tonnes / ha farmyard manure in combination with 100% neutralization of RSC by gypsum enhanced radish seed since both improved the growth, yield traits and seed yield during both of the years.

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Evaluation of oxyfluorfen and quizalofop-ethyl weedicides for weed control in onion (*Allium cepa*)

Rakesh Kumar* and Pramod Kumar Gupta[1]

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Krishi Vigyan Kendra (NHRDF), Ujwa, New Delhi 110 073, India

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ABSTRACT

An on-farm trial to evaluate Oxyflurofen and Quizalofop ethyl weedicides for weeds control on Onion (*Allium cepa* L.) was undertaken during *Rabi* 2015-16, 2016-17 and 2017-18 at farmer fields in south west district of Najafgarh, New Delhi. The study the herbicidal treatment combination were taken of Oxyfluorfen @ 150 ml/ha + Quizalofop-ethyl @ 750 ml/ha foliar spray 35 days after transplanting recorded lower weed density (39.66/m^2), dry matter weight of weeds (42.22 g/m^2) and higher weed control efficiency (77.61%), followed by treatment$_1$ farmers' practice (Pendimethalin + one hand- weeding) 48.21%. The application of Oxyfluorfen @ 150ml/ha + Quizalofop-ethyl @ 750 ml/ha foliar spray 35 days DAT proved to be most effective weed control treatment, recording highest bulb yield (277.44 q/ ha), net return (₹ 171, 952/ha) and B:C ratio (3.77), followed by farmers' practice (252.22 q/ ha), net return (₹ 129276/ha) and B:C ratio (3.01). The increased returns as a result of increased quality bulb yield of onion with pre-post herbicides applications showed significant effect with more appreciation.

Key Words: Bulb yield, Farmers fields, Weed management, Weed density

Onion (*Allium cepa* var. aggregatum L.) is widely cultivated all over the world. Its productivity is very less as compared to the national average due to a number of factors but the main constraint is weed infestation depending upon the nature of intensity and duration of weed competition, weed infestation can reduces bulb yield up to 40-80% (Vishnu *et al.*, 2014). The herbicides become the vital part of crop production and its current use is approximately 47% of the world's pesticide consumption. In India, due to acute labour scarcity and boom in cost of weed management, the herbicide use has been increased 30-33% currently (Sondhia, 2014). The conventional methods of weed control (hoeing and hand weeding) are laborious, expensive and time consuming. Moreover, due to non-availability of timely labour, weeds are not controlled at the proper stage. In view of the facts, evaluation of Oxyflurofen 23.5% and Quizalofop Ethyl 5% EC herbicides on weed yield of onion and their economics was done.

MATERIALS AND METHODS

On-farm trial for weeds control in onion (*Allium cepa* L.) at farmers' fields in south west district of Najafgarh, New Delhi, during *rabi* 2015-16, 2016-17 and 2017-18. A series of adaptive on-farm trials were conducted at farmers' fields on the same sites. Five farmers were selected and experiment was laid out on 0.4 ha area of each. The soil and irrigation water quality were almost similar for all selected farmers' fields and all recommended packages of practices were adopted uniformly. The combination of Oxyfluorfen 23.5% EC @ 150 ml/ha + Quizalofop Ethy l 5% EC @ 750 ml/ha foliar spray at 35 DAT and farmers practice, i.e. Pendimethalin + one hand weeding as the control at five different locations (replication) of the same village, respectively.

The experiment was conducted on sandy loam/ sandy clay loam and light to medium in texture, low water-holding capacity, pH slightly saline with low organic matter content. The experiment was laid out in randomized block design, consisting of two treatments, *viz.* T_1- (control) farmers' practice (pendimethalin + one hand-weeding), T_2 combination of Oxyfluorfen @ 150ml/ha + Quizalofop Ethyl @ 750 ml/ha foliar spray at 35 DAT. About 45 days old onion seedlings of onion, NHRDF Red were transplanted in the plot with a spacing of 15 cm × 10 cm. All recommended packages

*Corresponding author : rakesh4565k@gmail.com
[1]Director, NHRDF, Janakpuri, New Delhi

of practices were adapted uniformly to all the treatments except weed management practices to raise a good crop. The data were recorded for plant height and yield. The economics was calculated on the basis of prevailing local market price of onion bulbs and cost of inputs.

Weed flora differ widely in their diversity depending upon environmental and soil conditions, hence the information on weed spectrum in onion field will be of great use for the formulation of effective weed management practices. The observations on weed density (weeds / m^2) and dry- matter weight of weeds (g / m^2) were recorded 90 days after transplanting of seedlings by placing a quadrate of 50 cm × 50 cm randomly from three places in each plot. Based on weed control, weed count efficiency was calculated using following formula.

$$WCE\ (\%) = \frac{DMC - DMT}{DMC} \times 100$$

where, DMC is dry-matter weight of weeds in the control plot and DMT dry-matter of weeds in treated plots. The data on plant height (cm) and bulb yield (q / ha) were recorded from net plot at harvesting. Economic analysis was done as per prevailing market prices of different outputs and inputs.

RESULTS AND DISCUSSION

The weed density / m^2 at all growth stages was significantly lowest in weed-free treatment. Among the herbicidal treatment, Oxyfluorfen @ 150 ml / ha + Quizalofop Ethyl @ 750 ml / ha recorded significantly least number of weeds (39.66 / m^2) over other treatment like farmers' practice (85.21 / m^2). Similar results were reported by Sabel *et al.* (2013). Early post emergence application of Quizalofop-ethyl at 750 ml / ha recorded lower weed density and dry weight which resulted in increased yield of onion under grass dominated field conditions (Dhananivetha *et al.,* 2015). These results are in agreement to the finding of Kolse *et al.,* (2010), Sable *et al.* (2013) and Shinde *et al.,* (2012) and Pugalendhi *et al.,* (2011).

The treatment Oxyfluorfen @ 150 ml / ha + Quizalofop Ethyl @ 750 ml / ha recorded the lowest weed biomass (42.32 g / m^2) and weedy check treatments farmers' practice recorded highest weed biomass (89.99 g / m^2). This might be due to highest weed intensity and its dominance which utilized the sunlight, nutrients, moisture *etc.* over crop plants and resulted into higher growth and ultimately the higher weed biomass in weedy check. An increase in bulb yield of onion by 62.69% with pendimethalin at 2.5 l / ha than unweeded plots was recorded by Zubiar *et al.* (2009).

There was significant variation among treatments. The trends of weed control fluctuated due to environment factors and responses of proper weeds management practices was positive (Table 1). The highest weed control efficiency (77.61%) was recorded with treatment T_2 and lowest (48.21%) with treatment T_1. In onion, pendimethalin at 1.0 kg / ha + hand-weeding and oxyfluorfen at 0.24 kg / ha recorded higher weed control efficiency of 80.6 and 73.4 per cent (Patel *et al.,* 2011). Pre-emergence application of oxyfluorfen (23.5% EC) at 200 g / ha recorded lesser weed density and dry weight in onion (Sathya Priya *et al.,* 2013). The higher weed control efficiency in these treatments might be due to significant reduction in weed dry matter because effective weed control practices through application of pre-emergence and / or post-emergence herbicides. Similar results were also reported by Shinde *et al.,* (2013).

Significantly highest total bulb yield (277.44 q / ha) was recorded in T_2 and plant height 39.55 cm. This might be due to vigorous growth of crop due to availability of sufficient nutrient, moisture, light and space owing to absence of weed or presence of minimum weed densities because of higher weed control efficiency which would compete for the same. This enabled plants to efficiently utilize sunlight and water for photosynthesis which leads to higher plant height, increased number of leaves and finally the increase in bulb yield.

The lowest onion bulb yield (252.22 q / ha) was recorded in farmers practice as the presences of more weed which interfered with growth and development of the crop and compete for the nutrients, moisture, light and space. The similar results were reported by Vashi *et al.,* (2011), Bharathi *et al.,* (2011), Patel *et al.,* (2012). Plant height, number of leaves, fresh and dry weight were higher under weed-free condition and pendimethalin treated plots. Taller plants, neck thickness and dry matter accumulation were observed under pendimethalin applied plots by Patel *et al.,* (2011). Rahman *et al.* (2012) reported lower bulb yield of onion in weedy check to the fact that weeds appeared immediately after sowing and competed with onion crop until harvesting. Higher bulb yield was recorded under early post emergence application of quizalofop-ethyl under grass dominated field as recorded by Dhananivetha *et al.,* (2015) Plant height, number of leaves, fresh and dry weight were found to be higher under weed free condition and pendimethalin treated plots as reported by Sharma and Khandwe (2008). Taller plants, neck thickness and dry matter accumulation was observed under pendimethalin applied plots by Patel *et al.,* (2011).

Table 1. Weed density, weed control efficiency and dry matter weight of weeds as influenced by different treatments

Treatment	Weed density/ m^2			Weed control efficiency (%)			Dry matter weight (g/m^2)		
	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18
T_1 - Farmers' practice (Pendimethalin+ one hand weeding)	88.66	82.66	84.33	44.66	47.66	52.33	95.33	89.33	85.33
T_2 - Oxyfluorfen 23.5% EC @ 1ml/Lwater + Quizalofop Ethyl 5% EC @ 2ml/L water 35 days after DAT	38.33	41.33	39.33	78.86	76.33	77.66	38.66	41.66	46.66

Table 2. Growth and yield as influenced by different treatments

Treatment	Plant height (cm)			Yield (qt/ha)		
	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18
T_1 - Farmers' practice (Pendimethalin+one hand weeding)	33.66	31.33	30.33	284.00	255.00	217.66
T_2 - Oxyfluorfen 23.5% EC @ 1ml/Lwater + Quizalofop Ethyl 5% EC @ 2ml/L water 35 days after DAT	40.66	40.33	37.66	304.00	286.66	241.66

Table 3. Effect of herbicides on yield

Treatment	Bulb yield (q/ha)			Cost of cultivation (₹/ha)			Net monetary returns(₹/ha)			B:C ratio
	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18	
T_1 - Farmers' practice (Pendimethalin + one hand weeding)	284.0	255.0	217.6	63500/-	65000/-	65000/-	154700/-	131500/-	101628/-	3.0
T_2 - Oxyfluorfen 23.5% EC @ 1ml/Lwater + Quizalofop Ethyl 5% EC @ 2ml/L water 35 days after DAT	304.0	286.7	241.7	61250/-	62500/-	62500/-	168200/-	154328/-	193328/-	3.77

Economics

The gross monetary returns (₹ 2,33,952 / ha) and net monetary returns (₹ 1,71,952 / ha) were significantly higher in weed-free treatment Oxyfluorfen @ 150 ml / ha + Quizalofop Ethyl @ 750 ml / ha 35 DAT (Table 3). It was followed by farmer's practice (pendimethalin + one hand weeding) which recorded gross monetary return (₹ 1, 93,776 / ha) and net monetary return (₹ 1,29,276 / ha.) Oxyfluorfen @ 150 ml / ha + Quizalofop Ethyl @ 750 ml / ha foliar spray at 35 DAT recorded highest benefit cost ratio, (3.77) followed by farmer's practice (pendimethalin+ one hand-weeding) (3.01). Economic analysis by Patel *et al.*, (2011) revealed that higher net profit (₹ 2,69,422 / ha.) in onion crop was obtained with application of pendimethalin at 1.0 kg / ha+ HW on 40 DAT, followed by oxyfluorfen at 1.0 kg / ha + HW on 40 DAT (₹ 2,51,910 / ha) and weed free control. In onion higher net return (₹ 1,85,600 / ha.) was registered with the application of oxyfluorfen (Saini and Walia, 2012).

The higher net monetary returns were obtained with preemergence application of oxyfluorfen at 100 g / ha supplemented with one hand-weeding on 25 DAT (₹ 33,650 ha^{1}) followed by fluchloralin at 750 g ha^{-1} + hand weeding (₹ 31,983 / ha), pendimethalin at 750 g / ha + hand weeding (₹ 31,450 / ha) and oxyfluorfen at 200 g / ha (₹ 31,400 / ha). There was net loss of ₹ 3,900 / ha under weedy check. Pre-emergence application of pendi-methalin at 1.00 kg / ha supplemented with one hand-weeding in onion gave the higher net return of ₹ 51,296 / ha with maximum benefit cost ratio of 8.77.

CONCLUSION

The application of Oxyfluorfen @ 150 ml / ha + Quizalofop Ethyl @ 750 ml / ha foliar spray 35 DAT recorded lower weed density (39.66 / m^2), dry matter weight of weeds (42.22 g / m^2) and higher weed control efficiency (77.61%), followed by farmers' practice (Pendimethalin + one hand-weeding) 48.21%. The treatment also gave highest bulb yield (₹ 277.44 q / ha), net return (₹ 1,71,952 / ha) and B:C ratio (3.77), followed by farmers' practice bulb yield (252.22 q / ha), net return (₹ 1,29,276 / ha) and B:C ratio (3.01).

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Varietal assessment of chrysanthemum (*Dendranthema grandiflora*) under south Gujarat agro-climatic conditions

S L Chawla[1*], R B Patel[2], B K Dhaduk[3], Sudha Patil[4] and Dipal Bhatt[4]

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ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat 396 450

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ABSTRACT

The study was carried out to evaluate 20 varieties of chrysanthemum (*Dendranthema grandiflora* Tzvelev) for three years, viz. 2009-10, 2010-11 and 2011-12 in *rabi* season. Wide variations were recorded in growth, flowering and yield parameters. The maximum plant height (58.27 cm) and branches/plant (11.91) were recorded in Ratlam Selection, while Maghi recorded maximum plant spread (39.94 cm). The Harvest recorded earliest flowering (63.38 days), whereas maximum flowering duration (60.22 days) was found in Ravi Kiran. Significantly maximum diameter of flower (8.55 cm) and weight of 10 flowers (47.96 g) were recorded in Miss India. Variety Maghi gave highest number of flowers/plant (133.78), whereas Silk Brocade recorded maximum flower yield (200.29 g/plant and 288.44 q/ha). Dolly White recorded maximum vase-life (11.44 days), whereas IIHR-6, Miss India, Shyamal, CS-16 and Yellow Gold were found sensitive to aphid. The highest net realization as well as Benefit: Cost Ratio were recorded by Ratlam Selection because of higher price due to white colour and good quality flowers which are in more demand.

Key Words: Varieties, Flower diameter, Vase-life, Variation

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) ranks third in production after jasmine and rose. Since most chrysanthemum improvement programmes concentrate on aesthetic qualities such as flower and plant characteristics, genetic base of the modern cultivars is becoming more and more narrow. Coupled with global marketing and adoption of these cultivars worldwide, many heir loom varieties of these crops are being replaced by modern narrow genetic base cultivars, resulting in continuous loss of our traditional cultivars of high potential. Hence, characterization of germplasm is essential to provide information on the traits of accessions assuring the maximum utilization of the germplasm collection for the benefit of end user. However, very little systematic study has been done to evaluate chrysanthemum varieties in south Gujarat. Therefore, an experiment was designed to identify high-yielding varieties of chrysanthemum for farmers of south Gujarat.

*Corresponding author : shivlalchawla@yahoo.com
[1] Associate Professor
[2] Retd. Associate Professor
[3] Retd. Professor & Head
[4] Assistant Professors, ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari, Gujarat 396 450.

MATERIALS AND METHODS

The present study was carried out for three under Establishment of Research Project on Floriculture at Floriculture Research Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) which comes under the south Gujarat Heavy Rainfall Zone-I, AES-III. Navsari is situated at 20° 95' North latitude and 75° 95' East longitude at an altitude of 10 meters above mean sea level. The experiment consisted of twenty varieties, viz. Shyamal, IIHR-6, Silk Brocade, Flirt, Himani, John Webber, Miss India, Ravi Kiran, Nilima, Harvest, Ratlam Selection, Maghi, Red Gold, Dolly White, Jaya, Ragini, CS-16, Yellow Gold, Sonar Bangla and Punjab Gold for evaluation as treatments and replicated thrice in randomized block design which were statistically analysed as suggested by Panse and Sukhatame (1985). Rooted cuttings of 40 days old having 4-5 true leaves were planted at the spacing of 30 cm in row to row distance and 30 cm in plant-to-plant distance on raised beds of 15 cm height in the first week of October.

Uniform cultural practices were adapted for all varieties. Five plants were randomly selected from each treatment for recording observations on vegetative and flowering parameters, except yield per ha which was estimated on the basis of net plot area. Only mean data of pooled analysis of three years.

RESULTS AND DISCUSSION

It is apparent from the data (Table 1) that varieties of chrysanthemum evaluated under the study significantly differed in vegetative and flowering characteristics. Plant growth which is considered to be a good index of plant vigour also contributes towards greater productivity. The maximum plant height (58.27 cm) was recorded in Ratlam Selection followed by Red Gold (54.33 cm) and Jaya (54.10 cm), while minimum plant height was found in Himani (32.84 cm). Significantly maximum plant spread (39.94 cm) was recorded in Maghi which was followed by CS-16 (34.85 cm) and Silk Brocade (34.49 cm), whereas minimum spreading of plant was obtained in Miss India (23.68 cm). However, Ratlam Selection produced significantly maximum number of branches per plant (11.91) which was at par with IIHR-6 (10.84) and Ragini (10.60) while Himani produced minimum branches (6.11). Vegetative characters like plant height, spread and number of branches are attributed to be an important varietal character that depends upon the genetic constitution. The variation in vegetative characters among the various genotypes might be due to genotypic differences in phenotypic expression of characters and which is further modified by prevailing environmental conditions. Ratlam Selection had maximum plant height with maximum branches which showed vigorous vegetative growth and these are important characters which might be helpful in yielding good quality flowers. Similar findings have also been reported by Roopa *et al.* (2018) and Swaroop *et al.* (2019).

The harvesting recorded the earliest induction of flowering variety (63.38 days) which was at par with variety CS-16 (67.38 days) and Ratlam Selection (67.82 days), while late flowering was started in Maghi (97.84 days). Moreover, maximum duration of flowering (60.22 days) was recorded in Ravi Kiran followed by Harvest (52.78 days) while shortest flowering period of 30.56 days was noticed in Himani. Difference in number of days for flower bud appearance among different cultivars might be due to presence of sufficient genetic traits in different varieties of chrysanthemum.

Table 1. Vegetative and flowering parameters as influenced by different varieties of chrysanthemum (pooled data of 3 years)

Variety	Plant height (cm)	Plant spread (cm)	Branches per plant	Days to first flowering	Flowering duration (days)
Shyamal	45.36	26.33	7.00	78.27	43.78
IIHR-6	53.35	24.09	10.84	68.76	40.60
Silk Brocade	44.97	34.49	8.96	83.93	39.24
Flirt	41.79	24.64	6.84	82.31	39.40
Himani	32.84	26.12	6.11	75.98	30.56
John Webber	50.39	30.86	10.24	70.24	46.47
Miss India	42.10	23.68	7.51	88.00	37.36
Ravi Kiran	44.89	29.88	8.16	91.64	60.22
Nilima	44.74	28.25	8.62	73.56	39.42
Harvest	38.47	30.03	9.49	63.38	52.78
Ratlam Selection	58.27	27.29	11.91	67.82	45.16
Maghi	49.34	39.94	10.38	97.84	46.82
Red Gold	54.33	25.67	9.04	69.09	47.58
Dolly White	35.64	29.50	9.07	70.16	39.91
Jaya	54.10	33.95	7.84	91.84	40.33
Ragini	44.43	33.60	10.60	78.38	43.09
CS-16	42.00	34.85	8.36	67.38	42.62
Yellow Gold	44.48	32.50	7.42	69.02	30.64
Sonar Bangala	36.06	28.48	7.84	68.33	43.00
Punjab Gold	33.27	25.36	9.24	68.82	44.20
CD (5%)	3.24	3.33	1.34	4.78	3.85
CV (%)	7.74	12.03	16.27	6.68	9.62

The early flower bud appearance had been primarily dependent upon food reserve in plants that could be related to growth rate of plant regulating accumulation of carbohydrates (Uddin *et al.,* 2015). This could be due to more dry-matter accumulation because of absorption of more nitrogen and other nutrients and nutrients uptake in addition to prevailing favourable environment *i.e.* low night temperature and short day lengths. The genetic control of all these characters and modification in their expression due to species type and prevailing environmental conditions might be possible causes of observed variation (Kim *et al.,* 2014).

The maximum flower diameter (8.55 cm) and weight of 10 flowers (47.96 g) were recorded in Miss India followed by Silk Brocade (7.69 cm and 40.25 g, respectively) while smallest flowers were produced by Dolly White (3.65 cm) with minimum weight of 10 flowers (14.73 g) (Table 2). This variation may be due to differences in genetic make-up of cultivars as well as genotypic differences in phenotypic expression of flower diameter (Baskaran *et al.,* 2010). The weight of flowers are clearly in relation with size of flowers. The greater the size of flowers, greater would be the fresh weight of flowers. This variation in flower weight among varieties might be attributed to the higher water and carbohydrates level in the flower. Water plays a very important role to maintain flower turgidity, freshness and petal orientation. The ultimate effect of all these factors resulted into strong and long flower stalks, large sized buds or flower and finally increases in flower weight (Kanamadi and Patil, 1993). Similar variations have also been reported previously by Singh and Baboo (2013), Gupta *et al.* (2013) and Kumar *et al.* (2013).

Significantly maximum number of flowers / plant (133.78) was recorded in Maghi followed by Jaya

Table 2. Economics of different varieties of chrysanthemum

Variety	Flower yield (q/ha)	Income (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C ratio
Shyamal	113.73	341181.13	173940.53	167240.61	0.96
IIHR-6	97.37	389477.19	172713.70	216763.49	1.26
Silk Brocade	218.44	436878.82	181793.96	255084.87	1.40
Flirt	144.79	434364.76	176270.12	258094.64	1.46
Himani	78.03	273096.66	171263.07	101833.58	0.59
John Webber	134.32	402953.60	175484.84	227468.76	1.30
Miss India	115.58	462324.77	174079.59	288245.18	1.66
Ravi Kiran	191.58	478950.93	179779.53	299171.40	1.66
Nilima	88.58	265731.87	172054.30	93677.57	0.54
Harvest	103.26	309786.60	173155.67	136630.94	0.79
Ratlam Selection	157.51	630026.14	177223.99	452802.15	2.55
Maghi	157.42	393557.35	177217.72	216339.63	1.22
Red Gold	169.29	507863.63	178107.59	329756.04	1.85
Dolly White	116.76	350279.11	174167.98	176111.13	1.01
Jaya	183.62	459054.09	179182.62	279871.47	1.56
Ragini	153.71	307413.70	176939.01	130474.69	0.74
CS-16	123.12	492470.65	174644.82	317825.82	1.82
Yellow Gold	113.08	452339.09	173892.36	278446.73	1.60
Sonar Bangla	87.99	351956.57	172010.19	179946.39	1.05
Punjab Gold	99.67	398669.99	172886.06	225783.93	1.31

Selling price of flowers		**Input cost (₹)**
Varieties	(₹/kg)	
IIHR-6, Miss India, Ratlam Selection, CS-16 Yellow Gold, Sonar Bangla, Punjab Gold	40	1. Rooted cutting = ₹ 1/cutting
Himani	35	2. Picking = ₹ 0.75/kg
Shyamal, Flirt, John Webber, Nilima, Harvest, Red Gold, Dolly White	30	3. Common cultivation cost = ₹165411/ha
Ravi Kiran, Jaya, Maghi	25	
Silk Brocade, Ragini	20	

(124.13), whereas minimum flowers (27.45) were produced by Miss India. Number of flowers is related to recurrent blooming habit due to their genetic make-up (Vetival and Jawaharlal, 2014) that could have also been influenced by environmental conditions, especially temperature and photoperiod prevailed during the experimental trial period in chrysanthemum (Parul Punetha *et al.,* 2011). Variation in number of flowers in chrysanthemum germplasm was also reported by Baskaran *et al.* (2004), Joshi *et al.* (2009), Uddin *et al.* (2015), Ona *et al.* (2015), Kulkarni and Reddy (2004) and Kumar (2014).

The maximum flower yield (200.29 g/plant and 218.44 q/ha) were recorded by Silk Brocade, followed by Ravi Kiran (173.44 g/plant and 191.58 q/ha). Significantly minimum production was noted in Himani (70.64 g/plant and 78.03 q/ha). Higher yields were due to heavier flowers, vigour of plants, plant height and flower diameter. The varietal differences with respect to number of flowers, flower weight and yield are genetically determined when grown in similar environments (Palai, 2009). The variation in flower yield is might be due to optimum flower size and presence of fairly more number of ray florets and thickness of ray florets (Uddin *et al.,* 2015).

The maximum vase-life (11.44 days) was recorded in flowers of Dolly White, followed by Maghi (10.76 days), while minimum vase-life (8.04 days) was noted in IIHR-6. Highly significant variation for vase-life in plain water among different chrysanthemum varieties may be due to different genetic make-up with prevailing environmental conditions, which finally affects physiological processes like cell turgidity, water uptake through xylem tissue, water loss through transpiration, respiration and breakdown of the reserved food and senescence responsible enzyme which reduce vase life under lab condition.

With respect to disease and pest incidence, IIHR-6, Shyamal, CS-16 and Miss India were found slightly sensitive to aphid infestations, while rest of the varieties were resistant. The variation in infestation among varieties was attributed to genotype of plant, environmental influence and other management factors. These resistant varieties can be useful for development of resistance variety in future.

Looking to the economics (Table 2), maximum net return (₹ 4,52,802.15/ha) as well as BCR (2.55) were recorded by Ratlam Selection followed by Red Gold (₹ 3,29,756.04/ha and 1.85, respectively). Net return with highest BCR in Ratlam Selection is due to huge market demand of white coloured flowers with more prices. Thus, it was concluded that Ratlam Selection (white) is most suitable chrysanthemum variety for commercial cultivation under south Gujarat agroclimatic conditions. Moreover, there is market demand for yellow and red colour which can be met by growing Red Gold (red) and CS-16 (yellow) varieties which produce better quality flowers.

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Study of floral biology and meiotic behaviour in kantakari *(Solanum surattense)*

M Boomiga[1*], J Suresh[1], M Kumar[2], L Nalina[1], R Gnanam[3], K Rajamani[1] and D Uma[4]

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[1]*Department of Medicinal and Aromatic Crops, HC & RI, TNAU, Coimbatore*

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ABSTRACT

The experiment was conducted to study floral biology and meiotic behaviour in kantakari *(Solanum surattense)* at the Department of Medicinal and Aromatic crops, TNAU, Coimbatore during 2019-2020. The observations were recorded on basic morphology, floral characters, floral biology and meiotic behaviour. There was about 4-7 branches with medium violet flowers present in clusters. Heterostyly mechanism similar to brinjal is also observed. Flowers were long style set fruits, while the short and pseudo style do not come to fruiting unless it is pollinated manually. Both self and entomophilies (honey bee) mode of pollination were observed. Hence, kantakari behaves like an often cross- pollinated crop. The peak time of anthesis (64.70%) was observed between 3 and 5 AM. Anther dehiscence happens immediately after anthesis. During cell division, triad formation takes place instead of tetrad. This basic study is useful information to start breeding programme.

Key Words: Kantakari, Anthesis, Anther dehiscence, Heterostyly, Floral biology, Meiosis

Kantakari (*Solanum surattense* Burm. F), belonging to family, Solanaceae, is a spreading annual plant with thorns in all parts except flowers. This plant can be seen in dry tracts, roadsides and wastelands. Due to over exploitation for its high medicinal value and indiscriminate and destructive collection from the habitat, the species is in threatened position and lead to an endangered status (Khan and Frost, 2001). There is huge number of information describing its uses. But, availability of crop and cultivation practices are not up to the expectations. Basic studies on understanding its botany, floral biology are important for development of elite varieties for desirable cultivation. Hence, an experiment was conducted to study its reproductive biology, floral biology and chromosomal behaviour.

MATERIALS AND METHODS

The experiment was conducted at the Department of Medicinal and Aromatic Crops, Tamil Nadu Agricultural University, Coimbatore, during 2019-2020 to study the basic information on branching pattern, number of branches, number of flower clusters, date of initiation of flower cluster, days for anthesis, nature of flower and days taken for initiation of flower cluster to anthesis, time of anthesis, time of anther dehiscence, stigma receptivity and heterostyly in kantakari. Since, there is no DUS for kantakari, observations were taken based on DUS of brinjal. Meiosis study was done using young buds (3-4 days of flower cluster initiation) collected during morning hours (9.00 - 10.00 AM) and fixed with glacial acetic acid and alcohol (1:3).

The buds were rinsed with distilled water. Anthers were carefully taken out with the help of sterilized forceps and needles and kept on sterilized slides. Gentle tap was given to the anther to release the pollen mother cells (PMC) from the anther. A drop of acetocarmine was added to squeezed PMC. Cover slip was placed in the slide and gentle heat was given. Then slide was observed under the compound microscope with 40X magnification to see the different phases of meiosis.

RESULTS AND DISCUSSION

Kantakari is normally a spreading annual with 4-7 branches. Thorns are present in stem, leaves, petioles, internodes and even in calyx. Flowers are medium in size, violet in colour and present in clusters

*Corresponding author : boomigamani@gmail.com
[2] Department of Plant Breeding and Genetics, TNAU, Coimbatore
[3] Department of Biotechnology, CPMB&B, TNAU, Coimbatore
[4] Department of Biochemistry, TNAU, Coimbatore

but not solitary. Four to six flowers are present in a cluster. Leaf, flower and other morphological characters in also investigated like kantakari in bael (Singh et al., 2021). This crop is grouped under self-pollinated crop but cross-pollination also occurs to an extent of 30%. Hence, this crop comes under often cross-pollinated crop category. The cone shaped anther is sufficient for self pollination but the protruded stigma and visit of insects (honey bee) make this crop as often cross pollinated crop especially entomophilies. Similar findings were also reported in brinjal.

Anthesis was observed from 2.00 to 8.00 AM (Table 1). The peak time of anthesis was observed between 3 to 5 AM (64.70%). Anther dehiscence was observed immediately after anthesis. But times of anthesis and anther dehiscence are much influenced by geographical location, day length, sunlight and temperature. Diameter of the opening flower was recorded at 20 minutes interval from 4.00 AM to 6.30 AM. It was 1.00 cm at 4.10 AM and it reaches 3.00 cm by 6.30AM. This study is done by observing the anthesis time on 51 flowers. Kantakari partially behaves like brinjal for anthesis and anther dehiscence. In brinjal, anthesis starts from 6-7.30AM extends upto 11AM. Peak anthesis time is 8.30-10.30AM. Anther dehiscence takes place from 9.30 to 10AM. In bael anthesis was reported from 5. 00AM onwards (Singh *et al.*, 2011 and 2016).

The flowers are present in clusters not solitary as mentioned. Different length of style, viz. long styled, short styled and pseudo-styled flowers are present. Four to six flowers are found per cluster. Among them, 2-3 flowers are short and pseudo styled. In long styled flowers, the length of the style was about 7-9 mm and in short styled flowers, length of the style is about 3-4 mm. The ratio of long and short or pseudo styled flowers are recorded as 3:1. Long styled flower only sets fruits. Short styled flowers do not resulted in fruits unless it is pollinated manually. While pseudo short styled flowers never set fruits even if it is pollinated manually. In brinjal also, the same finding was reported with 4 types of styles, viz. long, medium, short and pseudo short styled flowers. Long (70-86.7 %) and medium (12.5-55.6%) styled flowers set fruits whereas short and pseudo styled flowers never set fruits.

Table 1. Time of anthesis in *Solanum surattense*

Time	No. of flowers opened out of 51 flowers	Flower opening (%)
2.00 AM - 3.00 AM	8	15.00
3.00 AM - 4.00 AM	17	33.33
4.00 AM - 5.00 AM	16	31.37
5.00 AM - 6.00 AM	7	13.73
6.00 AM - 7.00 AM	2	3.92
7.00 AM - 8.00 AM	1	1.96

The meiosis study was done to know the chromosomal behaviour during different stages of meiosis. The study revealed triad formation of PMC instead of normal division (tetrad formation) during the second division of meiosis.

CONCLUSION

Kantakari is spreading annual with thorns. It has about 4-7 branches with medium violet colour flowers present in clusters. Heterostyly mechanism is observed as that of brinjal. Flowers with long style set fruits while the short and pseudo style does not bear fruit unless it is pollinated manually. Both self and entomophilies (honey bee) mode of pollination are observed. Hence, it is an often cross-pollinated crop. In kantakari, peak time of anthesis (64.70%) was observed between 3-5 AM. Anther dehiscence happened immediately after anthesis. During cell division, triad formation takes place instead of tetrad. This basic study will give useful information to start up hybridization programmes.

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Vivipary in litchi (*Litchi chinensis*) : new report

Narayan Lal[1*], Awtar Singh[2], AK Gupta[3], ES Marboh[4], Abhay Kumar[5] and Vishal Nath[6]

Litchi (*Litchi chinensis* Sonn.), Sapindaceae family, is an evergreen subtropical fruit tree. A study was carried out at ICAR-NRC on Litchi, Muzaffarpur, during 2017-18 to assess the occurrence of vivipary in 600 open seedling populations. Based on morphological characters, 82 promising genetic stocks were identified and vegetatively propagated, and planted in the field in 2014 for further evaluation. Vivipary can be divided into two major different forms, viz. true vivipary and crypto vivipary. Litchi showed crypto vivipary in which zygotes significantly develop but do not penetrate the pericarp before dispersal.The fruits of litchi NRCL-29, when cut and exposed the seed, the germinated seeds inside fruit were found very clearly. Out of these, NRCL-29 exhibited most precocious for flowering and fruiting on account of third year of planting. However, stress can induce flowering and fruiting in younger plants.

Perspectives : The vivipary deserves more attention because it is unconventional and understudied reproductive strategy. There is ample opportunity to investigate the phenomenon of vivipary in litchi from physiological and evolutionary perspectives. The challenge is to fill in the gaps with knowledge and advantages of vivipary in litchi can be explored in problematic soil where germination is a most common problem so that it plays a role in contributing to the fruit industry of the world.

*Corresponding author : narayanlal.lal7@gmail.com
[1] Scientist, ICAR-Indian Institute of Soil Science, Bhopal
[2] Principal Scientist, Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi
[3,4,5]Scientist, ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar
[6] OSD, ICAR-IARI, Hazaribagh, Jharkhand

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New oil palm hybrids

H P Maheswarappa[1], R K Mathur[2], S Sumitha[1], M Kalpana[3], M S Gawankar[4] and M Tamil Selvan[5]

The intensive evaluation of African germplasm D × D and D × P of oil palm (*Elaeis guineensis* Jacq.) at ICAR-IIOPR, Pedavegi, resulted in identification of high-yielding accessions. Ten hybrid cross combinations were evaluated. The hybrid cross combination NRCOP-4 (Godavari Swarna) gave higher FFB yield (30.11 tonnes / ha) and appeared to have better prospects for adaptation under West Godavari area (Andhra Pradesh) and Tungabhadra command area (Karnataka). At Mulde (Maharashtra), hybrid NRCOP-2 (Godavari Ratna) recorded higher FFB yield (22.69 tonnes / ha) with better prospects under Konkan in Maharashtra. NRCOP 17 (Godavari Gold) recorded significantly highest FFB (28.37 tonnes / ha) yield under Cauvery Delta region in Tamil Nadu.

[1] ICAR-AICRP on Palms, ICAR-CPCRI, Kasaragod, Kerala
[2] ICAR-IIOPR, Pedavegi, Andhra Pradesh
[3] AICRP on Palms, HRS, Vijayarai, Andhra Pradesh
[4] AICRP on Palms, College of Horticulture, Mulde, Maharashtra
[5] AICRP on Palms, Agricultural Research Station, Pattukotai

Dr YSRHU Year of Citrus 2021-22

R V S K Reddy[1] and T Janakiram[2]

Dr Y S R Horicultural University, Venkataramannagudem, Andhra Pradesh, India

With the initiative of Dr T. Janakiram, Vice-Chancellor, Dr YSRHU, Andhra Pradesh, Sri Kurasala Kannababu Garu, Hon'ble Minister for Agriculture, Cooperation, Marketing & Food Processing, Government of Andhra Pradesh, announced the year 2021-22 as 'Dr YSRHU Year of Citrus 2021-22' and released its Logo on 8 June 2021. In our country, Citrus fruits are growing in Andhra Pradesh, Maharashtra, Assam, Punjab, Karnataka, Telangana, Bihar, Madhya Pradesh and Gujarat. In India, mandarins, sweet orange, limes, lemon, etc. hold a prominent place, covering 10.58 lakh ha with an annual production of 14.03 million tonnes and productivity of 13.26 tonnes / ha. Andhra Pradesh has a lot of scope to emerge as a citrus hub by expanding the area under acid lime and sweet orange, occupying 1.39 lakh ha with a production of 2.99 million tonnes and productivity of 21.52 tonnes / ha. The year of Citrus consists of:

Action Plan

- All the 42 institutes under Dr YSRHU have initiated the special programmes on Citrus.
- Planting of ten (10) citrus seedlings in block or border rows in all Colleges, Polytechnics, Research Stations and KVKs including Private Affiliated Colleges and Polytechnics under Dr YSRHU on 30 June 2021 same day as a mark of Dr YSRHU Year of Citrus.
- Conducting of training programmes on Citrus Production / Protection / Value-added Products to Village Horticultural Assistants / Village Agricultural Assistants of Rythu Bharosa Kendras, Farmers and Field Level Extension Personnel.
- Awareness programmes on Citrus technologies, especifically in adopted villages under 'Vice-Chancellor to Village Programme'.
- Every Monday Phone-in-Programmes and "Udyana Vani" programmes (community radio) on Citrus.
- Programmes on Citrus under "Udyana Mitra"- a supportive e-extension to RBK channel.
- Phone-in-Live on Citrus on Doordarshan.
- Webinars on Citrus technologies.
- Student READY programme on Citrus.
- Technological backstopping for Citrus FPOs in Andhra Pradesh.
- Documentation of success stories of Citrus farmers / entrepreneurs marketing personnel.
- International level seminars on Citrus in collaboration with ICAR-CCRI, Nagpur.
- Organization of 'Citrus Kisan Mela'.
- Student rallies by displaying placards on Citrus technologies.
- Encouraging students / staff to write songs / poems / *kavithas/harikatha/burrakatha* on Citrus.
- Honouring progressive successful Citrus farmers.
- Identify Dr YSRHU Innovative farmers.
- Commercialization of Citrus technologies
- Citrus technology posters for Rythu Bharosa Kendras.
- Creation of song on Citrus technologies
- Articles on Citrus technologies
- Release of souvenir on Citrus.

The awareness coupled with technological developments and potential for export of varieties has resulted in manifold increase in area and production. The climate in Andhra Pradesh is highly conducive to Citrus crop which has lead to drastic increase in production. Microirrigation systems have proved to be very useful in meeting its water requirement. Renewed efforts are being made consistently by Dr YSRHU to develop and refine varieties and technologies through certified disease-free quality planting material to increase the production through ICAR-AICRP Citrus Research Centre. The varieties released namely, Balaji of acid lime and Sathgudi of sweet orange are important milestones that have contributed for increase in productivity from 13.55 (2000-01) to 21.52 tonnes / ha (2020-21).

Acid Lime: Balaji

- Tolerant to citrus canker.
- Annual yield: 3000-5000 fruits / tree.
- Fruit weight: 40-50g.
- Fruits spherical, smooth and develops attractive yellow colour when fully ripe.
- Peel is very thin, adhering to segments.
- The juice sacs are slender and spindle shaped, juice 47%, and Brix 6-7°, acidity 6.8-7% and ascorbic acid 25-27mg / 100g of juice.
- Average number of seeds: 7 / fruit

Acid Lime: Petlur Selection-1

- Cluster bearer and high yielder than local varieties.
- Tolerance to bacterial canker disease.
- Juice percentage: 55.8
- Citric acid: 7.3 mg / 100g
- Yield during summer season: 210-220 kg fruits / plant / year.

[1]Director of Research; [2]Vice-Chancellor

Current Horticulture: Improvement, Production, Plant Health Management and Value-Addition

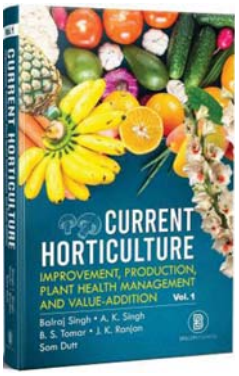
Singh Balraj, Singh A K, Tomar B S, Ranjan J K and Dutt Som (Eds)

Barillion Publishing, 22B/5, D.B. Gupta Road, Karol Bagh, New Delhi 110 005, India

E-mail: info@brillionpublishing.com

In our country, fruit, vegetable, flower, medicinal and plantation crops provide food, nutritional, health, economic and environmental security to the people. A number of books and manuals on horticultural crops have been brought by scientists and working groups. The books, ***Current Horticulture: Improvement, Production, Plant Health Management and Value-Addition,*** in two volumes, is a compilation of the latest scientific information to be followed for furtherance of horticultural science and will serve as an encyclopedia for all stakeholders.

In both volumes, consisting of 38 chapters each, authors have attempted to compile the advances in horticultural science, especially on improvement, production, post-harvest management and value-addition systematically. Both volumes cover prospects, challenges, research and developments related to horticultural crops, contributed by experts and eminent horticulturists. Authors have incorporated and compiled most of the scientific information; advances in crop improvement, production technology, biotic and abiotic stresses, and post-harvest management in



general and prospects, challenges and future thrust of horticultural crops in particular.

Major issues and concepts, and how to mitigate with changing climatic scenario have been elaborated perfectly and comprehensively in easy-to-understandable language. Overall the chapters are nicely written which will be of immense uses to the researchers, growers, industrialists, policy-makers, students etc. Thus, the wealth of information documented in these books will serve as a reservoir for exploitation of useful information on various horticultural aspects. Keeping in view the various issues related to horticultural crops, such books are the need of hour to enrich the knowledge of workers in the field of research and development as well as growers and horticultural entrepreneurs of the country.

— Dr T Janakiram
VC, Dr YSR Hort. Univ., Andhra Pradesh

Tribute to Dr Sanjay Singh


Late Dr Sanjay Singh

The SHRD salutes late Dr Sanjay Singh, the great horticulturist, died on 22 April 2021 owing to pandemic of Covid-19. Dr Singh was one of the founders and Honorary Fellow of the SHRD. He developed many varieties as developer and co developer of under-utilized hot semi-arid fruit crops, and a number of technologies. All of them have tremendous impact on farmers' economy, increasing the availability of nutritious fruits to masses. The varieties and technologies developed by Dr Sanjay Singh have increased fruit production, enriching the fruit basket of India. The striking features of his contribution are popularization of hot semi-arid underutilized and nutritionally rich fruits among common men. He was heading the CHES (ICAR-CIAH) at Godhra, Gujarat. Dr Sanjay has developed varieties of jamun (Goma Priyanka and Thar Kranti), mahua (Thar Madhu), chironji (Thar Priya), khirni (Thar Rituraj), phalsa (Thar Pragati), tamarind (Goma Prateek) and karonda (Thar Kamal), as a developer, besides many varieties of other fruit crops as co-developer.

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