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Research Review

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Improvement in cucurbits for drought and heat stress tolerance — a review

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ABSTRACT

Cucurbits are sensitive to environmental extremes, and thus high temperature and limited soil moisture are major causes of low yield in hot arid region and will be further magnified by climate change. Some abiotic stresses directly reduce growth, while others affect development in a way that reduces or eliminates the crop's value. The response of plants to environmental stresses depends on developmental stages and length and severity of the stress. Plants may respond similarly to avoid one or more stresses through morphological or biochemical mechanisms. Plant breeders need to translate these findings into stress-tolerant varieties by using all tools available that include germplasm screening, marker-assisted selection and genetic transformation besides conventional breeding methods. Therefore, breeding is one of the most efficient approaches for managing abiotic stresses. The genetically complex responses to abiotic stresses are multigenic and thus more difficult to control and engineer. Several abiotic stress tolerant varieties have been developed utilizing conventional breeding approaches. However, rapid progress is required to reduce the gap between potential yield and actual yield in abiotic stress prone environments. Thus, there is an urgent need of breeding climate-smart varieties of cucurbits tolerance to abiotic stresses which have great potential for meeting increased demand. Keeping in view, an attempt has been made to compile the scattered information on concepts, mechanisms and breeding approaches of abiotic stress tolerance in cucurbits.

Key Words: Abiotic stresses, Breeding approaches, Cucurbits, Drought stress, Heat stress

The crops belonging to family Cucurbitaceae are generally known as 'Cucurbits'. The family Cucurbitaceae includes about 118 genera and 825 species, many of which are economically important crops, notably those of the genera are *Cucumis, Cucurbita, Citrullus, Momordica, Lagenaria, Luffa, etc.* They consist of a wide range of vegetables either used for salad (cucumber) or for cooking (all gourds) or as dessert fruit (muskmelon, watermelon) or candied or preserved (ash gourd). Majority of cucurbits are characterized by presence of bitter principle, *i.e.* cucurbitacin at some portions of plant and at some stages of stages of development. Cucurbits are extensively grown in tropical, subtropical and milder zones of India.

They are good source of vitamin (A and C), calcium and iron and play an important role in nutritional security and economic viability of the country. India is the primary centre of several cucurbits like cucumber, ridge gourd, sponge gourd, wax gourd, pointed gourd, ivy gourd, certain species of watermelon and muskmelon (Vavilov and Löve, 1992). A wide range of genetic diversity exists among cucurbits in India and the important crops are listed in Table 1. Among cucurbits, watermelon, muskmelon, round-melon, bottle gourd, ridge gourd, *kachri*, longmelon, snapmelon, several non-dessertic forms of *Cucumis* species, *etc.* are mainly grown in arid regions of India.

Improvement in vegetable crops has traditionally focused on enhancing a plant's ability to resist pests and diseases. That is evidenced by the large number of disease- or insect-resistant / tolerance cultivars released and germplasm used in crop improvement programme. Research on crop resistance or tolerance to abiotic stresses (drought, heat, cold, excess of moisture, salt, pH, *etc.*) has not received much attention (Mou, 2011). On the other hand global warming is widely accepted as fact, although there are still different opinions and modeling results regarding how much the planet will warm up. The changing environments pose serious challenges to global agriculture and place unprece-

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Table 1. Cucurbitaceous crops found in India

Common name	Botanical name	Chromosome number (2n)
Cucumber *(khira)*	*Cucumis sativus*	14
Wild cucumber	*C. hardwickii*	14
Bitter gourd *(karela)*	*Momordica charantia*	22
Sweet gourd *(kakrol)*	*M. cochinchinensis*	28
Spine gourd *(kartoli)*	*M. dioica*	28
Ash gourd *(petha)*	*Benincasa hispida*	24
Ivy gourd *(kundru)*	*Coccinia grandis*	24
Snake gourd *(chichinda)*	*Trichosanthes anguina*	22
Pointed gourd *(parwal)*	*T. dioica*	22
Bottle gourd	*Lagenaria siceraria*	22
Ridge gourd	*Luffa acutangula*	26
Sponge gourd	*L. cylindrica*	26
Satputia	*L. hermaphrodita*	26
Chow-chow *(chayote)*	*Sechium edule*	28
Watermelon	*Citrullus lanatus*	22
Bitter apple *(tumba)*	*C. colocynthis*	22
Muskmelon	*Cucumis melo* L.	24
Snapmelon *(phoot)*	*C. melo var. momordica*	24
Kachri	*C. callosus*	24
Longmelon *(tar kakri)*	*C. melo var. utilissimus*	24
Arya	*C. melo var. chate*	24
Roundmelon *(tinda)*	*Pracitrullus fistulosus*	24
Pumpkin	*Cucurbita moschata*	40
Summer squash	*C. pepo*	40
Winter squash	*C. maxima*	40
Fig leaf gourd	*C. ficifolia*	40
Buffalo gourd	*C. foetidissima*	40

dented pressures on the sustainability of horticulture industry.

The warmer climate threatens the production of many vegetable crops in arid region, especially those summer season crops. The amelioration of crop environments is either impossible or costly. The breeding of varieties resistant to environmental stress is the most effective economical means to improve and stabilize yield under conditions of stress. Crop resistance to various environmental stresses is being improved by traditional and costly breeding methods that involve the stability of yield performance over different environments as a major criterion (Blum and Jordan, 1985).

Forecasts show that warming over the next several decades will take place irrespective of any action taken today. Therefore, development of vegetable crops that can cope with heat, cold, drought and other climate extremes brought by a warming planet may well be the single most important step to adapt to the changes in the future. However, breeding a new variety takes time, often about ten years. The ability to breed such new varieties is undermined by the rapid loss of biological basis of horticulture which is in turn accelerated by climate changes. There is an urgent need to mitigate these abiotic stresses through improvement of vegetable crops. Moreover, vegetables are more sensitive to abiotic stresses as compared to many other crops which cause huge loss in production worldwide. Seeing the large gap that exists between our country and other developed countries, breeders need to take collective action in developing new cultivars better suited to stress environments.

Genetic-environment interaction is to be optimized through research on both breeding and cultural practices. In vegetables, there is a great potential of breeding abiotic stress tolerance cultivars through the contributions of wild relatives (Kumar *et al.*, 2012; Shah *et al.*, 2018). This enormous and difficult task requires tremendous efforts from multiple disciplines. Stress physiology research identifies mechanism of stress tolerance and provides approach, method and traits

for screening stress-resistant genotypes. Plant breeders translate these findings into stress-tolerant crop varieties by using all tools available that include germplasm screening, marker-assisted selection, plant transformation and conventional breeding methods.

Several physiological and biochemical processes essential for plant growth and development are significantly affected by abiotic stresses. Cullis (1991) opined that a perceptive of how the interaction of physico-chemical environment reduces plant development and yield will pave the ways for a combination of breeding methods for plant modification to improve tolerance against abiotic stresses. Bhardwaj and Yadav (2012) reported that abiotic stresses modifies photosynthetic rate, relative water content, leaf water potential and stomatal conductance. Ultimately, it destabilizes the membrane structure and permeability, protein structure and function, leading to cell death. However, plant develops various defense mechanisms against stresses at the molecular, cellular and whole plant levels to withstand.

Therefore, comprehensive understanding of abiotic stresses in vegetables is a pre-requisite for plant breeders to evolve tolerant genotype by adopting suitable breeding methodology. There is no single mechanism by which stresses can be alleviated. Recent advances in stress physiology allow embarkation upon breeding programs that employ distinct physiological selection indices for stress tolerance. Using physiological selection indices in breeding work require the definition of the importance and effectiveness of given physiological attributes under stress conditions, the design of a proper selection scheme within the logistic framework of the breeding program and the development of rapid and effective selection techniques. These requirements, the progress made and the future prospects are discussed for tolerance to drought and heat stresses in cucurbits.

TYPES OF ABIOTIC STRESSES

Abiotic stress is defined as the negative impact of non-living factors on living organisms in a specific environment. The non-living variable must influence the environment beyond its normal range of variation to adversely affect population performance or individual physiology of organism in a significant way (Vinebrooke *et al.,* 2004). Abiotic stress is the most harmful factor concerning the growth and productivity of crops worldwide. Research has also shown that abiotic stressors are at their most harmful when they occur together, in combinations ofbiotic stress factors. The abiotic stress may be due to moisture (excess or low), temperature (heat or cold), salts, pH (high or low), hail strom, cyclone, high wind velocity, *etc*. In arid parts of the country mainly water stress (drought) and temperature stress (heat) significantly decreased plant growth, development and yield.

Water stress

Among the environmental variables affecting plant growth and development water stress is one of the most important. The water stress may arise either from an insufficient water or drought stress or from excessive water activity or water logging. Moisture stress is one of the greatest environmental factors in reducing yield in the arid and semi-arid tropics. Drought stress is the major abiotic stress for many Indian states *viz*. Rajasthan, parts of Gujarat, Haryana and Andhra Pradesh (Mitra, 2001). Sinha (1986) defined drought as the inadequacy of water availability, including precipitation and soil moisture storage capacity, in quantity and distribution during the life cycle of a crop plant that restricts the expression of full genetic potential of the plant.

Drought is often accompanied by relatively high temperatures, which promote evapo-transpiration and affects photosynthetic kinetics, thus intensifying the effects of drought and further reducing crop yields (Mir *et al.*, 2012). Earlier researchers, Blum and Jordan (1985), Blum (2005 & 2009) and Kumar *et al*. (2012)also reviewed the information on concepts, genetics and breeding approaches of drought tolerance in vegetable crops.

Drought Tolerance

Drought is a sustained period of time without significant rainfall. However, cucurbits being warm season crops which are mainly grown during summer season and require irrigations at critical stages, *viz*. germination, vegetative phase, flowering stage and fruiting stages. At genetic level, the adaptive mechanisms by which plants survive drought collectively referred to drought tolerance (Jones *et al.*, 1980). Leonardis *et al.* (2012) grouped the drought response mechanism into the following three categories (Fig. 1). However, crop plants make use of more than one mechanism at a time to tolerate drought.

i. ***Drought escape:*** The ability of a crop plant to complete its life cycle before development of serious oil and plant water deficits is called as drought escape. This mechanism involves rapid phenol logical development i.e. early flowering and maturity, variation in duration of growth period depending on the extent of water scarcity.
ii. ***Drought avoidance:*** Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite a shortage of soil moisture. This mechanism is associated with physiological

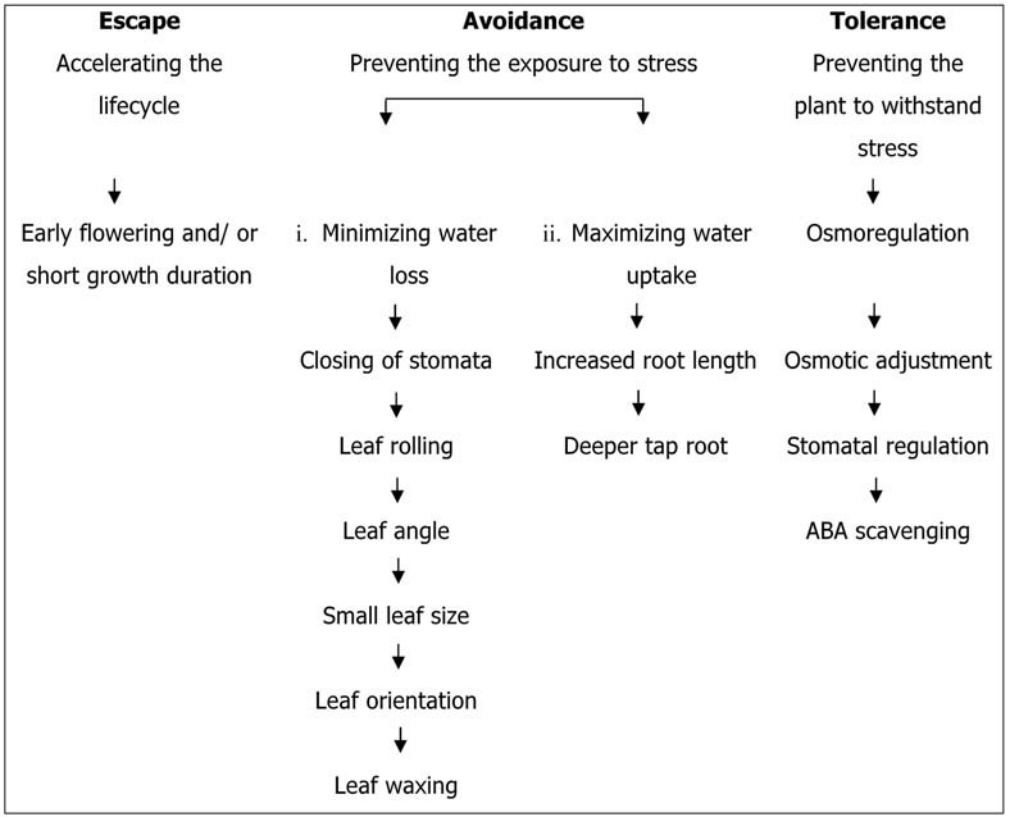

Fig. 1: Response mechanism of drought stress

whole-plant mechanisms such as canopy tolerance and leaf area reduction (which decrease radiation, adsorption and transpiration), stomatal closure, cuticular wax formation, adjustments of sink-source relationships through altering root depth and density, root hair development and root hydraulic conductance.

iii. ***Drought tolerance:*** The ability of a plant to produce its economic product with minimum loss under water deficit environment in relation to the water-constraint-free management is referred as drought tolerance (Mitra, 2001). Under drought condition, plants survive through a balancing act between maintenance of turgor with reduction of water loss. Drought tolerance mechanisms are balancing of turgor through osmotic adjustment (solute accumulation in cell), increase inelasticity in cell but decrease in cell size and desiccation tolerance by protoplasmic tolerance.

The drought tolerance mechanisms conferred by reducing water loss(such as stomatal closure and reduced leaf area) usually result in reduction of assimilation of carbon dioxide (Mitra, 2001). Drought tolerance can be increased through osmotic adjustment by maintaining plant turgor, but the increased solute concentration responsible for osmotic adjustment may have detrimental effect in addition to energy requirement for osmotic regulation. Therefore, crop adaptations to drought may be established through a balance between escape, avoidance and tolerance while maintaining adequate productivity. The source of drought tolerance may be cultivated varieties, landraces, relative wild species or introduced by genetic engineering. The potential sources of drought tolerance species and genotypes of cucurbits have been identified by More and Samadia (2008), More (2010), Choudhary and Sharma (2014) and Saroj (2017) and given in Table 2.

The other non-dessertic forms of Cucumis species like Banga, Kakdi, Mathkachra, etc. are naturally occurring in arid region are tolerant to drought.The success of any improvement programme of drought tolerance depends on selection criteria of germplasm therefore; it should be based on the following criteria.

- It should be easy to estimate/ score.
- It should have high (or at least moderate) heritability.
- A large genetic variability should exist for the trait.
- It should exhibit a significant association with drought (or the desired stress) tolerance.

Table 2. Drought tolerant genotypes/ species of cucurbits

Crop	Drought tolerant genotypes/ species	References
Kachri (*Cucumismelo* var. *callosus*)	AHK-119, AHK-200	Pandey *et al.,* 2011; Kusvuran, 2012 and Saroj, 2017
Snapmelon (*Cucumismelo* var. *momordica*)	VRSM-58, AHS-10, AHS-82	
Arya (*Cucumismelo* var. *chate*)	*Arya*	
Mateera / Watermelon	AHW-65, Thar Manak	More and Khan, 2009
	Citrullus colocynthis (L.) Schrad.	Dane and Liu, 2007

- It should exhibit a significant association with yield under stress.

Screening for drought tolerance

The diversity among the genotypes may serve as primary source for screening against drought stress. Drought tolerance is the interactive result of diverse morphological, physiological and biochemical traits and thus, these components could be used as strong selection criteria to screen out appropriate plant ideo type. Traditionally, plant breeders have addressed the problem of environmental stress by selecting for suitability of performance over a series of environmental conditions using extensive testing and biometrical approaches (Blum, 1988). Water stress, mostly at critical period of growth may drastically reduce productivity and quality of vegetables. Singh and Sarkar (1991) stated that a combination of different traits of direct relevance, rather than a single trait, should be used as selection criteria for drought stress. The screening procedure for drought tolerance is given in Table 3 and critical stages of drought stress and its impact in cucurbits is given in Table 4.

Table 3. Screening procedure for drought tolerance

Instruments/ techniques used	Purpose of screening
Infrared thermometry	Efficient water uptake (Blum *et al.,* 1982).
Banding herbicide metribuzin at a certain depth of soil, and use of iodine-131 and hydroponic culture under stress of 15 bar	Root growth (Robertson *et al.,* 1985).
Adaptation of psychometric procedure	Evaluation of osmotic (Morgan, 1983).
Diffusion porometry technique	Leaf water conductance (Gay, 1986).
Mini-rhizotron technique	Root penetration, distribution and density in the field (Bohm, 1974).
Infrared aerial photography	Dehydration postponement (Blum *et al.,* 1978).
Carbon isotope discrimination	Increased water-use efficiency (Farquhar and Richards, 1984).
Drought index measurement	Total yield and number of fruits (Ndunguru *et al.,* 1995).
Visual scoring or measurement	Maturity, leaf molding, leaf length, angle, orientation, root morphology and other morphological characters (Mitra, 2001).

Table 4. Critical stages of drought stress and its impact on vegetable crops

Crop	Critical stages for irrigation	Impact of water stress
Cucumber	Flowering as well as throughout fruit development	Deformed and non-viable pollen grains, bitterness and deformity in fruits, poorseed viability
Melons	Flowering and evenly throughout fruit development	Poor fruit quality in muskmelon due to decrease in TSS, reducing sugar and ascorbic acid, increase nitrate content in watermelon fruit, poor seed viability.
Summer squash	Bud development and flowering	Deformed and non-viable pollen grains, misshapen fruits.

BREEDING APPROACHES FOR DROUGHT TOLERANCE

The coined slogan 'more crop per drop' (Kijne *et al.*, 2003) as a target for crop improvement in water-limited environments emerged in recent years in the press and among research administrators and sponsors. It is a very catchy slogan indeed, but also a misleading one. It does not serve well the cause of breeding for water-limited environments, especially rain fed conditions. It led breeders to believe that crop production under water-limited conditions can be genetically improved by increasing plant production per given amount of water used by the crop. A misconception also developed that improved water-use efficiency (WUE) is synonymous with drought resistance and high yield under drought stress. It is possible to achieve 'more crop per drop' by certain crop and soil management practices (*e.g.* plant nutrition).

To develop a drought tolerance variety, the breeding methodology to be applied is the same as for other traits improvement programmes *viz.* recurrent selection for cross-pollinated crops. Conversely, if transfer of few drought tolerance traits to a high-yielding genotype is the aim, then back cross method is adopted (Yunus and Paroda, 1982). There is no single trait that plant breeders can use to improve productivity of a given crop under drought stress. Hence, alternative potential systematic approach is to pyramid a number of traits in one genotype which can be helpful for the improvement for its drought tolerance.

Some of the key traits for breeding for drought tolerance [*e.g.* phenology, rapid establishment, early vigor, root density and depths, low and high temperature tolerance, 13C discritunation (a measure of the extent to which photosynthesis is maintained while stomatal conductance decreases), root conductance, osmo regulation, low stomatal conductance, leaf posture, reflectance and duration, and sugar accumulation in stems to support later growth of yield components] are important traits for breeding point of view. However, priority should be given to those traits which can maintain stability of yield in addition to overall yield (Parry *et al.*, 2005).

Therefore, for the evolvement of an improved drought tolerant high yielding variety, it is necessary that the variety should have short life span (drought escape), well-developed root system, high stomatal tolerance, high water use efficiency (drought avoidance), and increased and stabilized yield during water stress period (drought tolerance). Although, a number of crop cultivars tolerant to drought stress have been developed through this method, this approach has been partly successful because it requires large investments in land, labour and capital to screen a large number of progenies and variability in stress occurrence in the target environment (Athar and Ashraf, 2009). The following breeding approaches have been proposed by various researches.

i. ***Breeding under optimum (irrigated) condition:*** This approach is used where the maximum genetic potential of yield is expected to be realized in optimum condition with a high positive association for performance in optimum and stress conditions (Johnson and Frey, 1967). The basic philosophy of this approach is that where a genotype performs better under optimum level will also yield comparatively well in drought stress condition. Often genotype x environment (G x E) interaction may restrict the performance of high-yielding genotype under drought condition.

ii. ***Breeding under actual drought condition:*** In first approach G × E interaction restrict the performance of high-yielding genotype under drought condition, therefore, breeding of high yielding genotypes under actual drought condition has been recommended (Hurd, 1971). However, relative expression of optimum genetic potential in the two extreme conditions may not always fit good for most of the traits. The desired goal to develop high yielding drought-tolerant genotype may be achieved through simultaneous selection in non-stress environment for yield and in drought condition for stability. Moreover, major drawback of this approach is that the intensity of drought is vastly variable from year to year and as a consequence environmental selection pressure on breeding materials changes drastically from generation to generation. This situation is compounded with lower heritability and makes the breeding activities lower and complicated (Roy and Murty, 1970).

iii. ***Integration of breeding methods:*** An alternative strategy to the above two approaches would be to improve drought tolerance in high yielding genotypes through integration of breeding methods based on morphological and physiological mechanisms of drought tolerance. Improving the yield potential of an already tolerant genotype may be a more promising approach, provided there is genetic diversity in such material (Bidinger *et al.*, 1995). Evolving a high-yielding potential variety along with drought stress through conventional breeding is usually carried out either through stability analysis to evaluate the response of the components of yield to stress or by incorporating traits that contribute directly, or indirectly, to yield stability.

Table 5. Response of physiological traits to drought conditions

Trait	Effects relevant for yield	Modulation under stress
Stomatal conductance/ leaf temperature	More/less rapid water consumption. Leaf temperature reflects the evaporation and hence is a function of stomatal conductance.	Stomatal tolerance increases under stress (Lawlor and Cornic, 2002).
Photosynthetic capacity	Modulation of concentration of Calvincycle enzymes and elements of the light reactions.	Reduction under stress (Lawlor and Cornic, 2002).
Single plant leaf area	Plant size and related productivity.	Reduced under stress (wilting, senescence, abscission) (Walter and Shurr, 2005).
Rooting depth	Higher/lower tapping of soil water resources.	Reduced total mass but increased root/shoot ratio, growth into wetsoil layers, re-growth on stress release (Sharp *et al.,* 2004).
Photosynthetic pathway	C3/C4/CAM, higher WUE and greater heat tolerance of C4 and CAM.	–
Osmotic adjustment	Accumulation of solutes: ions, sugars, poly-sugars, amino acids, glycine betaine.	Slow response to water potential (Serraj and Sinclair, 2002).
Membrane composition	Increased membrane stability and changesin aquaporine function.	Regulation in response to water potential changes (Tyerman *et al.,* 2002).
Accumulation of stress-related proteins	Involved in the protection of cellular structure and protein activities.	Accumulated under stress conditions (Ramanjulu and Bartels, 2002).

Utilization of available genetic variation at inter-specific, intra-specific and intra-varietal levels is of prime importance for selection and breeding for enhanced tolerance to any kind of stress (Serraj *et al.*, 2005). Several selection indices based on anatomic, physiological and biochemical criteria for breeding drought tolerant varieties are being employed *e.g.,* seed yield, harvest index, shoot fresh and dry weight, leaf water potential, osmotic adjustment, accumulation of compatible solutes, water use efficiency, stomatal conductance, chlorophyll fluorescence (Neumann, 2008) and therefore strategy for developing elite material against drought is basically inclined towards the physiogenetic approach. The response of various physiological traits to drought conditions is given in Table 5.

Heat tolerance

The global climate will witness an increase of 2-4°C temperature at the end of 21st century (IPCC, 2007). More importantly, the predictions based on global climate model analysis suggest that the tropical and subtropical regions of the world will be the worst sufferer from the forthcoming disaster of heat stress (Battisti and Naylor, 2009).Temperature is basic to life processes, which increases with temperature within a limited range. Abnormally high temperature may cause disruptions in normal physiological and metabolic processes. The temperature stress may affect cell growth, cell wall synthesis, hormonal relationships, protein synthesis, stomatal opening (respiration) and carbon dioxide assimilation (photosynthesis). Similarly, when the temperature goes below a threshold, which is often close to zero, life processes are disturbed enough to cause injury and death in sensitive genotypes.

Cucurbits require warm conditions for growth and development. However, at high temperature (38-45°C), growth at 2-4 leaf stage may be slowed and leaf margins may appear yellow depending on the species, cultivars, length of exposure and other environmental factors. An extremely high temperature (42-45°C), young leaves may appear light green to yellowish after relatively short exposures (24-48 hours). Flowers and fruit abort and sex expression changes from pistillate to staminate if the temperature rises above 38°C for any appreciable time. High temperature during fruit enlargement often results in decreased yield and fruit quality.

Heat stress resistance may be defined as the ability of some genotypes to perform better than others when they are subjected to the same level of heat stress. Generally various mechanisms of heat stress occur in plants are grouped in the following two categories.

Heat avoidance: It is the ability of a genotype to dissipate the radiation energy and thereby avoid a rise in plant temperature to a stress level. The primary mechanism of energy dissipation is transpirational cooling. The other contributory processes include reflective properties of leaves like pubescence, glaucousness, *etc*. This mechanism prevents the exposure of plants to heat stress.

Heat tolerance: Ability of some genotypes to withstand / perform better than others when their internal temperatures are comparable and in the realm

of heat stress is called heat tolerance. It permits the plant to withstand heat stress. Heat tolerance is largely associated with cellular and sub cellular components. Membrane stability, reduced heat sensitivity of photo system II, photosynthetic translocation, stem-reverse mobilization and osmoregulation are the important components involved in heat tolerance.

Breeding for heat tolerance

Increasing severity of high temperature worldwide presents an alarming threat to the humankind. As evident by massive yield losses in various crops, the escalating adverse impacts of heat stress are putting the global food as well as nutritional security at great risk. The genetic structure of heat tolerance is complex which offers a great challenge to breeders (Blum, 1988). It is further exacerbated by the presence of large magnitude of G x E and epistatic interactions. Breeding a vegetable crop for adaptation to a temperature regime that is higher than the recognized optimum for the species in question is an example of breeding for abiotic stress tolerance. Before embarking on a project to breed for such stress tolerance, there are several critical considerations or questions which must be addressed (Farnham, and Bjorkman, 2011) as mentioned below:

- What is the effect of the abiotic stress on the crop to be improved?
- What will be the conditions of the selection environment?
- What germplasm is available that contains the necessary genetic variation to initiate improvement?
- What breeding scheme will be used to facilitate improvement?
- What will be the specific goals of the breeding effort?

Cucurbits being warm season crops are mainly cultivated during summer season in arid regions, where during April to June the environmental temperature increases upto 42°C and goes beyond 45°C which drastically reduced the yield of cucurbits. The adverse effects of high temperature on cucurbits in arid region comprised of wilting of plants due to high rate of transpiration, sun scorching, more number of staminate flowers, improper pollination due to decreased population of honey bees, drying of ovary, fruit cracking, high incidence of mosaic disease, etc. which leads to low yield of poor quality.

Therefore, improvement of cucurbitaceous crops for heat tolerance is one of the priority areas of research. The selection of environment is one of the crucial factor while improvement of any crop for heat tolerance. Singh (2012) advocated four types of environment for screening of heat tolerance genotypes *viz.*, normal field environment, abnormal field environment, programmed environment and in vitro environment. The natural field environment is the simplest and the cheapest to use. But its effectiveness depends mainly on repeatability of the heat stress profile over years, and on the nature of heat tolerance being selected for.

At several locations normal field environment does not provide suitable heat stress conditions, 'abnormal' field environment available at certain locations or during the off-season may be used. Programmed environment is available in either growth chambers or greenhouses. Usually, it is desirable to avoid water stress during evaluation of heat tolerance. Under standings of selection criteria for heat tolerance are determined in terms of several features. Singh (2012) described the following selection criteria for improvement of crops against heat tolerance (Table 6).

Table 6. Different selection criteria for heat tolerance in plants

Characteristic	Measured as	Usefulness as selection criterion
Germination	Per cent germination under heat stress	Useful when crop faces heat stress at germination.
Growth during heat stress	Yield, biomass	Almost always used selection criterion.
Membrane stability	Solute leakage (conductivity test)	Reasonable correlation (r=~0.7) with yield under heat stress.
Photosynthesis sensitivity	Chlorophyll fluorescence at 685 nm	Becoming increasingly important; difficult to assay and especially interpret.
Recovery after heat stress	Yield, biomass, etc.	Used whenever relevant for the target environment.
Sensitivity of reproductive phase	Pollen fertility, flower/ fruit/ seed production	Useful selection criterion; accounted for in selection based on yield under heat stress.

Table 7. High temperature tolerant varieties of cucurbits developed at ICAR-CIAH, Bikaner

Crop	Varieties
Kachri (Cucumis melo var. callosus)	AHK-119, AHK-200
Snapmelon (*Cucumismelo* var. *momordica*)	AHS-10, AHS-82
Bottle gourd *(Lagenaria siceraria)*	Thar Samridhi
Ridge gourd *(Luffa acutangula)*	Thar Karni
Sponge gourd *(Luffa cylindrica)*	Thar Tapish
Longmelon/ *kakdi* (*Cucumis melo* var. *utilissimus*)	Thar Sheetal, AHC-2 and AHC-13
Mateera (Citrullus lanatus)	AHW-19, AHW-65, Thar Manak

The different approaches of improvement for heat stress in different crops have also been advocated by Blum and Jordan (1985) and Jha *et al.* (2014).The conventional crop breeding schemes relying solely on selection and intermating have unintentionally resulted in paucity in the genetic variation especially for economically important traits that underwent domestication / selection (Gur and Zamir, 2004; McCouch, 2004). Intrinsically, plants respond to high temperature stress by triggering a cascade of events and adapt by switching on numerous stress-responsive genes. However, the complex and poorly understood mechanism of heat tolerance limited access to the precise phenotyping techniques, and above all, the substantial G × E effects offer major bottlenecks to the progress of breeding for improving heat tolerance.

Therefore, accelerating crop improvement demands an extensive search for genetic variability in cultivated as well as in wild species. In the context, heat-tolerant gene(s) / QTLs and the component traits conferring heat tolerance must be explored thoroughly within the entire gene pool, especially targeting the non-adapted and underutilized crop wild relatives and the landraces (Lee, 1998; Fernie *et al.*, 2006). Thus, the progressive tailoring of the heat-tolerant genotypes demands a rational integration of molecular breeding, functional genomics and transgenic technologies reinforced with the next-generation phenomics facilities.

The hot arid region is endowed with vast genetic diversity of several local landraces of cucurbitaceous crops like *Kachri* (*Cucumismelo* var. *callosus*), *snapmelon* (*Cucumismelo* var. *momordica*), *Mateera (Citrulluslanatus), Tumba (Citrulluscolocynthis)* and several non-dessertic forms of *Cucumis* species *viz., Banga, Kakdi, Mathkachra, etc.* which are tolerant to heat stress (More and Samadia, 2008; More and Khan, 2009). Keeping 'yield' as the principal criterion, serious breeding efforts were made at ICAR-CIAH, Bikaner to develop high-yielding cultivars in most of the cucurbits grown in arid region. The institute is maintaining large number of germplasm of native cucurbits (More, 2010; Saroj, 2017) and is being utilized as source of heat tolerance in breeding programmes on heat stress.

The breeding methods comprised of selection among the available germplasm and recurrent selection. Intra-specific hybridization in *Cucumismelo* group followed by selection in succeeding segregating generations for yield, quality and heat tolerance could be utilized. The systematic breeding programmes resulted in identification and development of high temperature tolerant varieties from available germplasm of cucurbits with moderate yield potential through selection under normal field conditions (More, 2010; Saroj, 2017; Choudhary *et al.*, 2018) as given in Table 7.

Future thrusts

- Priority for collection of wild relatives and under exploited genetic resources.
- Introduction of targeted germplasm for crop improvement.
- Identification of stress tolerant germplasm of vegetables.
- Evaluation of germplasm for yield, quality and tolerance to abiotic stresses.
- Registration of germplasm, breeding lines and parental lines.

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Research Review

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Fruit crops under nutrient-capped scenario: a timeless journey

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ABSTRACT

The nutrient responsive nature of fruit crops predisposes them to multiple nutrient deficiencies, resulting in their economic manifestations on quality production is a formidable challenge to nutritionists. The crop-based soil health care is basic to any fruit nutrition program. But, still a bigger challenge lies in diagnosing the genesis of any nutrient deficiency at the right stage. It just starts and in the field itself. So that nutritional problems are addressed in the current season's crop. Various nutrient supply chain management for fruit crops have their own merits and demerits, but all of them address 4R nutrient stewardship principles. However, ISFM is still considered as another form of regenerative agriculture. Our current efforts should concentrate on these issues, so that soil health care becomes a grower's movement with visibility on long-term fruit industry.

Key Words: ISFM, Fruit crops, Nutrient deficiency, Nutrient diagnosis, Soil health care

Fruit crops have been cultivated for centuries, both commercially and in amateur orchards as a major part of agricultural production. 'An apple a day keeps the doctor away' is a popular adage, signifying the importance of fruit crops in human life. Presently, fruit crops globally touch 675 million tonnes (114 million tonnes of bananas) of the total fruit production with most popular fruit crops like bananas and apples, followed by grapes and oranges, offering a promising alternative to nutritional security option, besides easing the load on otherwise heavy per caput consumption of cereal crops. As we race towards a global population of 10 billion, the business as usual for stress free fruit farming is no longer appears an easy entrepreneurship, considering the fact that decoding the chemistry of signalling pathways as a connecting link between sensing stress environment and generating various structural and functional plant responses, have always been a daunting task.

Fruit crop: carbon sink

Entangled in multiple stresses, establishing a sustainable production system is the key challenge of present time fruit science. Decline in soil fertility due to nutrient mining is the major constraint, limiting the productivity of fruit crops (Srivastava and Singh, 2008a). Consistent reduction in nutrient density of different fruit crops is an indication of nutrient mining-induced decline in productivity over the time. Fruit crops by virtue of their perennial nature of woody framework (nutrients locked therein), extended demand for nutrient supply across physiological growth stages, differential root distribution pattern (root volume distribution) and preferential requirement of some nutrients over others, collectively make them nutritionally more efficient than annual crops (Srivastava *et al.,* 2008), beside playing an important role in carbon cycle of terrestrial ecosystems and sequestering atmospheric CO_2 (Lakso, 2010). An increase in yield of fruits like apple, grape, banana, pineapple, mango, citrus *etc.* in response to elevated CO_2 concentration has been extensively studied. It remains to be investigated, how accurate estimation of orchard C budget and feedback mechanisms of changes in soil carbon pool is developed in order to expand potential of C credits through perennial fruit crops.

Nutrient constraints diagnosis

Plant nutritionists across the globe are on their toes to find ways and means to identify nutrient

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constraints as early in standing crop season as possible while dealing with fruit crops. The conventionally used diagnostic tools of identifying nutrient constraints such as leaf analysis, soil analysis, juice analysis, and to some extent, metallo-enzyme-based biochemical analysis, all have been under continuous use and refinement. Therefore, development of nutrient diagnostics is an extremely complex exercise. The issue becomes still quite complex under the soil conditions facing multiple nutrient deficiencies (Srivastava and Singh, 2009a). Not surprisingly, proximal sensing through spectral signatures of crop canopies in orchards are more complex and often quite dissimilar from those of single green leaves measured under carefully controlled conditions. Even when leaf spectral properties remain relatively constant throughout the season, canopy spectra change dynamically depending upon variation in soil type, vegetation, and architectural arrangement of plant components (Srivastava and Malhotra, 2017).

Vegetation indices provide a very simple yet an effective method for extracting the green plant quantity signal from complex canopy spectra (Srivastava *et al.*, 2015). These are some of the glaring examples of identifying nutrient constraints on a real time basis. Ironically, micronutrient deficiencies are diagnosed through specific pattern of chlorosis, *e.g.* Fe versus Mn or Fe/Mn versus Zn backed up by nutrient concentration, capturing symptomatic pattern of chlorosis via spectral norms (signatures), irrespective of crop species further limit this concept towards wider application. In the light of these developments, a relatively new concept popularly known as 'Nutriomics', has emerged, revealing some lesser-known facts about fruit nutrition as a function of genomics (Yan *et al.*, 2006). Amongst destructive methods of diagnostics tools, none of them is capable of identifying the nutritional disorders in the current season's crop, thereby, aiming the outcome of diagnosis supposedly effective in next season's crop. Flower analysis, though still in infancy stage, holds a better promise (Srivastava *et al.*, 2008), since it offers a comparatively longer time from anthesis to fruit maturity to schedule the fertilizer recommendation without compromising with either fruit yield or any of the fruit quality parameters.

Rhizosphere ecology

Rhizosphere security (soil security) is the call of the day these days, where physico-chemical and biological properties of the soil inhabited by roots are shaped in accordance to crop metabolism. Ecological significance of rhizosphere in terms of genetic, functional and metabolic responses is another dimension in fruit crops; need an incisive analysis (Mylavarapu, 2010). However, it remains to be seen, whether or not and to what an extent, such ecosystem service functions of rhizosphere are governed by different soil microbial communities. Arbuscular mycorhizal fungi is one of the most influencial soil inhabiting fungi able to establish symbiotic relation with more than 90% of the plants representing terrestrial ecosystem. How does mycorrhizosphere of fruit crops aid in unravelling the hidden facts about fruit nutrition through elevated synthesis of glomalin-related-soil-protein (glycoprotein) in the backdrop of desired biochemical and physiological preparedness in response to abiotic and biotic stresses (Wu *et al.*, 2013; Shao *et al.*, 2018). Microbial inoculation off late, has assumed a much greater significance, ever since depleting soil organic carbon has reached to an alarming proportion to facilitate soil fertility and plant nutrition act in a coordinated manner.

In this persuit, microbial consortium showed clear cut superiority over single or dual microbial inoculation regulating functional dynamics of rhizosphere through biofertigation as a newest concept of fertigation, a little known nutrient supply system in fruit crops. Hence, these attempts are likely to provide some plausible answers with regard to top environmental problems, viz. microbial diversity loss, ecosystem collapse and climate change to later tailor them into sustainable organic production system.

Multiple nutrient constraints

Regenerative farming using fruit crops could be quite thrilling and remunerative for long term fruit production sustainability. Adopting organic and biodynamic methods using cosmic energy-based calendar operation are likely to throw up new vistas of addressing different soil fertility constraints towards an optimised performance. However, foliar nutrition coupled with growth hormone is still the way forward approach to produce nutrient dense fruit crops. But, nutrients aligning through phloem mobility and phloem immobility further pose some uncompromisable limitations, with the results, foliar feeding of nutrients still remains a formidable challenge. Overcoming the ever-increasing frequency of different soil fertility constraints, use of soilless method of cultivation is gradually gaining momentum in perennial fruit crops popularly known as field hydroponics, soilless method is not a popular concept and has many challenges to overcome before open field hydrophonics becomes a popular and conventional method of fruit crops cultivation (Srivastava, 2014).

Sustaining soil fertility with respect to fruit crops is another core agenda where biochar (essentially a charcoal having carbon residence time in soil extending

for > 100 years) proved its utility, mostly under tropical environment with acid soils, imparting an additional liming value to biochars. The much value-added biochars have been derived from banana and orange sun dried peels. Therefore, biochars need to be utilized for expanding carbon sequestration potential of soil, improving soil nutrient balances, especially in alkaline soils, soil-crop health under typical long-term field conditions. Additionally, biochar augers so well in organic production system need to look a fresh (Agegnehu *et al.,* 2017). Ironically, stress and plant nutrition hardly complement each other. Despite quantum of researches dedicated to salinity responses of fruit crops, physiological basis of salinity tolerance is yet little understood at molecular level, another core area of research in fruit crops has been addressed so beautifully.

Considering the thumping success of trunk nutrition, would not it be more advisable to analyse the xylem sap or phloem tissue for chemical and microbial constituents, since the signal transduction for various nutrients functioning mediate through these tissues only. Such attempts could provide some meaningful clues about the presence or absence of those signals to be later utilized in understanding the underlying principles of nutrient stress-induced warning mechanism. These studies could lay the solid foundation for developing some probe linked to transpiration stream of plant to act as early warning system for identifying deficiencies of various nutrients. Use of nano-fertilizers (synthesized or modified form of traditional fertilizers), though still not a popular option to conventionally used fertilizers, but offer some definite promise towards elevated use efficiency of applied fertilizers (Srivastava and Malhotra, 2014) through proper delivery system utilizing different types of nano-fertilizers. However, issues relating health hazards need thorough studies with regard to nano-fertilizes to turn them really effective cropwide.

The concept of nutrient-use-efficiency applied on the principles of 4R Nutrient Stewardship (right amount of fertilizers using right source is applied at right time and right place) provides an ultimate framework guide to fertilizer use to any crop, with fruit crops no exception. Such attempt is slated towards increased production, profitability, and environmental safety. A further understanding of nutrient-microbe synergy provides a solid foundation in unlocking the productivity potential of fruit crops, besides safe-guarding the soil health and possibility of doubling the yield coupled with nutrient-use-efficiency as central theme (Srivastava *et al.,* 2015). With the availability of more technical know-how on combined use of organic manures, prolonged shelf-life of microbial biofertilizers and inorganic chemical fertilizers, an understanding on nutrient acquisition and regulating the water relations would help switch orchards to better CO_2 sink (expanding carbon capturing capacity of rhizosphere), so that a more sustainable fruit-based integrated crop production system could be evolved (Srivastava *et al.,* 2019). A comprehensive comparative study of organic versus inorganic fertilizers will be a booster to add strength to such integrated approaches, where use of slow release fertilizers can be stitched quite effectively to match with nutrient demand with critical growth stages, a pre-requisite to another form of nutrient-use-efficiency, known as nutrient utilisation efficiency. However, the nutrient responsiveness of fruit crops aid in building up a parallel nutrient sink in tune with carbon sink offer another challenge to researchers in the background of fruit crops continue to offer multiple services to the mankind.

Epilogue

A cultivar evaluated under both intensive and organic farming system may not perform with similar magnitude of success. Considering the mentioned problem it is highly desirable to breed the plants for organic conditions (Sharma and Bardhan, 2017). Nutrient dynamics is another virgin area where limited attempts have been made using citrus as test crop (Srivastava and Ngullie, 2009). Amongst different nutrients, Zn has attracted worldwide investigation from various angles (Srivastava and Singh 2009a, 2009b). The changes in rhizosphere bring different simultaneous changes in microbial diversity *vis-a-vis* Cmic, Nmic, Pmic and nutrient regime especially for diffusion limited nutrients like P, Zn, Fe, Mn, *etc.* has to find serious considerations in any nutrient management program that involves ISFM-based corrective treatments (Srivastava *et al.,* 2007a; 2007b). Additionally, conditions under which citrus trees are most likely to respond to corrective Zn-treatments are still not fully understood (Srivastava *et al.,* 2006).

Out of different soil properties, the microbial biomass is the one biological property of soil that undergoes immediate change in response to fertilizer like input (Srivastava and Singh, 2007; 2008b). Studies, therefore, need to be undertaken with a view to explore the possibility whether microbial properties could be used as a potential tool for finding out soil fertility constraint instead of available supply of nutrients in soil. Simultaneously, an eye should be kept on long term changes in total carbon pool of soil to arrive at the logistic conclusion that sequestration of carbon through improved production level could rejuvenate the lost productivity potential of nutritionally depleted soil (Srivastava and Singh, 2015).

The molecular approach to breeding of mineral deficiency resistance and mineral efficiency would facilitate produce nutritionally efficient biotypes in order to maximise the quality production of fruit crops on sustained basis. Concerted efforts would be required to develop integrated soil fertility management (ISFM)-based yield monitors and soil quality indicators in order to develop a comprehensive system, whereby the concept of soil security could be effectively brought into a reality with an emphasis on development of minimum data set to define crop-based soil health card, the efforts on these lines are still in infancy. The efforts such as these are likely to transform climate smart ISFM as like a common conventional management system using fruit crops-based land uses.

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Critical stages of water requirement in sweet orange (*Citrus sinensis*)

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ABSTRACT

A field experiment was conducted on 10-year-old bearing sweet orange (*Citrus sinensis* Osbeck) cv. Sathgudi based on evaporation replenishment (ER) irrigation scheduling at different stages to identify the critical stage of irrigation water requirement through drip irrigation system during 2007-2017 at AICRP on Fruits (Citrus), Citrus Research Station, Dr Y.S.R Horticultural University, Tirupati. The fruit yield and quality significantly affected under various ER based drip irrigation scheduling treatments. Maximum number of fruits (353 fruits/ plant) and highest fruit yield (57.41 kg/plant and 15.92 t/ha) were recorded under drip irrigation scheduled at 80% ER in all stages. The best quality fruits (TSS:10.270 Brix and acidity 0.71%) with good TSS and acid blend (17.25) and highest benefit: cost ratio (2.68) were harvested in the same treatment and it was superior over all the treatments, indicating stage VI (November-December) is the best period for inducing stress for Ambe bahar crop. However, lowest yields were recorded when plants were supplied with 80% ER at stage I, II, IV, V, VI stages and 30% ER at Stage III (May-June), followed by plants supplied with 80% ER at stage II, III, IV, V and VI stages and 30% ER at stage I (January-February). Reduction in irrigation from 80% ER to 30% ER during stage III (May-June: fruit development stage) and stage I(January-February: flowering and fruit setting) resulted in significant reduction in yield, indicating both the stages are critical for water requirement in sweet orange.

Key Words: Critical stage, Flowering, Fruit setting, Irrigation scheduling, Stress, Sweet orange, Water requirement

Irrigation water is a key input for successful cultivation of *Citrus* spp. (Shirgure, 2012). Sweet orange (*Citrus sinensis* Osbeck) cv. Sathgudi is an important commercial cultivar, mainly grown in Rayalaseema region of Andhra Pradesh and adjoing states. In this region, to improve the productivity of sweet orange orchards irrigation is practiced from February to June and tube well water or canal water is the common source of irrigation for the crop. Drip irrigation is one of the potential water saving irrigation methods in citrus (Shirgure *et al.,* 2001b; Shirgure *et al.,* 2003a; Shirgure *et al.,* 2004; Panigrahi *et al.,* 2012). Reducing water supply to optimal level of crop water requirement in certain growth stages of crop improves water-use efficiency and quality of produce, without affecting the yield significantly (Shirgure and Srivastava, 2013; Shirgure *et al.,* 2016).

Irrigation scheduling based on depletion of available water content as 40-100% (Moreshet *et al.,* 1988) in 'Shamouti' orange, 80% (Shirgure *et al.,* 2001a; Shirgure *et al.,* 2016) in Nagpur mandarin and 70% (Shirgure *et al.,* 2003b) in acid lime have been suggested. Shirgure *et al.* (2014) reported that highest fruit yield of Nagpur mandarin was recorded in drip irrigation scheduled with 30% evaporation replenishment in stage-VI and 80% evaporation replenishment in stage I-V (17.25 t/ha and 21.48 t/ha respectively). The earlier studies indicated that the sweet orange crop is most sensitive to water stress at flowering and fruit setting stage which takes place during December-January in South India (Shirgure *et al.,* 2001b). The water scarcity caused by low water level in tube wells in summer months (March-June) has forced the orchard growers to opt for drip irrigation during this period (Shirgure *et al.,* 2016). In absence of the information on the

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responses of sweet orange cultivars of citrus to water stress in summer months, which coincides with fruit set development, is very limited. Further, the yield prediction under differential water stress condition is also limited in this crop. Therefore, an experiment was conducted to identify the critical growth stages of water requirement under pan evaporation based drip irrigation scheduling in bearing sweet orange.

MATERIALS AND METHODS

A field experiment on different drip irrigation schedules at six growth stages was conducted in the block of 0.3 ha with 6 m spacing on 10-year-old sweet orange orchard during 2000-2017 at AICRP Fruits (Citrus), Citrus Research Station, Dr Y.S.R. Horticultural University, Tirupati. The irrigations treatments were scheduled on per cent of pan evaporation replenishment (ER) at six stages of growth and fruit development. The different stages considered for study were stage-I (January-February), stage-II (March-April), stage-III (May-June), stage-IV (July-August), stage-V (September -October) and stage-IV (November-December).

The treatments were imposed as drip irrigation schedule with 30% ER in stage-I and 80% ER in stages II to VI (T_1), drip irrigation schedule with 30% ER in stage-II and 80% ER in stage I and stages III to VI (T_2), drip irrigation schedule with 30% ER in stage-III and 80% ER in stage I, stages II and IV to VI (T_3), drip irrigation schedule with 30% ER in stage-IV and 80% ER in stages I-III, V and stage VI (T_4), drip irrigation schedule with 30% ER in stage-V and 80% ER in stages I-IV and stage VI (T_5), drip irrigation schedule with 30% ER in stage-VI and 80% ER in stages I-V (T_6) and drip irrigation schedule with 80% ER in all stages I-VI (T_7) with three replications in randomized block design.

The soil type was sandy loam with 10% of clay content. Volumetric soil moisture content at field capacity (FC) and soil moisture characteristics were determined using pressure plate method. The FC and soil moisture at wilting of the experimental soil were observed as 9% and 3%, respectively. While, water holding capacity of the soil was worked out to be 11-12% considering soil bulk density as 1.5-1.6 g/cc, determined using core sampler having 100 cm3 volume. Based on the average weekly open pan evaporation, the irrigation quantities were calculated taking into account of pan factor (0.7), crop factor (0.75), spacing 6mx6m and wetted area factor (0.4). Monthly quantity of irrigation schedules, depth and quantity of irrigation was recorded. The quantity of fertilizers used in 100% RDF is 800:350:400 ($N:P_2O_5:K_2O$) along with basal application of 40kg FYM and 8 kg neem cake/ plant / year as per package of practices of Dr YSRHU, Andhra Pradesh.

Plant growth observations and analysis of biometric parameters of sweet orange plants (plant height and tree spread) were recorded during January for five years (2012-17). The plant scion girth was taken 15 cm and 25 cm above the soil surface. The canopy volume was calculated according to formula suggested by Castle (1983). Sweet orange fruit yield and quality analysis was also carried out as per procedures (Ranganna, 1986). The data on fruit yield and quality attributing to the different irrigation schedules for five years were analyzed by following analysis of variance method (Gomez and Gomez, 1984). The observations on root rot incidence prior to harvest were recorded in each irrigation treatment. Root rot incidence (%) in each treatment was calculated by counting number of diseased trees and total number of trees in each treatment and the ratio was expressed as percent disease incidence.

Economics of drip irrigation method was worked out to compute the net returns and benefit-cost ratio. For this purpose, the life period of polyvinyl chloride (PVC) items was considered as 10 years and that of the submersible pump set was taken as 15 years. One ha area, under each treatment was considered for comparison. The fixed cost, operation cost and total cost were worked out. Fixed cost consisted of interest on initial cost and depreciation on the system. The interest calculated on the capital was at the rate of 12 per cent per annum as per the prevailing bank rates. Operating cost is the amount which is actually paid by the cultivator in cash throughout the crop period for carrying various horticultural operations.

Total operational cost of the system is the operating cost plus interest on operational cost at the rate of 12 per cent. These are expenses incurred on land preparation, cost of planting material, fertilizers, manures and their application, intercultural operations, crop-protection measures, irrigation water, land revenue, incidental charges, interest on working capital, depreciation on asset and cost of harvesting. The gross return from the produce was estimated from prevailing average market price of ₹ 5,000 per ton.

RESULTS AND DISCUSSION

The requirement of irrigation water varied as per pan evaporation and growth stage of sweet orange. The daily weather data recorded from CRS, Tirupati was used for irrigation scheduling based on evaporation. The monthly precipitation, mean temperature and relative humidity for 2012-2017 varied from 47.20 to 1249.30 mm, 29.53 to 38.92ºC and 17.31 to 26.65ºC and 64.47 to 87.84% and 32.71 to 65.30% respectively

Various pan evaporation based irrigation schedules using drip irrigation system varied the water use of

Table 1. Daily water requirement (l/plant) in different irrigation schedules at various stages (2012-2017)

Treatment	Stage I		Stage II		Stage III		Stage IV		Stage V		Stage VI	
	Jan	Feb	Mar	Apri	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec*
T_1	4	8	24	25	28	24	19	9	4	8	12	0
T_2	10	23	9	9	28	24	19	9	4	8	12	0
T_3	10	23	24	25	11	9	19	9	4	8	12	0
T_4	10	23	24	25	28	24	7	3	4	8	12	0
T_5	10	23	24	25	28	24	19	9	2	3	12	0
T_6	10	23	24	25	28	24	19	9	4	8	4	0
T_7	10	23	24	25	28	24	19	9	4	8	12	0

*No irrigation water during December (*bahar* treatment).

bearing sweet orange (Table 1). The variation in water applied for different treatments was due to variation in pan evaporation and rainfall pattern, as the quantity of water applied was based on pan evaporation. The pooled mean (2012 -2017) irrigation water requirement of sweet orange plant varied from 2 to 11 l / plant / day with irrigation scheduling with 30% ER at six different stages of the crop. The same was 4 to 28 l / plant / day with the irrigation scheduled at 80 % ER in all the stages. The irrigation was not scheduled during December month of stage VI, for inducing stress (*Bahar* treatment) for Ambe bahar crop at Tirupati region.

The effect of different drip irrigation scheduling combinations based on per cent evaporation replenishment has not significantly influenced the biometric growth parameters of 10 years Sathgudi sweet orange trees. The pooled mean (2012-17) data revealed that there was no significant effect of irrigation schedules (Table 2) on plant growth of ten years old sweet orange cv. Sathgudi. The average plant height ranged from 2.68-2.88 m, stock girth from 42.22 to 44.88 cm and canopy volume ranged from 19.62 to 23.11 m^3.

The highest plant height (2.88 m) and stock girth (44.88 cm) were recorded in the 80% ER based irrigation schedule during all the six stages of plant growth. This may be mainly due to availability of constant and continuous soil moisture in plant root zone. Whereas, average canopy volume (23.11 m^3) was observed maximum in the irrigation scheduled with 80% ER in stages I, II, III, V and VI and 30% ER in stage-IV. This may be mainly due to the rains and high humid conditions favouring scion growth and development. Lowest Plant height (2.68 m), scion girth (42.22 cm) and canopy volume(19.62 m^3) were noticed when plants were supplemented with irrigation schedule at 80% ER in stage II to VI and 30% ER in stage I.

The plants grown under water stress conditions might have saturated the root zone, thereby reduced the oxygen level and respiration rate resulting into low uptake of nutrients and inhibited proper growth and vigour of plants. The similar type of observations were also recorded in the earlier studies on irrigation scheduling in Nagpur mandarin (Shirgure *et al.,* 2014), Kinnow mandarin by Panigrahi *et al.* (2014) and Nagpur mandarin by Shirgure *et al.*(2016).

Drip irrigation scheduled based on pan evaporation replenishment in six different stages had profound effect on the yield and quality of fruits during 2012-2017. The yield and fruit quality were significantly influenced by the different drip irrigation schedules during the six stages. The number of fruits / plant, fruit yield, TSS and acidity were found significant (Tables 2 and 3). The average number of fruits per plant varied from 281 to 353.

The number of fruits / plant was highest (353 fruits / plant) in irrigation schedule with 80% ER at all stages. Whereas, lowest fruit number was recorded in the irrigation schedule at 80% ER in stages I, II, IV, V and VI and 30% ER in stage III . From this it is evident that the stages III is critical and the stages II, IV, and VI are less critical for irrigation water requirement of Sathgudi sweet orange. The highest fruit yield (57.41 kg / plant, 15.92t / ha) was recorded in the drip irrigation schedule with 80% ER in all stages, followed by irrigation schedule with 80% ER at I, III to VI stages and 30% ER in stage-II (50.15 kg / plant and 13.91 t / ha) (Table 2).

It is well established that water is very much essential during growth and development of fruits as water helps mobilization of nutrients and food materials to the growing fruits. These results are in association with the findings of Panigrahi *et al.* (2012) who observed highest yield of Nagpur mandarin under DI at 80% Ecp followed by 100% Ecp whereas lowest under 40% Ecp compare to basin irrigation. The similar results of lower fruit yield with higher level of deficit irrigation were earlier reported by Garcia-Tejero *et al.* (2010) in Salustiana orange, Panigrahi *et al.* (2014) in kinnow

Table 2. Critical stage of water requirement for growth and yield of sweet orange Tirupati (pooled data: 2012-2017)

Treatment	Plant height (m)	Scion girth (cm)	Canopy volume (m^3)	Fruits /tree	Fruit weight (g)	Fruit yield (kg / tree)	Fruit yield (t/ha)	BC Ratio
T_1	2.68	42.22	19.62	300.98	167.64	48.14	13.35	1.93
T_2	2.84	43.20	20.87	309.76	168.13	50.15	13.91	2.09
T_3	2.78	43.11	20.72	281.11	174.23	47.07	13.05	1.84
T_4	2.87	44.10	23.11	303.96	181.87	49.36	13.69	2.03
T_5	2.76	43.29	22.03	295.20	169.18	48.64	13.49	1.97
T_6	2.75	43.28	20.57	308.44	170.83	49.30	13.67	2.02
T_7	2.88	44.88	22.68	353.11	176.61	57.41	15.92	2.68
CD @ 5%	NS	NS	NS	37.21	NS	5.20	1.44	--
SE(m)±	0.08	0.90	1.05	12.82	3.62	1.79	0.49	--
CV%	6.63	5.06	12.05	10.21	5.14	8.78	8.79	--

T_1 -(30-80-80-80-80-80% ER), T_2 -(80-30-80-80-80-80% ER), T_3 -(80-80-30-80-80-80% ER), T_4-(80-80-80-30-80-80% ER), T_5-(80-80-80-80-30-80% ER), T_6-(80-80-80-80-80-30% ER), T_7-(80-80-80-80-80-80% ER), Cost of fruit : ₹ 25, 000/ tonne.

mandarin and Shirgure *et al*. (2016) in Nagpur mandarin. Lowest fruit yield was observed in the drip irrigation schedule with 80% ER in stage I, II, IV and VI (47.07 kg/plant and 13.05 t/ha) and 30% ER in stage III followed by the irrigation schedule with 80% ER in stage II to VI (48.14 kg/plant and 13.35 t/ha) and 30% ER in stage I.

This clearly indicates that the stage-III (May-June) and stage-I (January-February) are critical for water requirement in due to increase in temperature and rise in evapo-transpiration demand of the plants as these two stages coincides with fruit growth and development (May-June) and flowering and fruit setting (January-February) stages respectively. Highest benefit: cost ratio (2.68) was recorded with 80% ER based irrigation schedule at all stages and was superior over all the treatments under study, indicating Stage VI (November-December) is the best period for inducing stress to get economic yields in Ambe bahar crop, while the lowest B:C ratio of 1.84 was recorded with 80% ER in stage I, II, IV and VI and 30% ER in stage III followed by with 80% ER in stage II to VI and 30% ER in stage I (1.93).

Significantly maximum TSS (11.21°Brix), low acidity (0.71%) and TSS: acid ratio (17.25) were noticed in irrigation scheduled with 80% ER in stages I-VI. The high TSS: acid ratio is indicator of sweetness of the fruit of Ambia flush during December- Jan. If the TSS to acid ratio is high, it means that the fruits have more total soluble solids and less acidity (Table 3). This clearly indicates that water supply is very essential to get good quality fruits.

Pruning of dry shoots is considered to be one of the cultural practices in sweet orange cultivation as shoots are dried up every year due to various reasons. Dry root rot incidence was also high in (43.75%) with

Table 3. Critical stage of water requirement for fruit quality and dry root rot incidence in sweet orange (pooled data : 2012-2017)

Treatment	Juice (%)	TSS (°Brix)	Acidity (%)	TSS/ acid	Dry root rot (%)
T_1	40.21	9.69	0.72	13.91	6.25
T_2	40.51	9.51	0.76	13.01	12.5
T_3	42.06	10.29	0.74	14.48	43.75
T_4	41.81	10.61	0.72	16.25	6.25
T_5	39.09	9.50	0.85	11.32	12.5
T_6	39.80	10.00	0.77	13.71	0.00
T_7	42.05	11.21	0.71	17.25	12.5
CD@5%	NS	0.95	0.06	2.48	
SE(m)±	0.86	0.33	0.02	0.86	
CV%	5.18	7.95	6.83	14.68	

T_1-(30-80-80-80-80-80% ER), T_2-(80-30-80-80-80-80% ER), T_3-(80-80-30-80-80-80% ER), T_4-(80-80-80-30-80-80% ER), T_5-(80-80-80-80-30-80% ER), T_6-(80-80-80-80-80-30% ER), T_7-(80-80-80-80-80-80% ER).

80% ER in stage I,II, IV and VI and 30% ER in stage III and indicated that regular watering in dry periods is not only needed for fruit production but also for maintenance of plant health and vigor.

In conclusion, the fully-irrigated Sathgudi sweet orange plants produced the highest vegetative growth while, maximum fruit yield with better quality. Deficit irrigation or reduction in irrigation from 80 to 30 %ER during fruit growth and development (May-June) and flowering and fruit setting (January-February) has significantly decreased fruit yields and severe incidence of dry root rot indicating these two stages are the most critical stages for water requirement in Sathgudi sweet orange. Hence, there is a need to provide protective irrigation during two critical stages (January-February and May- June) to get economic yields for Ambe Bahar crop in sweet orange growing areas of Andhra Pradesh.

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Effect of plant elicitors on growth, yield and quality of papaya *(Carica Papaya)*

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ABSTRACT

The field cum laboratory study was carried out to find out the effect of plant elicitors on papaya (*Carica papaya* L.) cv. Red Lady, during November, 2015 to October, 2017 at Horticultural Research Station, Anantharajupeta, Kadapa district, Andhra Pradesh. The application of salicylic acid twice (at 45 and 120 DAT) @ 150 ppm (T_9) recorded significantly highest plant height (257.58 cm) at 210 DAT, which was at a par with T8(S.A @ 100 ppm at 45 DAT and 120 DAT) (225.08 cm and 34.21 cm). T_9 (SA @ 150 ppm at 45 and 120 DAT) recorded significantly highest fruit weight (1.06 kg), fruit length (18.33 cm), fruit girth (43.02 cm). The values for all these parameters were found to be at par with T_8 and T_7, whereas lowest values was recorded with T_{13} (control), *i.e.* fruit weight (0.84 kg), fruit length (16.20 cm), fruit girth (33.35 cm). Significantly highest number of fruits/plant (60.37) was observed in T_8 which was found to be at par with T_9 (59.29) and T_7 (57.94). Weight of fruits/plant (kg), yield/plot (kg) and yield/hectare (tonnes) were highest in T_9 (49.78 kg, 552.42 kg and 116.06 tonnes/ha) which was at par with T_8 (47.17 kg, 546.59 kg and 114.83 tonnes/ha). The lowest values in this regard were recorded in control (T_{13}) (25.20 kg, 370.57 kg and 77.85 tonnes/ha).

Key Words: Elicitors, Jasmonic acid, Micronutrients, Plant height, Salicylic acid

Papaya (*Carica papaya* L.) is an important fruit of tropical and subtropical regions of the world (Pinal *et al.,* 2020). Positive influence of salicylic acid on plant height, chlorophyll content (both chlorophyll a and b), carotenoids content, number of branches and leaves per plant, dry weight and shoot dry weight was also reported in tomato (Yildırım and Dursun 2009). Application of SA increased chlorophyll a and b as well as carotenoids in *Syngonium podphyllum* plants (Sweify and Abdel-Wahid 2008). Besides, SA has the ability to induce systemic acquired resistance (SAR) (Farousk and Osman 2011). Bhalerao *et al.* (2014) reported positive effect of micronutrients on papaya. Rasmussen *et al.* (1991) mentioned that SA levels increased 10 - 100 fold in phloem exudates of cucumber inoculated with tobacco necrosis virus, *Colletotrichum lagenarium*, or *Pseudomonas syringae*, and these increases preceded SAR development and induction of a defense-associated peroxidase activity. Major function of JA and its various metabolites is regulating plant responses to abiotic and biotic stresses as well as plant growth and develop-ment. Regulated plant growth and development processes include growth inhibition, senescence,flower development and leaf abscission. Hence, effect of foliar application of plant elicitors, *viz.* salicylic acid and jasmonic acid on growth, yield, quality of papaya cv. Red Lady was studied.

MATERIALS AND METHODS

The experiment was conducted at Horticultural Research Station, Anantharajupeta, Kadapa district, Andhra Pradesh, during November 2015 - October 2016 and November 2016 - October 2017 in a randomised block design with 13 treatments and three replications. The treatments were T_1, salicylic acid @

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Table 1. Effect of salicylic acid and jasmonic acid on plant height (cm) at different intervals in papaya cv. Red Lady

Treatment	Plant height (cm)											
	150 DAT			180 DAT			210 DAT			240 DAT		
	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data
T_1 : Salicylic acid @ 50 ppm at 45 DAT	151.25	146.33	148.79	200.93	187.61	194.27	244.31	229.31	236.81	268.56	255.63	262.10
T_2 : Salicylic acid @ 100 ppm at 45 DAT	158.43	153.19	155.81	198.84	185.89	192.36	255.71	227.35	241.53	271.20	252.51	261.85
T_3 : Salicylic acid @ 150 ppm at 45 DAT	160.23	160.34	160.29	212.84	200.37	206.61	257.23	226.07	241.65	276.59	268.53	272.56
T_4 : Jasmonic acid @ 50 µM at 45 DAT	153.64	154.19	153.92	205.34	200.21	202.78	242.14	224.70	233.42	258.90	241.28	250.09
T_5 : Jasmonic acid @ 100 µM at 45 DAT	157.99	153.19	155.59	201.03	187.93	194.48	256.51	227.00	241.75	265.31	257.48	261.40
T_6 : Jasmonic acid @ 150 µM at 45 DAT	158.97	149.55	154.26	203.49	190.22	196.85	259.86	228.20	244.03	272.23	262.90	267.57
T_7 : Salicylic acid @ 50 ppm at 45 DAT and 120 DAT	164.38	162.95	163.67	218.17	204.63	211.40	265.75	239.56	252.65	274.88	269.35	272.12
T_8 : Salicylic acid @ 100 ppm at 45 DAT and 120 DAT	167.73	162.39	165.06	220.95	209.55	215.25	265.35	244.81	255.08	278.97	272.38	275.67
T_9 : Salicylic acid @ 150 ppm at 45 DAT and 120 DAT	168.55	172.23	170.39	222.46	205.13	213.80	271.91	243.25	257.58	286.69	275.07	280.88
T_{10}: Jasmonic acid @ 50 µM at 45 DAT and 120 DAT	164.32	160.29	162.31	214.23	208.13	211.18	263.25	226.37	244.81	276.71	266.53	271.62
T_{11}: Jasmonic acid @ 100 µM at 45 DAT and 120 DAT	158.70	152.92	155.81	208.65	200.33	204.49	256.38	221.53	238.96	272.12	260.71	266.41
T_{12}: Jasmonic acid @ 150 µM at45 DAT and 120 DAT	158.70	154.28	156.49	207.90	200.89	204.40	249.11	221.38	235.25	268.53	259.63	264.08
T_{13}: Control	144.75	141.00	142.87	192.19	189.51	190.85	231.74	214.60	223.17	255.35	225.37	240.36
S.Em	3.09	4.09	3.46	4.29	2.42	2.35	3.58	4.83	3.10	4.13	3.77	2.32
C.D. (5%)	9.02	11.94	10.12	12.51	7.08	6.87	10.45	14.08	9.05	12.05	10.99	6.77

DAT; Days after transplanting

Table 2. Effect of salicylic acid and jasmonic acid on fruit traits of papaya cv. Red Lady

Treatment	Fruit length(cm)			Fruit girth (cm)			Average fruit weight (kg)			Total soluble solids(°Brix)		
	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data
T_1 : Salicylic acid @ 50 ppm at 45 DAT	17.08	16.10	16.59	37.69	39.55	38.62	0.90	0.94	0.92	11.65	11.42	11.54
T_2 : Salicylic acid @ 100 ppm at 45 DAT	16.91	16.53	16.72	37.87	36.25	37.06	0.91	0.91	0.91	11.78	11.51	11.65
T_3 : Salicylic acid @ 150 ppm at 45 DAT	17.63	17.27	17.45	38.56	38.50	38.53	0.98	0.97	0.98	11.81	11.68	11.75
T_4 : Jasmonic acid @ 50 µM at 45 DAT	17.07	15.80	16.44	38.09	36.67	37.38	0.91	0.94	0.92	11.59	11.34	11.47
T_5 : Jasmonic acid @ 100 µM at 45 DAT	16.52	16.55	16.54	38.54	36.98	37.76	0.95	0.92	0.94	11.53	11.28	11.41
T_6 : Jasmonic acid @ 150 µM at 45 DAT	16.64	16.47	16.55	37.27	36.17	36.72	0.90	0.92	0.91	11.79	11.69	11.74
T_7 : Salicylic acid @ 50 ppm at 45 DAT and 120 DAT	17.98	17.83	17.90	41.43	41.25	41.34	1.00	1.00	1.00	12.28	12.13	12.21
T_8 : Salicylic acid @ 100 ppm at 45 DAT and 120 DAT	17.75	17.83	17.79	41.19	43.28	42.24	1.06	1.03	1.04	12.31	12.25	12.28
T_9 : Salicylic acid @ 150 ppm at 45 DAT and 120 DAT	18.18	18.49	18.33	43.20	42.83	43.02	1.06	1.07	1.06	12.39	12.38	12.39
T_{10}: Jasmonic acid @ 50 µM at 45 DAT and 120 DAT	17.51	17.15	17.33	40.08	39.56	39.82	0.95	0.95	0.95	11.81	11.73	11.77
T_{11}: Jasmonic acid @ 100 µM at 45 DAT and 120 DAT	17.12	16.38	16.75	39.80	36.51	38.16	0.96	0.90	0.93	11.76	11.48	11.62
T_{12}: Jasmonic acid @ 150 µM at 45 DAT and 120 DAT	16.72	16.54	16.63	39.31	38.22	38.77	0.91	0.94	0.93	11.86	11.39	11.63
T_{13}: Control	16.35	16.05	16.20	33.18	33.52	33.35	0.83	0.84	0.84	10.74	10.56	10.65
S.Em. ±	0.25	0.24	0.19	1.24	1.38	0.79	0.01	0.02	0.01	0.09	0.11	0.07
C.D. (5%)	0.74	0.71	0.56	3.63	4.02	2.29	0.03	0.06	0.04	0.25	0.32	0.21

DAT; Days after transplanting

Table 3. Effect of salicylic acid and jasmonic acid on fruit yield in papaya cv. Red Lady

Treatment	No.of fruits/plant			Weight of fruits/plant (kg)			Yield/plot (kg)			Yield (tonnes/ha)		
	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data	I Year 2015-16	II Year 2016-17	Pooled data
T_1 : Salicylic acid @ 50 ppm at 45 DAT	54.13	53.50	53.82	33.12	33.21	33.17	460.89	458.51	459.70	96.83	96.32	96.58
T_2 : Salicylic acid @ 100 ppm at 45 DAT	56.00	56.00	56.00	35.39	33.53	34.46	496.99	478.46	487.72	104.41	100.52	102.46
T_3 : Salicylic acid @ 150 ppm at 45 DAT	57.00	58.87	57.94	39.03	37.48	38.26	516.75	521.27	519.01	108.56	109.51	109.04
T_4 : Jasmonic acid @ 50 µM at 45 DAT	52.00	51.33	51.67	31.69	33.30	32.49	435.83	455.72	445.78	91.56	95.74	93.65
T_5 : Jasmonic acid @ 100 µM at 45 DAT	53.20	52.87	53.04	34.26	33.78	34.02	473.31	464.62	468.97	99.44	97.61	98.52
T_6 : Jasmonic acid @ 150 µM at 45 DAT	54.23	53.77	54.00	34.21	34.04	34.12	474.95	470.58	472.77	99.78	98.86	99.32
T_7 : Salicylic acid @ 50 ppm at 45 DAT and 120 DAT	58.93	57.47	58.20	41.29	40.48	40.89	529.69	527.98	528.84	111.28	110.92	111.10
T_8 : Salicylic acid @ 100 ppm at 45 DAT and 120 DAT	60.33	60.40	60.37	47.80	46.53	47.17	549.16	544.02	546.59	115.37	114.29	114.83
T_9 : Salicylic acid @ 150 ppm at 45 DAT and 120 DAT	59.80	58.77	59.29	49.85	49.71	49.78	553.49	551.35	552.42	116.28	115.83	116.06
T_{10}: Jasmonic acid @ 50 µM at 45 DAT and 120 DAT	53.33	52.47	52.90	34.56	34.93	34.74	482.91	476.54	479.72	101.45	100.11	100.78
T_{11}: Jasmonic acid @ 100 µM at 45 DAT and 120 DAT	55.33	54.07	54.70	35.83	35.05	35.44	492.38	482.81	487.59	103.44	101.43	102.44
T_{12}: Jasmonic acid @ 150 µM at 45 DAT and 120 DAT	56.60	54.77	55.69	35.89	35.72	35.80	499.02	496.31	497.67	104.84	104.27	104.55
T_{13}: Control	50.53	50.33	50.43	25.56	24.84	25.20	373.76	367.38	370.57	78.52	77.18	77.85
S.Em.±	1.04	1.32	1.08	1.07	1.40	0.94	6.24	6.97	4.62	1.24	1.44	0.79
C.D. (5%)	3.03	3.86	3.15	3.12	4.10	2.74	18.21	20.36	13.49	3.63	4.21	2.31

DAT; Days after transplanting

50 ppm at 45 DAT; T_2, salicylic acid @ 100 ppm at 45 DAT; T_3, salicylic acid @ 150 ppm at 45 DAT; T_4, jasmonic acid @ 50 µ M at 45 DAT; T_5, jasmonic acid @ 100 µ M at 45 DAT; T_6, jasmonic acid @ 150 µ M at 45 DAT; T_7, salicylic acid @ 50 ppm at 45 DAT and 120 DAT; T_8, salicylic acid @ 100 ppm at 45 DAT and 120 DAT; T_9, salicylic acid @ 150 ppm at45 DAT and 120 DAT; T_{10}, Jasmonic acid @ 50 µ M at 45 DAT and 120 DAT; T_{11}, jasmonic acid @ 100 µ M at 45 DAT and 120 DAT; T_{12}, jasmonic acid @ 150 µ M at 45 DAT and 120 DAT; T_{13}, control (no spray).

RESULTS AND DISCUSSION

The highest plant height recorded in the treatment T_9 (SA @ 150 ppm at 45 and 120 DAT) was 168.55, 172.23 and 170.39 cm , which was on a par with T_8, T_7, T_{10} and T_3 at 150 DAT. In pooled mean, highest plant height (215.25 cm) was recorded with T_8, which was comparable with T_9 (213.80 cm), T_7 (211.40 cm) and T_{10} at 180 DAT. In pooled mean highest plant height (257.58 cm) was recorded with T_9 which was at a par with T_8 (255.08 cm) and T_7 (252.65 cm) at 210 DAT. In pooled mean data, at 240 DAT showed that highest plant height (280.88 cm) was recorded with T_9 (SA @ 150 ppm at 45 and 120 DAT) and T_8 (SA @ 100 ppm at 45 and 120 DAT) (275.67 cm) treatment. Both the treatments were at par with each other. Thus, plant height was significantly influenced by application of salicylic acid and jasmonic acid. Compared to the control treatment, plant height increased 19.7, 12.7, 15.4 and 16.8% respectively at 150, 180, 210 and 240 DAT by the application of salicylic acid @ 150 ppm at 45 and 120 DAT (T_9). The effect of salicylic acid was more profound when applied twice (at 45 and 120 DAT) compared to its one time application except at higher concentration (Table 1).

The increase in plant height by salicylic acid in our study could be due to conserved IAA and gibberellins (Tomaszewski and Thimman 1996) and also because of the activity of salicylic acid in regulationof pentose - phosphate pathway and there by induced cell growth and elongation in plants (Pankaj and Sharma 2003).

T_9 (SA @ 150 ppm at 45 and 120 DAT) recorded significantly highest fruit weight 1.06 kg , fruit length (18.33 cm) and fruit girth (43.02 cm) (Table 2). Yield parameters were significantly influenced by the application of salicylic acid @ 150 ppm at 45 and 120 DAT (T_9). Significantly high number of fruits / plant (60.37) was recorded in T8 which was on a par with T_9 (59.29) and T_7 (57.94). The lowest number of fruits / plant were recorded with T_{13} (50.43). Weight of fruits per plant (kg), yield / plot (kg) and yield (tonnes / ha) were found to be highest in T_9 (49.78 kg, 552.42 kg and 116.06 tonnes / ha) which was on a par with T_8 (47.17 kg, 546.59 kg and 114.83 tonnes / ha). The lowest values were recorded in control (T_{13}) (25.20 kg, 370.57 kg and 77.85 tonens / ha). (Table 3).

Application of salicylic acid reduces the production of ethylene farming enzyme (EFE) that converts amino cyclopropane carboxylic acid (ACC) to ethylene (Leslic and Romani 1986) leading to increased fruit number by reduction of fruit abscission and consequently increased fruit yield / plant. Salicylic acid enhances the biosynthesis of natural hormones and carbohydrates, stimulates cell division and tolerance of plants to all stresses namely diseases, water and salt stresses and protects plant cells from oxidation by free radicals (Raskin, 1992).

Enhancement of yield by salicylic acid could also be due to the tolerance of different biotic stresses by its antifungal, antibacterial properties and to different abiotic stresses like drought, temperature stress, salinity stress *etc.* It was mainly because of enhanced activities of antioxidant enzymes including superoxide dismutase, catalase, ascorbate peroxidise and also by activating ascorbate - glutathione path way to protect the plants from oxidative burst. Similar increase in yield by salicylic acid application was reported by Ahmed *et al.* (2015) in mango, Shaaban *et al.* (2011) in apple, Gioushy (2016) in Washington navel orange and Bindhyachal *et al.* (2016) in guava.

The highest TSS content observed with salicylic acid treatment might be due to its dramatic effect on sugar metabolism. Salicylic acid improved the fruit quality by enhancing the biosynthesis and translocation of plant pigments and sugars (Raskin, 1992). Salicylic acid was involved in the regulation of invertase, which plays an important role in hydrolysis of sucrose. (Leclere *et al.,* 2003).

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Assessment of pre- and post-harvest losses of vegetables in Kanpur district of Uttar Pradesh

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ABSTRACT

The study was carried out to find out pre and post-harvest losses in vegetable, *viz.* tomato (*Solanum lycopersicum* L.), brinjal (*Solanum melongena* L.), okra (*Abelmoschus esculentus* L.), cauliflower (*Brassica oleracea* var. botrytis) and bottle gourd *(Lagenaria siceraria)* in Kanpur district of Uttar Pradesh, during 2017-18. Multistage sampling was done for selection of 100 vegetable growers. The sample also included 30 market functionaries. The maximum aggregate losses was found in tomato, followed by brinjal, cauliflower, bottlegourd and okra. The pre-harvest losses at farmers' level contributed for more than 40% of the total losses at farmers' level in all vegetables except cauliflower. The study has recommended that establishment of producer co-operatives to handle various activities relating to production and marketing of vegetables would help in reducing losses.

Key Words: Cooperatives, Farming level, Market functionaries, Multistage sampling, Post-harvest losses, Pre-harvest losses

The losses in vegetables are much higher due to inadequate post-harvest handling, transportation and storage facility. Sharma and Singh (2011), reported 24% of the total production. Many studies have been attempted to estimate the post-harvest losses at various stages of marketing of fruits and vegetables (Waheed *et al.,* (1986); Atibudhi, (1987); Aradya *et al.,* (1990); Madan and Ullasa, (1993); Gauraha, (1997); Srinivas *et al.* (1997); Sudha *et al.* (2005); Murthy *et al.,* (2003); Verma and Singh (2004); Gangwar *et al.,* (2007); Guhara and Thakur, (2008); Kumar *et al.,* (2008). The losses in vegetables specifically after ripening occur mainly at farm level and during harvesting and marketing of vegetables. The farm level losses or pre-harvest losses (after ripening) occur before harvesting begins, and may be due to insect attack, weeds and rusts. The pre-harvest losses specifically after ripening and before harvesting are inevitable, whereas losses occurring during harvesting and marketing (post-harvest) may be eliminated with proper handling. Most of the studies conducted so far consider all the losses after ripening as post-harvest losses, which has aggravated the situation. Thus, study was carried out to access both pre- and post- losses of vegetables in Kanpur district of Uttar Pradesh.

MATERIALS AND METHODS

The study was carried out at Kanpur Nagar district of Uttar Pradesh during 2017-18. For selection of vegetables growers and market functionary's multi-stage sampling was used. At first stage, two blocks, namely Sarsaul and Bilhaur based on maximum area under vegetables were selected. At the second stage, a list of all villages of blocks having at least 15% of their cropped area under vegetables was prepared. From this list, five villages of each selected block were selected randomly. In all, 10 villages were selected. At third stage, 10 farmers per village were selected on the basis of probability proportion of area under vegetable cultivation. Thus, sample size consisted of 100 vegetable growers from 10 villages of 2 selected blocks in Kanpur Nagar district.

The sample also includes market functionaries/ traders dealing in selected vegetables. One wholesale

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market, Chakarpur, and two retail *subji mandis*, *viz.*, Ramadevi and Kalyanpur, were selected, due to adequate arrivals of seasonal vegetables from the study area. Ten traders were selected from each market. As such total numbers of traders selected for the study were 30.

A list of vegetables along with their acreage was prepared for Kanpur Nagar district. Two each major vegetables, brinjal and okra, of *kharif* seasons, tomato and cauliflower of *rabi* season and bottlegourd of zaid season were considered.

The study was based on primary data collected from selected farmers and market functionaries involved in marketing, using a pre-structured schedule developed by personal interview method. Data from the different agencies were collected during the year 2017-18.

The losses in vegetables have estimated at different stages, to find out which vegetable incurred maximum loss, as well as at which stage. Simple statistical tools like averages and percentages were used in the study.

RESULTS AND DISCUSSION

The post-harvest losses occurred either due to inefficiency of growers or their ignorance in implantation of proper post-harvest technique like grading, packaging, storage and transportation etc. The pre-harvest losses were estimated at field level, viz., diseased, hailed, damage by birds and animals, and under sized; whereas post-harvest losseswere estimated at both farmers and traders level.

The data reveals that sample of vegetables are varied in nature, *i.e.* from semi-perishables like bottlegourd, cauliflower to highly perishable like tomato, brinjal and okra (Table 1). Therefore, pre-harvest losses varied from vegetable to vegetable as well as at different stages. The maximum loss was estimated in brinjal (6.38%), followed by tomato (5.13%), cauliflower (2.44%), okra (2.39%) and bottlegourd (2.23%). Thus in brinjal, tomato and cauliflower, the maximum loss was due to under-sized fruit production. The okra registered maximum loss due to disease.

The production of brinjal on sample farms was 160.28 q. The farm utilization was 9.61% of total production. The quantity given to relatives, accounted for 1.57%, spoilage was 2.45%, kind payments was 2.72% and home consumption was 2.42% respectively. The marketed surplus was 145.61 quintals (90.84%) on sample farms.In okra, total was 144.80 q. The break-up of utilization reveals that spoilage (3.67%), kind payments (2.94%), produce given to relatives (2.29%) and home consumption (2.16%), respectively were major items of utilization of okra production. Okra is highly perishable in nature, due to more than one season of production and lower unit value, the practice of putting them into cold storage is practically absent. Therefore, the marketable and marketed surplus was equal.

The average total production of tomato on sample farms was 280.37 q. Total farm utilizations were 10.31% of the total production. The quantity given to home consumptions was 10.73 q, kind payments was 8.24 q, spoilage was 4.77 q and for relatives 4.71 q, respectively. The marketable surplus was 89.85% (Table 2).

In cauliflower, total production was an average as

Table 1. Vegetable production and pre- harvest losses at farm level (kg)

Particulars	Brinjal	Okra	Tomato	Cauliflower	Bottlegourd
Quantity produced	17122	14835	29554	24514	23604
Diseases	226.42	148.28	342.73	152.27	127.3
	(1.32)	(1.00)	(1.16)	(0.62)	(0.54)
Hailed	74.58	45.56	97.72	68.38	62.71
	(0.44)	(0.31)	(0.33)	(0.28)	(0.27)
Damaged by birds and animals	158.62	117.33	163.81	142.35	138.76
	(0.92)	(0.79)	(0.55)	(0.58)	(0.59)
Under sized	633.2	43.58	912.34	234.71	198.71
	(3.70)	(0.29)	(3.09)	(0.96)	(0.83)
Total	1092.82	354.75	1516.6	597.71	527.48
	(6.38)	(2.39)	(5.13)	(2.44)	(2.23)
Actual production	16029.18	14480.25	28037.4	23916.29	23076.52
	(93.62)	(97.61)	(94.87)	(97.56)	(97.77)

Figures in parentheses indicate percentage of total production

Table 2. Utilization pattern of selected vegetables on sample farms (kg)

S.No.	Particulars	Brinjal	Okra	Tomato	Cauliflower	Bottlegourd
a.	Production	16029.18	14480.25	28037.40	23916.29	23076.52
		(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
b.	Utilizations Home consumption	388.02	314.14	1073.02	882.11	878.14
		(2.42)	(2.17)	(3.83)	(3.69)	(3.81)
c.	Kind payments	436.01	426.08	824.19	663.02	723.11
		(2.72)	(2.94)	(2.94)	(2.77)	(3.13)
d.	Spoilage	392.02	531.87	477.15	494.01	693.02
		(2.45)	(3.67)	(1.70)	(2.07)	(3.00)
e.	Other relatives	252.01	331.09	471.01	617.04	664.04
		(1.57)	(2.29)	(1.68)	(2.58)	(2.88)
f.	Total (a to d)	1468.06	1603.18	2845.36	2656.18	2958.31
		(9.16)	(11.07)	(10.15)	(11.11)	(12.82)
g.	Marketable surplus	14561.12	12877.07	25192.04	21260.11	20118.21
		(90.84)	(88.93)	(89.85)	(88.89)	(87.18)
h.	Marketed surplus	14561.12	12877.07	25192.04	21260.11	20118.21
		(90.84)	(88.93)	(89.85)	(88.89)	(87.18)

Figures in parentheses indicates percentage of total production

239.17 q on sample farm. The utilization worked out the home consumptions being 3.69%, kind payments was 2.77%, spoilage was 2.07% and for relatives 2.58% respectively. The marketable surplus was observed 88.89% as well as marketedsurplus was also found equal.

In bottlegourd, total production observed on an average was 230.76 q. It varied in utilization and was calculated on an average as 3.80, 3.13, 3.01 and 2.88% in home consumption, payment in kinds, spoilage and other relatives, respectively. The marketable surplus and marketed surplus were equal and it was found that 87.18% on bottle gourd vegetable farms.

The percentage of marketable surplus on an average varied in different vegetables. It was highest 90.84% in brinjal, followed by 89.85, 88.94, 88.89 and 87.18% in tomato, okra, cauliflower and bottle gourd, respectively. However, marketable surplus among different vegetables did not show much variations. It was due to their perishable nature and also requirement of cash income by growers from the sale of vegetables.

Loses at trader's level were accessed in two forms, *viz.*, damage during handling and sorting. Major share of vegetables produced in Kanpur Nagar district is being sent to distant markets for remunerative prices. Due to delicate nature of tomato, cauliflower, and long transit distance without safe packing cannot withstand as compared to other vegetables. Therefore, wooden boxes with all round padding of prime needles are used for their packing. The Brinjal, okra, cauliflower and bottlegourd transported to the markets are packed in gunny bags. In case the vegetables are sent to local market, plastic crates are used for tomato and cauliflower. The extent of post-harvest losses of selected vegetables at farmer's level and traders' level as shown in (Table 3).

The data reveals that sample of vegetables are varied in nature, from semi-perishables to highly perishables. Therefore, the extent of losses varied from vegetable to vegetable as well as different stages. On overall basis, maximum post-harvest losses at farmer's level was in brinjal (6.45%), followed by tomato (6.18%), cauliflower (5.35%), bottlegourd (2.97%) and okra (1.42%) (Table 3). Maximum loss was during preparing the produce for marketing except cauliflower where maximum loss was observed during transportation of the produce. During the transportation, maximum losses were registered as physical losses.

The wholesale transaction in vegetables were performed from early morning till around 11 AM everyday while retail transactions were performed throughout the day. The wholesalers were not found taking title green vegetables due to their perishability. The losses at trader's level were worked out (Table 3). The post-harvest losses were maximum in tomato (10.62%), followed by bottle-gourd (10.23%), cauliflower (8.87%), okra (8.93%) and brinjal (8.35%). The maximum losses were observed while sorting the produce. The maximum loss during sorting was in tomato.

The total losses were maximum in tomato (21.93%) and minimum in okra (12.74%) (Table 4). Hazarika

Table 3. Losses in vegetables at different levels (kg)

Particulars	Brinjal	Okra	Tomato	Cauliflower	Bottlegourd
Marketable surplus	14561.12	12877.07	25192.04	21260.11	20118.21
	(100)	(100)	(100)	(100)	(100)
Losses during marketing preparation (kg)					
Picking/ harvesting	148.34	54.8	261.77	127.11	183.27
	(1.02)	(0.43)	(1.04)	(0.60)	(0.91)
Assembling	158.79	36.34	245.96	61.57	-
	(1.09)	(0.28)	(0.98)	(0.29)	
Grading/ sorting	153.71	24.62	228.65	218.36	92.57
	(1.06)	(0.19)	(0.91)	(1.02)	(0.46)
Packing of produce	38.47	17.31	76.12	26.85	23.84
	(0.26)	(0.13)	(0.30)	(0.13)	(0.12)
Sub total	499.31	133.07	812.5	433.89	299.68
	(3.43)	(1.03)	(3.23)	(2.04)	(1.49)
Losses during transportation					
Physical loss (pack marked/ pressed ambient temp.)	321.27	30.66	517.4	436.64	217.43
	(2.21)	(0.24)	(2.05)	(2.06)	(1.08)
Economic loss (weight loss, rotten, broken/ damaged)	118.14	18.92	227.39	266.37	80.14
	(0.81)	(0.15)	(0.90)	(1.25)	(0.40)
Sub total	439.41	49.58	744.79	703.01	297.57
	(3.02)	(0.39)	(2.95)	(3.31)	(1.48)
Total loss at farmers level (kg)	938.72	182.65	1557.29	1136.9	597.25
	(6.45)	(1.42)	(6.18)	(5.35)	(2.97)
Loss at traders level					
Damage during handling	243.82	278.34	546.53	324.77	414.3
	(1.67)	(2.16)	(2.17)	(1.53)	(2.06)
Sorted out thrown out weight loss discarded	972.15	872.37	2128.35	1561.68	1643.79
	(6.68)	(6.77)	(8.45)	(7.34)	(8.17)
Total losses at trader's level (Kg)	1215.97	1150.71	2674.88	1886.45	2058.09
	(8.35)	(8.93)	(10.62)	(8.87)	(10.23)
Total losses	2154.69	1333.36	4232.17	3023.35	2655.34
	(14.80)	(10.35)	(16.80)	(14.22)	(13.20)

Figures in parentheses indicates percentage to total production

Table 4. Total losses in vegetables (percentage)

Particulars	Brinjal	Okra	Tomato	Cauliflower	Bottlegourd
Pre-harvest losses at farmer level	6.38	2.39	5.13	2.44	2.23
Post-harvest loss at farmer level	6.45	1.42	6.18	5.35	2.97
Total losses at farmer level	12.83	3.81	11.31	7.79	5.20
Total losses at trader's level	8.35	8.93	10.62	8.87	10.23
Total losses	21.18	12.74	21.93	16.66	15.43

(2006) and Sharma and Singh (2011) have also observed maximum losses in tomato. The brinjal ranked second in the list registering 21.18% of losses, followed by cauliflower (16.66%) and bottlegourd (15.43%). Across different the losses were maximum at grower's level in brinjal and tomato, whereas for bottlegourd, okra and cauliflower the losses were found maximum at trader's level. The pre-harvest losses at farmer's level contributes for more than 40% of the total losses at farmer's level for all vegetables except cauliflower. Moreover, tomato, brinjal and okra, pre-harvest losses are 45.36%, 49.62% and 62.73% of the total losses at

farmer's level respectively. The study explored that without inclusion of pre-harvest loss the post-harvest losses may be overestimated, for instance the total loss in tomato was 21.93% but the post-harvest loss was only 16.80%.

The losses were found maximum in brinjal (12.83%), followed by tomato (11.31%), cauliflower (7.79%), bottle gourd (5.20%) and okra (3.81%). The pre-harvest losses at farmer's level contributes for more than 40% of the total losses at farmer's level for all vegetables except cauliflower. The highly perishable vegetables like tomato, brinjal and okra registered pre-harvest loss of 45.36%, 49.62% and 62.73% of the total losses at farmer's level respectively. At the trader's level, tomato registered maximum loss followed by bottlegourd, cauliflower, okra and brinjal. The maximum aggregate losses were tomato, followed by brinjal, cauliflower, bottlegourd and okra. The inclusion of pre-harvest losses, which so far has been ignored in estimation, indicated that existing methods have unduly over estimated the losses. Thus, it is appropriate to account for pre-harvest losses separately for precise estimation of total loss.

Thus establishment of producer co-operatives to handle various activities relating to production and marketing of vegetables could be a solution. This will not only help to reduce the losses but will also increase the bargaining power of growers in marketing. It will help them in adopting consumer-oriented approach to vegetable marketing.

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Characterization of mango *(Mangifera indica)* varieties for pickle making

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ABSTRACT

An experiment was conducted on characterization of mango (*Mangifera indica* L.) varieties using morphological characters for selection of best pickle varieties for pickle making, at Horticultural Research Station, Ananthrajupet, Andhra Pradesh during 2015-16. Eleven mango varieties were characterized morphologically for fruit and stone characters. The bigger fruit-sized was seen in Gaddemar, while smaller-sized fruits were in Alipasand and Amrigola. Other collections exhibited medium-sized fruits. Gaddemar showed maximum fruit weight (936.2g), fruit width (111.19 mm) and pulp thickness (1.68 mm), whereas Amrigola exhibited lowest fruit weight (76.5g), fruit width (52.26 mm) and pulp thickness (10.20 mm). The mango variety, Chilaka Mukku showed highest TSS (14.6° Brix) and minimum TSS in Alipasand (6.5° brix). Peddarasam showed maximum stone weight (102.5g) and lowest stone weight in Amrigola (8.0g). Gaddemar showed highest fiber length (16.72 mm) while least fiber length (2.8 mm) was noted in Peddarasam. Gaddemar and Alipasand were identified for pickle making due to higher acidity, presence of fibre and lower TSS values.

Key Words: Acidity, Morphological characters, Fibre, Pickle, TSS, Stone weight, Pulp

Mango (*Mangifera indica* L.) is one most popular and choicest fruit of India. A few mango varieties are extremely sour and far from sweet taste and hence, are not used as edible purposes, but are valued for their aroma. These fruits are processed into pickle which is a widely used and appreciated for a common man of this region, no meal is complete without the extraordinary effervescent taste of these mango pickles (Vasudeva and Rajeshwari, 2014).

Pickles and chutneys are major products commonly made from raw mango (Maneepun and Yunchalad, 2004). It is a major source of income for rural landless poor (Tesfaye *et al.*, 2015). The studies on physi-cochemical characteristics of some important mango varieties with respect to pickling have been carried out (Jha *et al.*, 2003; Kambale *et al.*, 2004; Shinde *et al.*, 2002). These types are distinct from other cultivated fruit varieties with respect to morphological characters such as fruit size, shape, taste, aroma, crown shape, height, and resistance to pest and diseases. Morphological characterization is the first step that should be done before more profound biochemical or molecular studies are carried out (Hoogendijk and Williams, 2001). Therefore, an attempt was done to avaluate mango varieties for pickle making.

MATERIALS AND METHODS

The experiment was conducted at Horticultural Research Station, Anantharajupet, Dr YSR Horticultural University, during 2015 and 2016. Eleven mango fruit varieties, Gaddemar, Proddaturu Avakaya, Alipasand, Peddarasam, Amrigola, Rumani, Najuk Pasand, Nunepasand, Mutte Bangalora, Chilaka Mukku and local cultivar were collected from Andhra pradesh and characterized morphologically for fruit and stone characters based on descriptors for mango (IPGRI, 2006).

RESULTS AND DISCUSSION

There was a wide variability in fruit characters, *viz.* fruit length, width, weight, peel thickness, TSS, pulp thickness and acidity. The fruits of Gaddemar showed highest fruit weight (936.2g), fruit width (111.19 mm) and pulp thickness(1.68 mm), whereas Amrigola

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exhibited the lowest fruit weight (76.5g), fruit width (52.26 mm) and pulp thickness(10.20 mm) (Table 1). Our findings are supported by Begum *et al.* (2016) and Hima Bindu *et al.* (2017).

There was maximum fruit length in Chilaka Mukku (162.61 mm) and minimum in Amrigola (49.75 mm) maxiumum fruit skin thickness was recorded in Alipasand (2.25 mm), followed by Mutti Bengalura (1.86 mm), which was on a par with Najuk Pasand (1.86 mm) and minimum fruit skin thickness was noted in Rumani (1.09 mm). Similarly, Manohar Sunagar *et al.* (2015) characterized 12 varieties of aromatic pickle mangoes and observed that all 'whole-fruit pickle' varieties showed smaller diameter (2.87-4.29 cm) and fruit length (4.84-7.62 cm); while 'sliced-pickle' varieties recorded larger diameter (5.07-8.22 cm) and larger length (6.30-10.4 cm).

The mango collection, Chilaka Mukku showed highest TSS (14.6° Brix) and minimum TSS observed in Alipasand (6.5° Brix), but maximum acidity (3.62%) was noted in Nune Pasand, which was on a par with Gaddemar (3.37%) and lowest acidity value of 1.47 in Najuk Pasand (Table 1). Vasugi *et al.* (2008) reported that Mani Bhatta Appe (3.28%) produce best quality pickle with better colour, texture and flavour. Gaddemar showed highest stone length 151.73 mm and minimum stone length observed in Amrigola (41.68 mm) and with regard to stone weight, Peddarasam had maximum value (102.5 g) and lowest stone in Amrigola (8.0 g). Gaddemar showed highest fiber length of 16.72 mm and least fiber length of 2.8 mm in Peddarasam (Table 3). We observed that 158.24 mm, 90.41 mm, 586.5g and 8.2°Brix in fruit length, fruit width, fruit weight and TSS, respectively in Peddarasam and similarly Begum *et al.* (2013) found fruit length, fruit width and fruit weight ranging from 9.70 to 18.50 cm, 5.80 to 10.00 cm and 210.00 to 627.00 g, respectively in Peddarsam except for TSS.

The bigger fruit size was seen in Gaddemar and all other collections exhibited medium size (Gajanana *et al.*, 2014). Amrigola and Rumani had round shape, Gaddemar and Alipasand showed ovate reniform, while Peddarasam, Produtur Avakay and Chilaka Mukku fall under ovate and Najuk Pasand, Nunepasand, Mutte Bangalora and local cultivar showed ovate oblique (Table 2). Shoulders exhibited ending in a long curve, sinus was either absent or slight with rounded to broadly pointed apex, and color of mature skin was green except Najuk Pasand that showed yellow orange green.

There was not much variation in skin texture and all collections including Peddarasam produced smooth skin texture except Gaddemar (Rough) and even with other fruit character, *viz.* basal cavity, in maximum varieties it was absent except Gaddemar and local cultivar, which had shallow. Himabindu *et al.* (2019) noted that Peddarasam showed skin texture smooth and sinus absent and similarly Abhinav Kumar Singh *et al.* (2019) reported that Rumani showed skin texture smooth and sinus present. Amrigola, Rumani, Najuk Pasand, Nunepasand, Gaddemar, Chilaka mukku and local cultivar had beak type with A point and others, Proddutur Avakai, Peddarasam and Mutti Bangalora showed beaked curved and Alipasand had mammiform type of beak, whereas stalk insertion was square in maximum collections except Proddutur Avakai and Alipasand falling under inserted oblique category.

The stone characters were also studied where veins on stone were elevated in six varieties and depressed in four varieties and with regard to pattern of venation, all mango varieties exhibited parallel except Rumani and Amrigola that showed forked venation (Table 3) and fiber was present in all the collections studied.

Thus, it is concluded that Gaddemar, with higher

Table 1. Fruit characters of mango varieties for pickle making

Variety	Fruit length (mm)	Fruit width (mm)	Fruit weight (g)	Fruit skin thickness (mm)	TSS (°Brix)	Pulp thickness (mm)	Acidity (%)
Gaddemar	151.74	111.19	936.2	1.68	7.1	26.44	3.37
Prodaturu Avakaya	104.63	78.93	306.6	1.82	8.4	16.85	2.78
Alipasand	105.68	73.13	268.5	2.25	6.5	16.65	2.13
Peddarasam	158.24	90.41	586.5	1.74	8.2	17.85	1.74
Amrigola	49.75	52.26	76.5	1.41	7.6	10.2	2.96
Rumani	73.97	77.91	310.2	1.09	8.2	15.27	2.52
Najuk Pasand	99.68	77.07	288.8	1.86	10.1	16.91	1.47
Nune Pasand	107.7	75.37	317.5	1.97	6.9	16.45	3.62
Mutti Bangalora	107.7	80.91	348.7	1.86	8.7	18.45	2.85
Local cultivar	89.36	69.79	221.8	1.48	9.7	15.14	1.92
Chilaka Mukku	162.61	85.24	533.0	1.25	14.6	16.75	1.90

Table 2. Fruit characters of mango varieties for pickle making

Variety	Fruit size	Fruit shape	Shoulders	Sinus	Apex	Form of base	Colour of mature skin	Skin texture	Basal cavity	Beak type	Stalk insertion
Gaddemar	Big	Ovate reniform	Rounded	Shallow	Broadly Rounded	Slightly flattened	light green	Rough	Shallow	A point	Square
Prodaturu Avakaya	Medium	Ovate	Slooping	Absent	Rounded	Rounded	Green	Smooth	Absent	Beaked curved	Inserted oblique
Alipasand	Small	Ovate reniform	falling Abruptly	Deep	Rounded	Tampering	Green	Slightly Smooth	Absent	Mammiform	Inserted oblique
Peddarasam	Medium	Ovate	Slooping	Absent	Rounded	Rounded	Green	Smooth	Absent	Beaked curved	Oblique
Amrigola	Small	Roundish	Rounded	Absent	Rounded	Slightly flattened	Green	Smooth	Slight	A point	Square
Rumani	Medium	Roundish	Rounded	Slight	Rounded	Slightly flattened	Green	Smooth	Slight	A point	Square
Najuk Pasand	Medium	Ovate Oblique	Ending in a long curve	Absent	Broadly pointed	Extended	Yellow Orange Green	Smooth	Absent	A point	Square
Nune Pasand	Medium	Ovate Oblique	Ending in a long curve	Slight	Rounded	Extended	Green	Smooth	Absent	A point	Square
Mutti Bengalura	Medium	Ovate Oblique	Ending in a long curve	Absent	Rounded	Rounded	Green	Smooth	Absent	Beaked curved	Square
Chilaka Mukku	Medium	Ovate	Ending in a long curve	Slight	Broadly pointed	Oblique rounded	Green	Smooth	Absent	A point	Oblique
Local cultivar	Medium	Ovate Oblique	Raising and than rounded	Slight pointed	Broadly rounded	Oblique	Green	Smooth	Shallow	A point	Square

Table 3. Stone characters of mango varieties for pickle making

Variety	Stone length (mm)	Stone weight (g)	Fiber length (mm)	Veins on stone	Pattern of venation	Fibre
Gaddemar	151.73	88.8	16.72	Elevated	Parellel	Present
Prodaturu avakaya	76.59	33.7	4.65	Elevated	Parellel	Present
Alipasand	81.77	31.5	4.34	Depressed	Parellel	Present
Peddarasam	100.5	102.5	2.80	Elevated	Parellel	Present
Amrigola	41.68	8.0	5.69	Depressed	Forked	Present
Rumani	53.86	30.2	3.90	Depressed	Forked	Present
Najuk Pasand	83.32	29.62	10.31	Depressed	Parellel	Present
Nune Pasand	81.45	38.37	3.25	Elevated	Parellel	Present
Mutti Bengalura	85.66	25.7	4.13	Elevated	Parellel	Present
Chilaka Mukku	128.89	42.9	6.98	Elevated	Parellel	Present
Local selection	68.92	18.32	6.45	Elevated	Parellel	Present

acidity (3.37%) and maximum pulp thickness (26.44 mm) with presence of fiber and Alipasand with lower TSS (6.5°Brix) showing higher pulp thickness (16.65 mm) and presence of fiber have potential to be promoted for pickle making purpose and further these collections can be studied for genetic evaluation.

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Effect of planting time and spacing on yield, yield-attributing characters and ascorbic acid content of king chilli *(Capsicum chinense)* under polyhouse condition

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ABSTRACT

An experiment was conducted to find out the optimum time of planting and plant density on chilli in polyhouse at Department of Horticulture, CAU, Imphal, during *rabi* season of 2014-15. Four planting times *viz*. 30 November, 19 December, 7 January and 26 January were considered as factor A and three spacings, *viz.* 60 cm × 60 cm, 60 cm × 45 cm and 45 cm × 45 cm were considered as factor B. The experiment was laid out in FRBD (Factorial Randomized Block Design) with 3 replications. The highest number of fruits/plant (67.83), fruit yield/plant [fresh (279.00 g) and dry (71.77g)] and fruit yield/ha [fresh (13.78 t/ha) and dry (3.44 t/ha)] were exhibited when seedling were transplanted on 7 January at a spacing of 45 cm × 45 cm ((D_1S_3). Similarly, maximum fruit length (5.77 cm) and diameter (2.57 cm) were shown when planting was done on 26 January at a spacing of 60 cm × 45 cm (D_4S_2). Highest individual fruit weight (6.07 g) was achieved when planting was done on 7 January at a spacing of 60 cm × 60 cm (D_3S_2). Highest ascorbic acid (149 mg/g) content was obtained from the treatment D_3S_2 which was planted on done 7 January at a spacing of 60 cm × 45 cm.

Key Words: Ascorbic acid, Planting time, Poly-house, Spacing, Yield

King chilli, *Capsicum chinese* is considered to be an interspecies hybrid, more of *Capsicum chinense* and some genes of *Capsicum frutescens* (Paul and Baral, 2007). The chilli is rich in vitamin C and vitamin A, even superior to that of tomato and brinjal (Bora, 2000). It is the highest source of capsaicin which in turn has many industrial and medicinal uses. Defence Research and Development Organization, India, is trying to include this chilli for defense purposes for example preparation of aerosol spray. The crop is cultivated by traditional ways since time immemorial in north-eastern part of India. However, very little research towards scientific cultivation has been done in protected cultivation under polyhouse and till now scientific package of practices is not available. Thus, standardization of technology like planting time and spacing for production under polyhouse condition will help develop scientific package of practices for higher yield of quality fruits.

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MATERIALS AND METHODS

The experiment was conducted during *rabi* season, 2014-15 at Department of Horticulture, CAU, Imphal Four planting times, *viz*. 30 November (D_1), 19 December (D_2), 7 January (D_3) and 26 January (D_4) were considered as factor A and 3 spacing, *viz*. 60 cm × 60 cm (S_1), 60 cm × 45 cm (S_2) and 45 cm × 45 cm (S_3) were considered as factor B. The experiment was laid out in FRBD (Factorial Randomized Block Design) with 3 replications. Thus, there were altogether 36 treatment combinations. Locally available seeds were collected and sown in nursery- bed inside polyhouse to raise seedlings which were later transplanted in beds. The proper irrigation, nutrient management and other inter cultural operations were carried out at regular interval for optimum growth of the plants.

For evaluation of planting time maximum and minimum temperature as well as daily sunshine period were recorded as they are directly correlated with accumulation of photosynthates in plants. Monthly mean minimum and maximum temperature during the experiment varied from 11.2°C to 34.3°C and

maximum temperature was recorded during June 2015 and minimum during December 2015. Mean monthly minimum and maximum sunshine ranged from 2.5 to 7.5 hours / day. Twenty fruits from each picking (first three pickings) from the sample plants from each treatment were taken and fruit length, width, weight were measured from those samples and mean was taken. Mean yield / plant was taken to find out fruit yield / plant. Yield / ha was calculated from fruit yield / plant data. Ascorbic acid or vitamin C content of fruit was determined by standard distillation method given by Sadasivam and Theymoli (1987).

RESULTS AND DISCUSSION

The treatment combinations significantly affected yield, yield attributing traits as well as ascorbic acid content (Table 1). Maximum number of fruits / plant (56.34) was shown by planting time D_1, whereas minimum number of fruits / plant was found by planting time D_4 (23.37). Maximum number of fruits / plant (45.05) was given by wider spacing S_3, while lowest number of fruits by spacing S_2 (36.20). Interaction of planting time and spacing D_1S_3 gave maximum number of fruits / plant (67.83) and minimum number of fruits by D_4S_2 (23.6). So, it can be concluded that temperature is directly related with no. of fruits / plant which is similar to result obtained by Alam *et al.* (2011).

Maximum fruit length (5.68 cm) was shown by planting time D_3, whereas minimum fruit length was found by planting time D_4 (5.46 cm). Maximum fruit length (5.73 cm) was shown by spacing S_2, while lowest fruit length by wider spacing S_1 (5.45 cm). Maximum fruit length (5.77 cm) was shown by interaction D_4S_2 whereas minimum fruit length by D_4S_1 (5.28 cm). Maximum fruit diameter (2.43 cm) was given by planting time D_3, whereas minimum fruit diameter by planting time D_1 (2.12 cm). Maximum fruit diameter (2.36 cm) was shown by spacing S_2, while lowest fruit diameter wider spacing S_1 (2.25 cm). Maximum fruit length (2.57 cm) was given by interaction D_4S_2, whereas minimum fruit length by D_1S_1 (2.10 cm). Maximum fruit weight (5.44 g) was shown by planting time D_3, whereas minimum fruit weight by planting time D_1 (4.08 g). Maximum fruit weight (4.82 g) was given by spacing S_2, while lowest fruit weight by wider spacing S_1 (4.64 g). Interaction of planting time and spacing D_3S_1 showed maximum fruit weight (6.07 g) and minimum fruit weight by D_2S_1 (3.46 g). Thus, fruit

Table 1. Effect of planting time and spacing on fruit traits, fruit yield and ascorbic acid content of chilli

Treat-ment	No. of fruits/plant	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit yield/plant (fresh) (g)	Fruit yield/plant (dry) (g)	Yield (fresh) (t/ha)	Yield (dry) (t/ha)	Vitamin C (mg/g)
D_1	56.34(7.50)	5.56	2.12	4.08	234.66	60.37	9.08(3.05)	2.27 (1.64)	154.14
D_2	45.67(6.76)	5.57	2.3	4.45	208.30	53.59	7.85(2.87)	1.93 (1.55)	159.38
D_3	40.05(6.34)	5.68	2.43	5.44	217.65	56.11	8.38(2.94)	2.10 (1.59)	161.18
D_4	23.37(5.07)	5.46	2.36	4.89	123.20	31.69	4.77(2.27)	1.19(1.29)	150.12
CD.05	0.20	0.09	0.06	0.09	2.16	0.41	0.11	0.03	0.73
S_1	44.34(6.59)	5.45	2.25	4.64	199.30	51.36	5.53(2.43)	1.38(1.36)	155.57
S_2	36.20(6.01)	5.73	2.36	4.82	174.41	44.87	6.46(2.61)	1.61(1.44)	155.71
S_3	45.05(6.65)	5.53	2.3	4.69	214.15	55.09	10.57(3.30)	2.63(1.75)	157.33
CD.05	0.17	0.09	0.06	0.09	1.87	0.38	0.09	0.03	0.67
D_1S_1	59.40(7.73)	5.44	2.10	4.15	245.43	63.14	6.82(2.70)	1.70(1.48)	154.13
D_1S_2	41.80(6.50)	5.65	2.11	4.25	179.55	46.19	6.65(2.67)	1.67(1.47)	150.40
D_1S_3	67.83(8.26)	5.59	2.15	3.85	279.00	71.77	13.78(3.77)	3.44(1.98)	157.90
D_2S_1	56.03(7.51)	5.36	2.26	3.46	203.66	52.39	5.66(2.47)	1.41(1.38)	158.20
D_2S_2	45.60(6.78)	5.79	2.31	5.08	235.84	60.68	8.73(3.03)	2.15(1.62)	159.10
D_2S_3	35.40(5.98)	5.56	2.33	4.80	185.41	47.70	9.15(3.10)	2.22(1.64)	160.83
D_3S_1	38.23(6.22)	5.73	2.42	6.07	232.18	60.07	6.44(2.63)	1.61(1.45)	159.37
D_3S_2	33.80(5.85)	5.69	2.47	5.02	167.93	43.20	6.22(2.58)	1.55(1.43)	163.23
D_3S_3	48.13(6.97)	5.62	2.41	5.24	252.84	65.05	12.48(3.60)	3.16(1.91)	160.93
D_4S_1	23.70(4.91)	5.28	2.22	4.89	115.93	29.82	3.22(1.92)	0.80(1.14)	150.60
D_4S_2	23.60(4.90)	5.77	2.57	4.91	114.33	29.41	4.23(2.17)	1.06(1.24)	150.10
D_4S_3	28.83(5.41)	5.47	2.30	4.87	139.35	35.85	6.88(2.71)	1.72(1.48)	149.67
CD.05	0.35	0.18	0.14	0.20	3.80	0.79	0.20	0.06	1.37

*Value in parentheses are square root transformed value of the original data

*Data is based on mean of 3 replication

length, diameter and weight were significant with planting time, spacing and interaction at all stages of growth. Maximum fruit length, diameter and weight were maximum in case of D_3 as well as S_2 (60 × 45 cm) which is similar that of Islam *et al.* (2011).

Maximum fruit yield / plant (234.66 g) was given by planting time D_1, whereas minimum fruit yield / plant planting time D_4 (123.2 g). Maximum fruit yield / plant (214.15 g) was shown by closer spacing S_3, while lowest fruit yield / plant by spacing S_2 (174.41 g). Interaction of planting time and spacing T3 gave maximum fruit yield / plant (279 g) and minimum fruit yield / plant by T_{11} (114.33 g). Maximum fruit yield / plant per plant (60.37 g) was shown by planting time D_1, whereas minimum fruit yield / plant by planting time D_4 (31.69 g). Maximum fruit yield / plant (55.09 g) was given by closer spacing S_3, while lowest fruit yield / plant by spacing S_2 (44.87 g). Interaction of planting time and spacing T_3 showed maximum fruit yield / plant (71.77 g) and minimum fruit yield / plant was by T_{11} (29.41 g). Maximum fruit yield was exhibited by D_1 and closest spacing (S_3) which is similar to result obtained by Alam *et al.* (2011).

Maximum fresh fruit yield (9.09 t / ha) was shown by planting time D_1, whereas minimum fresh fruit yield was found by planting time D_4 (4.77 t / ha). Maximum fresh fruit yield (10.57 t / ha) was given by closer spacing S_3, while lowest fresh fruit yield by spacing S_1 (5.53 t / ha). Interaction of planting time and spacing D_1S_3 exhibited maximum fresh fruit yield (13.78 t / ha) and minimum fresh fruit yield by D_4S_1 (3.22 t / ha). Maximum dry fruit yield (2.27 t / ha) was given by planting time D_1, whereas minimum dry fruit yield by planting time D_4 (1.19 t / ha). Maximum dry fruit yield (2.63 t / ha) was given by closer spacing S_3, while lowest dry fruit yield by spacing S_1 (1.38 t / ha). Interaction of planting time and spacing D_1S_3 gave maximum dry fruit yield (3.44 t / ha) and minimum fruit yield by D_1S_1 (0.80 t / ha). Fruit yield / ha (both fresh and dry) was significant with planting time, spacing and interaction between spacing and planting time at all stages of growth. Maximum fruit yield / ha was exhibited by D_1 and closest spacing S_3. It may be due to accommodation of a greater number of plants than other two spacing methods which is similar to result obtained by Lal *et al.* (2014), Shakouri *et al.* (2014) and Alam *et al.* (2011).

Maximum ascorbic acid content (161.18 mg / 100g) was shown by planting time D_3, whereas minimum ascorbic acid content by planting time D_4 (150.12 mg / 100 g). Maximum ascorbic acid content (157.33 mg / 100 g) was shown by closer spacing S_3, while lowest ascorbic acid content by spacing S_1 (155.57 mg / 100g). Interaction of planting time and spacing D_3S_2 showed maximum ascorbic acid content (163.23 mg / 100g) and minimum ascorbic acid content by D_4S_3 (149.67 mg / 100 g). Ascorbic acid content of fruit was significant with planting time, spacing and interaction between spacing and planting time at all stages of growth. It can be observed that ascorbic acid content of fruit increased up to certain temperature, after which total ascorbic content was reduced. Thus, it depends upon temperature and solar radiation which is similar to result obtained by Das *et al*. (2011).

It can be concluded that planting on 30 November at a spacing of 45 cm × 45 cm can be recommended for economic yield of chilli under poly house condition. However, these observations are based on the data of two years only, hence further studies are needed to be taken up for confirmation of result before making recommendation for king chili under poly house condition.

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Effect of hot water treatment on dry date preparation from date palm *(Phoenix dactylifera)* cultivars in arid region

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ABSTRACT

An experiment was conducted to utilize the fruits of *doka* stage of date palm varieties for preparation of nutritious dry date (*Phoenix dactylifera* L.) *i.e. chhuhara*, at CIAH, Bikaner, during 2016-17. Dry dates were prepared by giving boiling water treatment of *doka* (hard ripen) fruits for 4-5 minutes and 8-10 minutes of four date palm cultivars fruits which were drying up to 20-30 per cent moisture content. The dry dates prepared by giving treatment in boiling water for 8-10 minutes and then drying was found suitable in term of recovery percentage and organoleptic score basis for taste, appearance and acceptability as well as nutritive point of view.

Key Words: Doka stage fruits, Dry dates, Pickle, Value-addition

Date palm (*Phoenix dactylifera* L.; Family: Arecaceae) is an important fruit tree for semi-arid and hot arid regions of the country. The flesh of mature date fruits contains about 80 per cent sugars on dry weight basis which can provide about 3,150 calories per kg. Dry date is rich source of minerals, vitamins and carbohydrates (Gopalan *et al.*, 1985). Besides fresh consumption, several value-added products, *viz.* dry dates *(chhuhara)*, soft date *(pind khajoor)*, jam, syrup, chutney, beverages, pickle, *etc.* have been prepared from date palm fruits (Chandra *et al.*, 1992; Singh and Dhandar, 2007). In India, date palm fruits are harvested during mid-June to August at *dokaor* khalal stage (hard ripe yellow, red or dark red colour) of maturity due to early monsoon rains. Due to short shelf life, fresh fruits need to be utilized immediately after harvesting. Kachchh region of Gujarat has maximum area (16,688 ha) with annual production of 1,23,490 tonnes where the maximum fruits are harvested at *doka* stage (Muralidharan *et al.*, 2008).

In Western Rajasthan, date palm plantations from tissue culture plants have started bearing fruits and since only limited fruits can be consumed as table purpose, there is ample opportunity to process date fruits into value-added products. In date-growing countries, a number of value-added products, *viz.* wine, syrup jelly, jam, *etc.* are prepared from *doka* fruits. However, in India, very limited work has been done on post harvest utilization of date fruits (Chandra *et al.* 1992, Gupta and Siddiqui, 1986).The fruits having astringent taste at *doka* and good pulp content can be effectively utilized for preparation of dry date *(chhuahara)*. Therefore, an experiment was conducted to prepare products from *doka* stage fruits.

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MATERIALS AND METHODS

The experiment as conducted on doka stage fruits of date palm (*Phoenix ductylifera* L.) cultivars at ICAR-CIAH, Bikaner, during 2016-17. The freshly harvested fruits of *doka (khalal)* stage and astringent in taste were used for preparation of *chhuhara*. Morphological characters of fruits were also observed before giving boiling water treatment for making dry dates. The fruits were washed in water after sorting green, over ripe and infected berries and then they were given hot water treatment for 4-5 minutes (T_1) and 8-10 minutes (T^2) for fruits of four varieties. After treatment in boiled water, the fruits were dried in open air and under sun for making *chhuahara*. The varieties, *viz.* Sewi, Saggai and Medjool and Local Red type were taken for comparative evaluation. One kg fruit sample of each cultivar in four replications were used. The dry dates were prepared during August as varieties were of late maturing type. After drying, dry weight were stored in qunnet in laboratory under normal room temperature

conditions (mean maximum temperature 23.26°C, mean minimum temperature 7.18°C) for biochemical analysis and organoleptic testing. The dry date sample were analyzed in lab for total sugars, antioxidant activity and tannins content. Total sugars in dry date were determined by anthrone method and after colour development the optical density was recorded at 630 nm as per standard procedure. Hedonic scale (0-10 marks) method was used for the organoleptic evaluation of dry date for colour, taste, appearance and acceptability by a panel of 10 judges. The mean data of score was assessed for sensory evaluation of dry dates *(chhuhara)*.

RESULTS AND DISCUSSION

Data on morphological fruit characters (Table 1) showed a significant difference in average weight of fruit at *doka* stage. The maximum fruit weight (13.75g) was recorded in cv. Medjool, while it was found the minimum in cv. Sewi (6.78g). The length and width of fruit was also differed significantly among cultivars. Difference in pulp: stone ratio was also recorded in fruits of cultivars. It was observed the maximum in cv. Local red type (12.89) followed by cv. Saggai (10.37) and same was least in Sewi (4.50). Total soluble solids (TSS) of doka fruits differed significantly among cultivars. The highest TSS (43.77° brix) content was observed in cv. Saggai followed by Medjool (40.30. brix).

The stone weight was significantly differed in date palm cultivars. The maximum stone weight was in cv. Medjool (1.45g), followed by Saggai (1.20g) the lowest weight of stone was noted in Local red type (0.88g). Significant difference was observed in recovery percentage of dry dates. The highest recovery percentage (54.45) was recorded in cv. Saggai, followed by cv. Medjool (45.75) and it was recorded the lowest in Sewi (39.00). The less recovery percentage was observed in cv. Sewi which may possibly be due to low pulp: stone ratio and weight of fruit. The variation in recovery percentage of dry date has reported by Gupta and Siddiqui (1986).

The dry dates were evaluated for its appearance, colour, acceptance, taste and sweet characters. The data on organoleptic testing revealed that the dry date prepared from both treatment were acceptable by the panel of judges (Table 2). The score of acceptability and taste characters indicated that chhuhara is the good value-added product of *doka* stage fruits to get income to the famers from post harvest utilization. The appearance of product was attractive at fresh harvest and then it declined gradually during storage period. This may possibly be due the biochemical changes during storage of the products. The appearance of dry date prepared from cv. Medjool secured the maximum (7.82) score, whereas cv. Sewi secured less (2.68) since fruit colour was greenish-yellow at the time of harvesting. Local red type also secure poor (4.10) score due to shrivelled and non attractive in colour. In sensory evaluation, taste is another important

Table 1. Fruit characteristics of date palm cultivars used for dry dates preparation and their recovery percentage

Character	Sewi	Saggai	Medjool	Local Red Type	SEm	C.D. (5%)
Av fruit weight	6.77	12.30	1375	10.30	0.56	1.75
Length of fruit (cm)	3.12	3.52	3.80	3.10	0.08	0.26
Width of fruit (cm)	1.80	2.05	2.42	2.12	0.05	0.17
Pulp : stone ratio	4.50	10.37	8.16	12.89	0.41	1.27
TSS (°Brix)	31.72	43.77	40.30	28.90	0.70	2.21
Dry date recovery (%)	39.00	54.45	45.75	40.75	1.02	3.18
Average stone weight (g)	1.20	1.06	1.45	0. 88	0.06	0.19

Table 2. Organoleptic test of dry dates *(chhuhara)* (on 0-10 score)

Character	Sewi		Saggai		Medjool		Local Red Type	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Appearance	2.45	2.68	7.27	7.00	7.19	7.82	4.00	4.10
Taste	2.18	2.00	7.00	7.00	8.18	7.45	4.10	3.54
Sweetness	2.10	2.18	6.73	6.55	8.55	7.64	4.00	3.64
Colour	2.10	1.73	6.64	7.10	7.27	7.36	3.63	3.27
Acceptability	1.00	1.19	6.27	7.00	8.10	7.45	3.45	3.27

The score of 0 was lowest while that of 10 highest for each parameter

Table 3. Nutritional characteristics of dry dates *(chhuhara)*

Variety	Total sugars (g/100 g of sample)	Antioxidant on dry sample weight basis MTE/g	Tannins (%)
Sewi	8.30	104.90	1.55
Saggai	38.60	122.75	0.64
Medjool	38.85	133.53	0.96
Local red type	16.20	84.04	0.34

factor after colour and softness. The score of taste character ranged from 2.18 to 8.18 among the cultivars, and it was acceptable on the basis of good hedonic rating scale. Score values for taste differed from variety to variety due to fruit qualitative and quantitative attributes (Singh *et al.* 2014, Singh *et. al.* 2020, Patel and Patil, 2016, Kalitha and Goswami, 2019) in different fruit crops.

Although, differences in organoleptic score did not show any variation between the treatments. However, it is recommended that boiling water dipping should be given for 8-10 minutes to stop all enzymatic activity and soften the date and also to improve the storability and palatability of the product.

The dry date prepared from cv. Medjool was superior over other cultivars fruits for high antioxidant value and total sugars content followed by cv. Saggai (Table 3). Sewi is a good cultivar but it was not acceptable by tasters possibly due to poor in taste as high tannins contents. Dry date made up from local red type was also not found good in terms of total sugars content while tannin was low(0.34%). During storage, changes in physico-chemical characters are common in any value added products. The finding is similar with the results reported by AL-Farsi *et al.* (2005).

Difference in the antioxidant activity was observed among dry date in date palm cultivars when it was estimated on dry weight basis (Table 3). The maximum antioxidant activity was recorded in cv. Medjool (133.53 MTE / g) followed by cv. Saggai (122.75 MTE / g). In cv. Sewi, it was comparatively low as compared to cv. Medjool. The variation in antioxidant activity may possibly be due to high tannins and low total sugars contents. Similar finding has also been reported by Faroogh Biglai *et al.* (2008) in Iranian date palm cultivars. The tannin content was high in cv. Sewi (1.55%) and lowest was in Local Red type (0.34%) even though it was not sweet in taste and also matured late. Total sugars content was also low in comparison to Medjool and Saggai cultivars.

Thus, it can be concluded that nutrient rich dry date *(chhuhara)* can be prepared by giving hot water treatment of *doka* stage fruits for 8-10 minutes followed by drying. The fruits of cv. Medjool were found suitable followed by Saggai for dry date preparation in terms of recovery percentage and quality. Hence, value addition at *doka* stage fruits provides an ample scope to date growers for utilization of available raw material for preparation of *chhuhara* which can be stored for a long time.

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In-vitro scape and bulb formation in garlic *(Allium sativum)*

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ABSTRACT

Garlic (*Allium sativum* L.) is one of the important spices crops that required on daily basis in kitchens and cuisines across the world. Scape or flowering stalk induction is highly important for crop improvement as garlic is a vegetatively propagated crop. However, scape formation has not achieved yet by any means. Meristems (0.1-0.3 mm) of garlic cv. Bhima Purple were cultured *in vitro* on basal MS medium fortified with 0.1 mgl^{-1} NAA, 1.0 mgl^{-1} Kinetin and 3% sucrose (w/v). Proliferated meristems (mericlones) were sub-cultured after 10-15 days. About 55-60 days old cultures were sub-cultured on MS + 1 mgl^{-1} Kinetin + 6% sucrose in liquid medium for microbulbil induction and maintained till its harvest. Microbulbils were induced on mericlones after about 70-75 days after initial inoculation. *In vitro* induced bulbils transformed into a small garlic bulb having 2-3 cloves or microbulbils after 110-115 days of initial culturing. Subsequently after 125-130 days the maiden *in-vitro* scape formation was observed. It showed a ray of light to use this alternative strategy, *i.e. in-vitro* scape induction to induce flowering stalk in garlic. Also, the successful *in-vitro* bulb development reported first time herein would give an opportunity of mass production of garlic without managing cumbersome field propagations.

Key Words: Bulbil, Mericlone, Scape

Garlic (*Allium sativum* L.), a world famous spice commodity. Despite second largest garlic production after China in the world, productivity in India is far meager (5.83 t/ha in 2018-19), as compared to 16.71 t/ha of world average (Murkute and Gawande, 2018). It is estimated that, to satisfy domestic consumption of the projected 1.7 billion population of India by 2050, the garlic requirement will increase to 1.66 million tons from 1.23 million tons at present (DOGR, 2013). With this assumption the increase in productivity to 6.77 t/ha against the existing 5.00 t/ha is mandated.

The meager availability of germplasm sources and lack genetic improvement programmes augment disappointment for stagnation of productivity. The perpetual limiting of garlic productivity due to viral infestation of seed material is one of the major causes (Murkute and Gawande, 2018), which also demands conventional breeding using resistant sources. Commercial garlic is vegetatively propagated crop and the crop improvement through conventional breeding techniques could not make any headway due to non-flowering. Therefore, flower or scape induction in garlic has received major research attentions. Also, there are reports of development of microbulbils *in vitro* (Murkute and Gawande, 2018). Yet, development of garlic bulb (cloves covered in tissue sheath) *in-vitro* has not been reported.

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MATERIALS AND METHODS

The present study was conducted using garlic cultivar Bhima Purple. Cold stored (4°C) bulbs were peeled to remove dry skin of cloves. In Laminar Air Flow (LAF) cabinet, cloves were surface sterilized by 70% (v/v) alcohol, followed by sodium hypochlorite (2% w/v) for 15 min and rinsed with sterilized double distilled water. Meristems (0.1 - 0.3 mm) were cultured *in vitro* on basal MS medium (Murashige and Skoog, 1962) fortified with 0.1 mgl^{-1} NAA, 1.0 mgl^{-1} Kinetin and 3% sucrose (w/v). The pH of medium was adjusted to 5.8 before autoclave (121°C and 15 lb/psi for 20 min) and medium was gelled using bactodifco agar (0.8%). Proliferated meristems were sub-cultured after 10-15 days on MS medium + 0.5 mgl^{-1} Kinetin with 3% sucrose, gelled with 0.8% agar. About 55- 60 days old cultures were sub-cultured on MS + 1 mgl^{-1} Kinetin + 6% sucrose in liquid medium for microbulbil induction

and were maintained on the same microbulbil induction medium up to harvesting.

RESULTS AND DISCUSSION

In-vitro scape formation was observed in garlic cv. Bhima Purple during production of microbulbils using mericlones, probably the first time. It was found that the proliferation in all the inoculated meristems started in about seven days without callusing on MS + 0.1 mgl^{-1} NAA, 1.0 mgl^{-1} Kinetin and 3% sucrose (w/v) medium. About 55- 60 days old proliferated meristems, *i.e.* mericlones were sub-cultured on MS + 1 mgl^{-1} Kinetin + 6% sucrose in liquid medium for microbulbil induction, which were induced 15 - 20 days after subculturing, *i.e.* 70 - 80 days after initial inoculation. The size and weight of microbulbils increased and sub-sequently 110-115 days after initial culturing it developed into a small garlic bulb having 2-3 cloves or microbulbils covered in a tissue sheath (Fig. 1). When cultures were further maintained on same medium, scape formation was initiated after 125-130 days in one of the cloves of *in-vitro* developed garlic bulbs and 140 - 145 days after initial culturing, again microbulbils were developed on that new scape (Fig. 2). Although *in-vitro* bulbil formation in garlic is standardized (Murkute and Gawande, 2018), formation of a garlic bulb, *i.e.* more than one clove covered into a tissue sheath was reported for the first time. The induction of bulbil on reproductive stalk, *i.e.* scape developed from the disc of original explants of *in-vitro* maintained garlic cultures was also a maiden report.

The discovery of fertile garlic plants (Etoh, 1986), which otherwise sterile and propagated asexually, increased the importance of study of garlic flowering and seed production. However, garlic genotypes vary considerable in their capacity to produce scape, umbels, fertile pollen and receptive stigmas (Etoh and Simon,

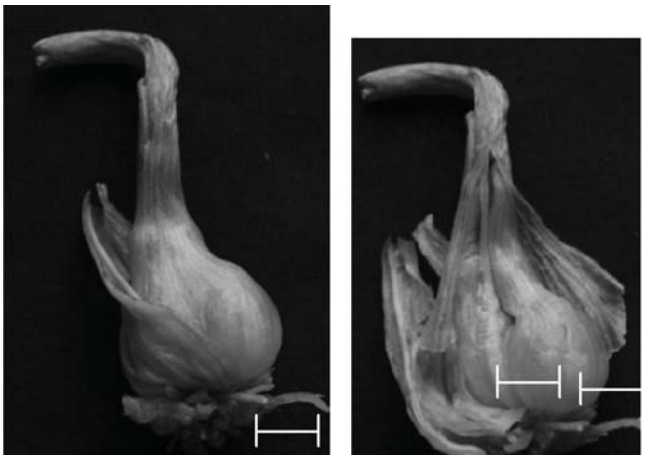

Fig. 1. (a) *in-vitro* developed garlic bulb; **(b)** two cloves of garlic bulb in tissue sheath. White bar in figure = 1 cm

2002; Kamenetsky *et al.*, 2004). There are four distinct phases identified in garlic florogenesis: 1) transition, 2) scape elongation, 3) inflorescence differentiation, and 4) completion of floral development to anthesis (Kamenetsky *et al.*, 2006).

It was observed that florogenesis in garlic can be promoted by exposure to proper environmental stimuli, during pre-planting storage and sprouting to the later growth stages (Mathew *et al.*, 2011). Also, low temperatures and long photoperiod promote floral development (Takagi, 1990). The transition of the apical meristem from a vegetative to reproductive state occurs during the active growing phase (Kamenetsky and Rabinowitch, 2001). Thus, *in-vitro* controlled conditions could have favored the scape formation. However, it is yet unclear whether the phase-specific photoperiod effect on florogenesis is universal.

A study of temperature and photoperiod effect on garlic growth and florogenesis provided an insight to the enigma of garlic sterility and offered environmental

Fig. 2. (a) *In-vitro* scape formation; **(b)** scape formation form disc of original explant along with microbulbil development at apex; **(c)** formation of scape from the clove and development of microbulbils on scape. White bar in figure = 1 cm.

tools for flowering regulation and fertility restoration (Kamenetsky *et al.,* 2004). Photoperiod, like other environmental stimuli, regulates plant response through internal signals and changes in hormones profile (King *et al.,* 2006). In shallot (*Allium cepa* var aggregatum), a relative of garlic, application of GA_3 along with long photoperiod was found beneficial to increase number of flowers per umbel and true seed production (Sopha *et al.,* 2014). *In-vitro* scape formation in garlic provides an opportunity to tamper the vegetative growing phase of garlic to induce flowering.

Also, it may be said that the *in-vitro* developed microbulbils are the rudimentary garlic bulbs and upon favorable conditions a complete bulb could develop instead of microbulbils. Production and establishment of virus free garlic is cumbersome as the *in-vitro* developed microbulbils takes two to four vegetative generations in the field conditions to reach the commercial size garlic bulb (Metwally *et al.,* 2012, Murkute and Gawande, 2018). Furthermore, during this field propagation period maintenance of vector free environment is very difficult. Therefore, development of *in-vitro* garlic bulb, *i.e.* with more number of cloves per bulb would help to produce disease free garlic planting material in short span of time.

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Effect of pomegranate (*Punica granatum*) peel extract on improving vase-life of cut carnation *(Dianthus caryophyllus)*

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ABSTRACT

The experiment involved the green synthesis of silver nanoparticles (AgNPs) from pomegranate (*Punica granatum* L.) peel extract to enhance the vase-life of cut carnation (*Dianthus caryophyllus* L.) flowers. Biosynthesized pomegranate peel extract (PPE)-AgNPs were characterized by UV-visible spectroscopy, fourier-transform infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). The intensity of peak at 378 nm in UV-vis spectra, attributed to the surface plasmon resonance of PPE-AgNPs, changes with reaction parameters. The SEM showed cubical shaped nanoparticles with an average particle size of 1 - 3 nm. The 15 mg/l PPE-AgNPs, treatment produced longest vase-life (11 days), while the control resulted in the shortest vase-life (7 days) of cut carnation flowers. Thus, these was positive role of PPE-AgNPs in increasing the vase-life of cut carnation flowers.

Key Words: Nanotechnology, Pomegranate, Silver nanoparticles, Spectroscopy, Vase-life

Carnation *(Dianthus caryophyllus)* plays a significant role in florist trade (Ali *et al.,* 2008). However, post-harvest senescence occurs in a few days, as a major limiting factor in marketing of cut carnation flowers. The premature aging and decreasing vase-life of cut flowers mainly resulted due to production of ethylene and vascular blockage. Ethylene causes the petals shedding and browning which severely reduces the quality and market value of flowers (Serek *et al.,* 2006). To enhance the vase life of cut flowers, several efforts have been made to reduce ethylene production in petals using various compounds, such as silver nitrate, 8 hydroxyquinoline citrate (8-HQC), aluminum sulphate, essential oils and nano-silver, nitric oxide, and 1-MCP by inhibiting the ethylene production and improve water uptake. (Bowyer *et al.,* 2003; Ichimura and Niki, 2014). A positive effect of AgNPs on the vase life of some commercially important plants, such as rose, carnation and gerbera cut flowers, has been observed (Liu *et al.,* 2009). Solgi *et al.* (2009) and Morones *et al.* (2005) found that treatment of AgNPs reduced bacterial growth in vase solution during the postharvest period. Therefore, analysis was done to synthesis of AgNPs using pomegranate (*Punica granatum* L.) peel extract, characterization of AgNPs using different approaches and evaluated vase-life potential of synthesize AgNPs in cut carnation flowers.

MATERIALS AND METHODS

Pomegranate fruits were collected from the local market, while carnation cut flowers were harvested early in the morning from a greenhouse. The stems were trimmed to 15 cm length with the help of a scissor. The flowers were kept under shade in the field until transported to the laboratory. To minimize the moisture loss, flowers were covered with a plastic film during transportation.

The peel of washed pomegranate fruit was removed and again washed with deionised water. Approximately 20g of pomegranate fruit peel was weighed and added in 250 ml flask containing 100 ml

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of distilled water and boiled it for 10 minutes. The boiled material was filtered through the Whatman no.1 filter paper. The resultant aqueous pomegranate peel (PPE) extract was used for the synthesis of AgNPs and synthesized NPs were designated as (PPE)-AgNPs. All glass wares were washed properly with deionised water. The combination of 25 different concentrations of silver nitrate (1, 2, 3, 4 and 5mM) and peel extract (1, 2, 3, 4 and 5ml) were used to synthesis NPs.

The synthesized AgNPs where characterized by UV- visible spectroscopy, FTIR and SEM. The best concentration of AgNPs were chosen for further characterization based on the data obtained from UV-visible spectro-scopy. The reduction in metal ions was monitored by measuring the UV-visible spectroscopy of reaction medium. The computer and spectrophotometer was turned on by switching on / off button. The cuvettes were washed with distilled water and the synthesized (PPE)-AgNPs were dissolved in 1ml Milli-Q water and transferred into cuvettes. Then cuvettes were placed in spectrophotometer and wavelength was adjusted to 200-800 nm. The baseline correction was done for reading of each metal nanoparticle. The UV-visible spectra analysis was done by using UV-visible spectroscopy.

The FTIR spectra were recorded in the range of 400-4000 cm-1 by KBr pellet method (Shimadzu), 0.1 g of potassium bromide was grinded to fine paste in mortar and pestle for 2 min and a small amount of liquid sample was mixed into it. A small amount of mixture was put into the open chamber, just enough to cover the bottom surface of chamber. Chamber was covered with lid and pressed hard and then pressure was released the metal piece was removed and pellet formed in the middle of metal piece was observed and found to be clear and free from cracks. This pellet was screwed to pellet holder and FTIR spectra was recorded by Shimadzu.

The morphology of (PPE)-AgNPs was studied using SEM. Thin films of the sample were prepared on a carbon coated tape by just placing a very small amount of the sample on the grid, extra sample removed using a blotting paper and then the film on the SEM grid were allowed to dry by putting it under a mercury lamp for 5 minutes. The SEM analysis was used to determine the structure of the reaction products that were formed.

The cut carnation flowers were placed in glass bottles containing 250 ml of synthesized (PPE)-AgNPs (5 mg/l, 10 mg/l, 15 mg/l) and Milli-Q water was used as the control. These flowers were kept under room temperature to observe the changes till it gets dry. Vase-life was determined in days until the flower showed the symptoms of wilting.

RESULTS AND DISCUSSION

We successfully synthesized green NP using PPE, to optimize the concentration of substrate and peel extract for the synthesis of AgNPs. The reaction was carried out by addition of different concentrations of PPE such as 1 ml, 2 ml, 3 ml, 4 m l and 5 ml to aqueous silver nitrate solution by keeping its concentration (4 mM) constant. Different parameters were optimized to get the best reaction condition including concentrations of silver nitrate and PPE, at 80°C. On increasing concentration of extract, there is increase in intensity of absorption. The UV-visible spectra was recorded after time intervals of 30 min. The decreases in absorbance were found with increasing in time interval and broadening of peak indicating polydispertion of particles. Further, increase in peel extract concentration showed low peak absorption. The best reaction conditions were obtained at 30 min time interval with 4mM $AgNO_3$ + 3 ml peel extract.

The synthesis was confirmed by UV-visible analysis that gave the peak at 378 nm with absorbance of about 412. Similarly, several study has been reported the green synthesis approach for synthesis of NPs using various extracts of fruit, fruits peels, callus and seed of Amla *(Emblica officinalis)* (Balaprasad *et al.,* 2005), sweet peppers *(Capsicum annum)*, papaya *(Carica papaya)* (Mude *et al.,* 2008), jatropha *(Jatropha curcas)* (Bar *et al.,* 2009), banana *(Musa spp.)* (Bankar *et al.,* 2010), sweet orange *(Citrus sinensis)* (Konwarh *et al.,* 2011), pomegranate peel (Mohamed, 2017).

The spectra and visual observation revealed that formation of AgNPs s occurred rapidly in 30 min. The appearance of the brown color was due to the excitation of the surface plasmon resonance (SPR). It was observed that the intensity of absorption peaks increase with increase in the concentration of the silver nitrate salt. The reduction of silver ions in the aqueous of silver nitrate during the reaction with the ingredients PPE were observed by the UV-Visible spectrophotometer analysis by wavelength scanning between 200 and 800 nm. The maximum absorption was found at 378 nm that corresponds to SPR of AgNPs. Similarly, Mohamed (2017) reveled that after addition of $AgNO_3$ to PPE, colors of mixture changed from yellow to dark brown. The UV-Vis spectroscopy analysis showed that solution peak at an average wavelength of 437 nm. Moreover, UV-vis spectral analysis CuNPs showed peak at 565 nm is due to the surface SPR of Cu colloids formation of non-oxidized CuNPs (Chung *et al.,* 2017).

The secondary metabolites are the main factors for the biosynthesis of $AgNO_3$, the plant extract contain phenolic, alcohol, amine, carboxylic acid, alkaloids and terpenoids that responsible for reduction and stabilizing

$AgNO_3$ (Jha *et al.,* 2009). The FTIR measurements were carried out to identify the possible bio molecules responsible for the reduction of Ag+ ions to AgNPs by PPE. The spectrum indicated major peak at 3286.7 cm^{-1} and other peaks were obtained at 2341.58 cm^{-1} 2360.87 cm^{-1}, 1635.64 cm^{-1} and 1082.7 cm^{-1}. The band at 33286.7 cm^{-1} was assigned to the stretching of alcohol group, while the other bands 2341.58 cm^{-1} 2360.87 cm^{-1} were assigned to silane. The bands observed at 1635.64 cm^{-1} and 1082.7 cm^{-1} can be assigned to the C=C and C-N were stretching to alkene and amine group respectively. Mohamed (2017) identified the alkynes, carbonyls, alkenes, alkyl halides and aromatics are the natural products present in pomegranate leaves extract responsible for the reduction of Ag+ ions to $AgNO_3$.

The SEM technique is used to visualize the size and shape of NPs. For SEM technique the dried (PPE)-AgNPs were mounted on a copper coated grid. The formations of (PPE)-AgNPs as well as their morphological dimensions in the SEM study demonstrated that the average size was between 1 to 3 nm and in cube shaped. The Solgi and Taghizadeh (2012) reported that SEM image show that AgNPs are relatively uniform in diameter and have spherical shape.

Vase-life is distance between to start treatment to flower senescence which associated with petals wilt and the leaves changing color and was expressed as days. The end of vase-life was determined as the flowers showed the symptoms of wilting, loss and discolorations of petals. Significant differences were found in extending the vase life of cut carnation. The flowers in the control, 5mg/l, 10mg/l, and 15mg/l last for 7, 9, 10, and 11 days. The longest vase life (11 days) was obtained with 15 mg/l concentration of $AgNO_3$ as shown in. The vase life of cut carnation exposed to control, 5 mg/l, 10 mg/l and 15 mg/l were 7, 9, 10 and 11 days respectively. There is significant visible difference was observed between various concentrations of (PPE)-AgNPs. This result showed that 15 mg/l is an optimum concentration of (PPE)-AgNPs to extend the vase life of cut carnation. Similarly, positive effect of nano-silver on longevity of cut flowers expressed in days was reported for carnations (Hashemabadi 2013), roses (Jowkar *et al.* 2013), gerberas (Kazemi and Ameri 2010, Liu *et al.,* 2009) and oriental lilies (Nemati *et al.,* 2013, Nemati *et al.,* 2013). Ethylene promoted flower senescence, the microbial contamina-tion at the stem base or in the vase solution produced ethylene. Ethylene causes the petals shedding and browning which severely reduces the quality in relation to marketability of flowers (Serek *et al.,* 2006). The treatment of $AgNO_3$ reduced bacterial growth in the vase solution during the postharvest period (Solgi *et al.,* 2009).

Thus, pomegranate peel was found as a good source for synthesis of $AgNO_3$ due to presence of crude pectin, sugars and ellagic acid (main phenolic compound) present in peel. Further study needs to analyze the effect of $AgNO_3$ is due to suppression of ethylene production and inhibiting bacterial growth in vase solution.

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Analysis of molecular chaperones in differentiating storage root compared to non-tuber forming fibrous root of sweet potato *(Ipomoea batatas)*

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ABSTRACT

The differential expression pattern of molecular chaperones genes was studied in developing storage and fibrous root tissues of sweet potato [*Ipomoea batatas* (L.) Lam.] using hybridization array. Out of 121 chaperone genes, 76 and 45 genes displayed more than 1.5-fold induced and reduced expression, respectively during the initial storage root development as compared to the non-tuber forming fibrous root of sweet potato. The differentially expressed genes belong to different chaperone family included DNAJ, HSP90, HSP100/ClpATPase, HSP20, families etc. These differentially expressed chaperones are known to play an important role in hormone signalling, nucleosome remodelling, protein import, protein folding and proteasomal degradation. Thus, our study shows the functional role of molecular chaperones in development of storage-roots of sweet potato, providing further scope for chaperone mediated functional genomics studies and CRISPER-mediated breeding of storage root development in sweet potato.

Key Words: ClpATPase, HSP20, HSP90, Molecular chaperones, Storage root, Sweet potato

Sweet potato [*Ipomoea batatas* (L.) Lam.], as a seventh most important staple crop which, is widely cultivated in tropical and subtopical regions of the world. Molecular chaperones are cellular proteins that play important role in plant growth and development and stress tolerance (Jeng *et al.*, 2015; Muthusamy *et al.*, 2016; Ma *et al.*, 2018). Chaperones constitutes a large number of proteins belonging to different families including HSP20, HSP40, HSP60, HSP70, HSP90, HSP100, DNAJ and proteases family members, *i.e.* ClpATPase, and FtsH, *etc.* (Trösch *et al.*, 2015; Muthusamy *et al.*, 2017a). In many cellular organelles, proteins are imported in non-native states and refolded into native state through molecular chaperones after its translocation (Flores-Pérez and Jarvis, 2013; Trösch *et al.*, 2015). In Arabidopsis, the H3/H4 his tone chaperone CAF-1 and the H2A/H2B his tone chaperone NRP1 and NRP2 play important role in maintaining stem cells during root development (Ma *et al.*, 2018). The p 23, a co-chaperone of HSP90 regulates root growth by modulating the auxin distribution pattern in Arabidopsis root meristem (D'Alessandro *et al.*, 2015). Thus, understanding the genes and regulatory networks involved in storage root development using the functional genomics approaches will help in breeding superior genotypes rich in yield and bioactive compounds with high keeping quality (Mukherjee *et al.*, 2015; Ravi *et al.*, 2016; Lenka *et al.*, 2019; Niu *et al.*, 2019). Microarrays have been employed in studying differential expression pattern of the genes involved in storage root development in sweet potato (Tao *et al.*, 2012; Ravi *et al.*, 2014, 2016). Ultimately, this information can be utilized for mining genes and development of molecular markers to develop improved climate-smart sweet potato cultivars resilient to climate change either through marker assisted breeding or by genetic transformation for transgenic crop development (Hirakawa *et al.*, 2015; Lenka *et al.* 2018; Kim *et al.*, 2011; Tripathi and Yogeesha, 2018). Therefore, differential expression pattern of chaperone family genes in the storage root (tuber forming root) and non-storage root (fibrous root) and the role of chaperone family genes in the storage root formation in sweet potato, were studied.

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MATERIALS AND METHODS

The total RNA was extracted from the storage root and fibrous root (non-storage root) tissues of sweet potato var. Sree Arun and expression analysis was performed using the Gene Expression Hybridization kit (Part Number 5190-0404; Agilent) as described by. The microarray-based expression datasets derived from the storage root and non-tuber forming fibrous root tissues of sweet potato were normalised and transformed into the log 2 ratio and features < 1.0 fold log values were filtered and the signatures were used to study the expression of molecular chaperones in the storage root and fibrous root (non-storage root) tissues of sweet potato. The chaperone family genes homologs were reconfirmed by blastn search in Arabidopsis genome database TAIR (https://www.arabidopsis.org/).

RESULTS AND DISCUSSION

In tuber crops, starch biosynthesis and storage take place in the Amyloplasts organelles of the tuber tissues (Geng *et al.,* 2017; Nazarian-Firouzabadi and Visser, 2017; Ravi *et al.,* 2018; Remesh *et al.,* 2019). Subsequently, several studies showed various regulatory role of molecular chaperones in development of tuber tissues including amyloplasts, modulating the signalling of auxin, jasmonic acid and brassinosteroids hormones, *etc.,* Bekh-Ochir *et al.,* 2013; D'Alessandro *et al.,* 2015; Katiyar *et al.,* 2015; di Donato and Geisler, 2019). We compared the expression pattern of molecular chaperones involved in developing storage and fibrous roots through analysing the microarray datasets captured during the development of storage, as well as fibrous and root tissues (Ravi *et al.,* 2016). Out of 55794 ESTs tested, 465 ESTs belonged to chaperone family genes.

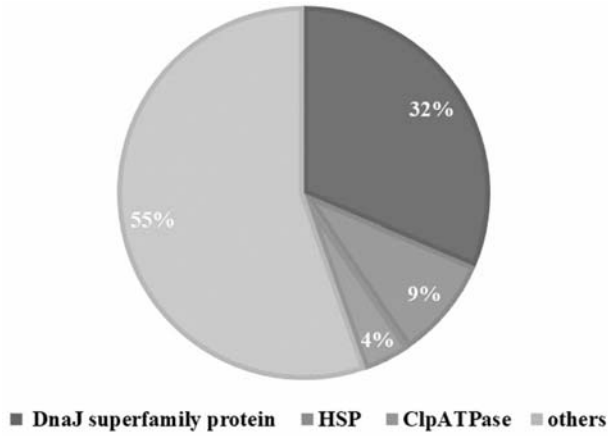

Fig. 1. Details of molecular chaper one families display differential expression during storage root development as compared to non-tuber forming fibrous root of sweet potato.

Among 465 genes studied, 121 genes displayed differential expression (>/< 1.5-fold) in storage root compared to fibrous (non-storage) root (Table 1 and Fig. 1). Out of 121 genes differentially expressed, 76 genes were up regulated and 45 were down regulated by 1.5-fold, respectively in storage root compared to fibrous (non-storage) root. The BIL2 gene, a member of DnaJ/Hsp40 family molecular chaperones regulates the brassinosteroid signalling during root development in Arabidopsis thaliana (Bekh-Ochir *et al.,* 2013). The DnaJ protein members express highly in root tissues of tomato (Kalidhasan *et al.,* 2015). In Arabidopsis, AtDJC17, a DnaJ molecular chaperons regulates the position-dependent cell fate determination during root development (Petti *et al.,* 2014).

In our study, 38 genes belonging to DnaJ family displayed differential expression pattern in storage root compared to fibrous (non-storage) root. Out of 38 genes, 25 were induced more than 1.5-fold, whereas 13 genes displayed reduced expression pattern in storage root compared to fibrous (non-storage) root (Table 1). These results indicate that myriad and complex roles of DnaJ family chaperone members in regulation and development of storage tubers in sweet potato (Pulido and Leister, 2018). HSP90 and its co-chaperones play crucial role in modulating the activity of the auxin receptors of auxin and jasmonic acid hormone (D'Alessandro *et al.,* 2015; di Donato, M. and Geisler, 2019). The auxin hormone plays an important role in regulating tuberous root formation and development in sweet potato.

The induced expression of eight HSP90 genes (JP105566.1, JP121814.1, JP152019, JP152019.1, JP146528.1, JP157072.1, JP138625.1 and JP152008.1) and reduced expression of one HSP90 gene (JP146072) in storage root compared to fibrous (non-storage) root, indicates the important role of HSP90 family chaperones in regulating the auxin distribution during storage root development in sweet potato (Table 1). HSP20 chaperones regulate various process in plant growth and development including stress tolerance in many plants (Muthusamy *et al.* 2017a). Thus, reduced expression of two HSP20 chaperones (JP132312 and JP117939) in storage root tissues reveals the regulatory role of these genes in storage root formation in sweet potato (Table 1).

The AAA+ super family chaperones regulates various molecular process in plant growth and developments including root development through assembly and disassembly of protein complexes (Muthusamy *et al.,* 2016). FiveClpATPase/AAA+ super family chaperones genes were differently expressed, two genes JP126934 and JP143048 were induced whereas, three genes JP114083, JP125261 and JP126972

Table 1. Molecular chaperone genes display differential expression during storage root development as compared to non-tuber forming fibrous root of sweet potato

Sweet potato array ID	Arabidopsis gene ID	Arabidopsis gene description
JP159080.1	AT5G22060.1	DnaJ-domain superfamily protein
JP147523.1	AT5G12430.1	DnaJ-domain superfamily protein
JP139241.1	AT3G57340	DnaJ heat shock amino-terminal domain protein
JP122794.1	AT4G19570.1	DnaJ-domain superfamily protein
JP117331.1	AT1G72416.1	DnaJ-domain superfamily protein
JP144815.1	AT5G37440.1	DnaJ-domain superfamily protein
JP156056.1	AT5G64360.1	DnaJ-domain superfamily protein
JP109990.1	AT5G22060.1	DnaJ-domain superfamily protein
JP133972	AT3G12170	DnaJ-domain superfamily protein
JP126921.1	AT4G21180.1	DnaJ-domain superfamily protein
JP142690.1	AT5G03160.1	DnaJ-domain superfamily protein
JP148076.1	AT5G64360.1	DnaJ-domain superfamily protein
JP140852.1	AT2G17880.1	DnaJ-domain superfamily protein
JP127989.1	AT2G26890.1	DnaJ-domain superfamily protein
JP148313.1	AT4G28480.1	DnaJ-domain superfamily protein
JP108603.1	AT3G08970.1	DnaJ-domain superfamily protein
JP145731.1	AT1G65280.1	DnaJ-domain superfamily protein
JP120468.1	AT2G42080.1	DnaJ-domain superfamily protein
JP120770.1	AT4G13830.1	DnaJ-domain superfamily protein
JP151493.1	AT4G28480.2	DnaJ-domain superfamily protein
JP113684.1	AT1G72416.1	DnaJ-domain superfamily protein
JP159325.1	AT3G06340.1	DnaJ-domain superfamily protein
JP110741.1	AT3G12170.1	DnaJ-domain superfamily protein
JP138724.1	AT5G09540.1	DnaJ-domain superfamily protein
JP123848.1	AT2G26890.1	DnaJ-domain superfamily protein
JP132992	AT5G21430.1	DnaJ-domain superfamily protein
JP133892	AT1G61770.1	DnaJ-domain superfamily protein
JP110239	AT5G27240.1	DnaJ-domain superfamily protein
JP112773	AT3G14200	DnaJ-domain superfamily protein
JP153637	AT4G28480	DnaJ-domain superfamily protein
JP139266	AT5G17840.1	DnaJ-domain superfamily protein
AB246796	AT1G80920.1	DnaJ-domain superfamily protein
JP119582	AT4G28480.1	DnaJ-domain superfamily protein
JP156113	AT5G01390.3	DnaJ-domain superfamily protein
JP135464	AT2G33735	DnaJ-domain superfamily protein
JP141912	AT3G06778.1	DnaJ-domain superfamily protein
JP143729	AT1G11040.1	DnaJ-domain superfamily protein
JP159853	AT1G62970.1	DnaJ-domain superfamily protein
JP152873	AT3G08970.1	HSP40 protein homolog
JP105566.1	AT5G56010.1	HSP90
JP117939	AT5G54660.1	HSP21.7
JP121814.1	AT2G04030.1	HSP90
JP132312	AT1G07400.1	HSP17.8
JP138625.1	AT4G24190.1	HSP90
JP146072	AT5G52640.1	HSP90
JP146528.1	AT4G24190.1	HSP90
JP152008.1	AT5G56010.1	HSP90
JP152019	AT4G24190.1	HSP90

Sweet potato array ID	Arabidopsis gene ID	Arabidopsis gene description
JP157072.1	AT5G56000.1	HSP90
JP126934	AT4G24790.1	AAA-type Atpase (ClpAtpase)
JP114083	AT5G15450.1	Chaperone protein ClpB3
JP125261	AT1G63440.1	Copper-transporting ATPase HMA5
JP126972	AT1G74310.1	CLPB1 description:Chaperone protein ClpB1
JP143048	AT4G29900.1	Calcium-transporting ATPase 10,
AF152903	AT1G49010	Duplicated homeodomain-like superfamily protein
JP106324.1	AT2G34100.1	Nonsense-mediated mRNA decay-like protein
JP109389.1	AT5G13500.1	Hydroxyproline O-arabinosyltransferase 3
JP109963	AT5G40590.1	Cysteine/Histidine-rich C1 domain family protein
JP115028.1	AT5G22700.6	F-box/RNI-like/FBD-like domains
JP117941.1	AT5G32470.1	Bifunctional TH2 protein
JP118167	AT1G70030.1	Paired amphipathic helix (PAH2) superfamily protein
JP118939	AT2G30410.1	Tubulin-folding cofactor A
JP120273	AT3G54420.1	EP3 chitinase
JP120876	AT3G44530.1	homolog of histone chaperone HIRA
JP120958	AT5G12320.1	Ankyrin repeat family protein
JP121286	AT3G56240.1	Copper Chaperone (CCH)
JP122168.1	AT3G58100	Plasmodesmata callose-binding protein
JP123242	AT5G27360.1	Major facilitator superfamily protein
JP123432	AT1G71440.1	Tubulin-folding cofactor E
JP123575	AT5G47200.1	Ras-related protein RABD2b
JP124079.1	AT5G02180.1	Amino acid transporter
JP124768	AT4G38960.1	B-box type zinc finger family protein
JP126351.1	AT4G08550.1	protein disulfide oxidoreductases
JP127691.1	AT5G22740.1	Glycosyltransferase
JP127790	AT3G50930.1	HYPER-SENSITIVITY-RELATED 4
JP128334.1	AT1G29340.1	RING-type E3 ubiquitin transferase
JP129043	ATCG01280.1	Ycf2
JP129065	At3g22670	Pentatricopeptide repeat-containing protein
JP129622.1	AT4G02760.1	RNI-like superfamily protein
JP129671.1	AT1G74675.1	Transmembrane protein
JP132350.1	AT4G15260.1	Glycosyltransferase chaperones
JP132385	AT1G15780.1	mediator of RNA polymerase II transcription subunit 15a-like protein
JP133320	AT4G36630.1	Vacuolar sorting protein 39
JP133620	AT3G57890	Tubulin binding cofactor C domain-containing protein
JP134121.1	AT3G15690.1	biotin/lipoyl attachment domain containing 3 protein
JP134174	AT1G79380.1	E3 ubiquitin-protein ligase RGLG4
JP135515.1	AT3G11350.1	Pentatricopeptide repeat (PPR) superfamily protein
JP137002	AT2G03140.1	alpha/beta-Hydrolases superfamily protein
JP137963	AT5G46580	Pentatricopeptide repeat-containing protein
JP138244.1	AT3G19940.1	Sugar transport protein 10
JP138348	AT5G42480.1	Accumulation and replication of chloroplast protein
JP139413	At2g16365	F-box protein
JP141935	AT1G43130	LCV2
JP142736	AT2G24540.1	F-box protein AFR
JP143605.1	BRL3	BRL3 description:Receptor-like protein kinase BRI1-like 3
JP144733	AT1G20650	PBL21
JP145231.1	AT4G00660.2	DEAD-box ATP-dependent RNA helicase

Sweet potato array ID	Arabidopsis gene ID	Arabidopsis gene description
JP146077.1	AT1G80920.1	A nuclear encoded soluble protein found in the chloroplast stroma. Negatively regulated by light and has rapid turnover in darkness.
JP146203.1	AT1G14980.1	chaperonin
JP146362.1	AT3G46720.1	UDP-glycosyltransferase 76E5
JP146669.1	AT5G51180.2	alpha/beta-Hydrolases superfamily protein
JP147032	AT5G62100.1	BCL-2-associated athanogene 2
JP149387.1	AT1G20060.9	ATP binding microtubule motor family protein
JP149700	AT3G58930.1	F-box/LRR-repeat protein
JP149750	AT1G76990.1	ACR3
JP151152.1	AT2G04740.2	BTB/POZ domain-containing protein At2g04740
JP152392	AT3G16800	protein phosphatase 2C
JP152392.1	AT3G29330.2	RNA-binding-like protein
JP153559.1	AT2G32930.2	DNA binding ZN protein
JP153665	AT4G14368.1	Regulator of chromosome condensation (RCC1)
JP155125	AT3G54890.1	Chlorophyll a-b binding protein
JP155509	AT5G02490.1	MED37D description:Probable mediator of RNA polymerase II transcription subunit 37c
JP156282.1	AT2G04160.1	Subtilisin-like protease
JP156701.1	AT3G15700.1	P-loop containing nucleoside triphosphate hydrolases superfamily protein
JP156962	AT3G50930.1	HYPER-SENSITIVITY-RELATED 4
JP157295	AT4G27745.1	Yippee family putative zinc-binding protein
JP158522.1	AT4G36890.1	Probable beta-1,4-xylosyltransferase IRX14
JP158769.1	AT3G12775.1	Ubiquitin-conjugating enzyme family protein
JP159226	AT5G08330	TCP21-Circadian oscillator protein which interacts with bZIP63 and regulates a response of the circadian oscillator to sugar
JP159634	AT1G15190.1	FLA19 (Fasciclin-like arabinogalactan family protein)
JP159704.1	AT2G27200.1	GTPase LSG1-1

displayed reduced expression in storage root compared to fibrous (non-storage) root (Table 1) and thus shows their regulatory role in root development in sweet potato.

Members of different chaperones families having diverse function including chromosome remodelling, nucleic acid (DNA / RNA) binding, co-chaperones, *etc.*, were also differently expressed in storage root compared to fibrous (non-storage) root (Table 1). These results suggest that the molecular chaperones play a key role in regulating the gene regulatory networks of storage root development in sweet potato. Several studies have shown the regulatory role of molecular chaperones in both biotic and abiotic stress response in plants (Muthusamy *et al.*, 2016, 2017a). Our study indicates the possible link of molecular chaperones in regulating the storage root development in sweet potato. Further functional studies on these family members would help to breed climate-resilient high yielding genotypes with enhanced stress-tolerance in sweet potato (Singh, 2013; Ravi *et al.*, 2014; Muthusamy *et al.*, 2017b).

CONCLUSION

The molecular chaperones belonging to DNAJ and HSP90were up regulated during initial storage root formation of sweet potato. These genes play diverse role mainly involved in protein import, protein folding, protein binding, nucleic acid (DNA / RNA) binding and proteasomal degradation of misfolded / denatured protein, thereby regulating the pathways involving hormone signalling. The chaperones like DNAJ, HSP90 and its co-chaperones modulates the structure of nucleosomes and regulates the transcription of genes involved in storage root development in sweet potato. Further, functional characterization of genes identified in this study will be useful in dissecting key genes for improving tuber development in swee tpotato leveraging the CRISPR-based gene editing technologies.

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Evaluation of wild edible plants of Andaman and Nicobar Islands for food and nutritional security

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ABSTRACT

About 153 wild plants were identified as edible used by tribals of the Andaman and Nicobar Islands, including 63 trees (2 small trees), 38 herbs, 23 shrubs, 16 climbers, 2 each creepers, twinners, grasses and sedges, and one each fern, vine and weed. Various parts of these plants were reported to be utilized as food, fruits, vegetables and utilized for making pickle/jam and jelly/beverages. Many tuber crops belonging to Dioscoreaceae family such as *Dioscorea esculenta, D. glabra, D. pentaphylla* and *D. vexans* are relished by the tribals. Therefore, conservation and enriching the population of these plants in tribal area is very important. The nutritional aspects and the presence of dangerous steroids in these plants if any have to be studied in detail.

Key Words: Andaman and Nicobar Islands, Conservation, Food, Nutrition, Tribes, Wild edible plants

Andaman and Nicobar islands represent one of the hotspots of rich biodiversity regions in India and are usually acknowledged as 'botanical paradise'. Many of wild plants are edible, in which tuber crops belonging to family Dioscoreaceae are relished mostly. Most of the plants are wild and hence may contain poisonous metabolites and may affect the health of tribal people who consume them in larger quantities. Hence gathering information on presence of such chemicals in these plants is essential along with their nutritional value. The documentation of wild edible plants of Andaman and Nicobar islands by tribal population is essential for conservation and effective utilization of these plant genetic resources in future, but very little works has been done on these aspects. Therefore, present study was undertaken to survey through interview/literature and document the wild edible plants utilized by the tribals of Andaman and Nicobar islands.

MATERIALS AND METHODS

A survey of literature was done on different publications during 2008-12 under a DBT financed project namely "Digital database on plant resources of Andaman and Nicobar Islands" and scrutinized for short listing the wild edible plants. For this purpose the whole publications on botany of the islands were glanced (Abraham *et al.*, 2008, Awasthi, 1988a; Awasthi, 1988b; Awasthi and John Jacob, 1987). The information was also gathered by resources such as Central Island Agricultural Research Institute (CIARI), Botanical Survey of India (BSI), NGOs *etc.* situated in Port Blair, Andaman and Nicobar islands.

The details on taxonomy, distribution, reproductive biology, phenology, uses, chemical, economic potential etc. were also referred. In total, 40 exploration trips were made during 2011-2013 and covered 75 sites belonging to all three districts, North and Middle Andaman, South Andaman and Nicobar Islands. During interactions with the tribes of islands, it was observed that more responsive received from tribal and settler farmers where the interactions/responses having mutual benefits. In general, visits were made mainly during dry period (November-April) which coincides the flowering time of most of the tropical plants.

RESULTS AND DISCUSSION

The distribution of wild edible plants used by tribals of Andaman and Nicobar Islands identified

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Table 1. Distribution of wild edible plants of Andaman and Nicobar Islands including endemic and introduced species

Distribution/ Location	Species
Andaman and Nicobar Islands (73)	*Spondias pinnata, Colocasia esculenta, Borassus flabellifer, Nypa fruticans, Wattakaka volubilis, Eclipta prostrata, Tridax procumbens, Wedelia biflora, Athyrium esculentum, Averrhoa bilimbi, A. carambola, Basella alba, Tamarindus indica, Cleome gynandra, Terminalia catappa, Commelina benghalensis, Ipomea campanulata, Trichosanthes bracteata, Cycas rumphii, Dioscorea esculenta, D. glabra, D. pentaphylla, Actephila excels var. javancian* var. *puberula, Antidesma acidum, Breyina vitis-idaea, Endospermum hirta, Mucuna gigantea, Sesbania grandiflora, S. sesban, Flagellaria indica, Gnetum latifolium, G. montanum, Leea indica,* L. *macrophylla, Lygodium circinnatum, Thespesia populnea, Urena lobata ssp. lobata, Marsilea minuta, Melastoma malabathricum, Ficus hispida, F. religiosa, F. rumphii, Musa acuminata, Ardisia solanacea, Syzygium polyanthum, S. samarangense, Pisonia aculeata, Nymphea stellata, Ximenia americana, Oxalis corniculata, Pandanus odoratissimus, Portulaca oleracea, Morinda citrifolia var. bracteata, Bruguiera gymnorrhiza, Smilax zeylanica, Physalis minima, Solanum nigrum, Sonneratia caselaris, Stenochlaena palusris, Corchorus olitorius, Pouzolzia zeylanica, Premna latifolia, Premna obtusifolia, Stachytarpheta indica, Annona squamosa, Aporusa dioica, Artocarpus heterophyllus, Benincasa hispida, Aclisia secundiflora, Merremia umbellata, Pisonia grandis, Manihot esculenta, Peperomia pellucida, Sonneratia alba* and *Tetrastigma lanceolarium.*
Andaman Islands (31)	*Mangifera andamanica, M. sylvatica, Willughbeia edulis, Scindapsus officinalis, Corypha utan, Oroxylum indicum, Bombax insigne, Cassia siamea, Capparis zeylanica, Garcinia xanthochymus, Terminalia bilata, Argyreia nervosa, Merremia mammosa, Momordica cochinchinensis, Trichosanthes bracteata, Dioscorea bulbifera, Elaeocarpus floribundus, Erythrina variegata, Ficus racemosa, Morus macroura, Pisonia aculeata, Cansjera griffithiana, Phoenix paludosa, Brachiaria ramosa, Monochoria vaginalis, Ziziphus oenophile* var. *Pallens, Gardenia turgidor, Aegle mermelos, Solanum indicum* and *Melochia corchorifolia*
South Andaman (16)	*Bouea oppositifolia, Garcinia lancaefolia, G. mangostana, Ipomea maxima, Momordica dioica, Trichosanthes dioica, Elaeocharis dulcis, Phyllanthus acidus, Pachyrrhizus erosus, Mollineria latifolia, Macrulaco cochinchinensis, Portulaca quadrifida, Pteridium aquilinum, Morinda umbellata, Solanum surattense* and *Cissus quadrangularis.*
Nicobar Islands (14)	*Bidens pilosa, Antidesma bunius, Antidesma ghaesembila, Atylosia scarabaeoides, Gnetum latifolium var. macropodium, Mangifera camptosperma, Uvaria cordata, Basella rubra, Garcinia cowa, Baccaurea ramiflora, Sauropus androgynus, Flacoutia jangomas, Gnetum gnemon, Tacca leontopetaloides* and *Pteris ensiformis.*
South Andaman and Nicobar Islands (10)	*Annona muricata, Carris aspinarum, Vernonia patula, Commelina communis, Gymnopetalum quinquelobum, Scleria biflora, Jatropha multifida, Artrocarpus chama, Bambusa vulgaris* and *Rubus moluccanus.*
Endemic (05)	*Mangifera andamanica, Terminalia procera, Dioscorea vexans, Pandanus lerum var. andamanensium* and *Manilkara littoralis.*
Introduced species (04)	*Trichosanthes cucumerina, Hibiscus sabdariffa, Syzygium jambos* and *Plantago major.*

through literature survey and interactions during exploration trips was presented (Table 1). Around 153 species belonging to 110 genera of 67 families were reported (Table 2) and these 153 wild plants were identified as edible by tribals of Andaman and Nicobar Islands. It includes 62 trees (2 small trees), 37 herbs, 23 shrubs, 16 climbers, 2 each creepers, twinners, grasses and sedges, and one each fern, vine and weed. The most prominent were trees followed by herbs, shrubs and then climbers. Various parts of these plants were reported to be utilized as food, fruits, vegetables and in making pickle/jam/jelly/beverages.

The plant parts used by tribes are tubers/rhizomes/roots of 17 species, fruits and floral parts of 72 species and stems/shoots of 3 species, leaves of 29 species and leaves/stems/fruits of 32 plants species

Table 2. Family-wise number, genus and species used by tribals of Andaman and Nicobar Islands

Family	Number of genus reported	Number of species reported	Family	Number of genus reported	Number of species reported
Anacardiaceae	3	5	Melastomaceae	1	1
Annonaceae	2	3	Moraceae	4	8
Apocynaceae	2	2	Musaceae	1	1
Araceae	2	2	Myrsinaceae	1	1
Arecaceae	3	3	Myrtaceae	1	3
Asclepiadaceae	1	1	Nyctaginaceae	1	2
Asteraceae	5	5	Nymphaceae	1	1
Athyriaceae	1	1	Olacaceae	1	1
Averrhoaceae	1	2	Opiliaceae	1	1
Basellaceae	1	2	Oxaladaceae	1	1
Bignonaceae	1	1	Pandanaceae	2	3
Bombaceae	1	1	Piperaceae	1	1
Caesalpinaceae	2	2	Plantaginaceae	1	1
Capparaceae	1	1	Poaceae	2	2
Cleomaceae	1	1	Pontederiaceae	1	1
Clusiaceae	1	4	Portulaceae	1	2
Combretaceae	1	3	Pteridaceae	1	2
Commelinaceae	2	3	Rhamnaceae	1	1
Convulvulaceae	3	5	Rosaceae	1	1
Cucurbitaceae	4	7	Rubiaceae	2	3
Cycadaceae	1	1	Rutaceae	1	1
Cyperaceae	2	2	Rhizophoraceae	1	1
Dioscoreaceae	1	5	Sapotaceae	1	1
Elaeocarpaceae	1	1	Smilaceae	1	1
Euphorbiaceae	10	12	Solanaceae	2	5
Fabaceae	5	6	Sonneratiaceae	1	2
Flacourtiaceae	1	1	Stenochilaenaceae	1	1
Flagellariaceae	1	1	Sterculiaceae	1	1
Gnetaceae	1	4	Taccaceae	1	1
Hypoxidaceae	1	1	Tiliaceae	1	1
Leeaceae	1	2	Urticaceae	1	1
Lygodiaceae	1	1	Verbenaceae	2	3
Malvaceae	3	3	Vitaceae	2	2
Marsileaceae	1	1	Total	110	153

(Table 3). Young leaves, pods and tender fruits were used mainly as vegetables. The leaves were mainly eaten. The wild edible plants especially used by different tribals and settlers of Andaman and Nicobar Islands identified are presented in Table 4. The *Dioscorea esculenta, D. glabra, D. pentaphylla* and *D. vexans* are relished by locals. A recent study by Romesh *et al.*, (2019) revealed that change in suitability of yam-growing areas in India assessed by using 22 GCMs of SRES-A1B emission scenario as -2.04 to 23.5 % and also projected a change in annual mean temperature and total annual precipitation as 0.9 to 1.3°C and 9 to 128 mm, respectively. Fruits of *Tamarindus indica* are used for souring curies, sauces and beverages, whereas tender leaves, flower and seedlings are eaten as vegetables. Fruits of *Garcinia xanthochymus* have juicy pulp, which is used for preparation of curries and vinegar preparation. Pickles were prepared by using fruits and leaves of *Artocarpus heterophyllus* (unripe fruit), *Averrhoa bilimbi, A. carambola, Bouea oppositifolia, Capparis zeylanica, Elaeocarpus floribundus, Trichosanthes dioica* and *Cleome gynandra,* respectively. Probiotics such as raw pickles and cultured vegetables rich in lactic acid microorganisms are far superior than synthetic drugs. Bacteriocins produced by these bacteria are of keen interest to food industry for their bio-preservative potential and antimicrobial properties as there is increasing demand for high quality 'safe' foods which are not extensively processed has created a niche for natural food preservatives (Garg and Kumar, 2014).

Table 3. Plant parts used by tribals of Andaman and Nicobar islands

Economic parts used (spp)	Species
Flowers, buds and aerial parts (04)	*Monochoria vaginalis* (Aerial parts); *Bambusa vulgaris* (Buds); *Cassia siamea; Manilkara littoralis.*
Fruits (61)	*Annona squamosa; Mangifera andamanica; M. camptosperma; Annona muricata; Uvaria cordata; Carris aspinarum; Corypha utan; Averrhoa bilimbi; A. carambola; Oroxylum indicum; Bombax insigne; Garcinia cowa; G. lancaefolia; G. mangostana; Terminalia procera; T. bilata; T. catappa; Aclisia secundiflora; Momordica dioica; Trichosanthes bracteata; T. cucumerina; T. dioica; Elaeocarpus floribundus; Baccaurea ramiflora; Aporusa dioica; Flacoutia jangomas; Gnetum latifolium; G. latifolium var. macropodium; G. montanum; Mollineria latifolia; Artocarpus heterophyllus; A. chama; Ficus hispida; F. racemosa; F. religiosa; F. rumphii; Morus macroura; Macrulaco cochinchinensis; Musa acuminata; Syzygium jambos; S. polyanthum; S. samarangense; Ximenia americana; Pandanus lerum var. andamanensium; Phoenix paludosa; Brachiaria ramosa; Ziziphus oenophile var. pallens; Rubus moluccanus; Gardenia turgidor; Morinda citrifolia var. bracteata; M. umbellata; Aegle mermelos; Bruguiera gymnorrhiza; Physalis minima; Solanum nigrum; S. surattense; S. torvum; Sonneratia alba; S. caselaris; Premna obtusifolia; Tetrastigma lanceolarium*
Fruits and leaves (07)	*Antidesma bunius; A. ghaesembila; Endospermum hirta; Phyllanthus acidus; Sauropus androgynus; Erythrina variegata; Leea macrophylla.*
Fruits, leaves and shoots (01)	*Ardisia solanacea.*
Leaves (28)	*Scindapsus officinalis; Bidens pilosa; Eclipta prostrata; Tridax procumbens; Vernonia patula; Wedelia biflora; Athyrium esculentum; Cleome gynandra; Argyreia nervosa; Actephila excelsa var. puberula; Antidesma acidum; Breyina vitis-idaea; Mucuna gigantea; Gnetum gnemon; Hibiscus sabdariffa; Thespesia populnea; Marsilea minuta; Pisonia grandis; Cansjera griffithiana; Oxalis corniculata; Plantago major; Smilax zeylanica; Solanum indicum; Stenochlaena palusris; Melochia corchorifolia; Corchorus olitorius; Stachytarpheta indica; Cissus quadrangularis*.
Fruits, flowers and leaves (02)	*Spondias pinnata; Melastoma malabathricum*
Leaves and flowers (02)	*Sesbania sesban; Wattakaka volubilis.*
Leaves and seeds (01)	*Commelina communis.*
Leaves, flowers and pods (01)	*Sesbania grandiflora.*
Plant (06)	*Ipomea maxima; Scleria biflora; Atylosia scarabaeoides; Peperomia pellucida; Portulaca oleracea; P. quadrifida.*
Rhizome (04)	*Colocasia esculenta; Commelina benghalensis; Nymphea stellata; Pteridium aquilinum.*
Roots (02)	*Urena lobata ssp. lobata; Pouzolzia zeylanica.*
Seeds, Fruits and roots (01)	*Borassus flabellifer.*
Stem/ shoots (03)	*Ipomea campanulata; Lygodium circinnatum; Pisonia aculeata.*
Stem/ shoots and leaves (03)	*Basella alba; Basella rubra; Leea indica.*
Stem buds (01)	*Nypa fruticans.*
Stem and fruits (01)	*Flagellaria indica.*
Tender floral leaves and terminal buds (01)	*Pandanus odoratissimus.*
Tender leaves, flower (01)	*Tamarindus indica.*
Tender leaves, seeds and pods (01)	*Willughbeia edulis.*
Tubers (11)	*Merremia mammosa; Elaeocharis dulcis; Dioscorea bulbifera; D. esculenta; D. glabra; D. pentaphylla; D. vexans; Jatropha multifida; Manihot esculenta; Pachyrrhizus erosus; Tacca leontopetaloides.*
Young fronds (01)	*Pteris ensiformis.*
Young fruits (03)	*Benincasa hispida; Gymnopetalum quinquelobum; Momordica cochinchinensis.*
Young leaves (01)	*Merremia umbellata.*
Young leaves and fruits (01)	*Cycas rumphii.*

Fruits of *Averrhoa carambola, Antidesma bunius, Phyllanthus acidus, Ficus racemosa, Ximenia americana* and *Solanum nigrum* were used in preparation of jams and jellies. The fruits of *Antidesma bunius* used for wine preparation. The flowers of nine species *(Spondias pinnata, Annona squamosa, Wattakaka volubilis, Cassia siamea, Tamarindus indica, Sesbania grandiflora, Sesbania sesban, Melastoma malabathricum, Manilkara littoralis)* and rhizomes of four species *(Colocasia esculenta, Commelina benghalensis, Nymphea stellata and Pteridium aquilinum)* were used by different tribals as vegetable and also as food. The tubers of eleven species, *viz. Merremia mammosa, Elaeocharis dulcis, Dioscorea bulbifera, D. esculenta, D. glabra, D. pentaphylla, D. vexans, Jatropha multifida, Manihot esculenta, Pachyrrhizus erosus* and *Tacca leontopetaloides* were used as vegetable by raw or after cooking.

Among 153 plants, 7 plants were found to be introduced and 5 were found to be endemic. Wild relatives of Rambutan *(Nephellium lapaceum),* Durian *(Durio zibethinus),* Mangosteen *(Garcinia mangostana),* Annona (Sreekumar *et al.*, 1996a), banana, wild jamun, morinda species, wild jack, mango species *(Mangifera species)* (Sreekumar *et al.*, 1996b) are present in these

Table 4. Specific wild edible plants used by tribals of Andaman and Nicobar Islands.

Botanical name	Family	Habit	Uses
Bouea oppositifolia	Anacardiaceae	Tree	Fruits are used for pickling by old settlers of Andaman
Mangifera camptosperma	Anacardiaceae	Tree	Fruits are consumed by the shompens.
Colocasia esculenta	Araceae	Herb	Consumed as vegetable. Rhizome boiled and eaten by shompen tribes.
Oroxylum indicum	Bignonaceae	Tree	Young fruits are eaten as Vegetable by the Burmese settlers and Onges
Garcinia cowa	Clusiaceae	Tree	Fruits edible and consumed by Jarawas and Great Andamanese.
Terminalia procera	Combretaceae	Tree	Kernels roasted and consumed by great Andamanese
Terminalia bilata	Combretaceae	Tree	Great Andamnese use the kernels as food.
Terminalia catappa	Combretaceae	Tree	Fruits are roasted; Kernels eaten by onges, shompens, Burmese and settlers of Andamans.
Dioscorea glabra	Dioscoreaceae	Herb	Tubers edible. Shompen tribes boil and consume and all tribes of the islands consume tubers after roasting.
Erythrina variegata	Fabaceae	Tree	Leaves and tender shoots are eaten as pot herb. Boiled seeds and raw pods eaten by Nicobarese and North eastern hill tribals.
Flagellaria indica	Flagellariaceae	Climber	Stems and fruits used as food by Onges and Shompen tribals.
Thespesia populnea	Malvaceae	Tree	Leaves eaten by shompens of Great Nicobar islands.
Ficus rumphii	Moraceae	Tree	Ripe fruits are eaten by Nicobarese.
Ardisia solanacea	Myrsinaceae	Tree	Fruits consumed by shompen tribes. Leaves are eaten as salad and tender shoots cooked as vegetable.
Pisonia aculeata	Nyctaginaceae	Shrub	Tender shoots are consumed by the shompen tribes.
Phoenix paludosa	Pandanaceae	Tree	The Great Andamanese consume the fruit after boiling.
Rubus moluccanus	Rosaceae	Small tree	Fruits edible and eaten by Shompens.
Gardenia turgidor	Rubiaceae	Tree	Fruits are reported to be eaten after cooking by North eastern tribals.
Morinda citrifolia var. *bracteata*	Rubiaceae	Tree	Fruits and leaves are eaten by Nicobarese and Shompen tribals.
Manilkara littoralis	Sapotaceae	Tree	Flowers are eaten by Great Andamanese and fruits by onges tribals.
Stenochlaena palustris	Stenochilaenaceae	Shrub	Nicobarese tribes eat the tender leaves as vegetable.
Tacca leontopetaloides	Taccaceae	Tuber	Tubers are boiled and eaten by Nicobarese and Shompen tribes of Great Nicobar.
Premna obtusifolia	Verbenaceae	Tree	Fruits consumed by Great Andamanese.
Stachytarpheta indica	Verbenaceae	Herb	Leaves are said to be cooked as vegetables by Nicobarese.

islands and used as food (Sharma *et al.*, 2010). *Musa balbisiana* var. andamanica (family - Musaceae), a new banana variety from Andaman Island was reported by Singh *et al.*, (1998). Mahapatra *et al.* (2012) reported that wild fruits have good nutritional value with protein, fat, ash, fiber, carbohydrates calcium, magnesium, phosphorus, iron, copper, sodium, potassium, thiamin, riboflavin, nicotinic acid, vitamin C and carotene.

Habits of consuming soft portion of bamboo and cane shoots were also noticed. Young shoots of fern plants are also nourished by tribals. The unripe fruits are eaten raw sometimes and seeds are boiled and taken. Pods of some plants are also reported to be eaten raw. These wild plants contain tremendous nutritional values. They are usually eaten and some of these plants serve as staple food of the aboriginals of these islands. These wild relatives serve as mainstay of the tribes for food as they rely on them for their livelihood. Some of plants are endemic too and hence conservation of these plants becomes essential. If population of these plants reduces habitat the general health of these tribes will be affected.

Since wild edible plants serve as vital source of food and vitamins for tribal population. Therefore, conservation enriching the population of these plants in tribal area is very important. The information pertaining to nutritional values of these plants is needed. Considering the harmful aspects of these wild species the study of dangerous steroids in these plants should also be undertaken. Variability studies and selection for promising clones will be useful. Future studies should also be focused on aspects of essential oils / volatile secondary metabolites produced by these diverse species for their regular use like cosmetics, perfumery, paint industry, paper and printing industry, and they can also be utilized beyond their aroma like aromatherapy, food preservation, preservation of fruits and vegetables, plant protection, weed management and veterinary pest management (Sachin *et al.*, 2016).

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Short Communication

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Excessive potassium fertilization intensifies fruit cracking in litchi *(Litchi chinensis)*

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Potassium (K) nutrition is very important for high yield and quality of litchi (*Litchi chinensis* Sonn.) fruits. However, overdose of fertilizer K, especially when the application ratio of fertilizer N:K_2O is <1:1, can induce fruit cracking in litchi by reducing Ca concentrations in all parts of the fruit. Common abbreviations and notes: K = potassium; N = nitrogen; Ca = calcium; B = boron; Mg = magnesium; OT = ordinary (litchi) trees; KT = litchi trees that received excess potassium chloride (KCl).

Litchi is one of the most favorable subtropical fruits in China. However, fruit cracking, a. common physiological disorder in litchi that occurs before fruit harvest, makes fruits unmarketable resulting in huge economic loss to the growers. The causes for this problem vary from case to case. Some authors attribute fruit cracking to nutrient disorder such as Ca deficiency in fruit (Lin, 2001), while others believe that fruit cracking occurs due to the combined effect of weather, water, nutrients (Ca and B), hormones etc. (Li, *et al.*, 2001).

In last early June, we were informed about the occurrence of fruit cracking in a litchi orchard in Gaozhou city, Guangdong province South China. According to the grower, most of the Baitangying litchi (a popular litchi variety in the region) in his orchard developed slight fruit cracking, while severe cracking was observed on trees that received an extra 1.5 kg KCl per tree in at the fast fruit swelling stage. We conducted an in-field investigation and in-lab nutrient analysis (K, Ca, Mg and B) to find out the real triggering cause(s) for fruit cracking in this litchi orchard at June 3.

Our in-field investigation showed that the extra KCl was broadcast at April 29, then it rained heavily from May 20 to 21, and fruit cracking began at May 23 and became more serious till late May. The fruit cracking rate was approximately 10-15% for ordinary trees (OT) and 50-60% for trees that received an extra 1.5 kg KCl (KT) (Fig. 1). In the orchard, Baitangying litchi was planted in 1991 with the size of 225 plants per hectare and the yield of approximately 60 kg per tree. Each fruit tree received 2 kg of ammonium bicarbonate (17% N), 4 kg of single superphosphate (12% P_2O_5), 2 kg of peanut meal, 2.5 kg of rapeseed meal, 15 kg of pig manure, and 0.5 kg of compound fertilizer (N-P_2O_5-K_2O 15-15-15%), while an extra 1.5 kg of KCl (60% K_2O) was added to each of the "favorite trees" chosen by the grower. These rates amounted to additions of 0.84 kg N, 0.82 kg P_2O_5 and 0.42 kg K_2O (N:P_2O_5:K_2O ratio of 1:0.98:0.5) to each OT, and 0.84 kg N, 0.82 kg P_2O_5 and 1.32 kg K_2O (N:P_2O_5:K_2O ratio of 1:0.98:1.57) to each KT. Based on our previous studies, nutrients removed by 50 kg of Baitangying litchi fruit were about 117.1 g N, 12.5 g P and 108.7 g K (N:P:K ratio of 1:0.11:0.93), and the optimal application ratio of N:K_2O fertilizers roughly as 1:1.2 in litchi (Yang *et al.*, 2015a). Thus, it is obvious that more fertilizer K was applied in this orchard at one dose, especially to the "favorite trees", than required for an optimal N:K_2O ratio. This may have caused nutrient (K, Ca, and Mg) imbalances in litchi trees resulting in severe fruit cracking since antagonism exists between K and Ca in litchi (Yang *et al.*, 2015b).

The analysis of nutrients in the fruit revealed that K concentrations in epicarp, endocarp, and core of fruits of KT were not increased, but K concentration in the fruit pulp decreased when compared with OT fruit (Fig. 1). Calcium concentrations in all parts of KT fruit were reduced, while Mg concentrations increased when compared with OT fruit. Extra KCl amendment

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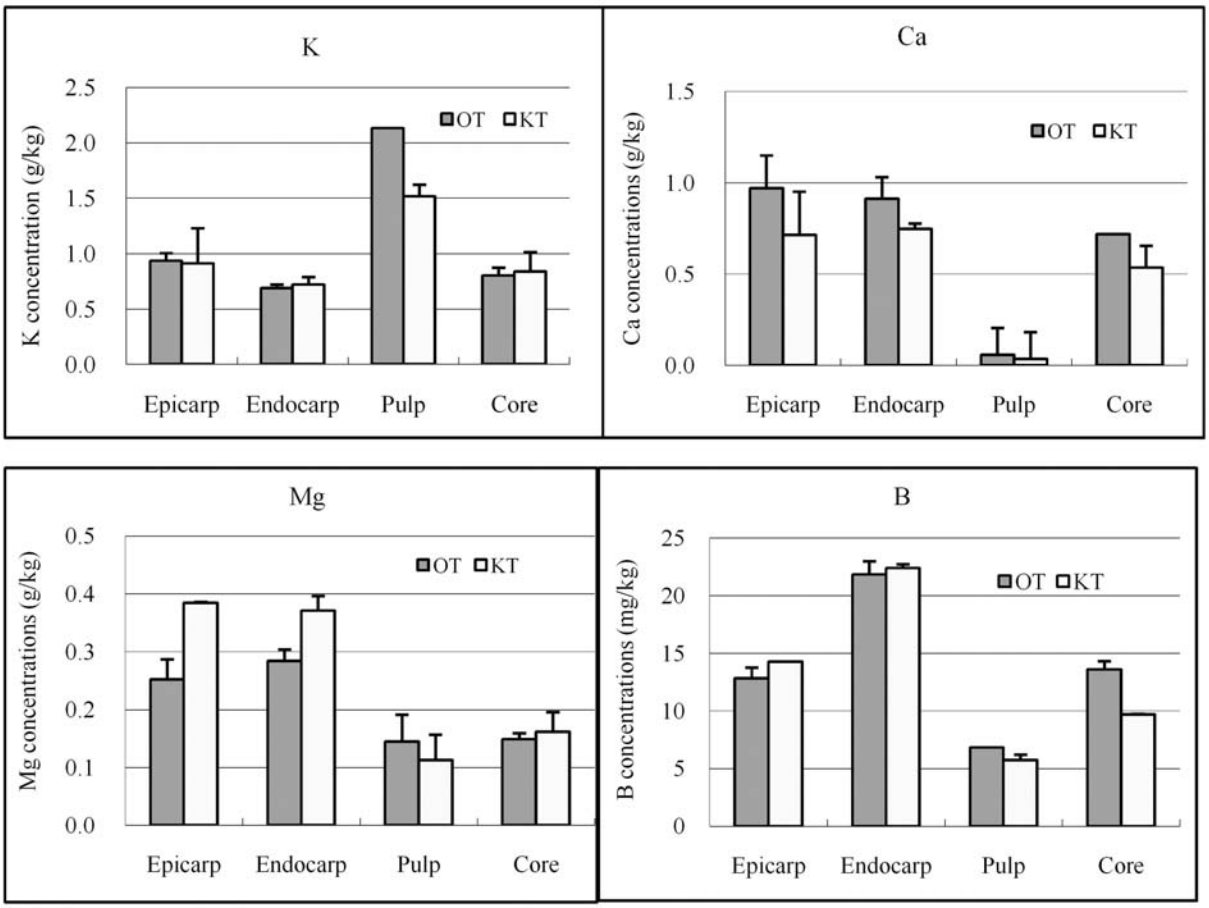

Fig. 1: Potassium (K), Ca, Mg, and B concentrations in fruits of ordinary trees (OT) versus the trees that received extra KCl (KT).

slightly enhanced B in both epicarp and endocarp, but decreased it in pulp and core in particular in comparison to OT fruit. The results indicated different interactions among K, Ca, Mg, and B in plant tissues.

Potassium (K), Ca, Mg, and B concen-trations in fruits of ordinary trees (OT) versus the trees that received extra KCl (KT) (Fig. 1). Since Ca is involved in the construction of cell walls and contributes greatly to the mechanical properties of plant tissues, it is widely regarded as an important nutrient factor related to fruit cracking (Shear, 1975; Vicente *et al.*, 2009). An array of literature has documented that Ca application can reduce fruit cracking in litchi. Our study demonstrated that overdose of KCl reduced Ca content in litchi fruits, especially in the peel, and this reduced Ca in fruits triggered serious fruit cracking. The slight fruit cracking that occurred in the litchi orchard was most likely due to rains after dry spells when application ratio of $N:K_2O$ was greater than the optimal ratio of 1:1.2.

Summary

The study emphasizes the importance of balanced fertilization in litchi for high quality litchi fruits as well as for preventing economic losses to growers due to fruit cracking.

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